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Goldman Sachs

Virtual and augmented reality have the potential to become the next big computing platform. All around us are examples of where VR (which immerses the user in a virtual world) and AR (which overlays digital information onto the physical world) can reshape existing ways of doing things– from buying a new home to interacting with a doctor or watching a concert. In the first of a new **Profiles in Innovation** series, we examine what VR/AR could become, the evolving use cases and the markets that could be created and disrupted.

Heather Bellini, CFA
(212) 357-7710
heather.bellini@gs.com
Goldman Sachs & Co.

Wei Chen
+886(2)2730-4185
wei.chen@gs.com
Goldman Sachs (Asia) L.L.C., Taipei Branch

Masaru Sugiyama
+81(3)6437-4691
masaru.sugiyama@gs.com
Goldman Sachs Japan Co., Ltd.

Marcus Shin
+82(2)3788-1154
marcus.shin@gs.com
Goldman Sachs (Asia) L.L.C., Seoul Branch

Shateel Alam
(212) 902-6785
shateel.alam@gs.com
Goldman, Sachs & Co.

Daiki Takayama
+81(3)6437-9870
daiki.takayama@gs.com
Goldman Sachs Japan Co., Ltd.

PROFILES IN INNOVATION

Virtual & Augmented Reality

Understanding the race for the next computing platform

Table of Contents

The following is an excerpt from "Virtual & Augmented Reality: Understanding the Race for the Next Computing Platform," published January 13, 2016, 64 pgs. All company references in this excerpt are for illustrative purposes only and should not be interpreted as investment recommendations.

PROFILES IN INNOVATION

This is the first report in a new *Profiles in Innovation* series analyzing how emerging technologies are creating profit pools and disrupting old ones.

Other contributing authors: *Robert D. Boroujerdi, James Covello, Simona Jankowski, CFA, Heath P. Terry, CFA, Matthew J. Fassler, Lindsay Drucker Mann, CFA, Noah Poponak, CFA, David Roman, Debra Schwartz, Gabriela Borges, CFA, Matthew Cabral, Doug Clark, CFA, Mark Grant, Takafumi Hara, Nicole Hayashi, Chelsea Jurman, Jack Kilgallen, CFA, Balaji Krishnamurthy, CFA, Giuni Lee, Jim Liu, Komal Makkar, Hideaki Mitani, Yukiko Nomani, Dan Powell, Connie Qian, Swapnil Sheth, and Tina Sun.*

Did you know…?

FINANCIAL BACKING

$3.5bn

The value of the 225 VR/AR venture capital investments made in the last two years. Facebook also paid $2bn to acquire Oculus in May 2014.

GLOBAL INTEREST

121

The number of countries represented in the viewership data for the first US Democratic presidential debate, which CNN streamed in VR.

SHIPPING OUT

2mn

The number of Google Cardboard head-mounted displays distributed since the product's June 2014 launch.

SELLING OUT

48 hours

The amount of time it took for Samsung's $99 Gear VR to sell out on Amazon.com and BestBuy.com—an indication of strong demand at lower price points.

INTEREST IN THE PAST

770k

The number of Virtual Boy VR gaming consoles Nintendo sold after its 1995 release, despite the platform's technological limitations.

READY TO BUILD

200k

The number of developers Oculus has registered to create games on the VR platform (as of September 2015).

A WAVE OF CONTENT ON THE WAY

100

The number of VR games Oculus says will be available in 2016, with 20 games developed by Oculus Story Studios.

RETAIL VALUE

$599

The price of the consumer version of Oculus (launched on January 6, 2016), with Oculus-ready PC bundles expected to sell for ~$1,500.

HOME REDESIGN, REIMAGINED

6

The number of Lowes home improvement stores featuring "Holorooms" to help customers visualize their remodeling projects.

EASIER TO IMAGINE YOURSELF AT HOME

$52bn

The size of the US real estate commissions market that VR stands to disrupt. Sotheby's is beginning to show luxury homes in VR.

