

January 2021

# Spatial Computing: 2020 Lessons, 2021 Outlook

An ARtillery Intelligence Briefing

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# Executive Summary

As we approach the turn of a new year, it's once again time for our annual ritual of synthesizing the lessons from the past twelve months and formulating the outlook for the next twelve. Notably, when kicking off this thought exercise, we realized that several of the topics look similar to last year.

Though there are lots of developments and new insights to break down, the topical containers that house those insights are beginning to coalesce into standard buckets. We're talking mobile AR engagement & monetization; AR cloud development; enterprise AR and the gradual march of VR.

This standardization is good news, in that it signals spatial computing's exciting – yet insecure – early days have transitioned to an adolescent period of its lifecycle. We have a firmer grasp on what's working and not working... versus 2017's wild speculation on the technology's world-shifting impudence.

For example, AR's near-term viability is supported by smartphone scale – estimated at **3.04 billion AR-ready** devices and **598 million active** devices. This has attracted reach-driven brand advertisers that are interested in immersive marketing. AR ad spending has reached an estimated **\$1.4 billion**.

Elsewhere in mobile AR, **Pokémon Go** is experiencing the most successful stage in its lifetime, recently passing an estimated **\$1 billion** in year-to-date revenue, and **\$4 billion** cumulatively. Speaking of **Niantic**, it joins the list of tech giants investing heavily in planet-scale spatial mapping that's hoped to power the next generation of AR experiences.

The list of companies assembling “AR clouds” otherwise includes **Google**, which continues to apply its vast knowledge graph as a visual database that can localize AR devices. It also includes **Facebook**, whose Project Aria is a step towards its Live Maps AR cloud ambitions. Meanwhile, **Amazon's** IoT data could represent an AR cloud sleeper.

All of the above mobile AR happenings will pave the runway and create a softer landing for consumer AR's fully-actualized head-worn era. Meanwhile, a different technology is working towards the same end: wearables. The device class will acclimate consumers to wearing sensors on their bodies – starting with **Apple**.

Speaking of **Apple**, its rumored AR glasses in the 2022 timeframe could determine the fate of the AR industry, given the company's proven “halo effect” on emerging technologies. This year, we learned many clues that signal the approach **Apple** may take, including elegant and ambient ways to enhance human vision.

But the story doesn't end there. What about enterprise AR? What about VR, given the sector's acceleration at the hands of **Oculus Quest 2**? Finally, what impact will an ongoing global pandemic have on spatial computing (spoiler alert: there will be mixed results)? We'll tackle these questions and more in this report through numbers & narratives.

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# Key Takeaways

- AR** Though 2020 was a turbulent year for the world, activity levels were relatively calm in spatial computing.
- AR** This is a positive sign, as the sector's early and erratic days have transitioned to slow & steady growth.
- AR** These are marks of an industry that's moving into adolescence, with a more defined path to maturity.
  
- AR** One bright spot for AR continues to be its mobile manifestations, given global smartphone penetration.
- AR** There are 3.46 billion global smartphones, 3.03 billion of which are *AR-ready* and 598 million are *AR active*.
- AR** Hardware evolution such as LiDAR will advance AR through underlying capability and consumer appeal.
- AR** Leading business models are in-app-purchases in mobile gaming (mostly Pokémon Go) and advertising.
  
- AR** Advertising is an AR revenue leader, with a projected \$1.4 billion in brand spending in 2020.
- AR** This continues to be driven by users' affinity for interactive lenses, and advertiser drive to follow that usage.
- AR** Brands are further attracted to AR advertising for its creative capacity to demonstrate products in 3D.
- AR** Further emboldening AR advertising is strong campaign results and ROI, causing brands to double down.
  
- AR** Mobile AR's most significant area of development continues to be the construction of the AR cloud.
- AR** This involves capturing spatial maps that serve as scaffolding for next-generation AR experiences.
- AR** The size of this endeavor compels crowdsourced approaches that utilize widely-deployed smartphone cameras.
- AR** Tech giants each have their own spin on AR clouds and road maps, signaling several potential outcomes.
  
- AR** Beyond mobile AR, another device class is paving the way for AR glasses: wearables.
- AR** Just as mobile AR *conditions* users for spatial experiences, wearables *acclimate* them to body-worn sensors.
- AR** Wearables impact is further underscored by its success as a product class, currently exploding in adoption.
- AR** Tech giants further propel wearables by investing in them as a way to offset maturing smartphone markets.
- AR** Beyond an AR glasses *acclimation* play, hearables *already* represent AR through spatial audio.
  
- AR** AR glasses themselves aren't ready for mainstream acceptance and won't gain significant ground in 2021.
- AR** There will be steady progress in the underlying technology and some commercial activity such as Nreal Light.
- AR** Most of the activity in AR glasses in 2021 will be "setting the table" for 2022 when they could arrive in earnest.
- AR** Much will hinge on Apple's rumored AR glasses, which could cause a classic Apple "halo effect" for AR.
- AR** Apple will prioritize style over graphical intensity, and could re-define augmentation through "lighter" AR.
- AR** For example, version 1 could feature thin notification layers or "filters" for corrective and enhanced vision.
  
- AR** Beyond all of the above consumer endpoints, enterprise AR will continue to push forward.
- AR** Enterprise AR won't reach its anticipated "tipping point" in 2021 but that could come soon after, in 2022.
- AR** The sector will make progress in 2021, mostly with organizational acceptance rather than tech advancement.
- AR** Organizational inertia continues to be enterprise AR's greatest barrier, born from resistance to change.
  
- AR** Beyond AR, VR will likewise experience steady gains in 2021, but won't be revolutionary.
- AR** VR's growth will continue to be fueled by Facebook's investments in hardware and content.
- AR** This can be seen most vividly in Oculus Quest 2, which has a compelling quality/price ratio.
- AR** 2020 experienced unit shipment declines in the aggregate, but sales will bounce back in 2021.
- AR** This is already happening as Facebook has emboldened its supply chain and is meeting demand for Quest 2.
  
- AR** The ongoing global pandemic will impact spatial computing sub-sectors differently and unevenly.
- AR** Mobile AR will be less affected because it's "Covid-friendly" (software, entertainment, and communications).
- AR** Mobile AR will also benefit as a value-added component of eCommerce and post-Covid "touchless" retail.
- AR** Enterprise AR benefits from Covid and post-Covid dynamics, as guided support aligns with remote work.
- AR** VR has suffered from supply-chain issues, but longer-term Covid-aligned demand inflections will offset them.

# Introduction: The Lifecycle

One striking realization about spatial computing is that we're almost **seven years** into the sector's current stage. This traces back to **Facebook's** Oculus acquisition in early 2014 that kicked off the current wave of excitement... including lots of ups and downs in the intervening years.

That excitement culminated in 2016 after the **Oculus** acquisition had time to set off a chain reaction of startup activity, tech-giant investment, and VC inflows for the "next computing platform." But when technical and practical realities caught up with the spatial computing industry... it began to retract.

Like other tech revolutions that came before it – most memorably, the dot com boom/bust – spatial computing has followed a common pattern. Irrational exuberance is followed by retraction, market correction, and scorched earth. But then a reborn industry sprouts from those ashes and grows at a realistic pace.

That's where we now sit in spatial computing's lifecycle. It's not the revolutionary platform shift touted circa-2016 (at least not yet). And it's not a panacea for everything we do in life and work as once hyped. But it will be transformative in less-sexy ways, and within a targeted set of use cases and verticals.



# Stepping Stone

Some of those areas of transformation are in view; some are already active today; and several more haven't been discovered. The applicable areas we know about include enterprise productivity, brand marketing, gaming, and utilities such as visual search.<sup>1</sup>

These developing areas owe their success to piggybacking on smartphone ubiquity. Of the **3.46 billion** global smartphones today, **3.03 billion** are compatible with at least one form of AR, including rudimentary web AR. And an estimated **598 million** devices are AR *active*.

This ubiquity is not only a pathway to scale, but it will assist AR's scaffolding. The "AR cloud" (explored later in this report) will continue to be the model for location-anchored data that empowers AR devices to activate meaningful graphics. And such efforts will crowdsource spatial mapping to the mobile masses.

But mobile AR's job doesn't end there. One key role will also be to *acclimate* the world to AR so that its fully actualized form – head-worn AR – has a softer landing. That includes consumer acclimation, as well as developers getting conditioned to *think spatially*.

One accelerant in that conditioning process will be wearables, as they acclimate consumers to worn sensors. The device class continues to inflict as companies like **Apple** lean in as a means to future-proof a hardware business that's overly reliant on a maturing iPhone.

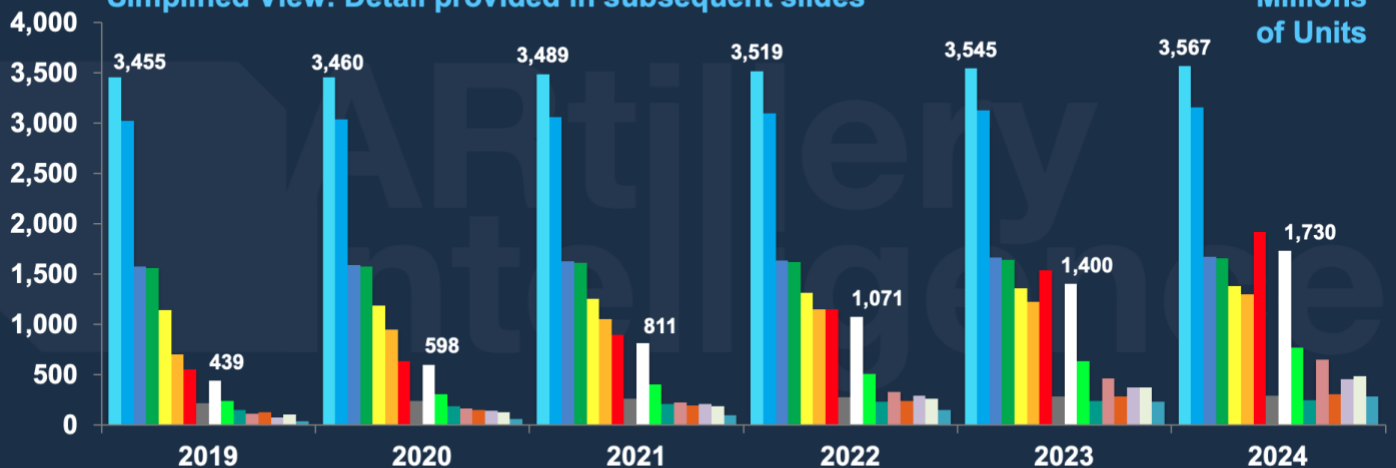
Speaking of **Apple**, we learned a great deal about its rumored AR glasses play this year, which could accelerate AR through a classic **Apple** "halo effect." But it won't be the graphics-heavy AR that we often envision – instead taking an elegant and LiDAR-enabled approach to *enhance human vision*.

## Mobile AR Global Penetration

2020 AR-Compatible Devices & Active Users, Across Platforms\*

Simplified View: Detail provided in subsequent slides

Millions of Units



\*Excludes platforms endemic to China.  
 \*\*Includes iPad  
 \*\*\* Includes Instagram & Messenger

- Smartphones (AR & Non-AR)
- Visual Search (Devices)
- ARCore (Devices)
- Facebook AR (Active)\*\*\*
- ARkit (Active)\*\*
- Web AR (Active)
- Web AR (Devices)
- ARkit (Devices)\*\*
- Snap AR (Devices)
- Snap (Active)
- TikTok (Active)
- Facebook AR (Devices)\*\*\*
- TikTok (Devices)
- Total AR Active (de-duped)
- Visual Search (Active)
- ARCore (Active)\*



# The Covid Era

All of the above covers consumer-based endpoints for AR, but what about the enterprise? Indeed, this is where AR's traction has erstwhile resided, given the technology's ability to guide industrial (assembly, maintenance) and corporate work (design collaboration) using line-of-sight annotations.

And what about VR? It continues to grow in several ways, further accelerated by **Facebook's** investment in high-quality, low-cost hardware such as Quest 2. The device is showing early signs of heavy demand, while **Facebook** amps up its supply-chain readiness in a world still reeling from a pandemic.

Speaking of which, the elephant in the room in all of the above is Covid-19. Like several other industries, it has affected AR & VR unevenly. For example, AR lenses align with the demand signals of shelter-in-place masses. This includes entertainment, communication, and the practicality of remote shopping.



Conversely, anything hardware based – including AR and VR glasses – have been impacted by global supply-chain impediments. But counterbalancing that to a certain degree is the technology's alignment with remote work, such as AR's remote assistance and VR's immersive presence.

The long-run result could be a net positive. This will happen as supply-chain shortages cause pent-up demand, which can already be seen with **Oculus** Quest 2. And COVID-pressured enterprise adoption could expose AR and VR, instilling permanent habits in the post-COVID era of semi-remote work.

All of the above is what we learned in a volatile 2020. The rest of this report will drill down on each of these areas, culminating with a list of five predictions for spatial computing in 2021. It will continue to be a transformative time for the world – and for spatial computing – as we roll into a new year.

# Mobile: The First Step

Drilling down into the individual areas introduced above, we'll start with AR's foundation: smartphones. Before AR's fully-actualized era of face-worn hardware arrives, its near-term opportunity is with the more realistic manifestation of the technology that's activated through the smartphone camera.

In fact, one of mobile AR's longstanding confidence signals is the sheer size of the smartphone installed base. Compared to the uphill battle that AR glasses face, mobile AR — though challenged in its own ways — has an easier climb due to ubiquitous hardware.

But more important than the smartphone base is the share of that universe that's AR-compatible. That number has been paraded around industry events and editorials for the past few years as "1-billion+."

But that figure is incomplete. It first started circulating in 2019 as a then-accurate tally of ARkit and ARCore-compatible smartphones. Given these platforms' explicit hardware specs for AR compatibility, in-market compatible devices were a relatively simple calculation.

