A Spatial Future Materializes

2025 Edition

An ARtillery Intelligence Report

ARtillery Intelligence

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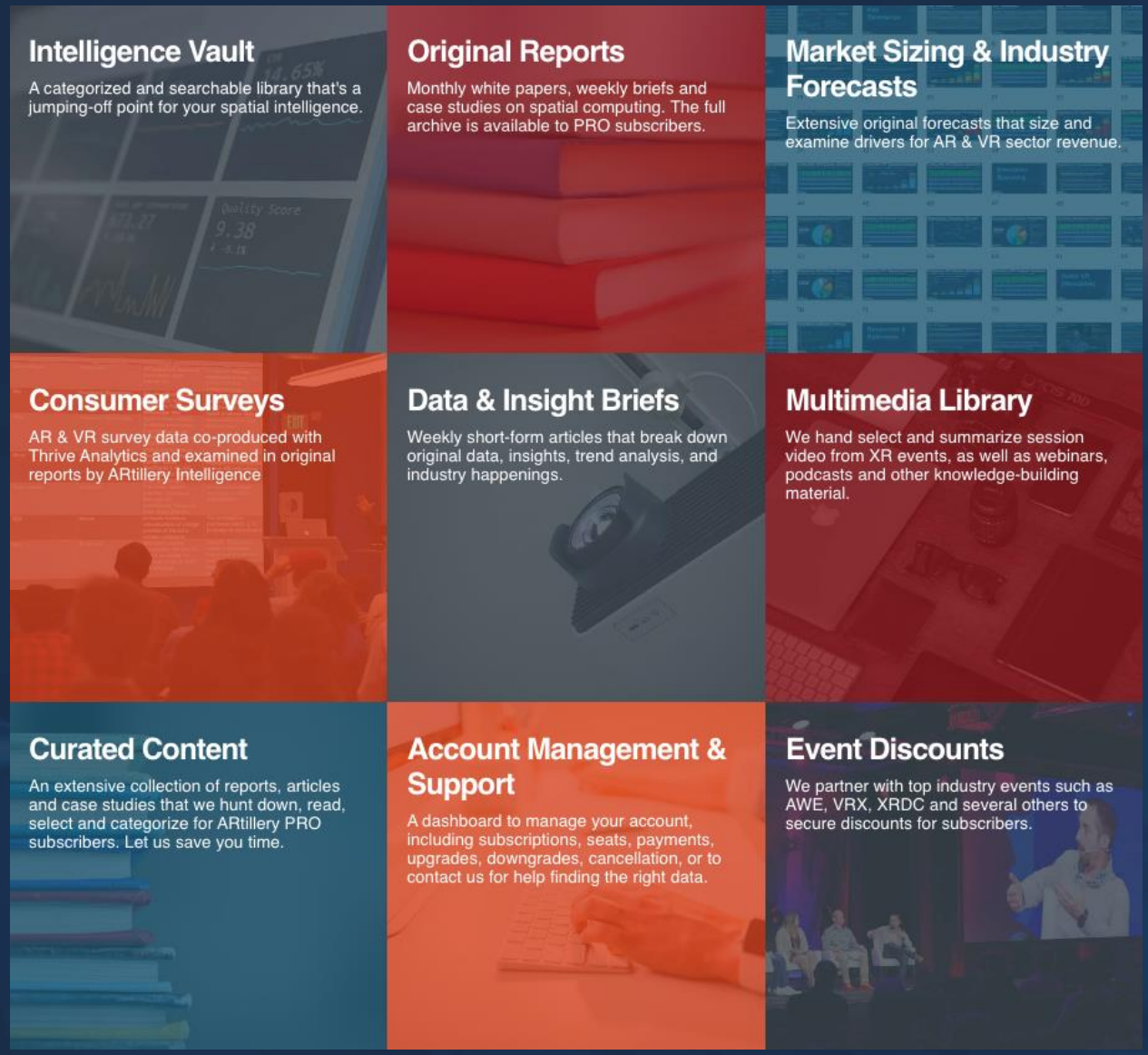

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Executive Summary

The State of Spatial

What's the state of spatial computing? As we enter a new year, we embark on our annual exercise of defining the sector, its players, events, and trajectory. As for findings and highlights, the collective grouping of subsectors known as XR continues to push forward and invest tens of billions per year to realize self-centric versions of a spatial future.

One byproduct of this process is mixed reality's elevated status as a new standard in VR, thanks to Meta Quest 3 and 3s. Meta isn't first to market with mixed reality, but it's combined the modality with the *element of affordability*. Along with this trend, HD color passthrough cameras broaden VR use cases and utility. They also advance AR, which can piggyback on the more mature and penetrated VR market.

Meanwhile, Ray-Ban Meta Smartglasses (RBMS) set the bar for headworn devices that are supported by AI. Among other advantages, this limits reliance on graphical dimensionality as a selling point. They rather rely on relevant information delivery such as personal alerts, social signals, shopping & commerce, and real-world object recognition. This utility is met with the style and wearability that's possible when you sidestep AR optical and display systems.

Then there's Meta Orion. Though only a working prototype, it has cracked the code on achieving both a visually-robust UX and style/wearability. Now, Meta must spend years cracking another code: marketing an Orion-like product for less than $10,000 – the device's current per-unit cost. But it has meanwhile demonstrated what's technically possible in AR today.

Parallel Tracks

Though many believe all the above approaches will someday meet in the middle for an ultimate XR device, we believe they'll continue to develop along parallel tracks. They'll be purpose built for varied use cases that map to their strengths – for the same reason you use a laptop and a smartphone, versus trying to do *everything* on a tablet. This multi-track approach also maximizes Meta's market opportunity amidst a challenged XR adoption environment.

Image Source: Meta

"Now, Meta must spend years cracking another code: Marketing Orion for less than $10,000. But it has meanwhile demonstrated what's technically possible in AR."

Executive Summary

Long Game

But it's not just about Meta. Like Orion, Apple Vision Pro achieves the extent of what's possible in spatial computing today – albeit a vastly different approach to augmentation. But unlike Orion, Vision Pro is available today, rather than sitting behind locked doors for internal use only. And though Vision Pro's sales have disappointed, Apple admits that it's "not a mass market product." Moreover, Apple is playing a long game with Vision Pro as the first step towards its massive and inherently-advantaged spatial ambitions.

Meanwhile, mobile AR leader Snap continues to make strong moves in headworn AR. Its latest Spectacles raise the bar for commercially-available (though only for developers at this stage) AR glasses. And in a similar device class for optical seethrough AR (definitions are detailed in this report), we continue to see compelling hardware from Xreal. Though it doesn't achieve dimensional AR like Spectacles and Orion, Xreal nails a simple and relatable use case: virtual private displays for entertainment & gaming.

Spatial Stack

Google and Samsung have also (re)entered the XR race, and have done so together. Android XR will be first available on Samsung headsets. This could be formidable, given Google's AI capabilities in Gemini, which are infused in Android XR. Like Apple, Google's platform position also offers advantages, such as bringing legions of existing Android apps into XR.

Speaking of platforms, it's not just about devices. With all the above, a spatial stack lies beneath. This involves a cast of supporting roles like processing (Qualcomm), creation (Adobe), and dev tools (Niantic). And while headworn XR continues to evolve, Mobile AR is here today on about **3 billion** devices.

Two Little Letters

Lastly, hanging over all the above are two little letters: AI. On one level, generative AI aids XR experience creation, thus streamlining developer workflows. On another level, it redefines user interfaces and inputs for XR devices ranging from smart glasses to mixed reality headsets. This is already happening.

So how is all of this coming together? What are these diverging and developing XR device categories? And who's best positioned in the spatial spectrum? We'll tackle these questions and others in this report series through numbers and narratives.

"On one level, AI can aid in XR experience creation. On another level, it can redefine user interfaces and inputs for XR devices ranging from smart glasses to mixed reality headsets."

Introduction: Getting Real

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Introduction: Getting Real

Diverge & Diversify

Like many tech sectors, spatial computing is defined by its devices. And on that measure, we've seen a bit of a shakeup in the last two years when it comes to the devices that characterize the industry at large. This is what we call the spatial spectrum and it continues to diverge and diversify.

Go-To Approach

Stepping back for context, the past decade of XR's lifecycle was dominated by consensus around winning formulas for device design. For example, in headworn AR, optical seethrough was a go-to approach – often involving waveguide-based optical systems (we'll define these and other classes later in this section).

Why was this the consensus? Mostly because the most well-funded companies – though not doing anything deliberately nefarious or manipulative – had chosen this path. This led to widely-held industry assumptions, and a sort of herd mentality, that it *must* be the right approach AR. This made it difficult for other display technologies to get funding and traction. But we're now seeing a turning point in this industry dynamic. And it's happening for one big reason: *the consensus didn't work*. The "leading devices" noted above have largely failed to validate a substantial market. For example, Microsoft HoloLens has all but retreated from the market, and Magic Leap continues to face sizable challenges in marketing its devices.

The Good News

The good news is that this means erosion to the consensus, and therefore openness to alternative flavors of XR. For example, over the past two years, we've seen the rise of passthrough AR as a new standard in VR, otherwise known as mixed reality. We're also seeing lower-end form factors gain traction including "flat AR" glasses. These don't offer visual elements that dimensionally interact with their surroundings but rather simpler fare, such as large private virtual displays that mirror entertainment or gaming content from one's phone, PC, or console.

Meanwhile, AI glasses like Ray-Ban Meta Smartglasses deviate even further from traditional approaches by eschewing display systems altogether. They rather rely on audio annotations for the physical world – a UX that's experientially meaningful even if graphically devoid. And the device's commercial success so far has validated this approach.

"We're now seeing a turning point where there's more openness to XR standards and approaches. And it's happening for one big reason: the consensus didn't work."

Introduction: Getting Real

Design Targets

Sticking with the last XR device category discussed on the previous page – simpler and graphically-toned-down approaches – they represent a key trend in XR: *getting real*. After a decade of chasing the vision of robust and dimensional visual-AR experiences, the industry is starting to realize that it can't yet be done in a form factor that consumers will wear in public.

So we've seen a proliferation of simpler AR experiences, often focused on a single use case. That includes Xreal's approach noted earlier, as well as Meta's AI-driven use case for audio annotations. Besides achieving greater simplicity and mainstream appeal, the targeted focus applied in these devices has allowed them to deliver compelling experiences at consumer-viable price points. Best of all, the simpler (or lack of) visual display systems unlock an elusive set of design targets in AR: *style & comfort.*

Lite AR

Stepping back, we've been obsessed with this "lite AR" construct for years. But there was always one big challenge: it's a bit underwhelming. At a time when XR advocates dreamed big and loud, "lite" wasn't in the vocabulary. But two things changed: "getting real" (per the above), and AI. Though AI isn't new, recent inflections in large-language models have elevated personal assistant functions. Applied to AR, this takes the burden off visuals as a central selling point. Freed from that burden, there's less of a dilemma in the classic tradeoff between visual UX and style/comfort.

Moreover, the AI-driven UX isn't "underwhelming." Its value often lies not in graphical intensity but in personalization and relevance. It's more about information than optics. It's experientially meaningful, even if graphically underpowered. That brings us back to Ray-Ban Meta Smartglasses. Besides upgraded audio, video capture, and live-streaming functions, multimodal AI brings all new flavors of utility to the table. It can identify and contextualize real-world objects using voice/visual input and voice output.

Pick a Lane

All the above boils down to the *art of the possible*. Meta, Xreal, and a few others have internalized AR's shortcomings and designed around them. The result is the best version of what's possible today, rather than trying – and failing – to be something that's unrealistic or impossible. Until we realize the futuristic dream of immersive optics *and* style/comfort in the same package, individual devices are starting to pick a lane.

"After a decade of chasing the vision of robust and dimensional visual-AR, the industry is starting to realize that it can't be done in a form factor that consumers will wear in public."

The Spatial Spectrum

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The Spatial Spectrum

Defining Devices

With that contextual backdrop for the spatial computing industry and the factors driving it today, what does the device spectrum look like? As devices continue to diverge and diversify in the ways explored in a previous section, what are their main categorizations? Before diving into the rest of this report, we'll take this opportunity to define the main device classes in the spatial spectrum...

Image Source: Viture

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Defining the Spatial Spectrum

Segments & Subsets

The spatial spectrum is varied so we've segmented it into classes for more analytical depth and dimension. These categories are defined as follows.

Video Passthrough (Handheld)

Attributes: Also known as *Mobile AR*, this category is defined by AR that happens on smartphones and tablets. It's technically a form of video passthrough AR, as it augments content from the device's camera feed. But the biggest distinction is that the form factor is handheld rather than headworn.