Portfolio manager's summary

Virtual reality (VR) and augmented reality (AR) have the potential to become the next big computing platform, and as we saw with the PC and smartphone, we expect new markets to be created and existing markets to be disrupted. There's no shortage of examples of how VR and AR can reshape existing ways of doing things– from buying a new home, interacting with a doctor, or watching a football game. As the technology advances, price points decline, and an entire new marketplace of applications (both business and consumer) hit the market, we believe VR/AR has the potential to spawn a multibillion-dollar industry, and possibly be as game changing as the advent of the PC. This report aims to show what VR/AR could become, the evolving use cases, the potential market disruption, and the challenge of moving from science fiction to widespread adoption. We see both VR (which immerses the user in a virtual world) and AR (which overlays digital information onto the physical world) as driving a trend towards the adoption of head-mounted-devices (HMDs) as a new computing form factor.

Given that VR/AR technology is still in the early stages of development, we've outlined three scenarios for hardware and software uptake over the next decade. In our base case, we estimate $80bn in revenue by 2025 ($45bn in hardware, $35bn in software) and assume that HMDs gain popularity as technology improves, but adoption is limited by mobility and battery life. Our "accelerated uptake" scenario predicts a $182bn market ($110bn in hardware, $72bn in software), where VR/AR technology evolves from a niche device to a broader computing platform. In our $23bn "delayed uptake" scenario ($15bn in hardware, $8bn in software) we assume VR/AR sees challenges in latency, display, safety and privacy, and the technology is used primarily for videogames. These forecasts compare with the current hardware markets for notebooks at $111bn, desktops at $62bn, and videogame consoles at $14bn.

We've outlined 9 use cases for VR/AR which we see as the most meaningful drivers of the market in the near-term: videogames, live events, video entertainment, healthcare, real estate, retail, education, engineering, and military. We conducted a bottom-up analysis to arrive at estimates for the potential market in each use case, assessing the number of users and the existing and potential revenue pools. While the videogame use case will likely take center stage in 2016, we see use cases in areas like healthcare and education evolving to help drive VR/AR awareness. The enterprise was the driver of the PC and the consumer was the driver of the smartphone, but we see both forces at work to drive VR/AR adoption, with consumer use cases driving the momentum in the beginning. In 2025, our base case software estimates imply that 60% of VR/AR software revenue is driven by the consumer while the remainder is supported by enterprise and public sector use cases.

Looking beyond videogames, we see real estate, retail, and healthcare among the first markets that VR/AR disrupts. VR/AR technology has the potential to change business models and the ways in which we transact. Sotheby's is beginning to show luxury homes in VR, which has potential to disrupt a $52bn US real estate commissions market (derived with data from the National Association of Realtors). Lowes has equipped 6 of its stores with "Holorooms" to help customers envision their home remodeling plans. VR/AR technology could also reduce the need for in-store display inventory and potentially accelerate the erosion in value of physical stores to the extent that the viewing experience can be deployed in the home and via mobile devices. Finally, doctors and medical professionals are experimenting with AR as a hands-free medical tool, playing into a $16bn patient monitoring devices market.

We view the user experience, technology constraints, the development of content and applications, and price as key hurdles to adoption. We believe the user experience will be the most important factor and expect technology advancements to reduce cyber sickness and increase mobility, expanding the use cases and pervasiveness of VR/AR. In

terms of content and applications, we see a chicken-and-egg issue where content and app developers are cautious to make investments in VR/AR without an installed base, while at the same time, consumers and enterprises are hesitant to buy VR/AR hardware without a strong supply of content and apps. We see Facebook, Google, Sony, and Microsoft supplying hardware and content/software. Finally, with the retail price of Oculus at $599 and Oculus-ready PC bundles costing ~$1,500, we believe price points need to decline to see wider adoption.