But things have gotten more complex as additional platforms gain ground. In fact, the fastest-growing AR compatibility in today's smartphone landscape happens outside of the above platforms with **Snapchat**, **Facebook**, and web AR, according to ARtillery Intelligence's Mobile AR forecast.<sup>ii</sup>

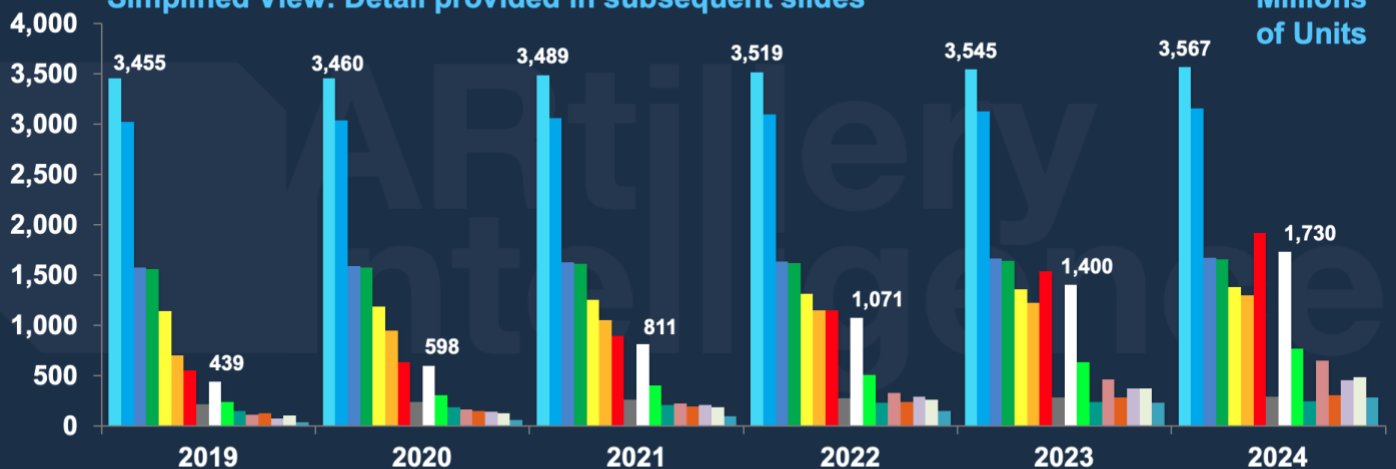
The greatest compatibility comes from web AR, with **3.04 billion** units. That's followed by Facebook (**1.58 billion**) ARkit (**1.19 billion**), TikTok (**950 million**), ARCore (**633 million**) and Snapchat (**240 million**).

## Mobile AR Global Penetration

2020 AR-Compatible Devices & Active Users, Across Platforms\*

Simplified View: Detail provided in subsequent slides

Millions of Units



\*Excludes platforms endemic to China.  
 \*\*Includes iPad  
 \*\*\* Includes Instagram & Messenger

# Ready & Active

The keyword in the above analysis is “compatible,” as it tallies devices that are AR-ready. A more important figure is how many are *AR-active*. Here we run into the reality of platform overlap, making it challenging to pinpoint one figure for global AR active devices.

By developing a de-duplication formula to reconcile the overlap, ARtillery Intelligence estimates that AR active devices at the end of 2020 total **598 million**. This is projected to grow to **1.73 billion** by 2024 as more advanced hardware cycles in, and as AR acclimates culturally.

But it’s important to note that there isn’t necessarily a correlation between compatibility rankings and active-use rankings. For

example, web AR’s compatibility lead is contrasted by its trailing active use – a mark of growth potential and ample headroom for the nascent AR modality.

**TikTok** is in a similar boat with promising reach but underdeveloped AR. **Snapchat** conversely has the lowest compatibility among platforms (**240 million**) but the second-highest active use (**187 million**). This gives it the greatest ratio of AR active users per compatible device.

**Facebook** sits somewhere in the middle with a diversified AR approach (News Feed, Messenger, Portal). But **Instagram** could be the real ace up its sleeve given a cultural match with camera-forward users, and natural monetization with the product-discovery use case it’s conditioned.

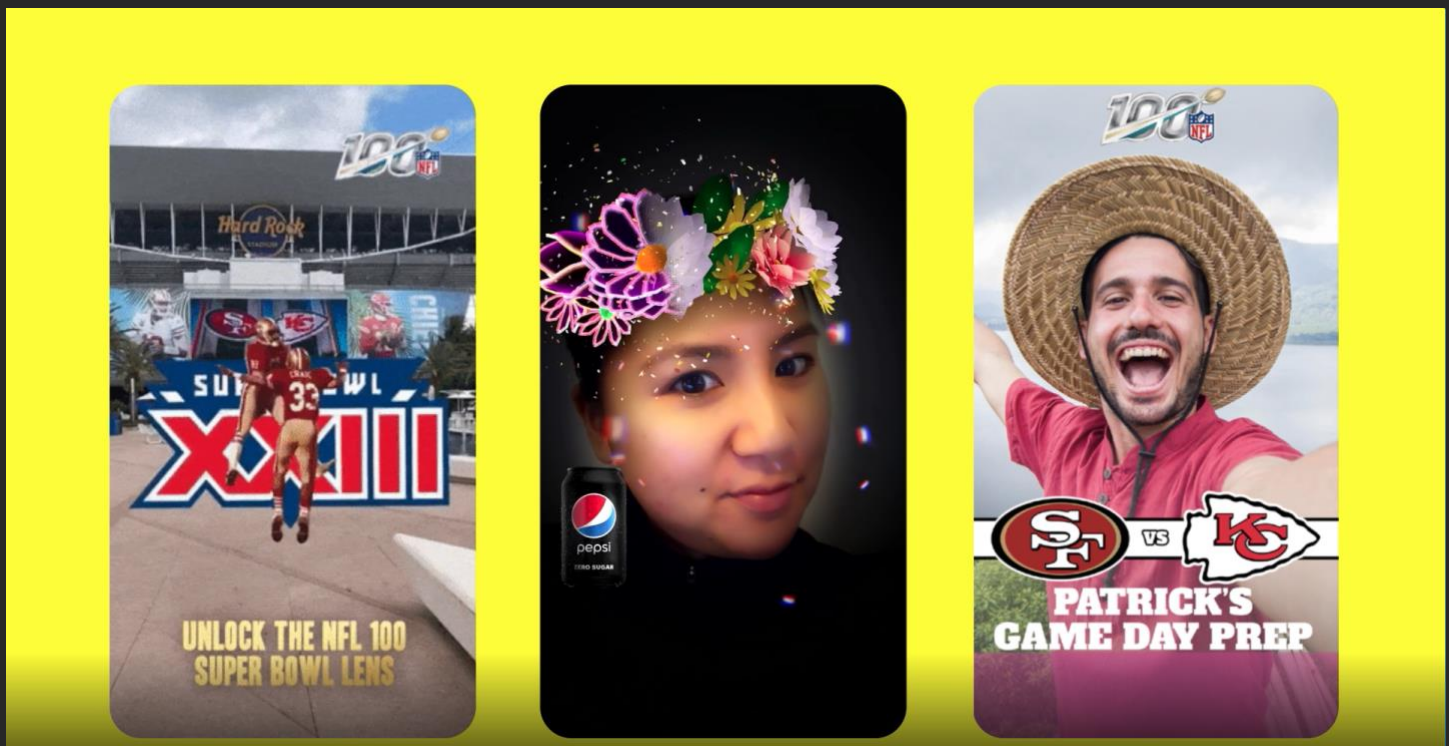


Image Source: Snap



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# Camera Marketing

Stemming from mobile AR's growing base, the question becomes what forms of AR are developing, and how are they monetized. For example, one of the most popular forms of consumer AR so far has been lenses, distributed through social channels like **Snapchat** and **Facebook**.

These lenses have lent themselves to brand sponsorship and paid distribution – a business model propelled by a few factors. Not only is advertising the primary business model of the aforementioned social players, but lenses themselves are conducive to branded experiences.

For example, branded AR lenses in channels like **Facebook** and **Snapchat** let consumers visualize products on “spaces & faces” through the smartphone camera. This involves paid distribution, which is similar to, but different than, brands’ self-distributed AR efforts, such as their own apps.

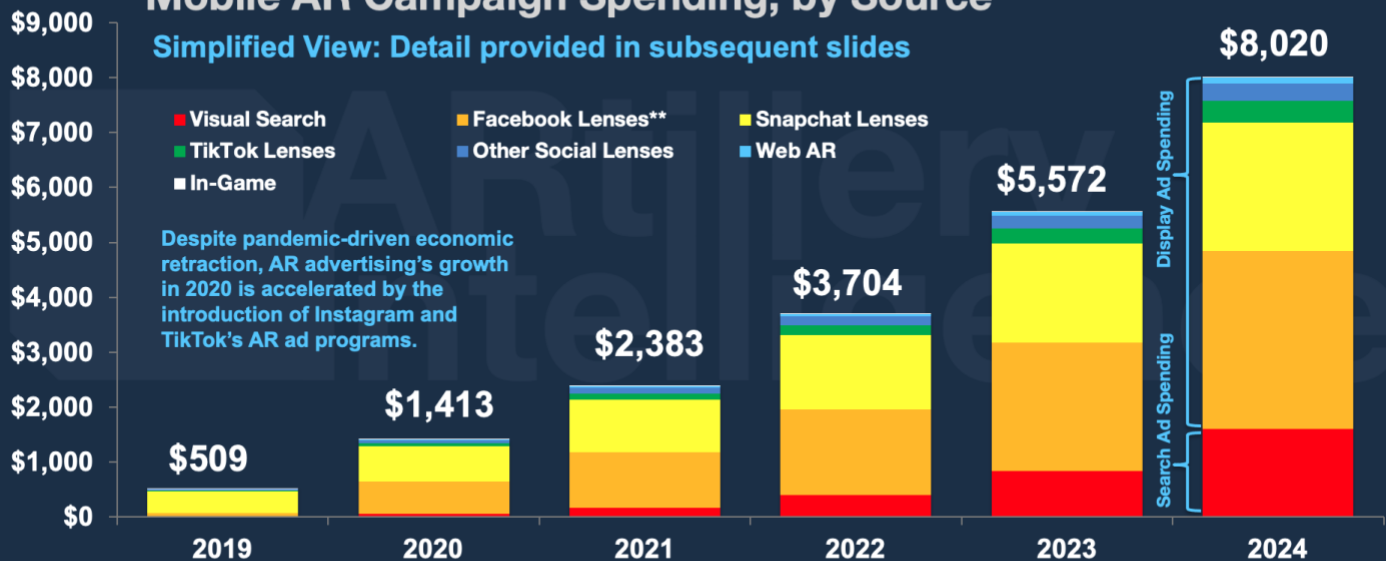
This branded/paid lens channel represents one of the leading AR sub-sectors today, with campaign spending estimated to **reach \$1.4 billion** in 2020 according to ARtillery Intelligence’s Global Mobile AR forecast<sup>iii</sup> (figures below). This total is projected to grow to just over **\$8 billion** by 2024.

## Mobile AR Ad Revenue

U.S. \$Millions

Mobile AR Campaign Spending, by Source\*

Simplified View: Detail provided in subsequent slides



Despite pandemic-driven economic retraction, AR advertising's growth in 2020 is accelerated by the introduction of Instagram and TikTok's AR ad programs.

\*Doesn't include platforms endemic to China

\*\*Doesn't include non-advertising marketing spend such as self-distributed brand apps and experiences

\*\*Includes Instagram, Messenger and all Facebook properties that distribute AR lenses

# Drivers & Dynamics

So what's driving the above advertising revenue? First, users are demonstrating high engagement with AR lenses as a way to enhance already-popular activities including media-sharing and enhanced 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 campaign performance metrics that continue to validate AR advertising's ROI.<sup>iv</sup>

Lastly, AR offers versatility. It can achieve upper-funnel engagement to reach Superbowl-sized audiences in places like **Facebook's** News Feed. And it can drive lower-funnel conversions through immersive product try-ons. Few ad media can claim this full-funnel capability.

As for who's doing what to tap into that advertiser demand, **Snapchat** is in the lead, due mostly to its dedicated focus on AR, and the medium's alignment with its "camera-company" mission. **Facebook** also looms large with greater global scale in its flagship app and News Feed distribution (see chart above).

**Facebook** has also begun to distribute AR through other properties like Messenger and Portal. But the real opportunity could be **Instagram**, where AR aligns with its camera-forward audience and business model.

**Instagram** has already cultivated a product-discovery use case that's fertile ground for AR.

Meanwhile, wild cards include **TikTok** which has ample — though uncertain — AR potential. There's also visual search,<sup>v</sup> which carries the same high user intent that made web search such a strong business. Other developing channels including web AR, messaging, and in-game AR.