Examples: *Snapchat Lenses, TikTok Effects.*

Video Passthrough (Headworn)

Attributes: This device class includes VR headsets that have HD color passthrough cameras to view the outside world inside the device. That capability is the precursor for augmenting physical objects and scenes with digital elements. This is also known as mixed reality and passthrough AR – a new standard in VR.

Examples: *Meta Quest 3, Apple Vision Pro.*

Non-Passthrough VR

Attributes: This device class includes *VR headsets* that *don't* include passthrough capabilities, nor mixed reality. User experiences within the headset are fully occluded, insular and immersive, including gaming and entertainment. It can include 3DoF (head tracking) or 6DoF (positional tracking) experiences.

Examples: *Valve Index, PlayStation VR*

Optical Seethrough (Dimensional)

Attributes: This category includes AR glasses with see-through lenses on which graphics are projected. It comes in two flavors: dimensional and flat. Dimensional AR features digital elements that interact with their surroundings through spatial understanding (SLAM). This hallmark of dimensional AR is enabled by external cameras/sensors and software that understands and accommodates spatial geometry. Due to these technical requirements – in both hardware and software – devices in this category are generally bulkier and costlier than other classes.

Examples: *Snap Spectacles, Meta Orion*

Optical Seethrough (Flat)

Attributes: Similar to the previous category, this includes *AR glasses* with seethrough lenses on which graphics are projected. However, it differs in that graphics don't have spatial understanding nor dimensional interaction with physical spaces. They're rather flat or floating overlays such as virtual displays. Use cases include private entertainment or gaming, mirrored from one's smartphone, PC, or console.

Examples: *Xreal One, Rokid Max*

Non-Display AI Smartglasses

Attributes: This category includes glasses that have no display system at all. Experiential augmentation happens through audio cues. These devices apply AI to achieve a level of utility that compensates for the lack of visual experiences. For example, multimodal AI applies camera-based visual recognition along with voice refinements (e.g., "What am I looking at?") to return audible answers. The lack of a display system meanwhile enables style and wearability. Devices are often sleek and light, resembling normal eyewear.

Examples: *Ray-Ban Meta Smartglasess*

Charting the Spatial Spectrum

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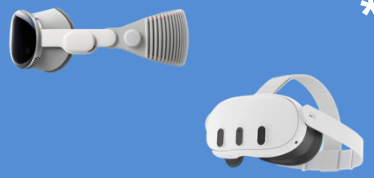
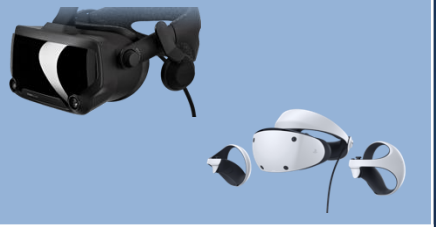
Handheld Headworn

	Mobile AR	Non-Display (AI Glasses)	Flat (3DoF & Floating)	Dimensional (6DoF & SLAM)
Video Passthrough (AR & VR)				 *
Optical Seethrough (AR)				
Fully Occluded (VR)			 **	

*Includes VR devices that perform passthrough AR, also known as mixed reality. These are categorized as VR, rather than AR, for the purposes of analysis and market sizing.
**Flat VR (3DoF) is a device class facing extinction (e.g., Oculus Go) in favor of flat AR devices like Xreal One, but it could could see future development.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ARtillery Briefs, Episode 88
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XR Devices: By the Numbers

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XR Devices: By the Numbers

Facts & Figures

Going one level deeper into device tiers and classifications, what's the market size of each? We'll dive into the numbers in the following several pages, including unit sales for key categorizations across the spatial spectrum. As a definitional side note, the following pages examine hardware unit sales only, leaving out software such as XR apps, games, and experiences (covered elsewhere in this report).

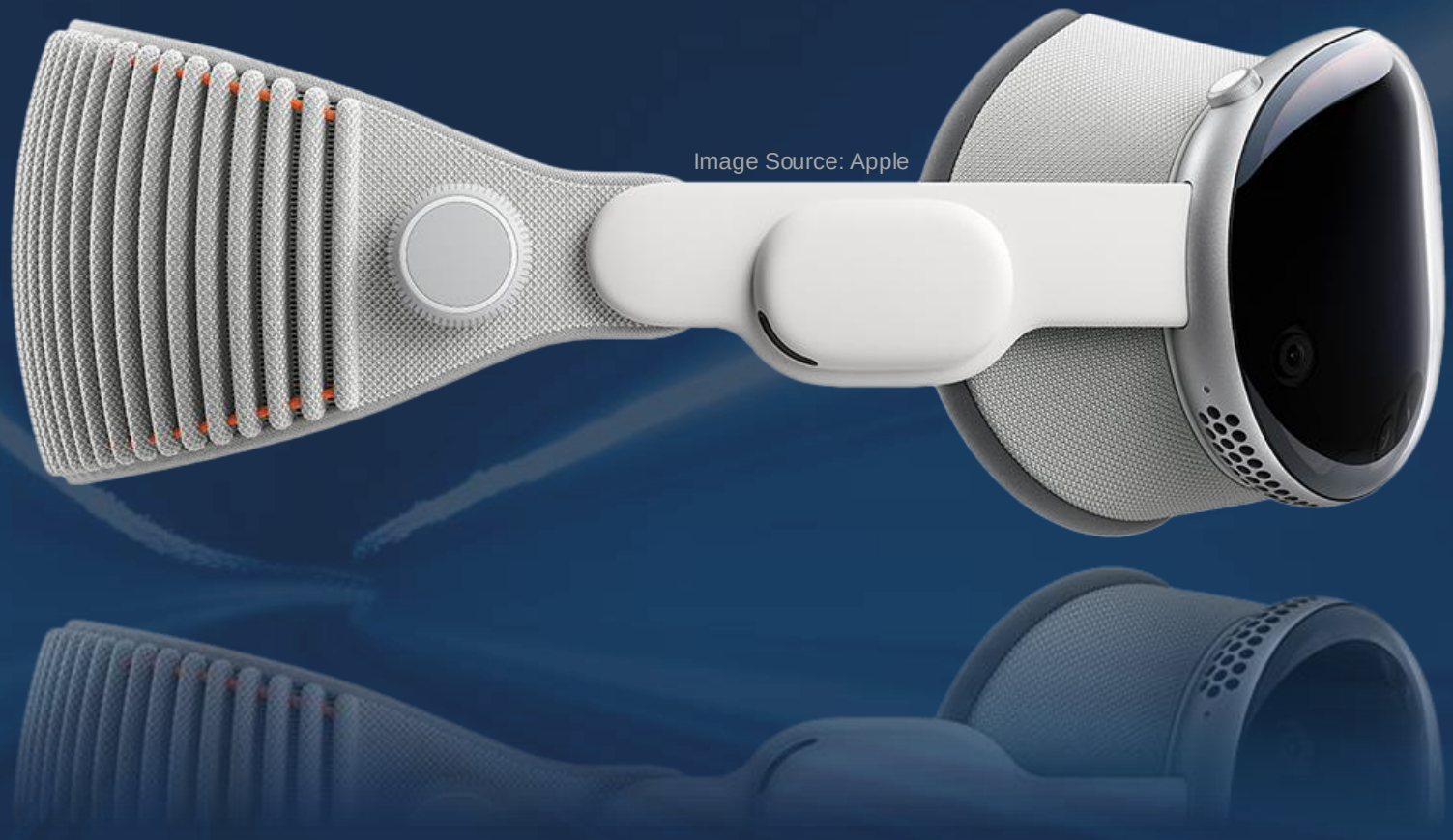

Image Source: Apple

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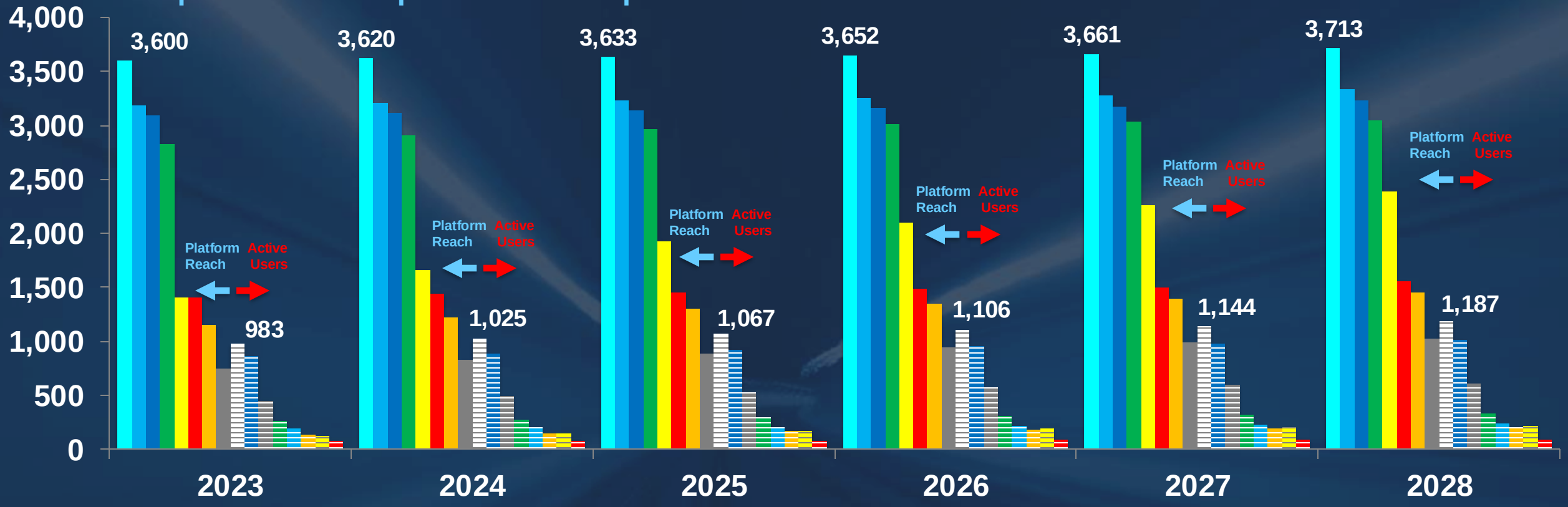
Mobile AR Global Penetration

AR-Compatible Devices & Active Users, Across Platforms*

Millions of Units

Simplified View: Detail provided in subsequent tables



*Excludes platforms endemic to China.
**Includes iPad.
***Google, Pinterest & Snap (de-duped).
****Includes Facebook & Instagram.

- Smartphones (of any type)
- Web AR (Devices)
- Visual Search (Devices)***
- Meta AR (Devices)****
- ARCore (Devices)
- ARkit (Devices)**
- TikTok (Devices)
- Snap Lenses (Devices)
- Total AR Active (de-duped)
- Visual Search (Active)***
- Snap Lenses (Active)
- Meta AR (Active)****
- Web AR (Active)
- TikTok AR (Active)
- ARCore (Active)*
- ARkit (Active)**

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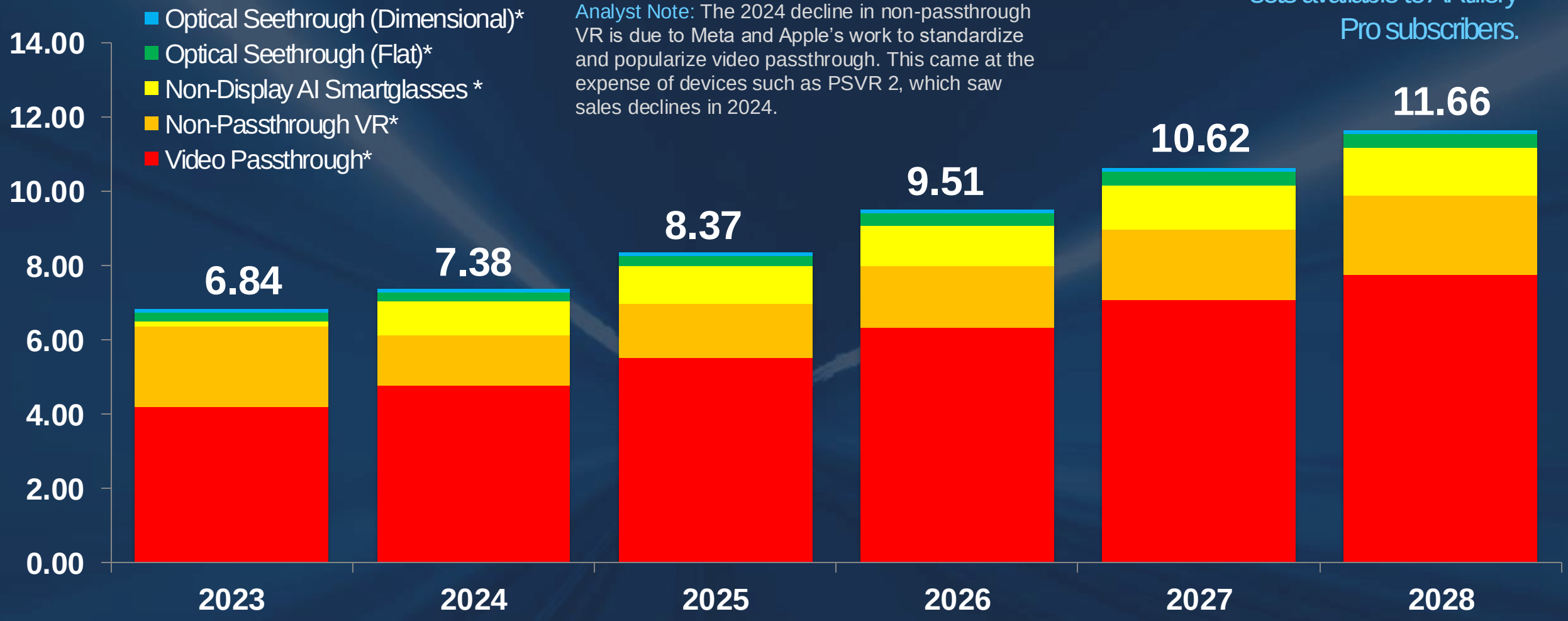
Headworn XR Devices

Annual Hardware Unit Sales Estimates, by Device Class

Millions of Units

Simplified View: Full data sets available to ARtillery Pro subscribers.