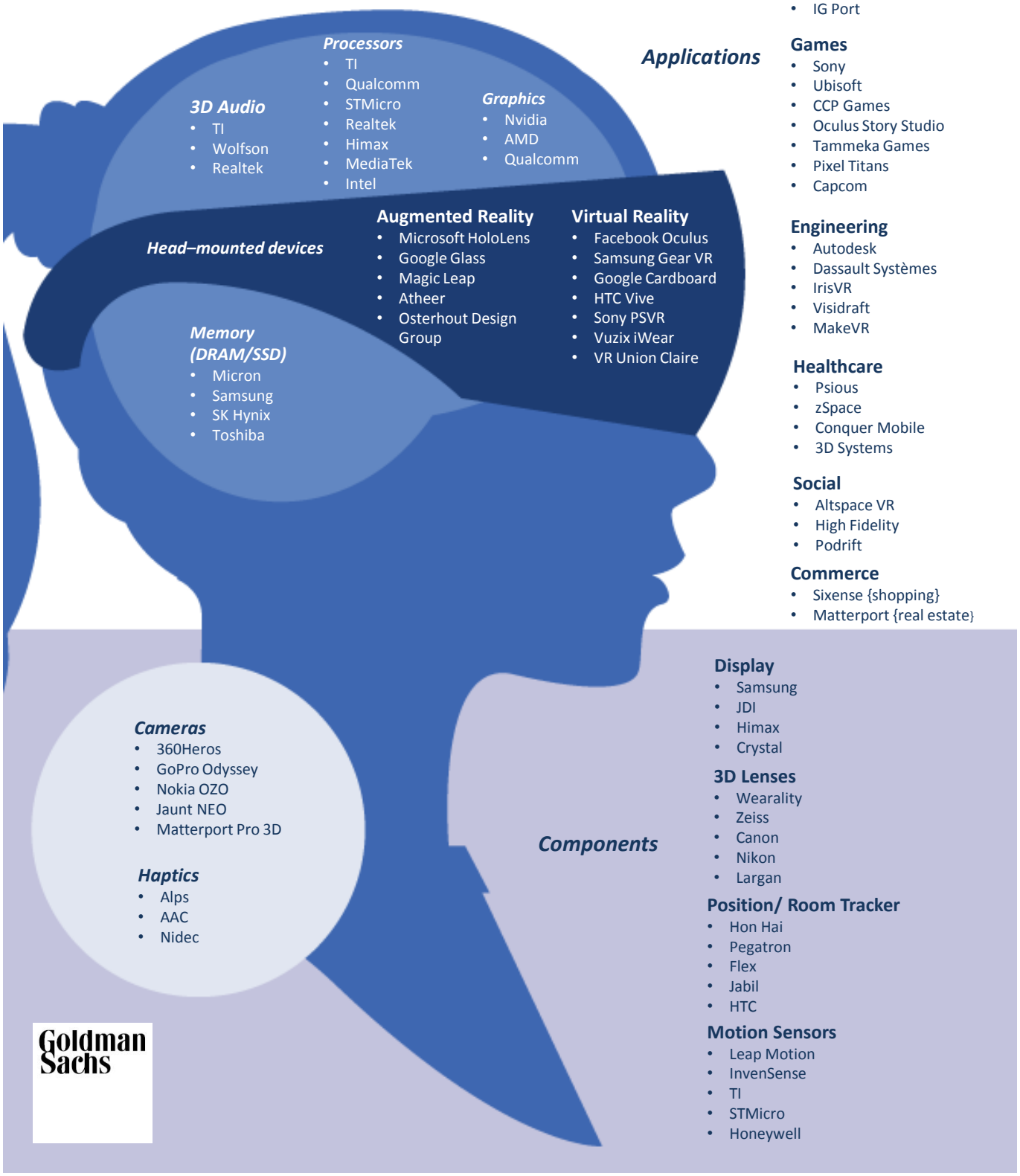
We believe VR/AR HMDs could experience similar cost reduction curves as we have seen on PCs and smartphones, with prices falling 5-10% annually. In our BoM (bill-of-materials) analysis, we found VR/AR HMDs contain components that highly overlap those of smartphones, such as display, motion sensors, processors, storage/memory and wireless connection. That said, there are also components unique to VR/AR devices such as 3D lenses and position tracking systems which currently drive the price up. We expect VR players such as Oculus, HTC and Sony to price their HMDs in line with their BoMs ($350-500) to drive user adoption. Looking forward, we expect BoM costs to decline with economies of scale, which would enable HMD makers to either reduce their selling prices to take more market share or maintain their ASPs to earn more profits, depending on their targeted market segments and pricing strategies.