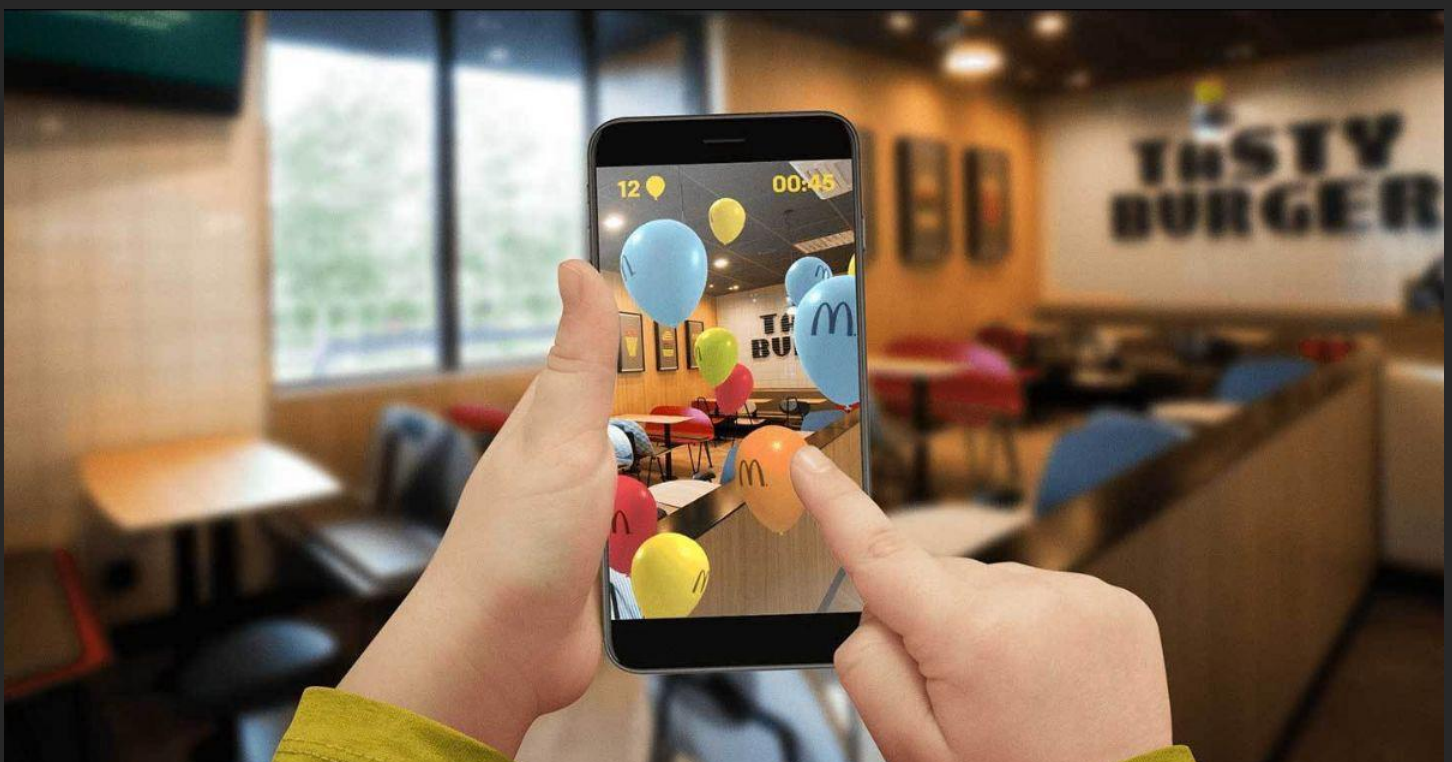


Image Source: McDonalds

# Elephant in the Room

The elephant in the room in all of the above is a global pandemic. As is the case across the global economy, mobile AR sectors will be impacted unevenly by ongoing global lockdowns. Given that software mostly fares well in shelter-in-place life, the impact on mobile AR will be mostly positive.

For example, quarantine-friendly consumer AR fare like social lenses are trending up,<sup>vi</sup> and social distancing compels enterprise remote-AR support.<sup>vii</sup> These factors will boost near-term adoption while exposing the technology... which in-turn supports its longer-term sustained adoption.

But when it comes to advertising, one thing counteracting the above factors is the fact that it's a famously recession-prone spending

category. In the end, AR ad revenues will grow in 2020, but estimates have been adjusted down at a slower rate than was projected pre-pandemic.

Longer term, mobile AR advertising could ultimately benefit as recessions cause advertisers to rethink and redeploy budget to more effective and cost-efficient formats. In fact, this is what happened to search circa-2003 and social advertising circa-2009.

AR could benefit from a similar shakeup by grabbing ad spend. Moreover, brands that try it may discover its virtues and add it as a permanent part of their marketing mix. This cycle is how emerging advertising technologies can inflect, and we expect to see similar with AR in the post-Covid era.

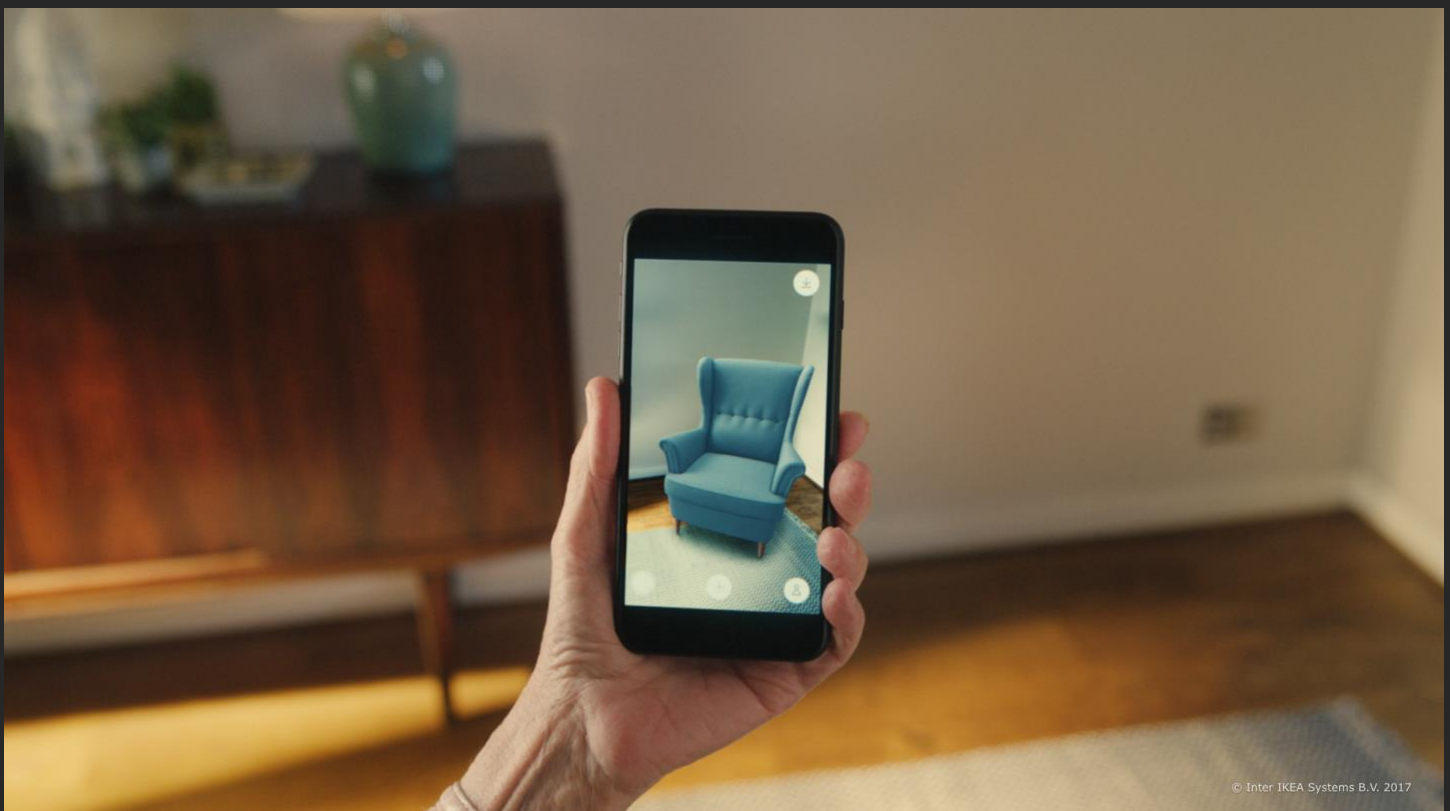
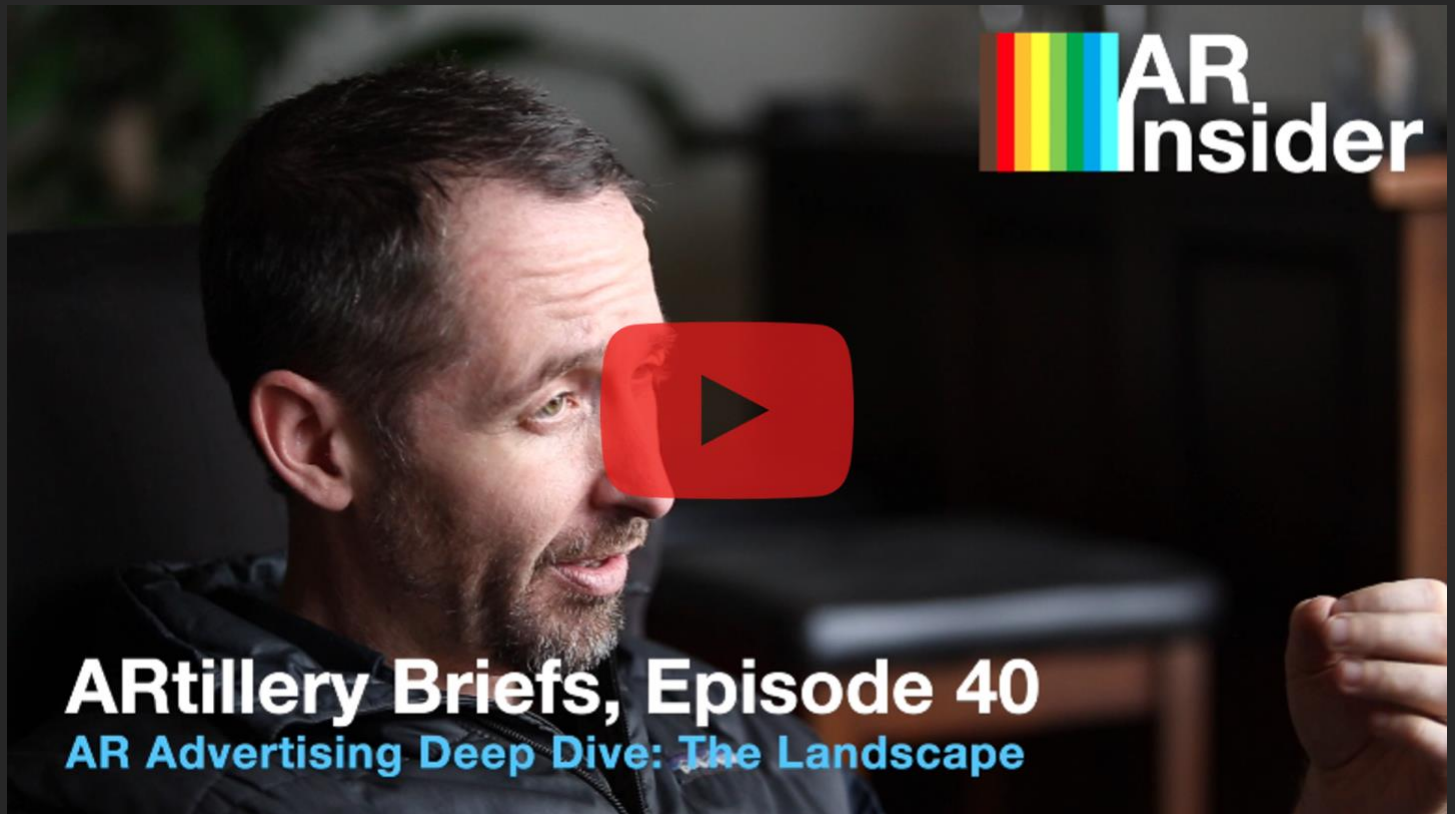


Image Source: IKEA



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# Pokémon Go-ing Strong

Another high-performing mobile AR category – in both user engagement and revenue generation – is location-based gaming. But rather than attribute the category in general, credit is more-accurately owed to its market-share leader, **Pokémon Go**. That's right... it's still going strong.

Though generalist tech press have moved on to other shiny objects, **Pokémon Go** is at the height of its popularity and continues to break new records. The latest figures from Sensor Tower estimate that the game has passed **\$1 billion** in 2020 year-to-date revenue.

This marks **Pokémon Go's** most successful year on record... and it only measured to November 1st. This puts the game on an

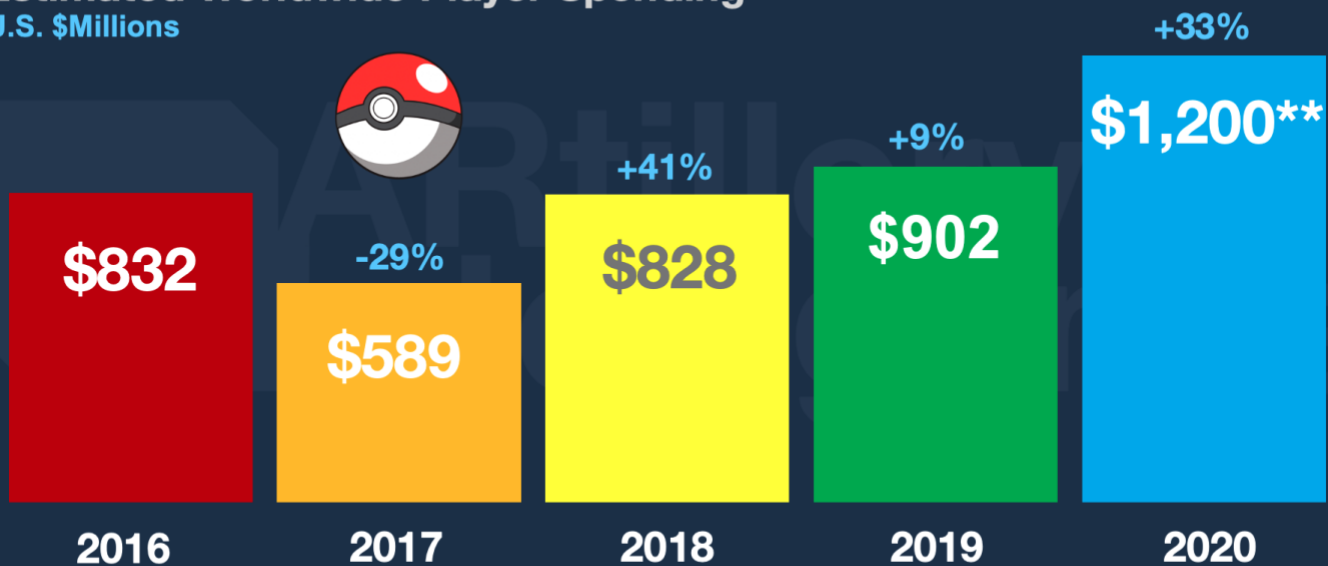
annual run rate of **\$1.2 billion**, which would be **33 percent** year-over-year growth. This is notable considering an accelerated pace from its 2019 growth rate.