Analyst Note: The 2024 decline in non-passthrough VR is due to Meta and Apple's work to standardize and popularize video passthrough. This came at the expense of devices such as PSVR 2, which saw sales declines in 2024.

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*See definitions and examples of each device class earlier in this report.

Segment Drilldown: Mobile AR

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Segment Drilldown: Mobile AR

Going Mobile

Now that we've defined and quantified spatial computing device tiers, it's time to drill down into each, and the subsectors they represent. We'll start here with mobile AR*. This includes a broader look at spending categories beyond the hardware figures examined in the previous section. That includes software, apps, and experiences adopted by both consumers and brands/enterprises. Let's dive in...

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Charting the Spatial Spectrum

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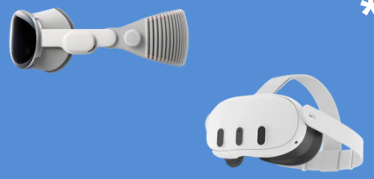
Covered in this Section | Handheld | Headworn

	Mobile AR	Non-Display (AI Glasses)	Flat (3DoF & Floating)	Dimensional (6DoF & SLAM)
Video Passthrough (AR & VR)				 *
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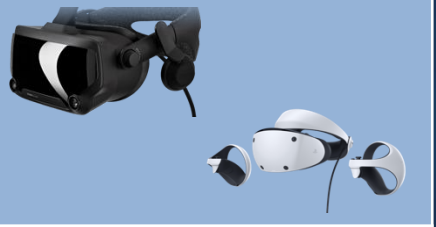
Fully Occluded (VR)			 **	

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**Flat VR (3DoF) is a device class facing extinction (e.g., Oculus Go) in favor of flat AR devices like Xreal One, but it could could see future development.

Segment Drilldown: Mobile AR

Path to Scale

When looking at the spatial spectrum and zeroing in on AR, there are two overarching form factors: handheld and headworn. The former is more colloquially known as mobile AR. Though it isn't AR's endgame nor its fully-actualized self – that designation goes to headworn AR – it does have advantages. The biggest one is scale, or at least its potential for scale.

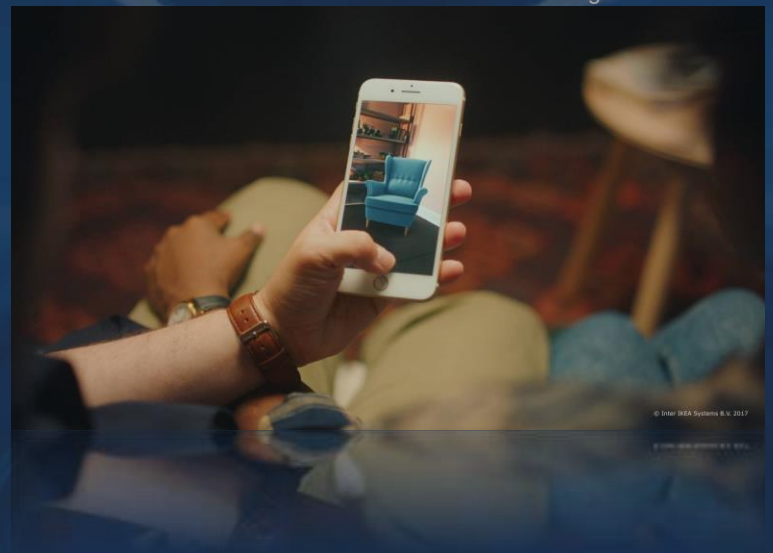
To put some numbers behind that claim, of the **3.6 billion** global smartphones today**, 3.2 billion** are compatible with at least one form of AR, including rudimentary web AR. This ubiquity is not only a path to scale, but a stepping stone: mobile AR acclimates the world to immersive content so that AR glasses can have a softer landing. This goes for consumer demand as well as developers learning to *think spatially.*

Platform Play

Mobile AR doesn't just tap into sheer scale but offers a wide variety of platforms. In other words, it's not just about the volume of AR-ready smartphones but the creation and delivery channels to reach all those devices. To name a few, there are native app development kits for iOS (ARKit) and Android (ARCore). These SDKs democratize and scale AR app creation through ubiquitous operating systems.

Social apps like Snapchat and TikTok have meanwhile gained traction for AR lenses that enhance multimedia sharing. They've correspondingly built free developer platforms to boost lens creation and engagement. Then there's web AR, including platforms like 8th Wall and Zappar, which bring AR to the mobile browser. Web AR advantages include less friction to launch, and amplified reach. Meanwhile, other influential AR platforms are developed by the likes of 8th Wall's owner Niantic (consumer), and PTC (enterprise).

Image Source: IKEA



"It's not just about the sheer volume of AR-ready smartphones, but the creation and delivery channels to reach all those devices."

Mobile AR Global Penetration

AR-Compatible Devices & Active Users, Across Platforms*

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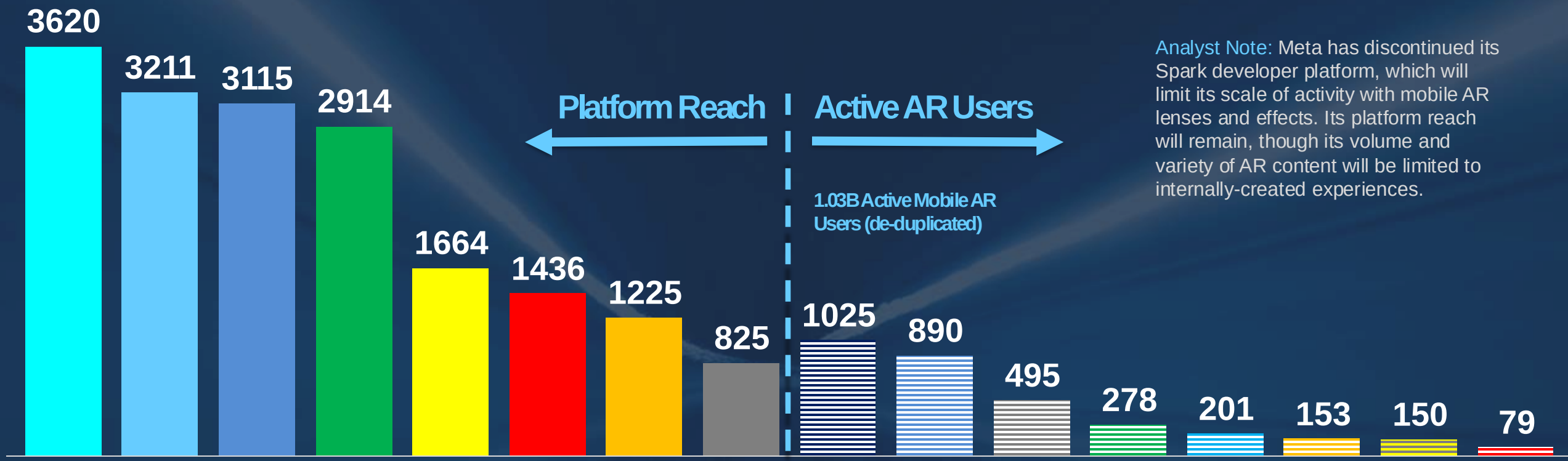

Analyst Note: Meta has discontinued its Spark developer platform, which will limit its scale of activity with mobile AR lenses and effects. Its platform reach will remain, though its volume and variety of AR content will be limited to internally-created experiences.

*Excludes platforms endemic to China.
**Includes iPad.
***Google, Pinterest & Snap (de-duped).
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- Smartphones (of any type)
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- Snap Lenses (Devices)
- Meta AR (Active)****
- ARkit (Active)**

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Segment Drilldown: Mobile AR

Brand Sponsored

In addition to enabling tech and creation tools, some of the players noted previously continue to establish and standardize AR revenue models. For example, one of the most popular forms of consumer AR so far has been interactive lenses that are distributed through social apps like Snapchat and Instagram.

These lenses lend themselves to brand sponsorship and paid distribution – a business model propelled by several factors. Not only is advertising the primary business model for most social players, but AR lenses are naturally conducive to brand-sponsored experiences. This is due to their engagement levels – and the results continue to show in case studies.*

Volume & Depth

As a result, the volume and depth of AR usage have become attractive for brand marketers. For example, branded AR lenses in channels like Instagram and Snapchat let consumers visualize products on "faces & spaces." This involves paid distribution through these apps' content discovery mechanisms and social graphs. Beyond paid amplification, brands can also self-distribute AR marketing through their own apps.

In total, immersive marketing represents one of the leading AR revenue sub-sectors today, with brand spending estimated to reach **$11.8 billion** by 2028 according to ARtillery Intelligence's Global Mobile AR Forecast.** This is a key revenue source for mobile AR given that consumers haven't adopted paid mobile AR experiences en masse, such as buying apps. In other words, most mobile AR experiences are *brand-sponsored* rather than *user-purchased.*

Image Source: Snap

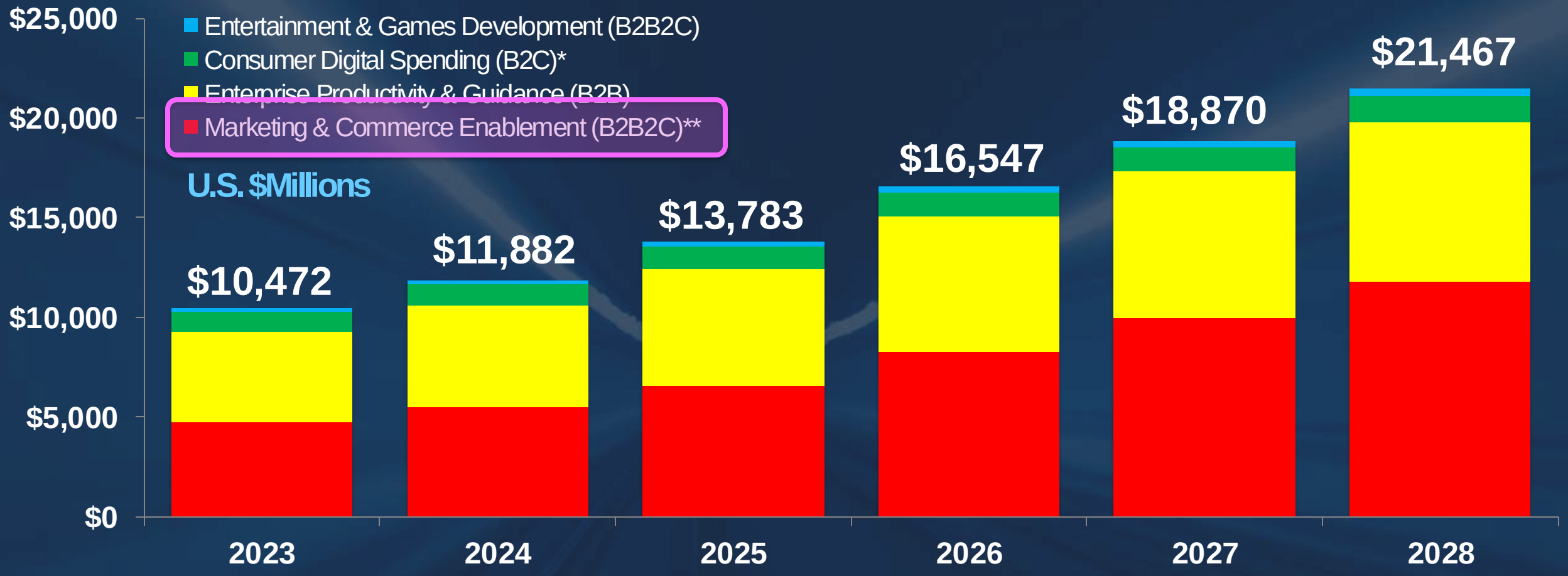
*See ARtillery Intelligence Report: AR Marketing Best Practices & Case Studies, Volume 4.
**See ARtillery Intelligence Report: Mobile AR Global Revenue Forecast 2023-2028.