At this stage, we have greater conviction in the relative success of VR versus AR given VR's technological progress and momentum, and the early formation of an ecosystem of vendors and partners. Our base case software scenario is driven 75% by VR use cases vs 25% for AR use cases. While we believe both VR and AR need to advance technologically, we see AR as having more significant hurdles to overcome, including challenges in display technology and the real-time processing and calibration of the real-world physical environment. That said, as AR technology matures, we see stronger enterprise use cases emerging, especially considering AR enables you to see your physical environment whereas VR completely blocks it.

Where could this go? We see qualities in VR/AR technology that can take this from niche use cases to a device as ubiquitous as the smartphone. Part of the mass appeal of smartphones is their ease of use with a touch screen interface; VR/AR technology has the potential to take this level of intuition to the next stage as the controls are driven by gestures and the interface is in 3D. Technology can often start with narrow use cases and evolve into broader platforms. For example, the iPod dominated in the music industry, cellular technology was added to it, and the device evolved into the iPhone. Soon after, third-party applications began to run on smartphones, creating a new market for business and consumer applications. In the long run, if VR/AR technology becomes as lightweight as a set of glasses, we see the potential for the evolution to be similar where multiple devices are combined into one, potentially replacing phones and PC environments.

The Ecosystem

Virtual Reality / Augmented Reality



The Ecosystem

Virtual Reality / Augmented Reality

Total Addressable Market

2025 Base Case VR/AR Estimates

VIDEOGAMES
$11.6bn
- Estimated users: 216mn
- Markets disrupted: videogames

LIVE EVENTS
$4.1bn
- Estimated users: 95mn
- Markets disrupted: live ticket sales

VIDEO ENTERTAINMENT
$3.2bn
- Estimated users: 79mn
- Markets disrupted: online streaming

RETAIL
$1.6bn
- Estimated users: 32mn
- Markets disrupted: e-commerce

REAL ESTATE
$2.6bn
- Estimated users: 0.3mn
- Markets disrupted: commissions

EDUCATION
$0.7bn
- Estimated users: 15mn
- Markets disrupted: K-12 and higher-ed software

HEALTHCARE
$5.1bn
- Estimated users: 3.4mn
- Markets disrupted: patient monitoring

MILITARY
$1.4bn
- Estimated users: 0.7mn
- Markets disrupted: defense training and simulation

ENGINEERING
$4.7bn
- Estimated users: 3.2mn
- Markets disrupted: CAD/CAM software

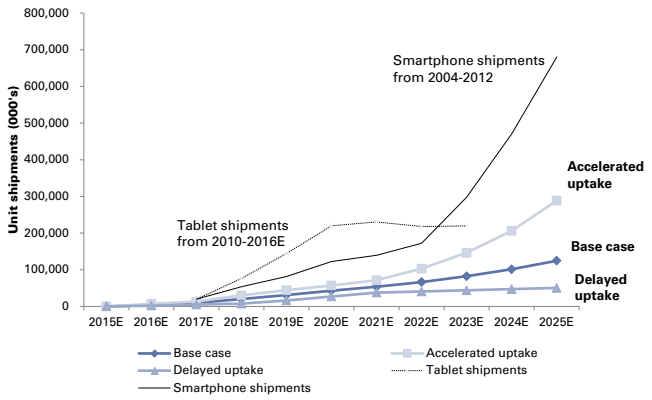
SOFTWARE
$35bn
- 60% of VR/AR software revenue will be driven by the consumer (vs. enterprise/ public sector)
- Videogames will be the first consumer market to develop
- Beyond videogames, we see real estate, retail and healthcare among the first markets disrupted