That trendline can be seen in the chart below. The game's lifetime revenue is also notable, which Sensor Tower pegs at **\$4.2 billion**. This follows the **\$3 billion** mark that was hit exactly one year ago.

To be clear, this isn't first-party data from **Niantic**, but Sensor Tower's extrapolated figures (and ARtillery's run-rate calculation). Sensor Tower is reputable and reliable in its network reach and sample sizes. Its consistent methodology over time also enables longitudinal analysis for revenue pacing.

## Pokémon Go Revenue

Estimated Worldwide Player Spending\*  
U.S. \$Millions



# Lessons & Learnings

One of the remarkable things about **Pokémon Go's** growth and sustained play over four years, is that the aforementioned record-setting period in 2020 coincided with a pandemic. Indeed, global lockdowns and shelter-in-place orientation don't inherently align with the game's migratory play.

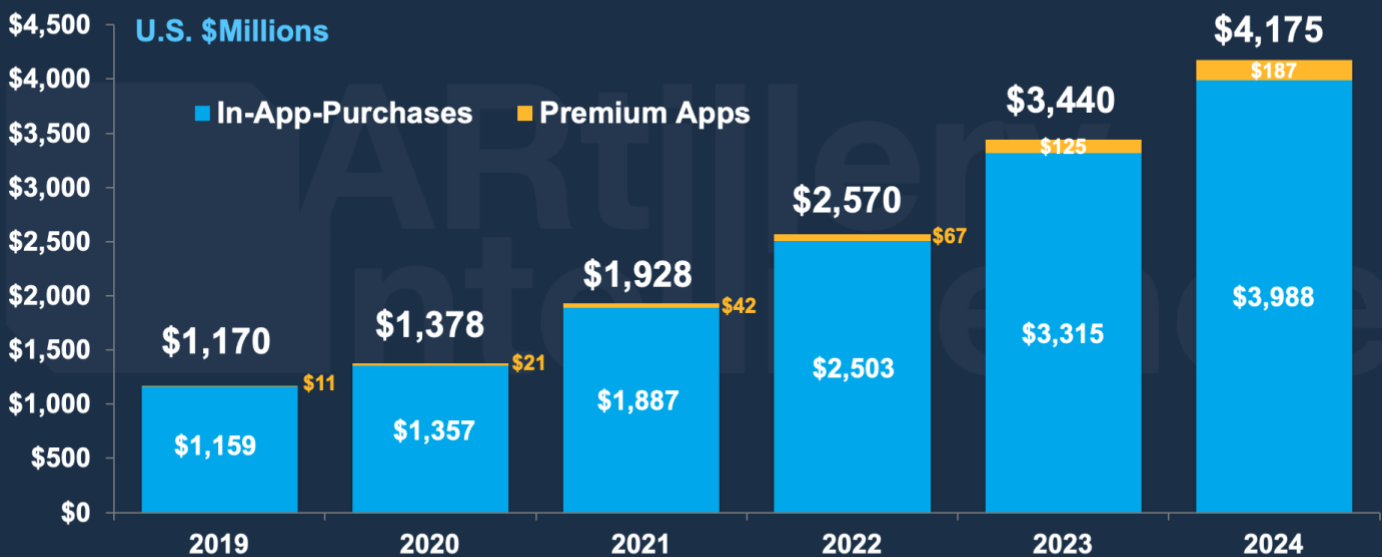
Here we'll credit **Niantic's** ingenuity to pivot quickly and adjust game mechanics to accommodate stationary at-home play – easier said than done from a UX perspective. The result: instead of usage declines, it was able to ride the wave of gaming's broader Covid-era inflections.

This move fits the profile for **Niantic** and its ability to achieve **\$4.2 billion** in lifetime revenue, as noted. Not only has it defied odds this year, but also in a broader sense. It's rare for mobile games to sustain active play for several years, due to challenges in maintaining novelty and game mechanics.

As we examined in a recent report,<sup>viii</sup> **Niantic** has accomplished this through timely in-game updates, well-devised game mechanics, and underlying design principles. Those include product philosophies like using still-unproven AR sparingly as a value-added feature, rather than a primary component.

## Consumer Mobile AR

Consumer Spending on Mobile AR Experiences



# Business Model Innovation

Beyond product innovation, **Niantic's** revenue milestone likewise validates business-model innovation. In-app-purchases (IAP) are a fitting revenue structure, given the behavioral economics of microtransactions. In a broader sense (beyond AR), the model drives **\$70 billion** annually in mobile gaming.<sup>ix</sup>

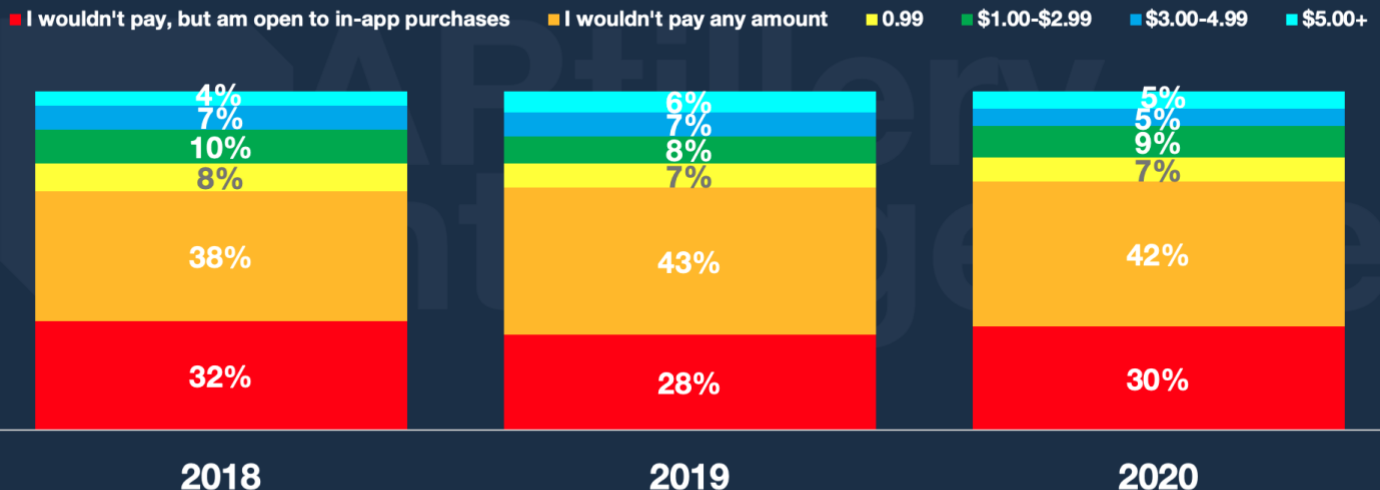
Not only is IAP validated in mobile gaming, but it's fitting to AR's early stages when users hesitate to pay upfront for apps. IAP is likewise supported by ARtillery's original consumer survey data in partnership with Thrive Analytics.<sup>x</sup> **30 percent** of prospective AR users report willingness to pay via IAP (see below).

ARtillery also projects mobile AR aggregate in-app-purchases at **\$1.4 billion** in 2020 (see chart above). This aligns with **Niantic's** previously cited **\$1.2 billion** run rate, given that it's the sector's dominant revenue leader. If those projections sustain, aggregate in-app-purchases could approach **\$2 billion** in 2021.

Stepping back, this is all worth watching as **Niantic** does the AR industry a favor through large-scale deployment. That can shine a light on key market dynamics and demand signals, which is valuable intelligence in early stages of any consumer technology.<sup>xi</sup>

## AR App Price Sensitivity

AR non-users: What's the most you'd pay for an app?





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 A large, stylized logo for ARtillery Intelligence. The word "ARtillery" is in a white, sans-serif font, and "Intelligence" is in a larger, bold, white, sans-serif font. To the left of the text is a graphic element consisting of a grid of colored squares in shades of blue, green, yellow, and red, arranged in a pattern that suggests a video player interface or a data visualization.



# The AR Cloud Materializes

To contextualize the future of AR and its ability to “just work” in several situations and locations, the AR cloud has become a foundational principle. Also known as *Mirrorworld* and other monikers, it’s about data that’s anchored to places and things that AR devices can process into meaningful content.

In order for AR to work in the ways we all envision, it first must understand its surroundings. Before placing graphics in a room, an AR device has to understand that room. And because the world’s spatial mapping data is too extensive to fit on one device, it must tap the cloud.

Another way to view the AR cloud – framed in the terminology of today’s technology – is an architecture that makes the physical world clickable. Technically, things won’t be *clicked*, but they’ll be activated in some way as AR graphics or informational overlays come to life.

Yet another analogy is the “internet of places.” Just as **Google** began indexing the web 20 years ago, the next technological revolution could be for someone to index the physical world in potentially more valuable ways. In fact, **Google** is a natural candidate to build this physical-world index

And it’s already started. After spending years assembling a knowledge graph on the web, **Google** has the building blocks for a “spatial web.” That includes a vast image database for object recognition and geo-specific place data from Street View, among other sources.

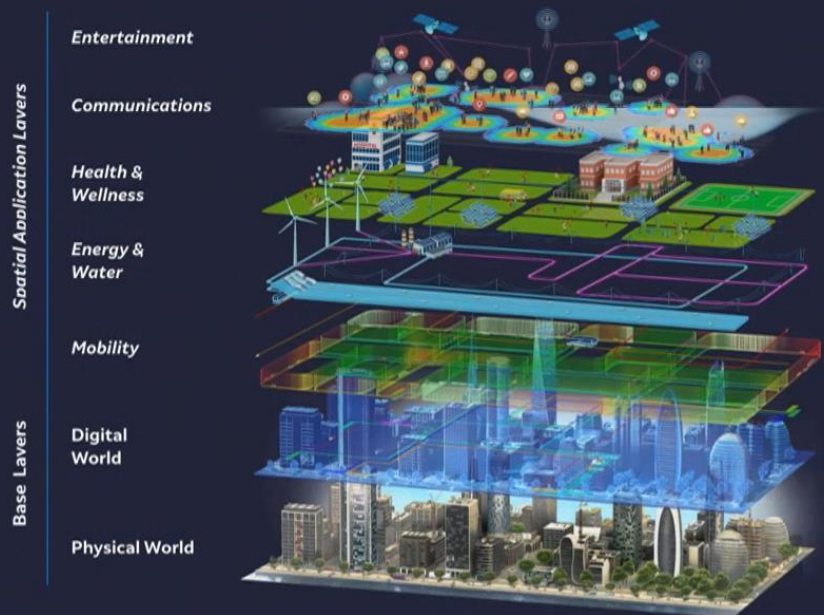
The latter powers **Google’s** Live View AR navigation tool for urban walking directions. It works by activating the smartphone camera to “localize” a device by recognizing where it is. Other **Google** data can then be utilized for informational overlays, such as storefront details from Google My Business.

## Magicverse Layers

### The Layers of Spatial Computing

A nearly infinite number of application layers make up the city-scale Magicverse.

User choices and contextual AI power this system of systems, navigated through a spatial computing interface.



# The Plurality

One implication from **Google's** many data sources is that there won't just be one AR cloud. It will be a large effort to map the physical world. And just like today's web, there will be various use cases, proprietary data, walled gardens and permission layers.

6D.ai, recently acquired by **Niantic**, will be one source. It enables mobile users to actively and passively assemble spatial maps as they're playing games like **Pokémon Go**. This approach could unlock the AR cloud's last-mile, where **Google** and others don't reach.

Meanwhile, AR cloud approaches will aim for various functions. If **Google** is the spatial web's *knowledge layer*, **Facebook** could be its *social layer*, **Microsoft** the *enterprise productivity layer*, and **Amazon** the *commerce layer*. **Apple** will be a hardware powerhouse to represent the physical touchpoint.

The pattern here is that each company's spatial web persona will mirror its core competency. Another way to view it is that each is motivated to future proof its core

business. So each's "version" of the AR cloud traces back to its core businesses – a "follow the money" principle we continue to espouse.<sup>xii</sup>

One key question that emerges from this "plurality" construct is the AR cloud's openness. Will it be open like the web, with common languages (HTML) and protocols (HTTPS) that anyone can use to plant their flag? Or will the spatial web be a constellation of walled gardens that don't talk to each other?

The answer is probably "both" just like we have today. There's an open web, unlocked and accessed through the browser. And then there are apps – everything from **Snapchat** to **Salesforce** – that connect in some ways to the web, but are otherwise self-contained.

The latter is inevitable given tech giants' incentive to build moats around monetizable assets. This is okay as long as there are common languages – again like HTML. This could involve standards such as "geo-pose" (position + heading) – which is could be a sort of *URL* for the spatial web.