"Not only is advertising the primary business model for most social players, but AR lenses are naturally conducive to brand-sponsored experiences."

Mobile AR Revenue Overview

Consumer & Enterprise Mobile AR Revenue Estimates, by Source

Simplified View: Full data sets available to ARtillery Pro subscribers.



*Includes digital goods (content, apps & experiences), not physical goods purchased using AR visualization or virtual try-ons.
**Includes software that enables AR-influenced physical-goods purchases, not the transaction value of goods themselves.

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Segment Drilldown: Mobile AR

Shoppable & Transactional

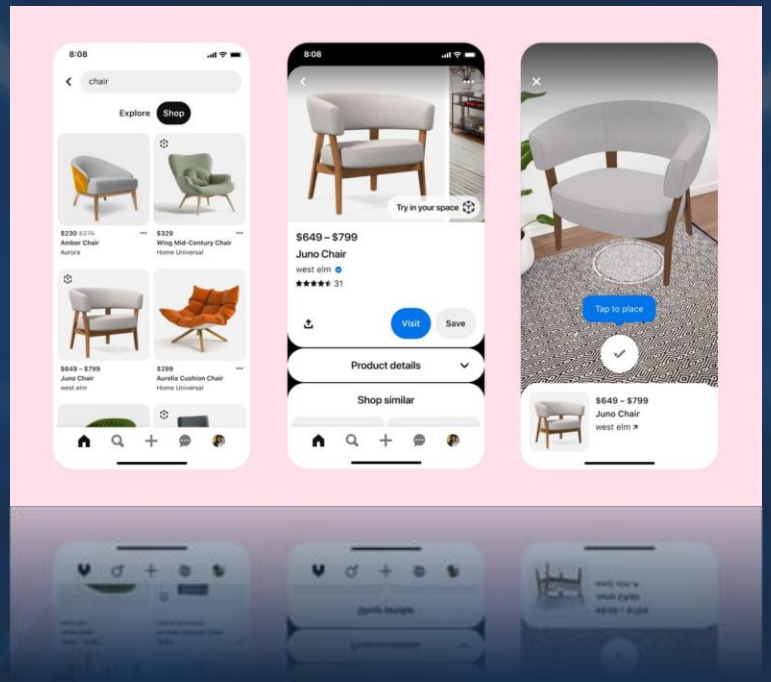
So what's driving all that AR marketing revenue? First, users are demonstrating high engagement with AR lenses to enhance already-popular activities including media-sharing and enlivened selfies. Second, advertisers are attracted to those eyeballs. More specific to AR's advantages, advertisers are drawn to its ability to let them flex creative muscles and transcend 2D media where they've been confined for years. There's also a strong business case shown in ongoing campaign performance metrics,* as noted.

Zeroing in on that last part, AR has the rare ability to span the traditional marketing funnel. It shines in high-reach branding campaigns as well as lower-funnel consumer action such as virtual try-ons. The former has cultivated a shopping use case that brings AR beyond marketing and advertising into the territory of direct-response eCommerce. This aligns AR with several other influential consumer trends underway.

Fashion Inspiration

For example, social apps like Snap, TikTok, and Instagram have become go-to places for fashion inspiration and product discovery. This has in turn led to the social commerce movement, where social feeds are increasingly shoppable and populated with 'buy' buttons. AR has meanwhile come along at the right time to support that behavior. It does so by adding dimension to products through 3D visualization and try-ons. This engenders more confident consumer purchases which lead to higher conversion rates.

Image Source: Meta



*See ARtillery Intelligence Report: AR Marketing Best Practices & Case Studies, Volume 4.

"In social commerce, feeds are increasingly shoppable and populated with 'buy' buttons. AR has come along at the right time to amplify all the above."

Segment Drilldown: Mobile AR

Intent Signaling

Beyond social lenses, a greater opportunity exists with visual search. It lets users point their phones at objects to identify them through informational overlays. This carries strong intent signaling – the same factor that makes web search so lucrative. Google calls it "search what you see." It brings the on-demand utility of web search and puts a visual spin on it. In that way, visual search inherits the virtues of web search, while finding unique and native value that flows from its visual and proximity-based use.

Use cases showing early promise include shopping, education, and local discovery. For example, users can discover new restaurants through their phone's camera, which can be more natural than typing or tapping text into Google Maps.

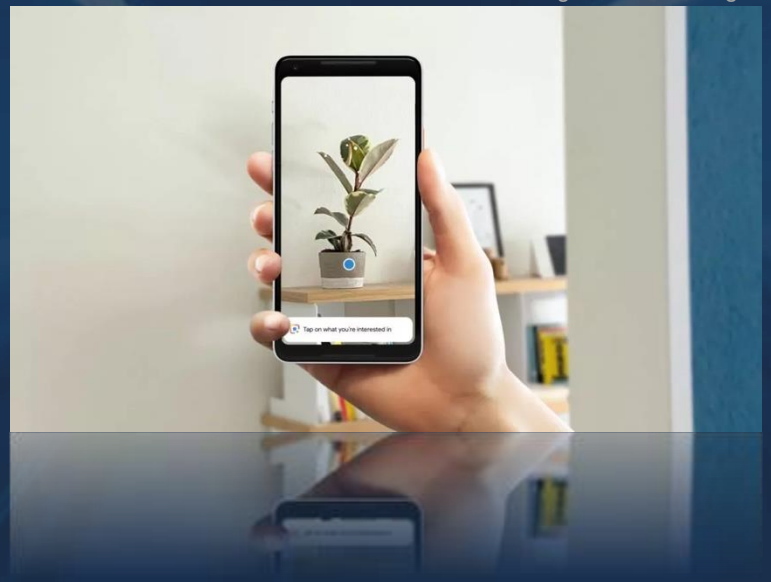
Common Attribute

Across visual search's potential use cases, common attributes include broad appeal and high frequency… again, just like web search. These factors give visual search a large addressable market in *quantity of users* and *volume of usage*. These are key ingredients for killer apps. Meanwhile, these use cases have another

Common attribute: *shopping*. The endgame is monetizable visual searches for shoppable items. Actively holding up one's phone to identify real-world items flows naturally into transactional outcomes… and Google knows it.

Amplifying these benefits is another factor: generation Z. It has a high affinity for the camera to interface with the world. And this will only grow as gen-Z collectively gains purchasing power and phases into the adult consumer population. This makes visual search a strong future-proofing move for Google and others.

Image Source: Google



"The endgame is monetizable visual searches. Holding up one's phone to identify real-world items flows naturally into transactional outcomes… and Google knows it."

Segment Drilldown: Mobile AR

Knowledge Graph

Speaking of future proofing, Google is primed for visual search. Its knowledge graph – built from 25+ years as the world's search engine – engenders a training set for AI image recognition, including products (Google Shopping) general interest (Google Images), and storefronts (Street View). Google is also highly motivated to lead the way in visual search. Along with voice search, it helps the company boost query volume, which correlates to revenue.

As Google drives things forward, ARtillery Intelligence projects that visual search will grow from almost no ad revenue today to **$2.34 billion** in 2028. Though it's under-monetized today – a model that will eventually evolve to mirror sponsored results in web search – it will grow to a leading share of AR ad revenue by 2028.

Influence & Impact

Though Google leads the way in visual search, it's not alone. Snap Scan and Pinterest Lens are visual search tools that map to their parent companies' positioning (think: fashion discovery). But beyond Google the most influence and impact in visual search will come from its latest entrants: Apple and Meta.

Taking those one at a time, Apple unexpectedly integrated visual search into the Camera Control feature in the iPhone 16. Utilizing a new button (rare for Apple) to quickly take photos, it also offers the ability to quickly conduct a visual search. Not only does this expose visual search to Apple-sized audiences but it sidesteps a big bottleneck: *activation energy*. Having to hold up one's phone and tap through several options creates friction.

Natural Form Factor

As for Meta's visual search play, the technology is a central selling point in the breakout-hit Ray-Ban Meta Smartglasses. Known as multimodal AI, this is an advanced form of visual search that lets users query the world through voice and visual inputs (hence "multimodal"). This is not only mainstreaming visual search but does so in a more natural form factor – line of sight glasses. That goes back to the above point about activation energy. Visual search will be a lot more appealing and effective when it's ambient and hands free. As such, smart glasses will be the form factor that unlocks visual search… and AR in general.

We'll pick things up there in the next section...

"Not only does Apple Camera Control expose visual search to larger audiences but it sidesteps a big bottleneck: activation energy."


Video Companion
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Mobile AR Revenue Outlook
ARtillery Briefs, Episode 81
ARtillery Intelligence

Segment Drilldown AR Glasses

ARtillery Intelligence

Drilling Down: AR Glasses

Handheld to Headworn

The previous installment of this report series ended by examining mobile AR. Now we shift focus from handheld to headworn. And we'll start with AR glasses. This category contains the device classes defined earlier as *optical seethrough (dimensional)*, *optical seethrough (flat)* and *non-display smartglasses*. Video passthrough (otherwise known as passthrough AR or mixed reality) conversely includes devices such as Apple Vision Pro and Quest 3, which are examined in a later section on VR.*

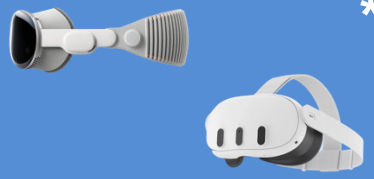
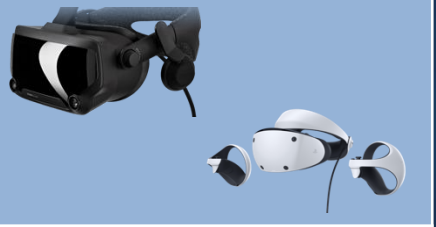
Image Source: Xreal

**To maintain definitional consistency and avoid double-counting in market sizing, devices that perform VR and passthrough AR – also known as mixed reality – are categorized as VR, rather than AR glasses, in this report.*

Charting the Spatial Spectrum

ARtillery Intelligence

Covered in this Section | Handheld | Headworn

	Mobile AR	Non-Display (AI Glasses)	Flat (3DoF & Floating)	Dimensional (6DoF & SLAM)
Video Passthrough (AR & VR)				 *
Optical Seethrough (AR)				
Fully Occluded (VR)			 **	

*Includes VR devices that perform passthrough AR, also known as mixed reality. These are categorized as VR, rather than AR, for the purposes of analysis and market sizing.
**Flat VR (3DoF) is a device class facing extinction (e.g., Oculus Go) in favor of flat AR devices like Xreal One, but it could could see future development.

Segment Drilldown: AR Glasses

AR's Endgame

Though mobile AR – examined in the previous section – is a more penetrated AR form factor, glasses represent the endgame. The headworn form factor will unlock AR's true potential. Until then, AR glasses remain in early stages of development, where they're challenged by critical design dilemmas. Many of these challenges represent deal breakers for consumer markets, such as device bulk, heat and cost.

Subdivisions & Spectacles

To further define the AR glasses landscape, there are various subdivisions. At one end of the spectrum is *dimensional AR* represented by Snap Spectacles and Meta Orion. This is AR's most immersive modality, but it involves higher cost and hardware bulk.

Elsewhere in the AR hardware spectrum is *flat AR*. These are mid-range devices that dial down the optical complexity to gain wearability. Devices like Xreal One offer private immersive viewing for flat content such as movies and 2D games. Though less immersive, private big-screen viewing with familiar formats resonates with consumers,* especially if it comes in a cheaper lighter, and more stylish vessel.

Increasingly Influential

Lastly, we have *non-display AI glasses*. These involve information via audio cues, as seen in Ray-Ban Meta Smartglasses. Here, the value of the UX lies not with its graphical complexity nor dimensionality but rather the personal relevance of the information delivered.