HARDWARE
$45bn
- 4 main devices used to experience VR/AR: HMDs, host systems, tracking systems and controllers
- Our forecast is specific to HMDs
- Our base case assumes 125mn annual shipments by 2025

Goldman Sachs

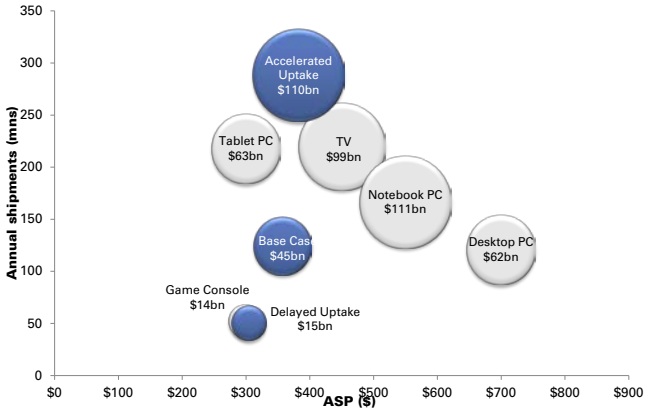
Virtual and augmented reality in 6 charts

Exhibit 1: Our VR/AR unit forecasts assume far slower adoption than smartphones or tablets



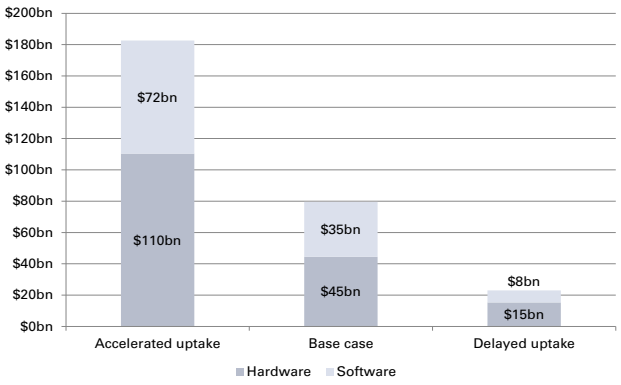
Source: Goldman Sachs Global Investment Research, IDC.

Exhibit 2: Our three scenarios for a 2025 VR/AR hardware market



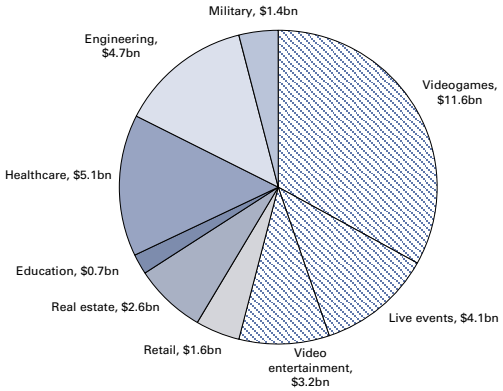
Source: Goldman Sachs Global Investment Research, IDC.

Exhibit 3: Our combined 2025 VR/AR hardware and software scenarios



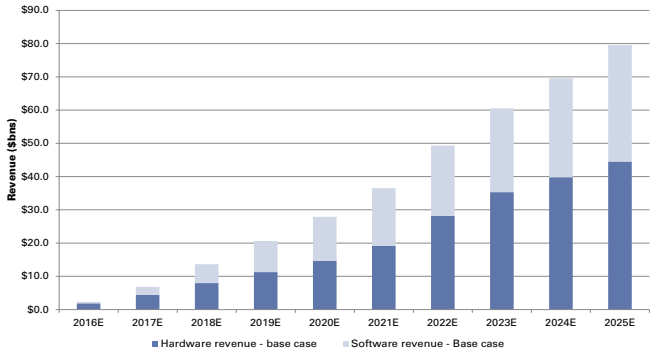
Source: Goldman Sachs Global Investment Research.