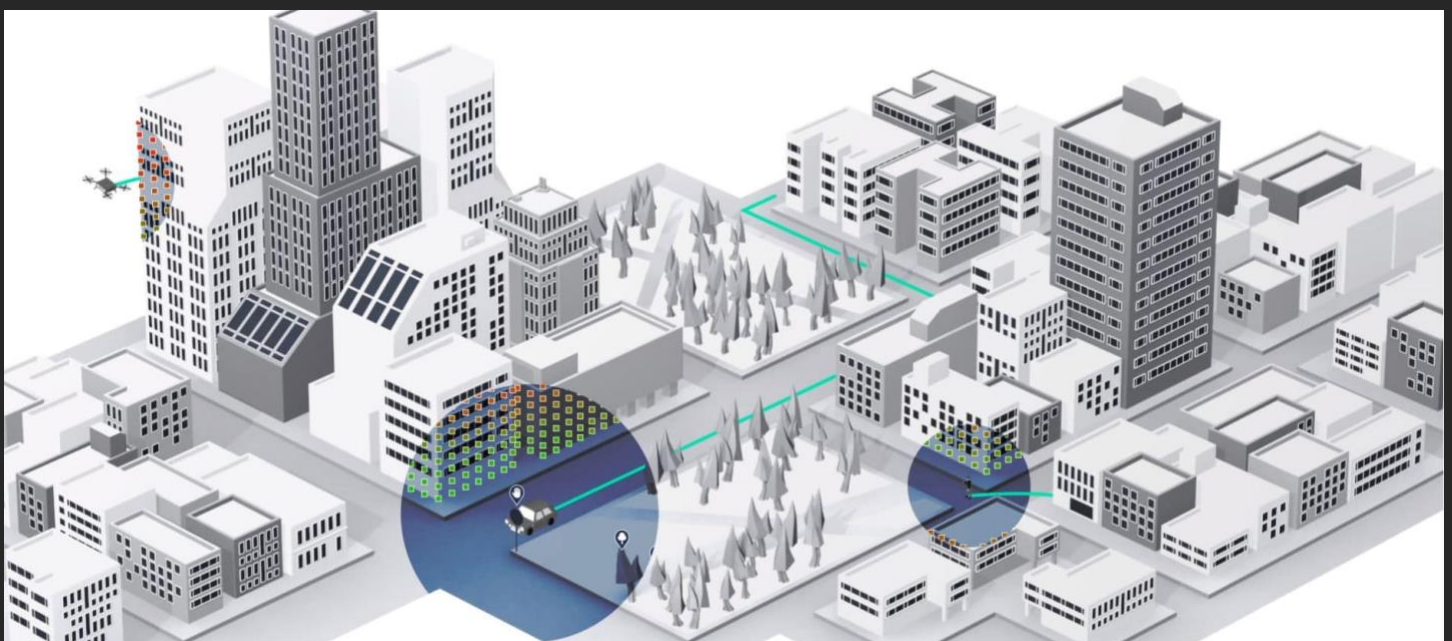


Image Source: Scape Technologies



# AR Killer Apps

The remaining question is what will be the killer apps of the AR cloud? We're bullish on visual search<sup>xiii</sup> – including everything from identifying items with your camera to navigating a new neighborhood. But like many historical technologies, killer apps take years to materialize (think: **Uber** on smartphones).

Speaking of historical lessons, one likely trait of AR cloud killer apps will be to elevate or improve activities we already perform. This not only resonates with consumers but it's less of a logical leap or education process, as it applies to things they already understand.

Examples so far include **Pokémon Go's** utilization of AR to enhance mobile gaming. **Snapchat** lenses meanwhile bring color and animation to the already-popular area of social media sharing. This is the "training wheels" principle, we've espoused in the past.<sup>xiv</sup>

Projecting areas that could have the same ingredients, *communications* is a high-impact behavior that has room for AR enhancement (which **Snapchat** has already done to a degree). Visual search<sup>xv</sup> likewise has inherent utility and usage frequency, as noted.

Finally, a key consideration for AR killer apps will be privacy. Given the level of personal data revealed through such immersive technology, strategic positioning and technical aptitude will mean nothing without user trust. This will be more challenging for ad-centric companies.

Indeed, privacy awareness has been heightened in the past five years, which could jump into hyperdrive in spatial computing due to its sensory immersion. That will create myriad signals and inputs that reveal consumer intent — everything from biometrics to spatial maps of your bedroom.

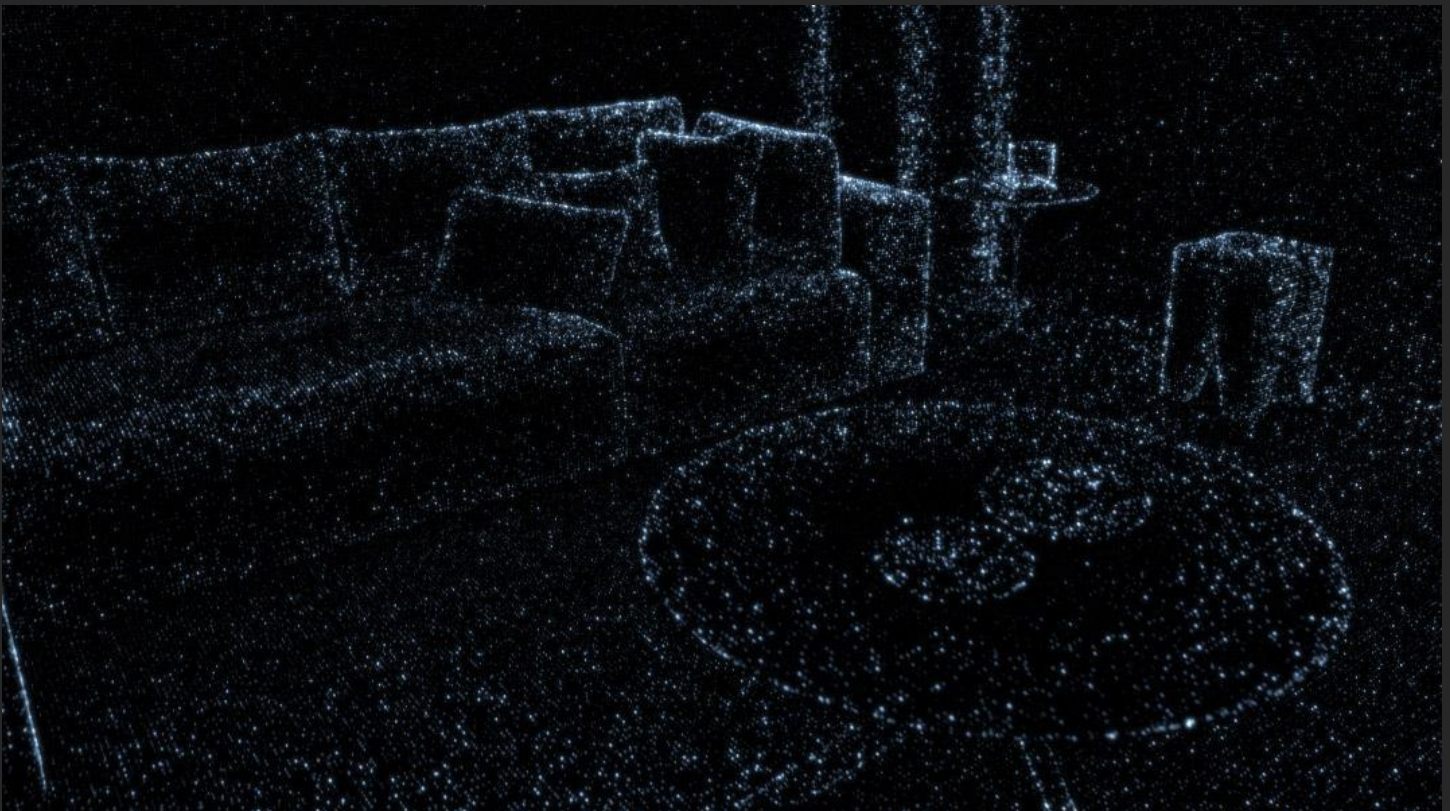


Image Source: Apple

# LiDAR: The Next Generation

The biggest advancement in AR in 2020 was likely **Apple's** iPhone LiDAR camera. Though it's only available on the iPhone 12 Pro and Pro Max, LiDAR will trickle down to the rest of the iPhone lineup in the coming years. This will unlock AR's next generation, and better enable the previous section's AR cloud endpoints.

Short for light detection and ranging, LiDAR involves sensors that track how long it takes light to reach an object and bounce back. This is the state of the art for depth sensing and is how autonomous vehicles achieve computational vision to “see” the road.

**Apple** integrated the technology in the iPad Pro last year, signaling that it would soon arrive at an iPhone near you. This aligns with **Apple's** AR master plan but more immediately

has photography benefits — a key focal point in the iPhone's horse-race against Samsung and Google flagships.

With smartphones maturing and each innovation cycle getting more rote and “incremental”, the camera has been one sexy component on which **Apple** has focused innovation and device marketing. That applies to AR and photography, but the latter is a much larger market today.

Meanwhile, smartphone cameras are all about innovating around space constraints and achieving DSLR quality with only millimeters of focal length. LiDAR now joins **Apple's** multi-camera and software-fueled systems for better autofocus and “seeing in the dark” in low-light scenes.



LiDAR Scanner

Image Source: Apple



## It Just Works

Beyond LiDAR's primary photography goals, what about its longer-term AR angle? As noted, it unlocks sharper and more acutely-tracked AR experiences. Exceeding the capabilities of the RGB cameras in the iPhone's last few generations, LiDAR will enable AR that "just works."

This will manifest in the mostly-unseen computational work that happens before AR graphics are shown, such as spatial mapping. LiDAR is better equipped to quickly scan room contours, which is the first step towards "believable" and dimensionally accurate AR that occludes physical objects.

Besides knowing that **Apple** is heading in this direction, based on LiDAR's inherent alignment with its AR trajectory, the company has explicitly mentioned AR and LiDAR in the same breath. Perhaps more notable, today's AR leader, **Snapchat**, is already on top of it.

Specifically, **Snap** has announced plans to integrate LiDAR into its Lens Studio AR creator platform. As it has stated publicly, LiDAR elevates capabilities in its Lens Studio, unlocking a new creative range for AR developers – a central principle of its broader AR strategy<sup>xvi</sup>

LiDAR will also benefit **Snap's** AR efforts by upgrading both the underlying capability and user-friendliness. The former involves better object tracking, which translates to graphics that interact with real-world items in more realistic ways. It can especially boost these capabilities in low light.

That will engender several new use cases for **Snapchat** lenses. For one, it will mean more

indoor activations, such as augmenting your office or bedroom. Second, it brings lenses more meaningfully to the rear-facing camera to augment the world, in addition to selfie lenses – a path Snap was already on.

As for user-friendliness, LiDAR can not only perform more accurate spatial mapping, but it can do so much faster than standard RGB cameras. To activate AR experiences, users don't have to wave their phones around – a more approachable UX that could appeal to a wider base of mainstream users.

And **Snap** isn't alone. **Niantic** and other AR leaders are incorporating LiDAR to elevate their AR platforms across the board. Some are even integrating it with other software such as Unity's physics engine for realistic AR that follows the laws of physics.

These integrations will continue to happen as developers get creative with LiDAR and formulate machine-learning magic for several combinations of experiences that haven't been imagined yet. Put another way... things just got a lot more interesting in AR.



Image Source: Apple

# Wearables Pave the Way

While things like LiDAR continue to evolve mobile AR capabilities, parallel developments are happening in other device classes. As examined earlier, mobile AR is warming people up to spatial experiences, which could provide a softer landing for eventual AR glasses.

But another device class could have an equal or greater impact towards that same end: wearables. The thought is that devices like **Apple** Watch and AirPods could condition consumers to wear sensors on their bodies, and thus acclimate to the cultural shift that will be required for AR glasses.

This possibility is amplified as wearables continue to be one of the fastest-growing consumer tech segments. That includes smart watches and “hearables” such as **Apple** AirPods and its equivalents. They’re even performing well during a pandemic, though sales are down slightly.<sup>xvii</sup>

Beyond consumer demand, tech giants are embracing wearables as they align with road maps and growth strategies. The poster child is **Apple**, which is motivated toward wearables as a revenue diversification play, given declining iPhone sales and a maturing smartphone market.

**Apple’s** year-over-year wearables growth is almost to the point of offsetting iPhone sales declines. Wearables also represent a long-term strategy to future-proof **Apple’s** multi-device ecosystem approach, consisting of Watch, AirPods, and (soon) smart glasses.

**Apple** is hoping that this device-constellation approach will collectively achieve holistic sensory augmentation where the whole is greater than the sum of its parts. It’s also hoping this approach motivates consumers to own several devices — an ARPU-boosting move that’s *classic Apple*.



# Trojan Horse

**Google** is meanwhile motivated toward wearables to maintain direct touchpoints to users. This was the same strategy that drove **Google's** Android OS years ago. Just like with mobile devices, **Google** can position itself closer to users as a "Trojan horse" for search.

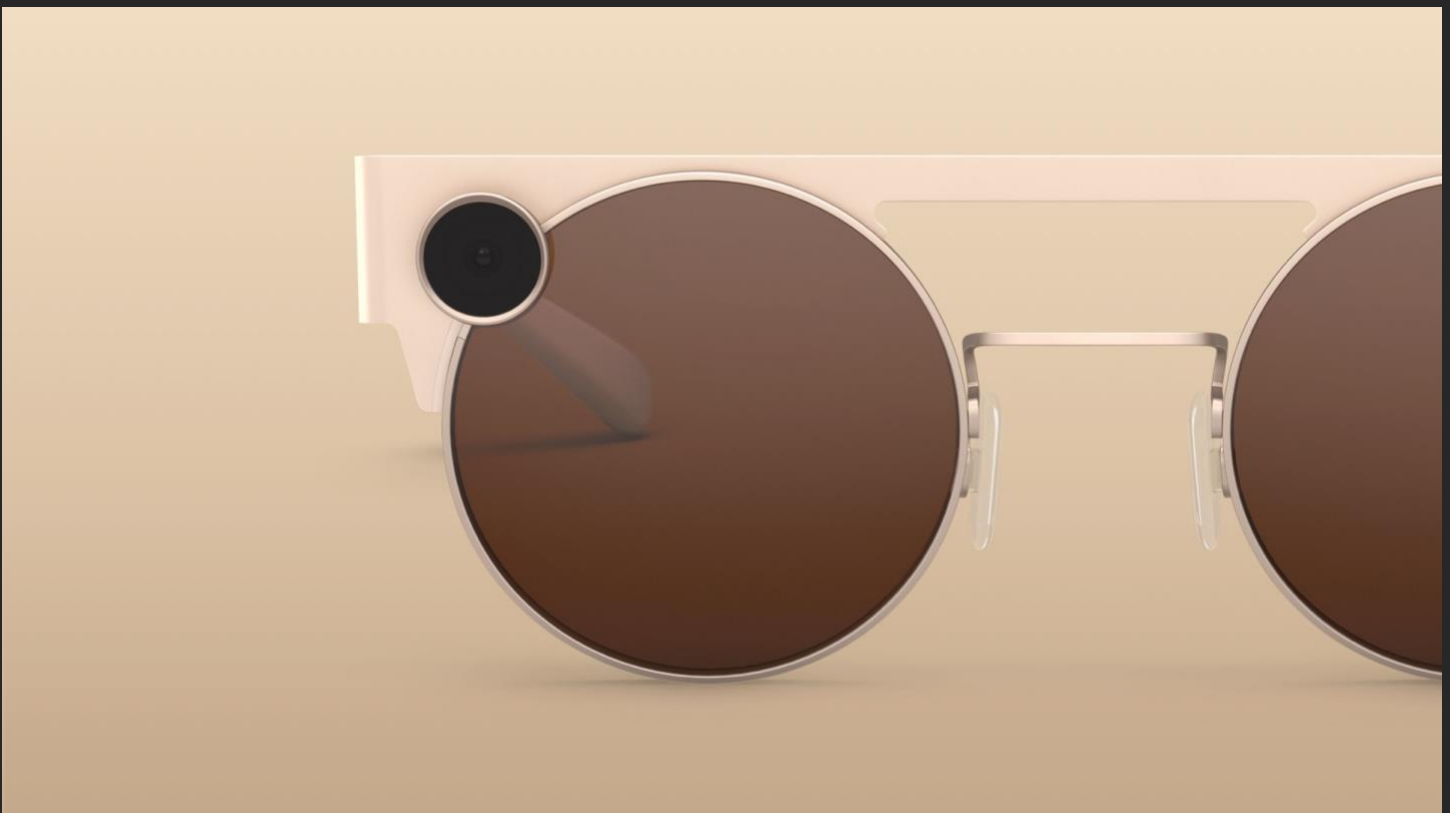
**Amazon** is motivated for similar reasons — a direct consumer touchpoint as a Trojan horse for its core business, which of course is eCommerce. The same thing drives its smart-speakers and Internet-of-things devices — the endgame being more frequent and larger eCommerce baskets.