That last part is critical and leans on an increasingly influential AR value driver: AI. In order to truly deliver relevant information – thus making up for the lack of graphical richness – AI-driven personalization is applied. We're talking social signals (are my friends nearby?), interest-graph signals (where is the closest coffee shop?) and commerce signals (where do I buy that jacket?).

Image Source: Meta

"AR is in early stages of development, where it's challenged by a set of key design dilemmas that are deal breakers for consumer markets."

*See ARtillery Intelligence Report: VR Usage & Consumer Attitudes, Wave 8.

Segment Drilldown: AR Glasses

By the Numbers

Adding up all the AR glasses categories outlined on the previous page, they're projected to grow in unit sales from **460,000** in 2023 to **1.76 million** by 2028. That compares with VR's estimated unit sales growth from **6.38 million** units in 2023 to **9.90 million** in 2028 (see later section). Meanwhile, both device classes are collectively dwarfed (83-1) by the global smartphone installed base of **3 billion+** units.

To clarify the above AR and VR unit sales estimates, Apple Vision Pro is included in the latter. This is to maintain definitional consistency in placing it in the same category as devices with similar passthrough video capabilities such as Meta Quest 3. These devices are examined in the VR section of this report.

Image Source: Meta

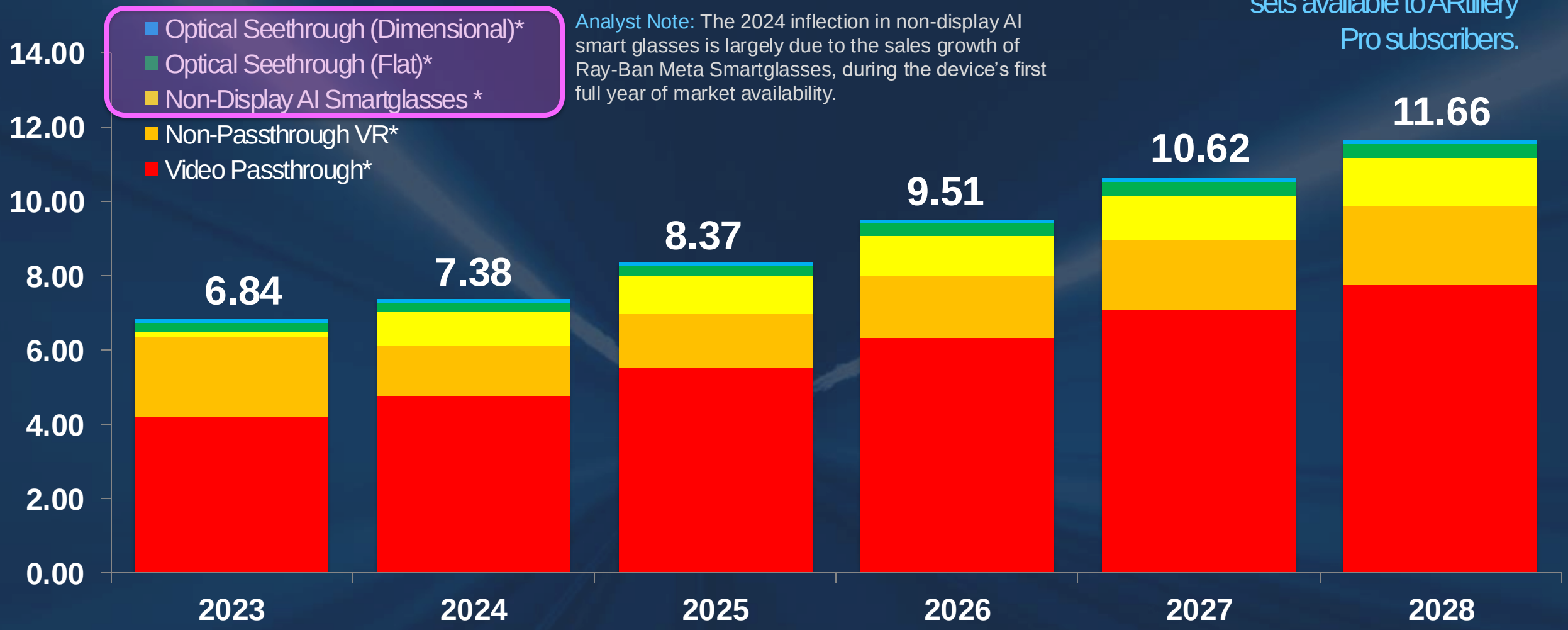
ARtillery Intelligence

Headworn XR Devices

Annual Hardware Unit Sales Estimates, by Device Class

Millions of Units

Simplified View: Full data sets available to ARtillery Pro subscribers.



Analyst Note: The 2024 inflection in non-display AI smart glasses is largely due to the sales growth of Ray-Ban Meta Smartglasses, during the device's first full year of market availability.

*See definitions and examples of each device class earlier in this report.

ARtillery Intelligence


Video Companion
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Headworn AR Revenue Outlook
ARtillery Briefs, Episode 84
ARtillery Intelligence

Meta Orion: The High-Water Mark

The High End

Going deeper into AR glasses subdivisions, we'll start at the high end: *dimensional AR*. This category is best represented today by Meta Orion. In fairness, we should preface any analysis with the fact that Orion is a working prototype rather than a product with a foreseeable release date. Meta first must bring down the $10,000 bill of materials (more on that in a bit).

That said, Orion can be reasonably described as the most advanced form of AR the world has yet seen. Highlights include the device's waveguide-based optical system with a micro-LED display and silicon-carbide lenses. That last part is the most expensive component and what enables a sizable 70-degree field of view (FOV) – Orion's most noteworthy UX attribute. It outmatches any AR headset on the market, and goes a long way in not breaking the illusion by cutting off digital objects at the margins.

Dimension & Utility

As for intended use cases, Orion was designed with specific AR activities in mind. These include holographic use cases as well as AI-based use cases. Taking those factors one at a time, holographic AR is the format that most people associate with AR. It's the dimensional interactions of digital objects in physical space. AI-driven activities meanwhile include contextualizing physical objects and spaces with informational overlays. This can include actions like live language translation or recipe suggestions.

These are the AI-driven use cases that Ray-Ban Meta Smartglasses (RBMS) are known for. But the idea with Orion is that it will handle all those functions *plus* visual content. All those AI functions – though valuable in RBMS through audible output – gain UX dimension and utility with visuals. After all, some things are better seen than heard, such as following a recipe.

Image Source: Meta

"AI-driven activities include identifying physical objects with informational overlays or other processing. This can include actions like live language translation or recipe suggestions."

Meta Orion: The High-Water Mark

Thought Exercise

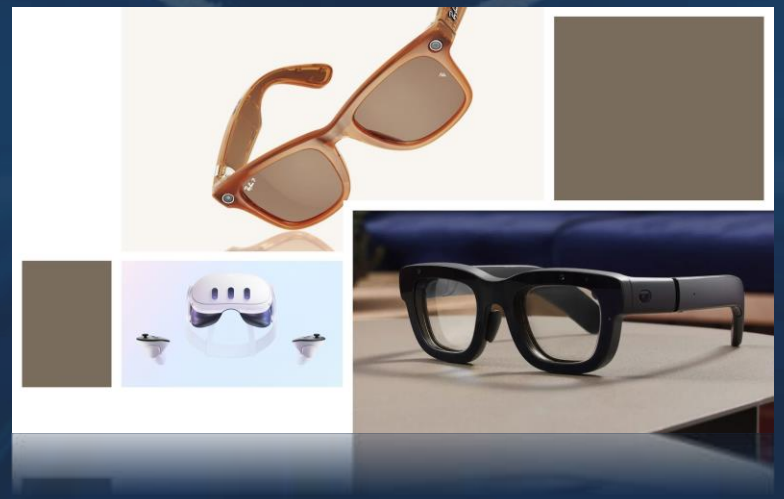
Stepping back, the entire analysis on the previous page is more of a thought exercise until Orion actually reaches the market. For that to happen, it must come down from $10,000 per unit, as noted. Though Meta Quest headsets are known for loss-leader pricing, there's a limit to how much money a device can lose. Or how much you can charge for it. It could take years for Orion to reach tenable levels on both measures.

It's also important to note that as this cost-cutting process unfolds, the eventual device will look different than today's Orion prototype. Meta has noted that its goals include higher resolution, higher brightness, and lower cost. To do this, a key tradeoff will likely be to remove the silicon carbide lenses which enable the lauded 70-degree field of view. These measures will achieve lower cost and about half the weight, which brings them into "all-day wearable" territory.

Many Horses

The underlying point is that the device Meta showed the world – though a feat of engineering – is not what we'll end up with. That should be remembered by anyone calling Orion a "Vision Pro killer" – a common refrain in the wake of Orion's unveiling. One of these devices is available today. The other is not.

In fairness, though Orion is a prototype, Meta should get credit for investing billions of dollars to accelerate AR's future; and giving us a glimpse of what it could look like. Meanwhile, Ray-Ban Meta Smartglasses are here today. This lets Meta cover both ends of the AR spectrum. Somewhere between those endpoints are Quest 3 and 3S, including passthrough AR functionality (see VR section). Altogether, Meta is betting on many horses and timelines. It's achieving realistic XR products today, while developing the right muscles to battle in tomorrow's competitive landscape.



"The device Meta showed the world – though a feat of engineering – is not what we'll end up with. That should be remembered by anyone calling Orion a 'Vision Pro killer' – a common refrain."

Device Spotlight: Snap Spectacles

Causing a Spectacle

Sticking with high-end dimensional AR, another innovative and standards-pushing device has hit the market: Snap Spectacles. We were there at Snap Partner Summit when it was unveiled and were given a pre-briefing and demo several weeks earlier. So to provide a representative sample of today's AR glasses innovation in this report, we'll dive deep into Spectacles' specs, strategy and market opportunity.

As quick background, Spectacles' first three generations were camera glasses while the last two, including this fifth generation, are AR glasses with display systems. It should also be noted who this device is meant for. Like Gen 4, it will only be sold to developers. At $99/month, the point is to get it into their hands first to build up a base of experiences that make headworn AR attractive to consumers en masse. Snap knows we're not there yet.

Design Decision

On to the device itself. It weighs 226 grams and employs an LCoS display system with a 46-degree field of view (3x that of Gen-4) and 37 pixel-per-degree resolution. It has a 45-minute battery with plug-in power for developers (again, the target user) doing desk-based work. It also has a Snapdragon dual SoC for distributed heat and weight, with each processor handling separate functions (optics, inputs, etc.). This design choice avoids split processing that requires a tethered phone. True to Snap's persona, it's going for socially-active use cases.

But perhaps the most notable thing about Spectacles is its operating system. This marks the debut of Snap OS, which handles core functions like spatial understanding and hand tracking (more on those in a bit). That way, developers can tap into established functions and focus instead on their creations.

Image Source: Snap

"The most notable thing about Spectacles is its operating system. This marks the debut of Snap OS, which handles core functions like spatial understanding and hand tracking."

Device Spotlight: Snap Spectacles

Vertically Integrated

All the above – especially Snap OS – makes Spectacles Gen 5 vertically integrated. And that shows throughout the UX. Positional tracking and plane detection are tight, while visuals are dimensionally accurate and properly occluded. Object interactions feel natural. The UI is also built around hand tracking. With the exception of using your phone as a tracked controller – such as a full-swing golf game we demoed – hand interactions rule. The UI is fairly slick and intuitive, including depth understanding (think: reaching for faraway objects).

Inherently Social

The glasses were comfortable to wear for the extent of our hour-long demo, with frames that have a malleable rubber mantle that will be forgiving to a range of head sizes. Battery life is relatively short but it should work for Spectacles' developer-intended use cases. Another deliberate design decision was to engender multi-user interaction. Snap's DNA is inherently social after all. To that end, Snap OS emphasizes spatial anchoring so several users can simultaneously and naturally experience digital elements, such as a chess game.

Speaking of social interaction, another factor that defines Spectacles is a portrait-oriented field of view. This is not only due to an established lens-based design language but practicality. In other words, a field of view that's "taller" is purpose-built for a deliberate subject: people. Again, social interaction is a north star… and humans are built vertically. That contrasts AR hardware like Xreal Air 2, built for lean-back entertainment and thus fitting to a landscape FOV.

We'll pause there and move on to other topics. For our full review & analysis, see ARtillery Intelligence report, *Slim & Slam: The Long Road to AR's Holy Grail*.

Image Source: Snap

"A field of view that's 'taller' is purpose-built for a deliberate subject: people. Again, social interaction is a north star for Snap… and humans are built vertically."