Exhibit 4: Our 2025 base case VR/AR software assumptions by use case



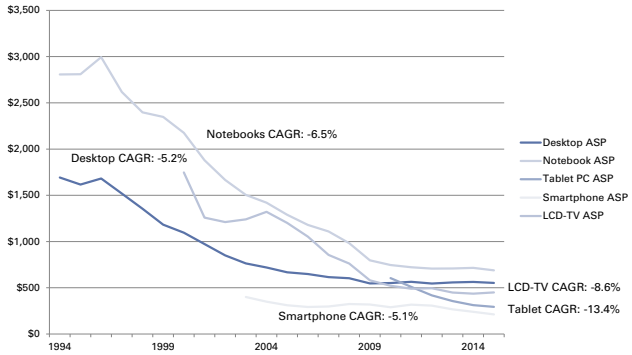
Source: Goldman Sachs Global Investment Research.

Exhibit 5: The progression of our base case hardware and software forecasts



Source: Goldman Sachs Global Investment Research.

Exhibit 6: HMD price declines could be similar to what we've seen in the past



Source: Goldman Sachs Global Investment Research.

Current state of the market

While virtual reality may currently be top of mind, this is not the first time. In the 1990s, when 3D gaming was introduced, virtual reality saw a similar boom. Gaming companies introduced 3D videogames, such as Virtuality's VR arcade pods and Nintendo's Virtual Boy. Movies, such as the Lawnmower Man, Virtuosity, and Johnny Mnemonic, portrayed new, immersive cyber-worlds. Books, including Snow Crash and Disclosure, similarly depicted this new type of reality. However, the technology was not able to keep pace with these unrealistic portrayals in the media. The 3D arcade games suffered from poor graphics, expensive prices, time lags, and low computing power. Eventually, these products failed, as consumers became unsatisfied with the technology, and the boom was over.

A similar hype began when Facebook acquired Oculus for $2bn in 2014 and we note that over the last 2 years there have been over 225 VC investments in VR/AR, raising $3.5bn in capital. So, what has changed that differentiates the current state from the 1990s flop? The answer is the technology, in our view. Today, computers are powerful enough to render realistic virtual worlds. Additionally, the mobile phone industry has improved the price, size, and performance of displays and sensors. Today's technologies have improved on the inefficiencies present in the 1990s. As a result of this progress, companies have become involved:

Exhibit 7: Recent involvement in virtual reality by technology giants

Company	Date	Details
Qualcomm	Jan-12	Raised seed funding for the mobile augmented reality startup Blippar
Google	Apr-12	Introduced augmented reality glasses, Google Glass, to the public
Sony	Mar-14	Sony announces Project Morpheus, later renamed PlayStation VR
HP	Mar-14	Launched Aurasma 3.0, an augmented reality platform that it acquired through Autonomy
Facebook	Mar-14	Acquired Oculus, a virtual reality startup, for $2bn
Samsung	Sep-14	Revealed its own head-mounted display, Samsung Gear VR, partnering with Oculus
Google	Oct-14	Invested $542mn in the startup Magic Leap
Intel	Apr-15	Invested in Series A funding for the virtual reality startup WorldViz
Apple	May-15	Reportedly acquired Metaio, an augmented reality software maker
Disney	Sep-15	Led a $65mn funding round in Jaunt, a VR content startup
Microsoft	Oct-15	Acquired Havok, a 3D physics engine used for videogames
Comcast & Time Warner	Nov-15	Participated in a $30.5mn funding round for NextVR, which captures live events in VR
Apple	Nov-15	Acquired Faceshift, a facial recognition capture and animation company
Fox	Jan-16	Acquired minority stake in Osterhout Design Group, a VR/AR HMD maker

Source: News sources, compiled by Goldman Sachs Global Investments Research.