Going down the list, **Microsoft** is motivated to drive and future proof its core product: enterprise productivity. That includes its Surface Buds which create deeper integrations to Office products such as language translation, or controlling slide presentations through voice commands.

Then there's **Facebook**, where wearables support AR glasses ambitions. Its project Aria is doing just that by feeling out AR glasses' social dynamics. Speaking of which, **Snapchat** is doing similar with Spectacles by testing the social waters to gain UX insights for its eventual AR glasses.

And beyond acclimating the world to AR's future, wearables in some ways *already are* AR. More accurately, the branch of wearables known as hearables represents AR's lesser-known cousin, audio AR. This involves spatially-aware and intelligent audio prompts about one's environment.

It's also worth noting that Covid-era lockdowns have created supply chain impediments. But wearables have been resilient. Moreover, Covid impact will mostly be felt in the near term, and wearables will be back on track by mid-2021 to continue paving the way for AR.





# Video Companion

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# ARtillery Intelligence



# AR Glasses: The Endgame

Picking up where the previous section left off – and where many of the previous sections have led – AR’s fully actualized form hasn’t arrived yet. We’re talking of course about AR glasses. This is the AR modality that will unlock the technology’s true potential.

AR glasses have already arrived if you consider deployment in enterprise settings. There, AR glasses’ stylistic drawbacks aren’t as much of an issue as they are in consumer markets. There are still form-factor issues such as comfort and heat, but enterprise AR has the early lead in sector spending.

Notably, those spending shares could flip as AR glasses get sleeker and more commercially viable. Consumer markets are generally bigger than enterprise markets due to population sizes, but enterprise-spending often leads in early days of emerging technologies.

To quantify that, ARtillery Intelligence projects AR glasses spending to grow from **\$822 million** last year to **\$13.4 billion** in 2024. Enterprise spending is **98 percent** of that total today, but will retract to **90 percent** by 2024 and continue to decline from there until consumer/enterprise trendlines intersect.

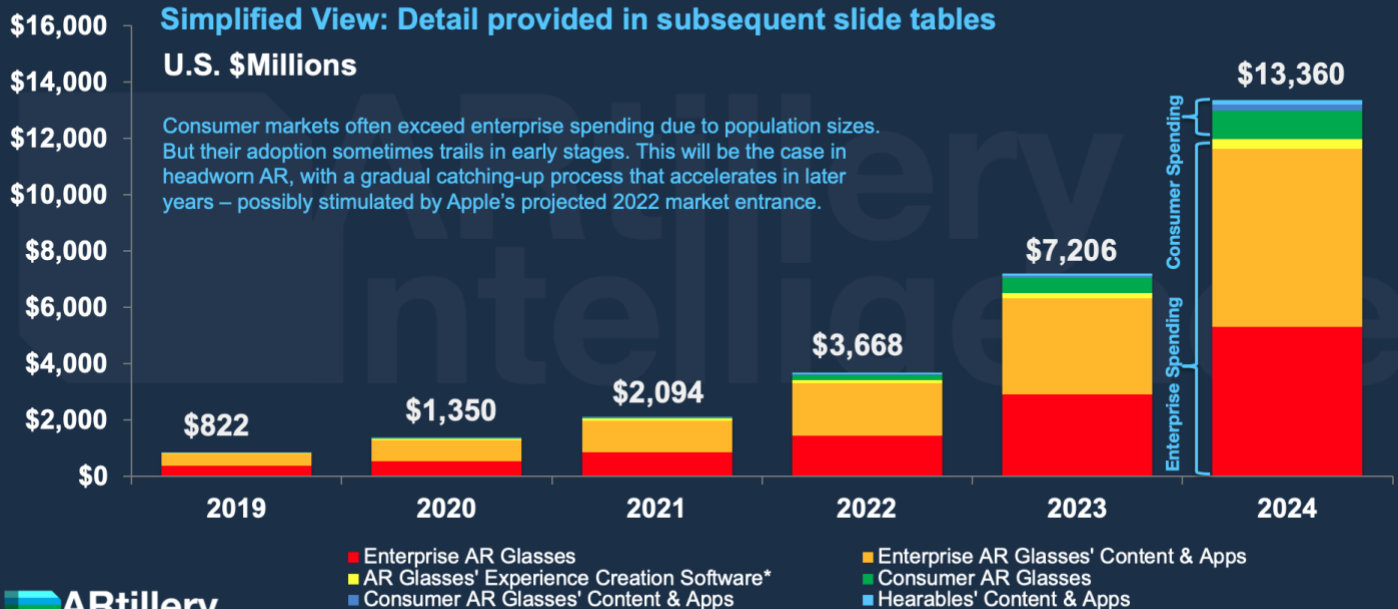
But that could take several years, not just due to requisite technical advancements, but also the cultural acceptance that was examined in the previous section. As seen in the **Google Glass** era, cultural acceptance and comfort levels for face-worn hardware (with a camera, no less) is an uphill climb.

But history tells us if anyone can accomplish that feat of mainstreaming emerging tech – or at least catalyze the process – it’s **Apple**.

## Headworn AR Revenue Overview

### Consumer & Enterprise AR Glasses Revenues, by Source

Simplified View: Detail provided in subsequent slide tables



# Apple of My Eye

Apple’s track record in mainstreaming emerging tech – also known as its “halo effect” – is the reason why you likely hear so much chatter about its rumored smart-glasses. The stakes are high for the AR industry, as Apple’s eventual moves could accelerate its ability to achieve scale.

But the question is what’s Apple’s strategy and what will its prospective glasses be and do? Starting with the former, Apple’s AR glasses strategy is driven by similar factors as its wearables play examined earlier: to future proof its core hardware business in the face of a maturing smartphone market.

Apple AR glasses could accomplish this by both propping up and succeeding the aging iPhone. The former happens as it creates reliance on the iPhone for local compute. In

other words, the iPhone gains importance – and user incentive to upgrade – if it powers your smart glasses.

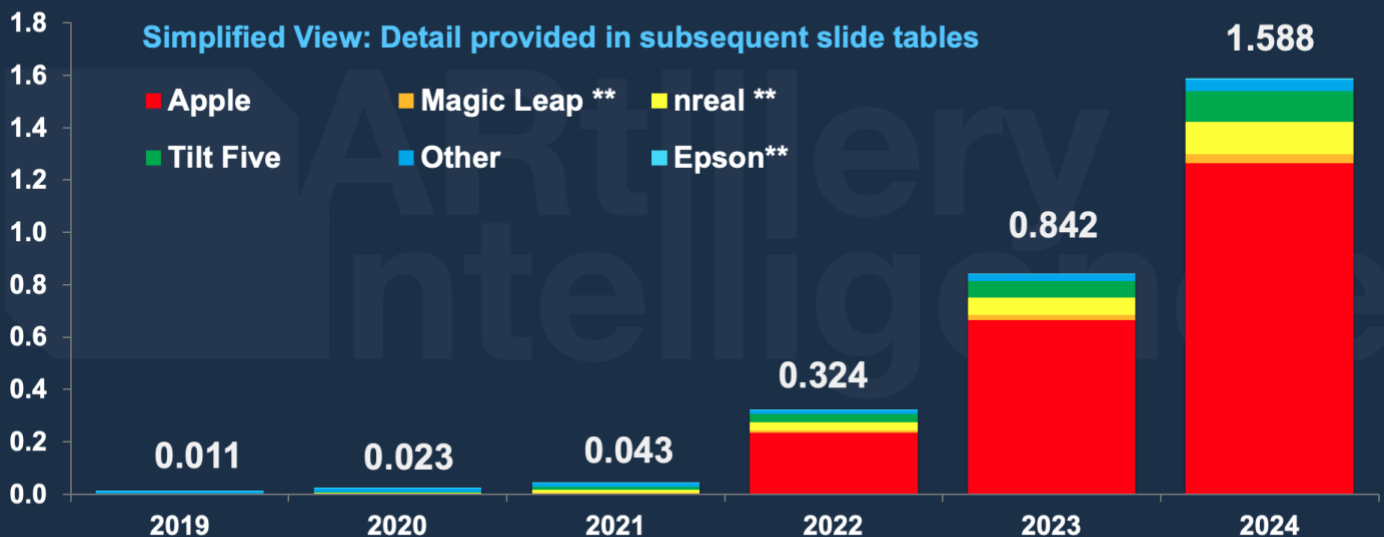
The iPhone succession plan is meanwhile accomplished through a suite of wearables that replaces the suite of iThings at the center of our computing lives. That could mean line-of-sight graphics through AR glasses, which accompany spatial audio from AirPods PRO, and biometrics from Apple Watch.

This theory fits the profile for Apple’s signature multi-device ecosystem play. Its marketing and product positioning will emphasize that the whole is greater than the sum of its parts, so you should own several devices (sound familiar?). In this way, AR glasses will be a key puzzle piece in Apple’s future road map.

## Consumer AR Glasses Projections

Consumer AR Glasses\* Annual Unit Sales

Millions of Units



\*\*These vendors have (or are projected to have) enterprise-targeted hardware as well, which is included in the enterprise spending section of this forecast

\*Totals represent projections for today’s in-market hardware, plus anticipated market entrants (e.g. Apple). Other providers will be added in future forecasts when their AR glasses plans become more evident (e.g. Facebook, Snap).

# AR Redefining AR

After covering the *why?* of **Apple's** AR glasses the remaining question addresses the *what?* What will they look like, and what will be the primary feature set? We don't know for sure, but many clues point to the likelihood that **Apple** will eschew common connotations with AR experiences.

In other words, **Apple** likely won't launch AR glasses — at least in version 1 — that employ “heavy AR.” This is world-immersive AR that has spatial and semantic understanding of its surroundings (see earlier AR cloud section). It's all about graphics that populate your field of vision in dimensionally accurate ways.

To achieve these functions, there are design tradeoffs such as bulk and heat, which would deviate from **Apple's** style and design sensibilities. So in the sliding scale between sleek glasses that power “light AR”; and bulky hardware that powers “heavy AR,” **Apple** will likely lean towards the former.

The first clue for this theory is the state of the underlying technology. It's not to the point where sleekness and graphical intensity are possible in the same device. The second clue comes from **Apple's** market size and resulting fiduciary drive to pursue massive markets.

Given that reality, “lite” AR glasses have a much larger addressable market than bulky sensor-heavy ones do, as the latter appeals to a subset of technophiles. **Apple's** mass-market requirements could lead it to something that is more along the lines of corrective eyewear or sunglasses.

In other words, eyeglasses and sunglasses are much larger markets than AR glasses. So **Apple** could enter the **\$200 billion** corrective eyewear market. AR features will include line-of-sight notifications that integrate other **Apple** apps, or biometrics from your **Apple** Watch.

Moreover, **Apple** will broaden the concept of “augmentation” beyond the AR world's current connotations. So instead of cartoon monsters, digital “layers” will be things that generally help people see better – either in a corrective sense or with digital filters that “brighten” your day in various ways.<sup>xviii</sup>

Other clues indicate practical mass-market functions, such as the integration with **Apple's** “project Gobi.” This involves retail point-of-sale codes that unlock product promotions or **Apple** Pay. This not only has mass-market applicability but could align well with a post-Covid world of “touchless” retail.<sup>xix</sup>

There could also be spatial audio integration with AirPods Pro (remember the ecosystem approach). This could involve an audible “notification layer” that joins its visual counterpart. Use cases could include identifying people or real-time foreign language translation. These could be true killer apps.

All of the above could represent **Apple's** first step into the realm of sensory augmentation. Like the iPhone 1's long evolutionary path to the pocket supercomputer we know today, “Apple Glass” will grow from simple augmentation to – eventually – the AR that's today confined to the domain of science fiction.