Analysis: Flat AR

Flat & Floating

The past several pages – including Meta Orion and Snap Spectacles – focused on higher-end AR glasses, or what we described earlier in this report as *dimensional AR*. Now we move down market to *flat AR*. These are seethrough AR glasses with display systems. However, the content involves flat or floating overlays, such as screens for gaming, entertainment, or productivity. 2D virtual screens are mirrored from one's PC, smartphone or gaming console, earning these devices the nickname "display glasses."

Master of None

The appeal of these display glasses is to access large virtual screens in a private, immersive environment. In fact, this use case is in greatest demand according to ARtillery's consumer XR surveys.* This affinity is driven by consumer comfort levels. In other words, more advanced forms of immersive AR and VR are technically more experientially rich… however consumers want what they know. Until more immersive forms of AR reframe their thinking – and come down in price – consumers will largely opt for simpler display glasses. They offer immersive versions of activities that consumers are already comfortable with. In addition to broader and more relatable appeal, display glasses often carry another advantage: *focus*. Because they sidestep AR's more dimensional and technically-challenged formats, they can be more focused and purpose built. They do one thing and do it well. This is what we've seen so far in devices like Xreal One and its virtual displays for entertainment and other purposes noted above. This deviates from traditional approaches, such as Magic Leap's AR devices, that try to do everything – which results in a "jack of all trades, master of none," dynamic.

Massive Markets

Lastly, all the above boils down to other practical advantages: cost and size. Being purpose-built for screen mirroring and virtual displays – a single use case – lets these glasses achieve lower price points, which further boosts their mainstream appeal. It could be argued that this "single use case" narrows the addressable market for flat AR glasses. However, if that focused use case has a big enough market on its own, it can be a prudent strategy. And that's indeed the case with flat AR, as entertainment, gaming and productivity are collectively massive markets. Xreal's market success so far validates this strategy.

*See ARtillery Intelligence Report: VR Usage & Consumer Attitudes, Wave 8.

"Because display glasses sidestep AR's dimensional and technically-challenging formats, they can be more focused and purpose built. They do one thing and they do it well."

Analysis: Non-Display AI Glasses

Sleek & Light

Stepping further down the spectrum of visual augmentation, we move on to *non-display AI glasses*. As noted earlier in this report, these involve smart glasses that deliver information and augment experiences via audio. AI meanwhile unlocks a level of utility that compensates for the lack of visual experiences. That includes personal alerts, social signals, shopping & commerce, and real-world object recognition. Limiting reliance on visuals in these ways enables style and wearability. Devices are often sleek and light, resembling normal eyewear. This has propelled their commercial success so far.

Experiential Centerpiece

This device class is best exemplified in the breakout hit Ray-Ban Meta Smartglasses. A big leap from the device's first generation, it carries impressive specs and effective execution of audible augmentation. As such, it sets the bar for headworn devices that are supported by AI. Specifically, multimodal AI applies camera-based visual recognition along with voice refinements (e.g. "What am I looking at?") to return audible answers. This is a sophisticated form of visual search – an AR use case we examined earlier.

Altogether, RBMS is the embodiment of AI's role as a force multiplier in AR. It can replace visual augmentation as an experiential centerpiece. Or, as Mark Zuckerberg said when launching Ray-Ban Meta Smart Glasses.

> *"Before the last year's AI breakthroughs, I kind of thought that smart glasses were only really going to become ubiquitous once we really dialed in the holograms and the displays, which we are making progress on but is somewhat longer. But now I think that the AI part of this is going to be just as important in smart glasses being widely adopted as any of the augmented reality features."*

Image Source: Meta

> ***"Ray-Ban Meta Smartglasses are the embodiment of AI's role as a force multiplier in AR. It can replace visual augmentation as a selling point and experiential centerpiece."***


Video Companion
(Click Here to Play)
Smart Glasses:
A New Hope
for AR?
ARtillery Briefs, Episode 86
ARtillery
Intelligence

Analysis: Enterprise AR

Effective & Efficient

Everything examined so far in this report has a consumer-heavy focus in terms of products, proposed use cases, and overall context. But one downside of consumer markets is the design dilemma that we've discussed throughout this report: it's difficult to balance a robust UX with style and wearability.

While these challenges are being hammered out, AR glasses have found some traction in the enterprise. This includes industrial functions where AR's line-of-sight guidance makes enterprises more effective and operationally efficient.* In these environments, AR glasses' style crimes aren't the same deal breaker that they can sometimes be in consumer markets.

Mental Mapping

Led by tools such as PTC Vuforia and Scope AR, remote collaboration, industrial support, and other valuable functions can be enabled. The scale and impact of such deployments will also be meaningful as AR continues to span enterprise verticals and environments – everything from corporate settings to industrial factory floors. To illustrate these scenarios further, in key functions like industrial assembly and maintenance, AR can expedite task completion and reduce errors. It accomplishes these ends by lessening cognitive load from "mentally mapping" 2D instructions to 3D space. There are several macro benefits too, such as retaining and disseminating institutional knowledge. Drilling down on the latter, it's all about mitigating knowledge loss from seasoned personnel retiring. Because baby boomers are retiring at a greater pace, it's getting harder to retain institutional knowledge – an expensive problem for industrial enterprises.

Image Source: Microsoft

*See ARtillery Intelligence Report: Enterprise AR Best Practices & Case Studies, Volume 4.

"Headworn AR has found traction in the industrial enterprise. In these settings, AR glasses' style crimes aren't the same deal breaker that they can sometimes be in style-conscious consumer markets."

Analysis: Enterprise AR

By the Numbers

For all the reasons on the previous page, ARtillery Intelligence has estimated that spending on AR glasses-based enterprise productivity will grow from **$1.69 billion** in 2023 to **$3.83 billion** in 2028, a **17.7 percent** compound annual growth rate.

Practical & Logistical

But even though AR boasts these advantages, it's easier said than done to execute. Practical and logistical barriers stand in the way – such as organizational inertia, politics, change management, and fear of new technology among key stakeholders. For example, the biggest stumbling block for enterprise AR is the dreaded "pilot purgatory." This is when AR is adopted at the pilot stage but never progresses to full deployment. It's the biggest pain point in industrial AR, and there are many reasons for it…most of them cultural.

An ARtillery Intelligence report in 2024 featured several case studies,* including tactics for avoiding pilot purgatory. An upcoming report will advance the narrative with a fresh batch of case studies that represent the latest challenges and strategies in enterprise AR. These case-study-driven reports will be an annual exercise, currently in Volume 5.

Image Source: Unity

*See ARtillery Intelligence Report: Enterprise AR Best Practices & Case Studies, Volume 4.

"Though AR holds advantages, it's easier said than done to execute. Practical barriers stand in the way such as politics, organizational inertia and change management."


Video Companion
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Enterprise XR
Best Practices &
Case Studies
ARtillery Briefs, Episode 85
ARtillery
Intelligence

Segment Drilldown: VR

ARtillery Intelligence

Segment Drilldown: VR

Virtual & Visceral

After covering AR's main modalities, we now switch gears to VR. Like we examined for AR glasses, there are several subdivisions in VR. These include the device classes defined earlier in this report as *video passthrough* and *non-passthrough VR*. Video Passthrough – otherwise known as passthrough AR or mixed reality – includes devices such as Apple Vision Pro and Quest 3. The former is sometimes categorized as AR, but we're classifying it as VR starting in 2025 due to its functional alignment with VR devices such as Meta Quest 3.* Let's dive into the dynamics & delineations.

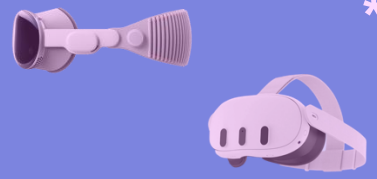
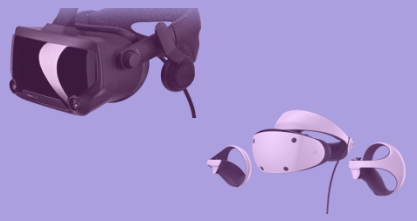
Image Source: Meta

**To maintain definitional consistency and avoid double-counting in market sizing, devices that perform VR and passthrough AR – also known as mixed reality – are categorized as VR, rather than AR, in this report and going forward.*

Charting the Spatial Spectrum

ARtillery Intelligence

Covered in this Section | Handheld | Headworn

	Mobile AR	Non-Display (AI Glasses)	Flat (3DoF & Floating)	Dimensional (6DoF & SLAM)
Video Passthrough (AR & VR)				 *
Optical Seethrough (AR)				
Fully Occluded (VR)			 **	

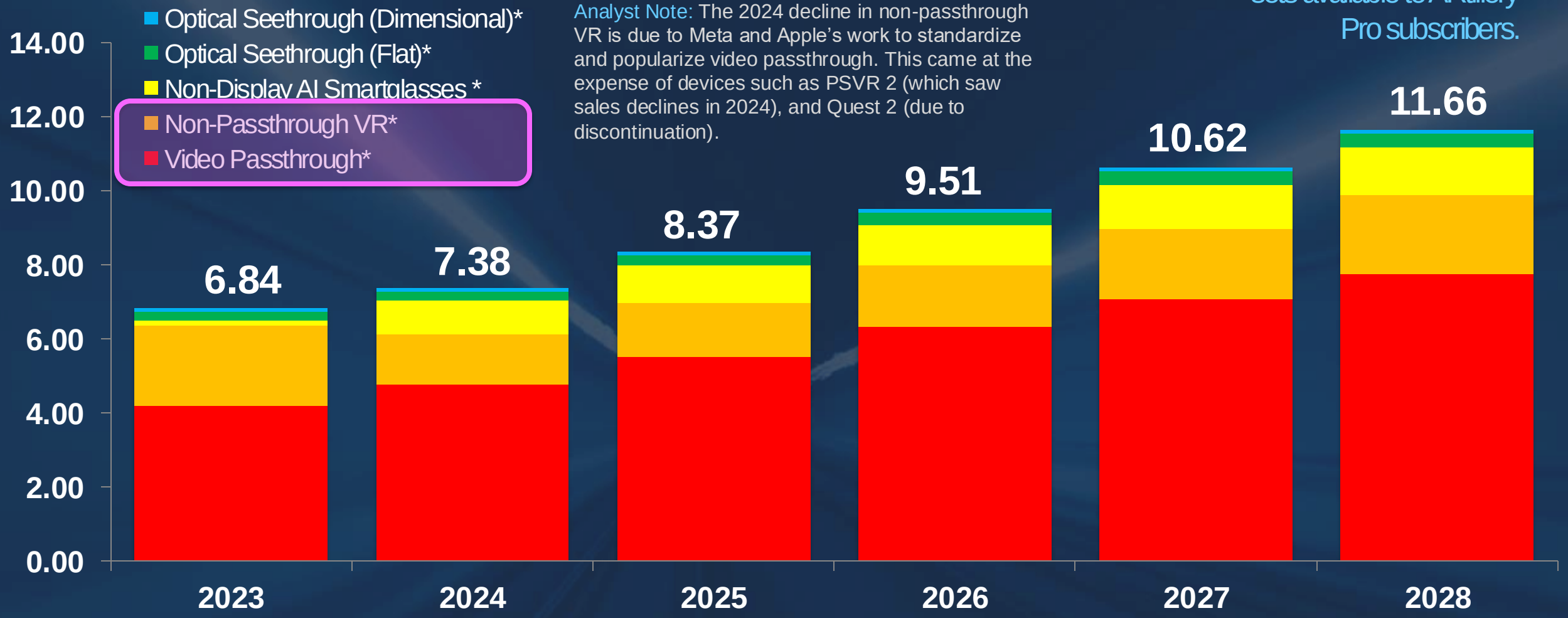
*Includes VR devices that perform passthrough AR, also known as mixed reality. These are categorized as VR, rather than AR, for the purposes of analysis and market sizing.
**Flat VR (3DoF) is a device class facing extinction (e.g., Oculus Go) in favor of flat AR devices like Xreal One, but it could could see future development.

Headworn XR Devices

Annual Hardware Unit Sales Estimates, by Device Class

Millions of Units

Simplified View: Full data sets available to ARtillery Pro subscribers.



Analyst Note: The 2024 decline in non-passthrough VR is due to Meta and Apple's work to standardize and popularize video passthrough. This came at the expense of devices such as PSVR 2 (which saw sales declines in 2024), and Quest 2 (due to discontinuation).

*See definitions and examples of each device class earlier in this report.

ARtillery Intelligence


Video Companion
(Click Here to Play)
VR Revenue Outlook
ARtillery Briefs, Episode 87
ARtillery Intelligence

Segment Drilldown: VR

Just Around the Corner

VR is a promising technology whose mainstream embrace always seems to be just around the corner. Though it has applicability to entertainment, gaming, and some enterprise functions, it's not the computing revolution that was heavily touted almost a decade ago. Its broad adoption continues to be challenged.