There are still improvements to be made. Oculus' Chief Scientist, Michael Abrash, has said that they are still focused on further developing haptics (use of hands), visual display (pixel density, quality), audio (compute power), and tracking (mapping). That said, we expect product releases in 2016 to begin addressing these challenges and to see continuous product improvement over the next 3-5 years.

Virtual reality vs augmented reality

Virtual reality (VR) and augmented reality (AR) have different use cases, technologies, and market opportunities so it's important to distinguish between the two.

- Virtual reality immerses a user in an imagined or replicated world (like videogames, movies, or flight simulation) or simulates presence in the real world (like watching a sporting event live). Examples of hardware players in VR are Oculus, Sony PlayStation VR, HTC Vive, and Samsung Gear VR.
- Augmented reality overlays digital imagery onto the real world. Examples of hardware players in AR are Microsoft HoloLens, Google Glass, and Magic Leap.

An easy way to differentiate between the two is that VR uses an opaque headset (which you cannot see through) to completely immerse the user in a virtual world whereas AR uses a clear headset so the users can see the real world and overlay information and imagery onto it.

As we discuss in more detail in the use cases section of this report, we currently see AR geared towards serving business use cases, VR having both consumer and business applications, and some areas where the two overlap. For instance, most videogame development is in VR right now, but Microsoft HoloLens is also creating AR games such as Minecraft.

While VR and AR can have different use cases, we view both technologies as driving the broader trend of HMDs as a computing form factor. Whether for consumer use or enterprise use, both VR and AR technology have the challenge of convincing the world that the value proposition is high enough to add another device to the current slate of offerings in desktops, notebooks, tablets, and smartphones. Further, both VR and AR are gesture-based where the controls are largely driven by head and hand movements; while we view these gesture-based controls as intuitive this will serve as a new way to navigate the computing environment.

Summary of current HMD product offerings

Pre-orders for the consumer version of Oculus launched on 1/6/16 (expected to ship in March) at a price of $599 (including two videogames and an Xbox controller) and the device will run on a PC requiring a high-end Nvidia or AMD graphics card and Intel processor. Nvidia estimates that only 13mn PCs are powerful enough to run Oculus (less than 1% of the PC installed base according to Gartner) and a PC meeting Oculus' requirements is expected to cost at least ~$1,000 (Oculus-ready PC bundles are expected to cost $1,500). Given these high price points and small installed base of PCs that are powerful enough to run Oculus, we believe initial adoption might be limited. PlayStation VR (to run on the PlayStation 4 gaming console) and HTC Vive (to run on a PC) are expected to launch in 1H16 while the Samsung Gear VR (runs on a Samsung phone) was initially launched in September 2014 with a new product released in September 2015 for $99.

Microsoft has announced that a developer's version of HoloLens will launch in 1Q16 at a price point of $3,000. Google Glass was initially launched in 2013 with a limited release for $1,500 but was discontinued in 2015; it has been recently reported by the press (WSJ) that a new Google Glass version could launch in 2016. Finally, Magic Leap has yet to announce when its augmented reality product will be released.

Currently, Apple has not indicated any major initiatives in VR/AR; however, we do expect them to participate over time, particularly following the recent acquisitions of several small VR/AR-related companies including Faceshift and Metaio. As the use cases of VR/AR are still in very early stages of development, we suspect that Apple is trying to gain a greater understanding of how consumers want to interact with the technology and the associated

challenges before making its first move. As for Amazon, we note that in December 2015 the company filed for an AR patent outlining how a person could control devices with hand gestures. We believe AR technology could eventually tie into Amazon's Echo product, the voice-activated personal assistant, where Amazon is trying to increase its presence in the home. We also note that Nintendo has yet to signal an entry into VR/AR. That said, given the company's long history in the gaming market, there has been speculation that the company could enter the market in either consoles or content market with games.