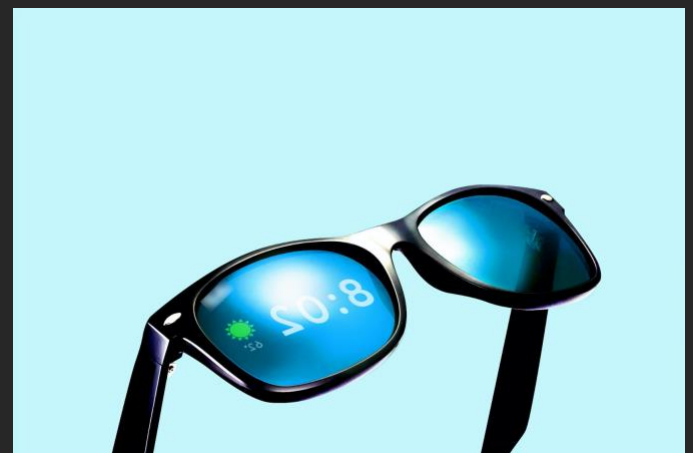


Image Source: Morning Brew



# Video Companion

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# ARtillery Intelligence



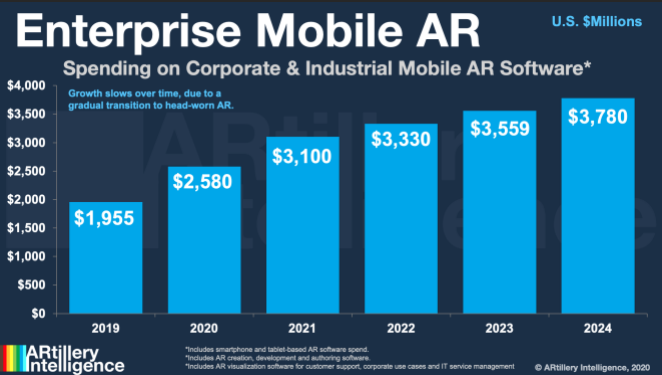
# AR at Work

While the above consumer AR challenges are being worked out, AR has found less resistance in the enterprise. There, the technology's style crimes aren't an issue, and the technology has clearer ROI and adoption drivers. That includes operational efficiencies that are brought by line-of-sight visualization.

In key functions like industrial assembly and maintenance, AR can expedite task completion and reduce errors by lessening cognitive load from "mentally mapping" 2D instructions to 3D space. There are lots of macro benefits too, such as distribution and retention of 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 and job turnover rates are increasing, it's getting harder to retain this institutional knowledge — an expensive problem for industrial enterprises.

For all of these reasons, ARtillery Intelligence has estimated that enterprise AR spending will grow from **\$2.77 billion** in 2019 to **\$15.8 billion** in 2024, a **41.6 percent** CAGR. This includes head-worn AR (hardware and software spending) as well as mobile & tablet-based AR (software spending).



## The Dark Side

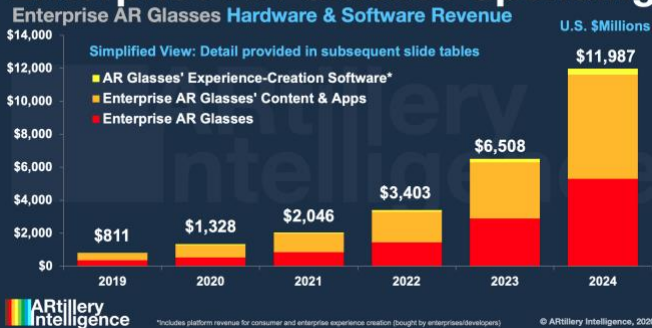
Though AR can alleviate the above challenges, it's easier said than done to get to the point of realizing those benefits. Practical and logistical barriers stand in the way — such as organizational inertia, politics, change management, and fear of new technology among key stakeholders.

These barriers exist even in a pandemic when social distancing measures compel AR's ability to facilitate remote assistance in the above ways. That factor could accelerate adoption to some degree and expose the technology's benefits... but organizational inertia persists.

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.

A recent ARtillery Intelligence report<sup>xx</sup> examined tactics for avoiding pilot purgatory; and an upcoming report in early 2021 will advance the narrative by featuring several case studies.

## Enterprise AR Glasses Spending



# VR: The Gradual Climb

This report so far has focused mostly on AR. But what about its spatial cousin, VR. The short version of VR's state of the union is that it represents a promising technology in gaming and entertainment, but its traction continues to be slow and steady.

We recently estimated in our global VR forecast<sup>xxi</sup> that sector revenue will grow from **\$4.98 billion** in 2019 to **\$12.2 billion** in 2024, a **19.6 percent** compound annual growth rate (CAGR). This consists of consumer (**\$2.67 billion** in 2020) and enterprise spending (**\$1.21 billion** in 2020).

Consumer spending is driven by gaming's lead as a VR use case. VR conversely has valuable but relatively-narrow use in enterprise settings due to its degree of sensory immersion that

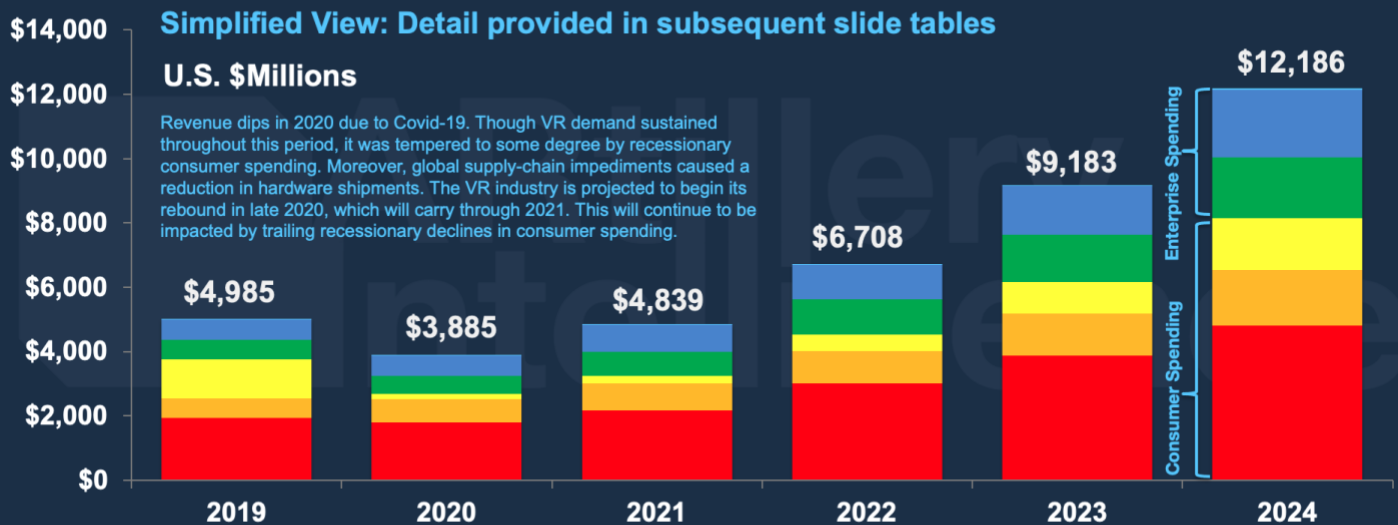
compromises factors like safety, social presence, and ergonomics. But it is showing promise as a training tool.

Like many sectors, VR has been impacted by the ongoing Covid-19 global pandemic. Though demand has remained strong during global lockdowns (VR is aligned with Covid-era demand signals such as gaming), the industry has suffered from supply-chain impediments

One key factor counteracting those declines is **Facebook's** multi-billion-dollar investments to seed content, user demand, and compelling hardware. These investments come at a sizeable short-term cost for **Facebook**, but they advance the company's long-term VR ambitions and network effect.

## Global VR Revenue Overview

### Consumer & Enterprise VR Revenues\*, by Category



\*\*Includes software licenses purchased by LBVR facilities.

■ Consumer Hardware
 ■ Consumer Software
 ■ LBVR Admissions
 ■ Enterprise Hardware
 ■ Enterprise Software\*\*
 ■ Advertising

## A Quest for Market Share

**Facebook's** VR strategy characterized above is best embodied in its latest hardware: Oculus Quest 2. By all measures, the device is a hit. After pre-launch rumors of a cheaper "lite" Quest or a more-loaded "Pro" Quest... we ended up getting the best of both: upgraded hardware with a **\$100** price dip.

One success metric is professional reviews, which are mostly unanimous in their praise of the device. Not to take away from UX execution, one factor at play is **Facebook's** aggressive pricing. Its long-term VR strategy lets it sacrifice near-term margins to build a network effect and win early market share.

This loss-leader pricing gives us a device that's much cheaper than it should be. That's great for consumers but the dark side of that equation is a device that's very hard to compete against — especially for margin-dependent hardware players in **Oculus'** competitive field.

"That's the shocker," said Tested's Norman Chan in his review of the device. "Quest 2 is not going to be more expensive than Quest 1. [It's] launching at **\$300** — a whole **\$100** less than Quest 1 [...] **Facebook** must be taking a huge loss with this because it's aggressive, aggressive pricing."



Image Source: Facebook

# Clues Emerge

But professional reviews and our analyst speculation admittedly only go so far. The true test will be how the market receives Quest 2. The VR industry has been waiting for its hero device to get over the mainstream adoption hump — wheels that were greased to some degree by Quest 1.

We don't know enough about Quest 2 sales volume but a few positive signals are beginning to materialize. This flows from our ongoing exercise to extrapolate VR unit sales using the marketplace's known quantities.

So what are those signals? One emerged during **Facebook's** Q3 earnings call in which Mark Zuckerberg reported a **5x** delta in pre-orders versus Quest 1. This comes soon after our September calculation of **one-million**

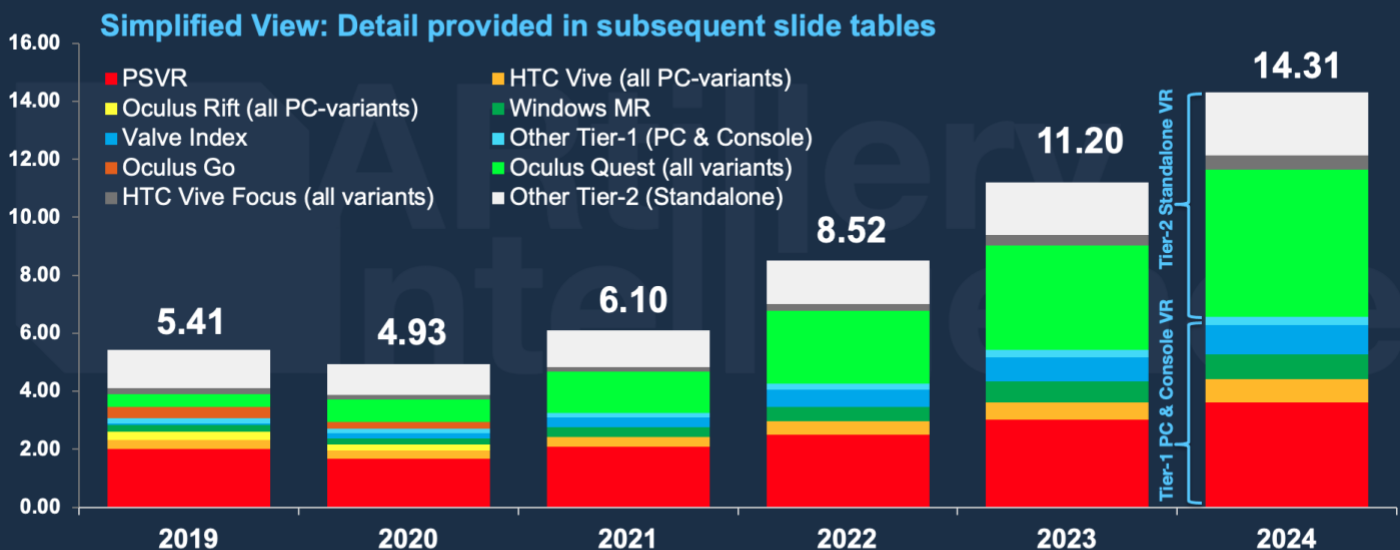
Quest sales to date,<sup>xxii</sup> which includes Quest 1 and 2 cumulative sales.

Looking forward, ARtillery Intelligence's global VR forecast projects Quest's 2020 sales (including Quest 1 and 2) to be **770,000** units. Moreover, cumulative Quest unit sales will reach an estimated **1.2 billion** at the end of 2020. These figures consider sales trending and several other signals we track.

These signals include **Facebook** disclosures, software/game sales, device availability, and **Facebook's** sizeable holiday marketing push. Given Quest 2's potential to mainstream AR with compelling hardware and an affordable (giftable) price point, Q4 2020 could be a "moment of truth" for its mainstream appeal.

## VR Headset Global Penetration

VR Headset Annual Unit Sales\* tier 1 & 2\*\* Millions of Units



\*This chart covers annual unit sales, see separate slide for year-by-year installed base (cumulative) figures.

\*\*Tier-1 includes console and PC VR headsets (e.g. PSVR). Tier-2 includes standalone VR headsets (e.g. Oculus Quest). These estimates exclude Tier-3 screenless VR viewers (e.g. Gear VR, Cardboard)



## Ready This Time

Another signal that helps us extrapolate Quest 2's sales volume is less about *demand* and more about *supply*. In other words, **Facebook** got a better sense of market demand with Quest 1, whose perpetual sold-out status throughout 2020 indicated underestimated and underserved demand.

In fairness, part of that undersupply was due to unexpected and Covid-inflicted supply-chain impediments. These exacerbated pre-Covid stock levels which were low or empty throughout most of the holiday 2019 timeframe (partially impacted by China's early COVID onset).

Regardless of the reason, **Oculus** gained key insights on market demand, which it now factors in to Quest 2's supply-chain strategy. It has scaled up to meet greater demand, so Quest 2's penetration — big or small — at least won't be supply-constrained. And it's already working, according to our stock checks.

"We really couldn't be happier," **Facebook** Reality Labs' Chris Pruett told Protocol in the only level of detail that he's understandably allowed to say publicly. "The device is selling quite well...faster than Quest did...and maybe a little bit beyond what we expected."





# Video Companion

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# ARtillery Intelligence

# Boiling it Down: 5 Predictions

Building from the analysis in the preceding pages, it's time to boil things down to five concrete predictions for 2021. These span the spatial computing spectrum, including AR, VR, and their revenue subcategories such as AR advertising, enterprise productivity, and consumer VR traction.