That said, VR has some bright spots. Hardware and software revenue is projected to grow from **$11.02 billion** in 2023 to **$19.75 billion** in 2028, a 12.37 **percent** compound annual growth rate. Much of this is driven by Meta's investments, including billions in quarterly R&D spend. This buys the company a technological edge. Its investments also involve subsidizing hardware through a loss-leader approach that stimulates a larger installed base. That in turn works toward a network effect and attracts reach-driven content creators.

Ups & Downs

To that last point, one factor that makes or breaks a given VR platform is content availability. Meta continues to invest in content by attracting developers to a larger hardware base as noted, as well as acquiring VR publishers and game studios. The latter injects cash into content creation and incentivizes content creators to enter the market – and venture funding to fuel them – through exit potential.

Meanwhile, the VR market has seen mixed results. Quest 3 and 3s continue to show strong signs, as does the broader mixed reality category that they represent. But we've seen declines in non-passthrough VR, such as PSVR 2. Though its predecessor was a VR leader, and its launch started strong, its sales declined considerably over 2024.

Image Source: Meta

"Though VR has applicability to entertainment, gaming, and some enterprise functions, it's not the revolution in computing heavily touted almost a decade ago."

Segment Drilldown: VR

Formidable Contenders

Though Meta continues to lead the way in VR – as its investments accelerate and define the VR landscape – there are other notable players. They include Valve Index in PC VR. And in the standalone category, competing with Quest 3 and Quest Pro, is the venerable VIVE XR Elite. With high-definition cameras for color passthrough AR, it's a formidable contender in the increasingly-prevalent mixed-reality segment. The same can be said for Apple Vision Pro, though it deserves its own drilldown (more on that soon).

Bridge to AR

Speaking of mixed reality, among the events in the VR scene over the past two years, the standout product launch was likely Meta Quest 3. It uplevels Quest 2's specs across the board and is more importantly a bridge toward Meta's AR ambitions. It accomplishes this through color passthrough cameras that display the outside world, like Vision Pro and others do.

This approach embodies Meta's spatial computing evolution, which spans VR and AR. Most of its focus has been on the former but it's increasingly tackling the latter. This involves a three-track approach. The first track occurs through non-display AI glasses a la Ray-Ban Meta Smartglasses (as examined in the previous section on AR glasses). The second track involves advanced dimensional AR in optical seethrough glasses, a la Orion (also explored in the previous section). The third track is where we pick things up in this section: passthrough AR in Meta's VR flagships. In that sense, Quest 3 represents an emerging class of mixed reality devices that accelerated in 2024; and will continue to evolve and gain market share in 2025.

Image Source: HTC

"This multi-track approach embodies Meta's spatial computing evolution, which spans VR and AR. Most of its focus has been on the former but it's increasingly tackling the latter."

Analysis: Mixed Reality

Occluded & Insular

Going deeper into mixed reality and video passthrough functionality, this capability continues to define today's VR standards. To pause and define mixed reality, it utilizes passthrough cameras to bring the outside world into VR. Characterized by Quest 3, Vive XR Elite and Apple Vision Pro, to name a few, mixed reality is becoming a primary feature in VR.

One advantage of mixed reality is that it broadens VR's appeal and use cases, including experiences that interact with the physical world as opposed to being occluded and insular. These expanded use cases include everything from workplace productivity (think: floating virtual monitors), to gaming that interacts with one's space (think: tables and floors).

Accelerate & Expose

Beyond offering a more comprehensive set of VR use cases, mixed reality's list of advantages includes elevating AR, as noted. In other words, the byproduct of mixed reality's rise will be an acceleration in headworn AR exposure. This will happen as AR piggybacks on – and is incubated within – the more popular and penetrated VR format. As a result, more consumers will get a taste for headworn AR, and many will turn into AR converts.

Moreover, video passthrough has some advantages over over the primary AR format in AR glasses: optical seethrough (examined in the previous section). Though video passthrough isn't AR's endgame nor ideal self – due to bulkier hardware that precludes all-day wearability – it offers a few technical benefits.

Image Source: Meta

"One advantage of mixed reality is that it broadens VR's use cases, including experiences that interact with the physical world as opposed to being occluded and insular."

Analysis: Mixed Reality

Full Control

Among video passthrough's advantages, it offers full control of every pixel of a VR display. This means greater definition, contrast, and field of view. See-through AR is conversely bound by physics such as manipulating (and often losing) light through waveguides and optical combiners. And because the background in optical seethrough AR is the physical world, it's difficult to recreate the color black as you can with pixels on a display – especially if OLED – leading to low contrast and washed-out images. Features like local dimming help when competing with natural light, but several physical challenges persist.

Addressable Market

As noted, the mixed-reality torch is being carried by Meta, given the positioning and priorities seen in Quest 3 and 3s. But to be fair, Meta isn't the first to market passthrough AR. Hardware from Varjo for example (see XR-4) has been available for years, with high-quality color passthrough AR.

But Meta's entrance – propelled by its signature loss-leader pricing – has introduced the *element of affordability*, as noted earlier in this report. The practical result is to bring mixed reality to a wider addressable market. This is where AR's accelerated exposure noted on the previous page will factor in, given Meta's greater mainstream reach.

Another practical outcome is that Meta has established a new standard with mixed reality. Given its influence on the VR market, we've predicted in the past that it will make mixed reality table stakes in VR. In other words, as consumers get a taste for mixed reality, it will be difficult for other VR players to compete without it.

Image Source: Varjo

"Meta isn't the first to market with passthrough AR. But its entrance – propelled by its signature loss-leader pricing – has introduced the element of affordability."

Analysis: Apple Vision Pro

Game Plan

Beyond Meta, HTC and others noted in the preceding pages, one can't invoke mixed reality without acknowledging Apple Vision Pro (AVP). In fact, much of the preceding mixed-reality analysis applies to AVP, however it will stand on its own at the high end. But the device should be seen as only a first step towards Apple's spatial computing long game. Apple even admits that it's not a "mass-market product" today.

Stepping back, Apple's motivation with AVP is to vault its core hardware business in the face of a maturing smartphone market. To that end, its game plan these days is all about revenue diversification. As smartphones reach maturity and revenue deceleration, the company must find other ways to maintain revenue growth, and do so at massive scale.

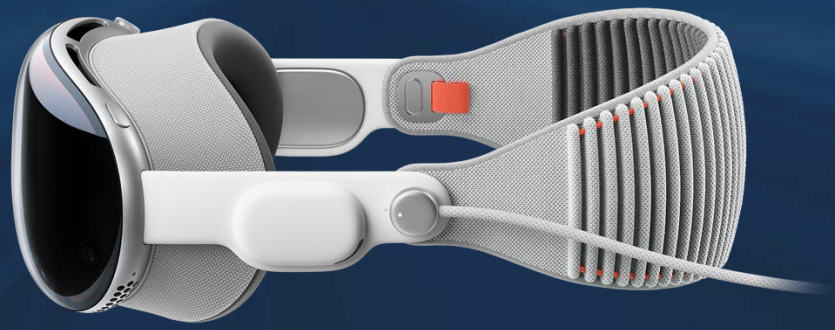
This is the main objective for Apple's wearables and services divisions. And AVP feeds into both. For wearables, revenue each quarter mostly offsets year-over-year iPhone revenue declines. Services (e.g., Apple TV+) meanwhile reached **1-billion** users in 2023, with revenues that continue to offset iPhone revenue declines. Consequently, wearables and services hold a great deal of importance, investment, and political capital in Cupertino.

Sensory Experience

So how does AVP align with that wearables play? The device will sync with sensory experiences in Watch and AirPods. Visuals will join spatial audio and biometrics (think: immersive fitness). And Apple's signature ARPU-boosting ecosystem approach incentivizes you to buy several devices for continuity.

For example, Apple has developed a finger pinch to control Apple Watch. This is suspiciously similar to the primary gestural input for AVP, suggesting that Watch will be an additive companion device. Similarly, AirPods' spatial audio has been upgraded for low-latency use cases. And the iPhone 15 records spatial video for stereoscopic playback on Vision Pro.

Image Source: Apple



"Apple Vision Pro should be seen as only a first step towards Apple's spatial computing long game. Apple even admits that the device is not a 'mass-market product' today."

Analysis: Apple Vision Pro

Immersive Capacity

But one question that continues to loom over AVP – as with any early tech product – is what's its main draw and primary function? This is otherwise known as a killer app, and they often take years to develop. Meanwhile, some clues can already be seen in the use cases that Apple has put forward in its AVP unveiling. For example, productivity & collaboration, capturing memories (a la spatial video), and entertainment will be central use cases. Entertainment includes private immersive viewing environments, such as at home and in-flight gaming & cinema.

Financial Obligation

That brings us back to Apple's broader goals and long-game. Entertainment is a Vision Pro use case that aligns with Apple's expanding content and subscription businesses, which in turn aligns with its revenue-diversification imperative noted on the previous page. It's also a use case that everyone can understand. That *approachability* underpins almost everything Apple releases. Why? It has a financial obligation to reach massive markets to maintain revenue growth at such a large scale. This is a common challenge among tech giants and the markets they choose to enter (think: Amazon and healthcare).

Furthermore, Apple – as it often does – has been waiting and watching the AR sector for the past several years and observing its mistakes. And one of the biggest mistakes has been AR's tendency to get stuck in techy territory, including esoteric messaging and acronyms. So when looking for killer apps to drive Vision Pro's demand – besides the appeal of its sheer gadgetry – an elite entertainment experience was a natural choice.

We'll pause there and move on to other topics. For our full review & analysis, see ARtillery Intelligence report, *Slim & Slam: The Long Road to AR's Holy Grail*.

Image Source: Apple

"Apple has a financial obligation to reach massive markets to maintain revenue growth at such a large scale. This is a common challenge among tech giants and the markets they enter."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AI: The Force Multiplier

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AI: The Force Multiplier

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Tech Fabric

AI has already been mentioned several times in this report. And that editorial orientation reflects its reality: it won't be a standalone phenomenon but rather integrated throughout technology sectors, including spatial computing. Think of that like smartphones. In the first few years of the smartphone revolution, they were a standalone topic and the focus of large conferences, industry associations, and publications. Now they're just a mundane part of the tech fabric. They're plumbing.

Until that point of maturity comes in AI's lifecycle, the technology is noteworthy as a standalone topic, and for its many points of entry into the spatial computing world. We've mentioned a few of them, but let's take the chance here to synthesize them all in one place. We'll bisect these opportunities between user-facing and developer/creator/enterprise-facing AI.

Critical Component

Starting with consumers, AI will be a force multiplier in VR and AR (especially the latter) as it will serve as the brains of the device. There are several ways it will do this in the typical AR user experience, but a few examples include generating AR content (e.g., lenses) on the fly using text prompts. This brings AR from something that's pre-ordained to a more open-ended and serendipitous set of potential experiences. And we're already seeing hints of this vision, such as Snap's work in Lens Studio 5.0 and Live Lenses.

Also on the consumer end, AI will serve as a digital assistant for intelligent and ambient AR. This includes making you smarter about your surroundings (e.g., visual search and multimodal AI), or controlling experiences through voice. The latter is relevant given headworn AR's lack of physical inputs. AI-enabled voice assistance will be a critical component.

Heavy Lifting

Lastly, moving on to the creator/developer-facing possibilities, generative AI has the potential to streamline creator workflows. This includes generating 3D models through text prompts – we call it *generative XR* – as well as working as a co-pilot to automate several rote and time-consuming aspects of XR experience creation. Already seen in tools such as Snap's GenAI Suite, this frees up creators to divert and deploy their valuable time and skills to their requisite intellectual and creative heavy lifting.

"AI will be a force multiplier in VR and AR (especially AR) as it will serve as the brains of the device. It will play the role of digital assistant for intelligent and ambient AR use cases."

Final Thoughts: The Next Ten Years

ARtillery Intelligence

Final Thoughts: The Next Ten Years

Purpose Built

This report examined several device classes in the "spatial spectrum." They include everything from passthrough video headsets to optical AR glasses and non-display AI glasses. But these delineations aren't meant to signal that there will be winners and losers among formats. There's a tendency in the tech press to name everything as an 'xyz killer.' For example, a common but misguided refrain is that Meta Orion is an Apple Vision Pro Killer.

There will rather be several competitors as diverging formats coexist and map to an expanding range of spatial computing use cases. Indeed, the reason the spatial spectrum continues to diverge and diversify is because devices are evolving to be *purpose built*.

Common Attitude

To tug a bit more on that thread, we'll illustrate it with an anecdote. During Snap's recent Partner Summit, we moderated a panel discussion about Spectacles, which had just been unveiled moments earlier (see our device review earlier in this report). One audience question stood out: Why did Snap choose an optical seethrough approach after Apple and Meta have both chosen and validated video passthrough approaches?

The question represented a common attitude towards binary winners and losers. Even in thoughtful XR circles, there's a bit of a consensus that passthrough AR is attractive today, but an eventual dead end. The thought is that it has optical advantages, as examined earlier in this report, but seethrough AR wins in the long run due to wearability and social acceptability.

Though this linear construct has merit, we foresee parallel evolutionary paths, where development and deployment for each modality are use-case-driven. Video passthrough and optical seethrough will coexist, while applied to the functions and use cases where they respectively outperform.

Image Source: Meta

"There will be several winners as diverging formats that coexist and map to various use cases. XR devices will diverge and diversify as they evolve to be purpose built."

Final Thoughts: The Next Ten Years

Parallel, Not Sequential

To expand on those use cases and how they map to XR formats, let's look at video passthrough versus optical seethrough. Video passthrough is more effective for lean-back entertainment, given its display performance, field of view, high contrast, and full-pixel control. Optical seethrough is better suited for socializing, driving, situational presence, or generally being seen in public. That last part is why AR proponents consider optical seethrough the long-run winner… and they aren't wrong given the need for all-day wearability and stylistic viability. But it's wrong to think that video passthrough is just a stepping stone towards that end. Think: parallel, not sequential.

The Hybrid Dilemma

This binary compulsion to name winners and losers in XR, manifests in another fallacy: that all formats will one day converge and meet in the middle for an ultimate killer device. For reasons already stated, video passthrough and optical seethrough will advance within their own evolutionary lanes. By definition, this engenders more divergence than convergence, as they can each become their best self, rather than aiming for common denominators.

The latter would present a hybrid dilemma – compromising each end of the spectrum for a "master of none" result. Just think: most people use laptops and phones versus ditching both altogether to do *everything* on a tablet. Needing the right tool for the job will always be a thing. Put another way, due to limitations in physics – unassisted by Moore's Law – seethrough AR can't be as good as passthrough AR for entertainment. And passthrough can't compete for the "all-day" stuff. Of course, breakthroughs and flying-car level innovations can shift the current course of technical realities, but that will take decades.

Image Source: Apple

"This binary compulsion to name winners and losers in XR, manifests in another fallacy: that all formats will one day converge and meet in the middle for an ultimate killer device."

Final Thoughts: The Next Ten Years

Expensive Miscalculation

Speaking of "decades," most of this report focused on the present and near-term outlook for spatial computing. But what about the longer-term? Indeed, when talking about emerging tech, the discussion should include both short and long-run perspectives. In that light, one key lesson learned after the circa-2016 period of elevated XR hype is that it's ill-advised to set overblown expectations. Many companies and investors got burned from believing that AR and VR's revolutionary impact was much larger and more imminent than it was... an expensive miscalculation.

Consumers have also been turned off by this hype cycle. That's not because these technologies aren't compelling, but because they've been disappointing relative to their hyped promises. Magic Leap's first headset is one example of this sequence... and the company has paid dearly for it.

XR's Tipping Point

With that backdrop, what's the timeline for fully actualized AR and VR? For example, when will we get all-day AR glasses that offer both graphically-robust UX and stylistic wearability? As examined in this report, this has been achieved... but in a prototype with a $10,000 bill of materials. The question is when a Meta Orion-like device reaches the market at a *viable* price point. That could be XR's tipping point.

The consensus is that such a milestone could be reached sometime in the 2030s. For example, Snap CEO Evan Spiegel is one executive who's been realistic about this longer time horizon in his public statements. Meta CEO Mark Zuckerberg has also begun to publicly acknowledge this reality.

Image Source: Meta

"Many companies and investors got burned by believing that AR and VR's revolutionary impact was much larger and more imminent than it was... an expensive miscalculation."

Final Thoughts: The Next Ten Years

Source Sentiments

To further underscore these sentiments from AR leaders, we've collected some of their public statements. Here they are for full effect:

Mark Zuckerberg on The Information Podcast.
"When we got phones, we didn't get rid of our computers. We maybe just shifted some of our time toward phones. My guess is that we'll have phones for a while too, so that part of what we do will always be important. But I think over time, [AR] will become the platform for more and more people, and I think there's a lot of awesome stuff that comes from that. If you can deliver a computing platform that's fundamentally more human and about creating natural interactions between people, that's sort of the dream that we've been chasing for a long time. If we can build that — and I do think it will be in a decade — a lot of the things we've talked about today should be delivered and at scale. I think that that will be very exciting. A lot of this stuff will start to come about in the 2020s. It may not really reach the full scale until 2030."

Evan Spiegel at TechCrunch Disrupt
"Spectacles represent a long-term investment in augmented reality hardware. […] So I think it'll be roughly ten years before there's a consumer product with a display that could be really widely adopted. But in the meantime, we've built a relationship with our community and all these people who love building [AR] experiences and we're sort of working our way toward that future, rather than go in a hole or in an R&D center, and try to make something that people like, then show them ten years later. We've sort of created a relationship with our community where we build that future together."

Image Source: Snap

"Over time, AR will become the platform for more and more people... A lot of this stuff will start to come about in the 2020s. It may not really reach the full scale until 2030."

Final Thoughts: The Next Ten Years

Along the Way

Though the road to all-day AR glasses is long and winding, there are meaningful wins along the way. The two tech leaders on the previous page helm companies that are achieving such milestones, including user engagement and real revenue in areas like AR brand marketing and consumer VR sales. But that's not often the story told in the signature schadenfreude of the tech press.

These short-term wins from the likes of Snap and Meta fuel their ability to speak honestly about the long term. They can temper expectations for AR glasses while armed with the confidence that the spatial computing work they're doing today is producing tangible and financial – albeit gradual – results. And they're getting closer to the AR holy grail, given Meta Orion and Snap Spectacles Gen 5, respectively.

Realistic Expectations

Put another way, these short-term wins make it easier to swallow the decade+ deferment of AR's fully-actualized self. And the sooner we all come to terms with that – including generalist tech articles that still parade AR glasses' and VR headsets' world-changing impendence – the more we'll set these technologies up to succeed through realistic expectations.

Image Source: Meta, Apple

"Short-term wins from the likes of Snap and Meta fuel their ability to speak honestly about the long term. And they're getting closer to the AR holy grail, given Orion and Spectacles."

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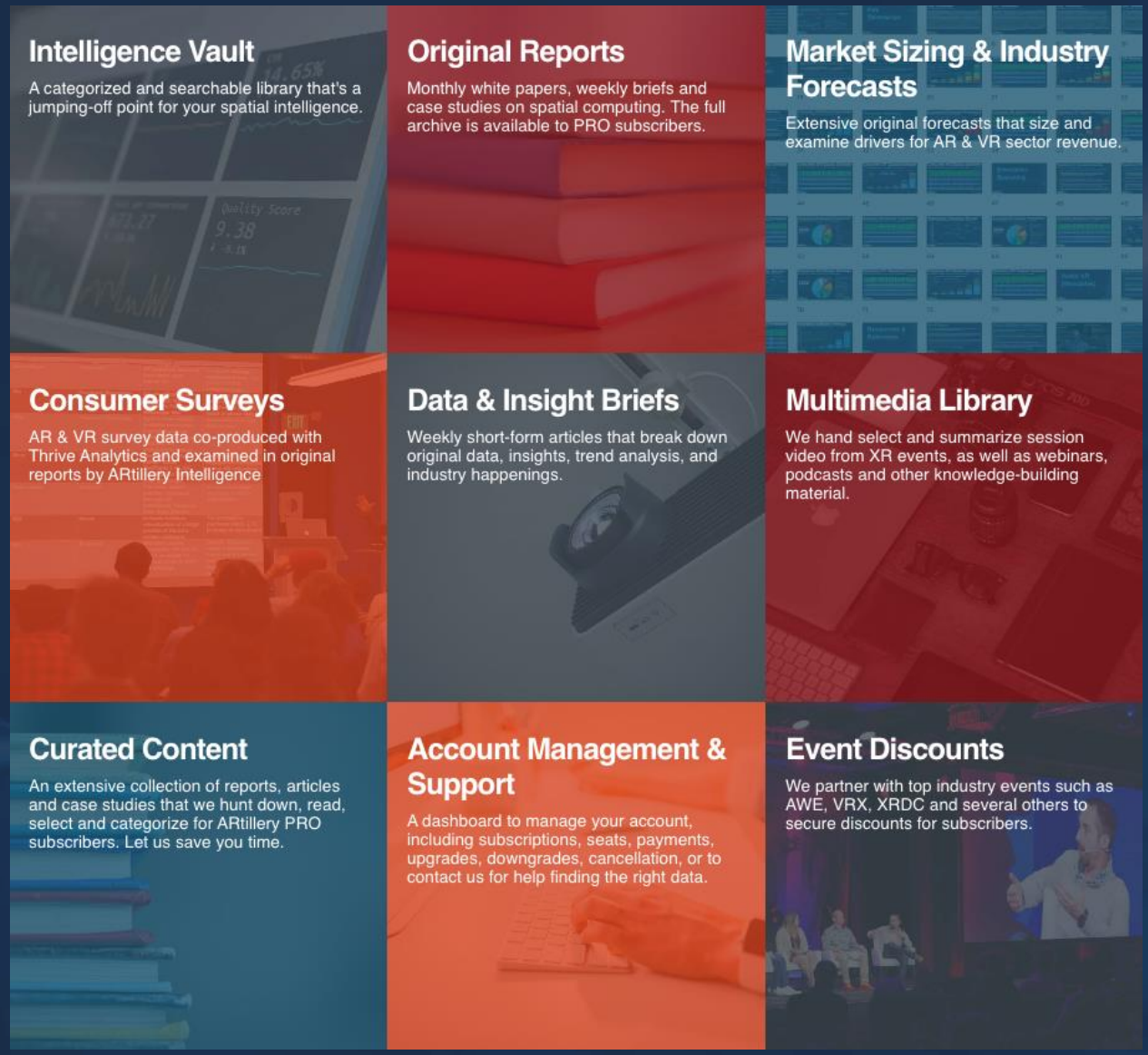

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About ARtillery Intelligence

ARtillery Intelligence chronicles the evolution of spatial computing (AR & VR). Through writings and multimedia, it provides deep and analytical views into the industry's biggest players, opportunities, and strategies.

Run by analysts and former journalists, coverage is grounded in a disciplined and reportorial approach. It also maintains a business angle: Though there are fun and games in spatial computing, cultural, technological, and financial implications are primary.

Products include the ***AR Insider*** publication and the ***ARtillery PRO*** research subscription, which together engender a circular flow of knowledge. Research includes monthly narrative reports, market-sizing forecasts, original consumer survey data, and multimedia – all housed in a robust intelligence vault.

Learn more **here**.

"Though there are fun and games in spatial computing, cultural, technological, and financial implications are primary."

About Intelligence Briefings

ARtillery Intelligence Briefings are monthly installments of spatial computing data and analysis. They synthesize original data to reveal opportunities and dynamics of spatial computing sectors. In addition to data, a layer of insights is applied to translate market events and raw figures into concrete insights.

More information, past reports, and editorial calendar can be seen here.

ARtillery Intelligence

About the Author

Mike Boland was one of Silicon Valley's first tech reporters of the Internet age as a staff reporter for Forbes (print) starting in 2000. He's been an industry analyst covering emerging and immersive tech since 2005; and is now Chief Analyst of ARtillery Intelligence and Editor of AR Insider.

Mike is a frequent speaker at industry conferences such as AWE, XRDC, Lens Fest, and the VR/AR Global Summit. He has authored more than 150 reports and market-sizing forecasts on the tech & media landscape. He contributes regularly to news sources such as TechCrunch, Business Insider, and Huffington Post.

A trusted source for tech journalists, his comments have appeared in A-list publications, including The New Yorker, The Wall Street Journal, and The New York Times.

Further background, history, and credentials can be read here.

Methodology

This report highlights ARtillery Intelligence viewpoints, gathered from its daily in-depth market coverage. To support narratives, data are cited throughout the report. These include ARtillery Intelligence original data, as well as that of third parties. Sources are linked or attributed in each case.

For market sizing and forecasting, ARtillery Intelligence follows disciplined best practices, developed and reinforced through its principles' 20 years in tech-sector research and intelligence.

This includes the past 10 years covering AR & VR exclusively, as seen in research reports and daily reporting.

This approach primarily applies a *bottom-up* forecasting methodology, which is secondarily vetted against a *top-down* analysis. Together, confidence is achieved through triangulating revenues and projections in a disciplined way.

More about ARtillery Intelligence's market-sizing methodology can be seen here and more on its credentials is here.

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