And because we generally disparage entities that make broad and safe predictions without any "teeth," we've included concrete statements or figures within each prediction. Here they are in no particular order:

## 1. Mobile AR Continues to Set the Stage.

Common wisdom states that smartphone-based AR is the forebearer to AR glasses, given that it has a head start with billions of AR-ready devices. But a small share of those devices is *AR-active*, so mobile AR has a long way to go in its own right. We project **811 million** global AR users by the end of 2021, propelled by the continued momentum of games like **Pokémon Go**, and the continued evolution of the underlying hardware, such as LiDAR. Another accelerant will be the investments of consumer brands to create experiences that are promotional in both exposure (e.g., film releases) and utility (e.g., shopping and product visualization).

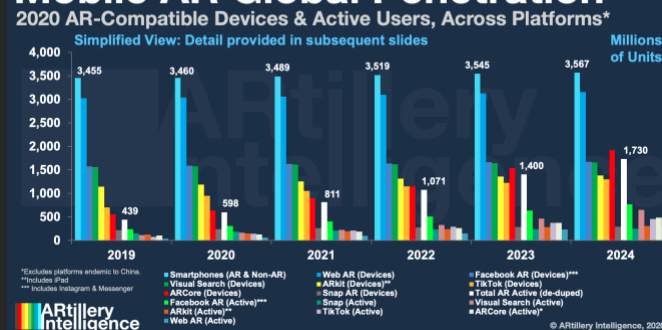


Image Source: Apple

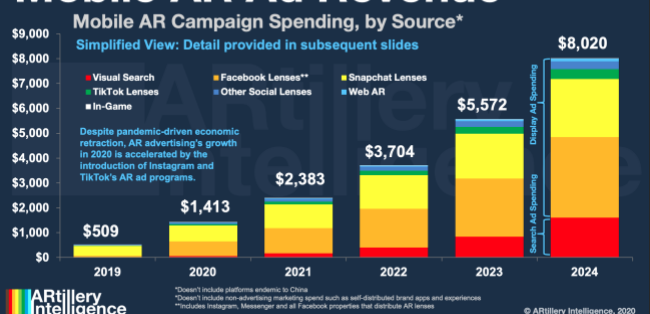
## 2. AR Advertising Continues its Revenue Lead:

Building from the previous prediction, paid advertising will emerge as AR's revenue leader in 2021 with a projected **\$2.4 billion**. This is driven by Gen-Z's continued affinity for camera-based experiences, brands' attraction to 3D product demonstration, and the ROI validation that continues to be seen in AR ad campaigns.<sup>xxiii</sup> Hardware evolutions like LiDAR will enable AR lens leaders like Snapchat to offer more robust rear-facing (world-immersive) lens campaigns. Though advertising is usually hit hard in recessionary periods, Covid-era factors will have a net positive impact on AR advertising. Downturns historically cause advertisers to re-examine and reallocate budget to emerging performance-based ad formats, as seen circa-2003 (search) and 2009 (social). AR will benefit from similar factors in 2021 as its existing momentum will inflect with brands' accelerated digital transformation.

## Mobile AR Global Penetration



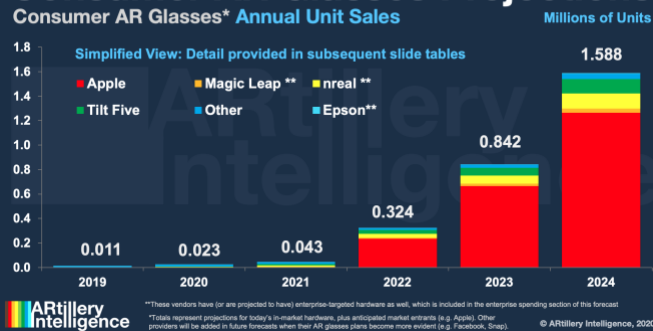
## Mobile AR Ad Revenue



### 3. AR Glasses Don't Inflect but Groundwork is Laid:

Consumer AR glasses won't arrive en masse in 2021 nor reach anything resembling ubiquity. Still, there will be progress made in key areas like consumer acclimation. That will continue to happen through smartphone-based AR, as well as the continued growth in wearables and hearables. The latter's momentum will sustain, reaching **145 million** units in 2021. In doing so, they'll help acclimate consumers to head-worn sensors. More importantly, we predict that **Apple** or **Google** will begin to make hearables more functional as "audio AR" devices by developing more intelligent apps that augment reality through contextually-relevant and spatially-aware audible cues. This could be followed by third-party SDKs to scale development, akin to what **Apple** has done with iOS-orbiting SDKs like tvOS and watchOS.

### Consumer AR Glasses Projections



### 4. Enterprise AR's Tipping Point Delays One More Year:

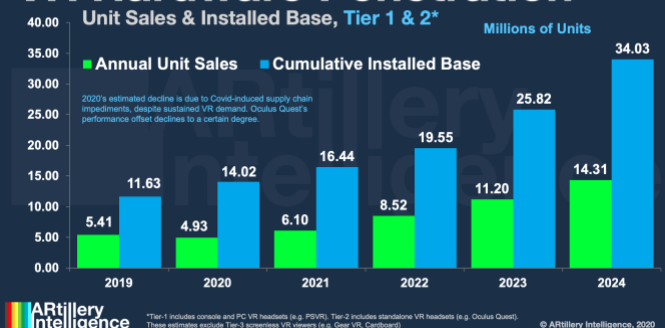
In our past enterprise AR analysis, we've theorized an eventual tipping point. As seen in past enterprise tech cycles, this tipping point is followed by accelerated adoption and herd mentality that carries a given technology to ubiquity. In last year's predictions, we theorized that this tipping point was still more than a year away, arriving in 2021. Given unforeseen circumstances of a global pandemic in 2020, we're pushing our projection of that tipping point another year to 2022. The good news is that Covid-era factors could benefit enterprise AR in the long run. This will happen as enterprise AR functions like

remote assistance align with the hybrid remote work models that will develop in the post-Covid era. This plus rebounding enterprise spending will position AR well on its path to a tipping point in 2022. Meanwhile, we project enterprise AR spending to reach **\$5.1 billion** in 2021.

### 5. VR Gains Ground in its Gradual Climb:

The VR world has come to terms with the fact that its revolutionary status trumpeted in the circa-2016 hype cycle was misguided. VR could transform several areas of media, entertainment, and enterprise productivity, but in narrower ways. And the timeline will be much longer. That said, 2020 was a positive year for VR (even with a global pandemic) and 2021 will accelerate the sector even more. This is mostly due to **Oculus Quest 2**, which continues to push the boundaries of consumer VR hardware, while having a compelling price to feature ratio (stemming from **Facebook's** long-term investment and loss-leader pricing). We estimate **770,000** Quest 1 and 2 unit-sales in 2020 and **1.42 million** Quest 2 unit-sales in 2021. Going forward, VR is positioned well due to its alignment with remote work and home entertainment. Though the world will bounce back from a pandemic in 2021, the post-Covid world will maintain some new models discovered in 2020, including hybrid-levels of remote work, home entertainment, and other dynamics that align with VR adoption. We project VR sales to reach **6.1 million** units in 2021, while its cumulative in-market installed base grows to **16.4 million**.

### VR Hardware Penetration





# Key Takeaways

- AR** Though 2020 was a turbulent year for the world, activity levels were relatively calm in spatial computing.
- AR** This is a positive sign, as the sector's early and erratic days have transitioned to slow & steady growth.
- AR** These are marks of an industry that's moving into adolescence, with a more defined path to maturity.
  
- AR** One bright spot for AR continues to be its mobile manifestations, given global smartphone penetration.
- AR** There are 3.46 billion global smartphones, 3.03 billion of which are *AR-ready* and 598 million are *AR active*.
- AR** Hardware evolution such as LiDAR will advance AR through underlying capability and consumer appeal.
- AR** Leading business models are in-app-purchases in mobile gaming (mostly Pokémon Go) and advertising.
  
- AR** Advertising is an AR revenue leader, with a projected \$1.4 billion in brand spending in 2020.
- AR** This continues to be driven by users' affinity for interactive lenses, and advertiser drive to follow that usage.
- AR** Brands are further attracted to AR advertising for its creative capacity to demonstrate products in 3D.
- AR** Further emboldening AR advertising is strong campaign results and ROI, causing brands to double down.
  
- AR** Mobile AR's most significant area of development continues to be the construction of the AR cloud.
- AR** This involves capturing spatial maps that serve as scaffolding for next-generation AR experiences.
- AR** The size of this endeavor compels crowdsourced approaches that utilize widely-deployed smartphone cameras.
- AR** Tech giants each have their own spin on AR clouds and road maps, signaling several potential outcomes.
  
- AR** Beyond mobile AR, another device class is paving the way for AR glasses: wearables.
- AR** Just as mobile AR *conditions* users for spatial experiences, wearables *acclimate* them to body-worn sensors.
- AR** Wearables impact is further underscored by its success as a product class, currently exploding in adoption.
- AR** Tech giants further propel wearables by investing in them as a way to offset maturing smartphone markets.
- AR** Beyond an AR glasses *acclimation* play, hearables *already* represent AR through spatial audio.
  
- AR** AR glasses themselves aren't ready for mainstream acceptance and won't gain significant ground in 2021.
- AR** There will be steady progress in the underlying technology and some commercial activity such as Nreal Light.
- AR** Most of the activity in AR glasses in 2021 will be "setting the table" for 2022 when they could arrive in earnest.
- AR** Much will hinge on Apple's rumored AR glasses, which could cause a classic Apple "halo effect" for AR.
- AR** Apple will prioritize style over graphical intensity, and could re-define augmentation through "lighter" AR.
- AR** For example, version 1 could feature thin notification layers or "filters" for corrective and enhanced vision.
  
- AR** Beyond all of the above consumer endpoints, enterprise AR will continue to push forward.
- AR** Enterprise AR won't reach its anticipated "tipping point" in 2021 but that could come soon after, in 2022.
- AR** The sector will make progress in 2021, mostly with organizational acceptance rather than tech advancement.
- AR** Organizational inertia continues to be enterprise AR's greatest barrier, born from resistance to change.
  
- AR** Beyond AR, VR will likewise experience steady gains in 2021, but won't be revolutionary.
- AR** VR's growth will continue to be fueled by Facebook's investments in hardware and content.
- AR** This can be seen most vividly in Oculus Quest 2, which has a compelling quality/price ratio.
- AR** 2020 experienced unit shipment declines in the aggregate, but sales will bounce back in 2021.
- AR** This is already happening as Facebook has emboldened its supply chain and is meeting demand for Quest 2.
  
- AR** The ongoing global pandemic will impact spatial computing sub-sectors differently and unevenly.
- AR** Mobile AR will be less affected because it's "Covid-friendly" (software, entertainment, and communications).
- AR** Mobile AR will also benefit as a value-added component of eCommerce and post-Covid "touchless" retail.
- AR** Enterprise AR benefits from Covid and post-Covid dynamics, as guided support aligns with remote work.
- AR** VR has suffered from supply-chain issues, but longer-term Covid-aligned demand inflections will offset them.

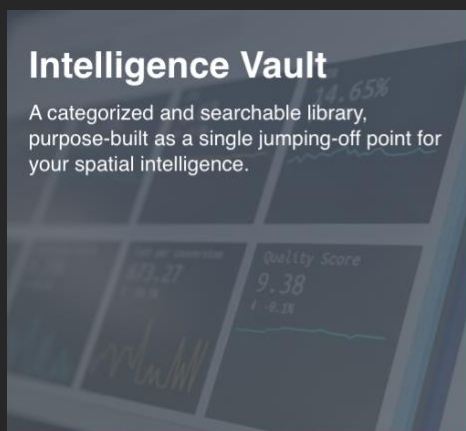








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# Companion Video

## *Get Spatial Smart*

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# ARtillery Intelligence



# About ARtillery Intelligence



**ARtillery Intelligence** chronicles the evolution of spatial computing. 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 journalistic approach. It also maintains a business angle: Though there are lots of fun and games in spatial computing, cultural, technological and financial implications are the primary focus.

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 consumer survey data and multi-media, all housed in a robust intelligence vault.

Learn more [here](#).





# About Intelligence Briefings

ARtillery Intelligence Briefings are monthly installments of spatial computing analysis. They synthesize original data to reveal opportunities and dynamics of spatial computing sectors. A layer of insights is applied to translate market events and raw figures into prescriptive advice.

More information, past reports and editorial calendar can be seen [here](#).

## 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 has been an industry analyst covering mobile and social media since 2005, and is now Chief Analyst of ARtillery Intelligence and Editor-in-Chief of *AR Insider*.

Mike is a frequent speaker at industry conferences such as AWE, VRLA and XRDC. He has authored more than 120 reports and market-sizing forecasts on the tech & media landscape. He contributes regularly to news sources such as *TechCrunch*, *Business Insider* and the *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 coverage of spatial computing. To support narratives, data are cited throughout the report. These include ARtillery Intelligence original data, as well as that of third parties. Data sources are attributed in each case.

For market sizing and forecasting, ARtillery Intelligence follows disciplined best practices, developed and reinforced through its principles' 15 years in tech-sector research and intelligence. This includes the past 5 years covering AR & VR exclusively, as seen in research reports and daily reporting.

Furthermore, devising these figures involves the “bottom-up” market-sizing methodology, which involves granular revenue dynamics such as unit penetration, pricing and growth patterns. More on ARtillery Intelligence market-sizing research and methodologies can be read [here](#).

## Disclosure and Ethics Policy

ARtillery Intelligence has no financial stake in the companies mentioned in this report, nor was it commissioned to produce it. With respect to market sizing, ARtillery Intelligence remains independent of players and practitioners in the sectors it covers, thus mitigating bias in industry revenue calculations and projections.

ARtillery Intelligence's disclosure and ethics policy can be seen in full [here](#).

## Contact

Questions and requests for deeper analysis can be submitted [here](#).





# Reference

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