Using the past to predict the future

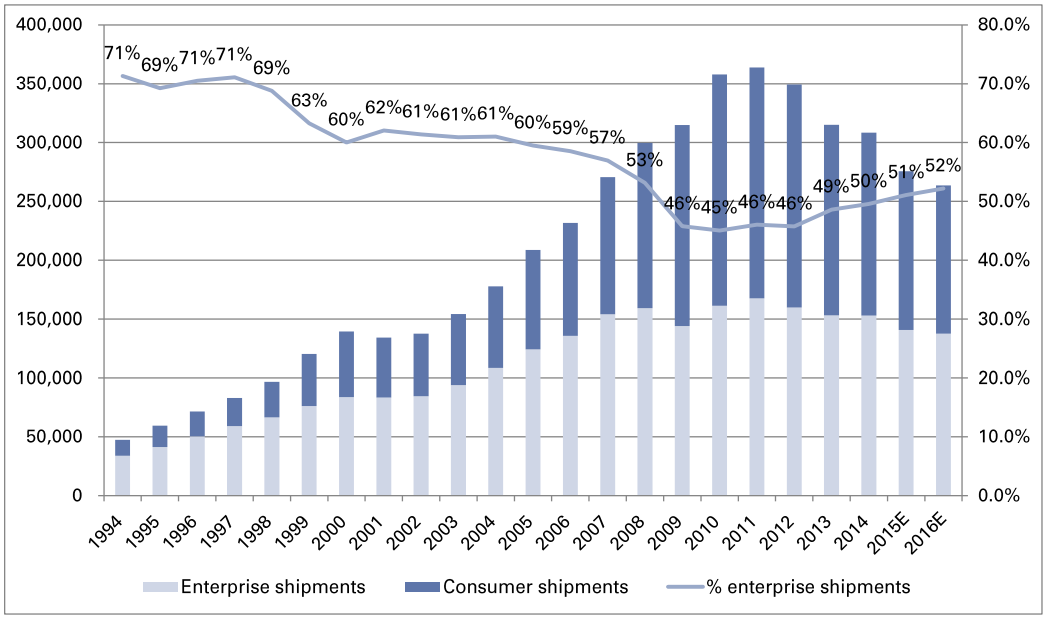
To ascertain the ramp of VR/AR, we analyzed the adoption curves and trends we saw in PCs, smartphones, and tablets to try to draw from the similarities and differences. We see VR/AR having a quick ramp among early adopters like tablets did, and see adoption being driven by a mix of consumer and enterprise use cases (while the PC was driven by enterprise and smartphone/tablets were driven by consumer).

The PC revolution

PCs changed the way people worked and essentially made the workforce more productive. Since the release of Windows 95, the PC industry saw rapid growth going from 50mn annual PC shipments in 1995 to over 350mn by 2010. Given the attribute of a productivity tool, it's no surprise that the business world drove PC adoption with the enterprise representing ~70% of PC shipments in the early years as illustrated in the exhibit below.

While the PC was driven by the enterprise the smartphone and tablet were driven by consumer with 90-95% of tablet shipments initiated by the consumer from 2010-2012, according to IDC. As we discuss in the use cases section, we see both consumer and enterprise use cases of VR/AR technology taking shape and believe both forces can be a driver of adoption.

Exhibit 8: PCs were revolutionary and driven by enterprise as they changed the way people work
VR/AR has both consumer and enterprise use cases developing and we see both sides driving adoption



Source: Goldman Sachs Global Investment Research, IDC

The rise of the smartphone and tablet

To understand what the pace of VR/AR adoption could look like, we analyzed smartphone adoption (as a function of share taken from feature phones) and tablet adoption (as a function of share taken from notebooks). We mapped the adoption of these technologies over Rogers' innovation curve where the first 15% of the applicable user base are considered to be innovators and early adopters, the next 34% are the early majority, followed by 34% late majority, with the final 16% being the laggards. In this analysis, we consider the percentage of unit shipments for the new technology (smartphones and tablets) versus the total applicable base (total handsets, total notebooks + tablets) to indicate the new technology's point on the adoption curve. For example, in 2007, 11% of total handset shipments were smartphones so we consider that year to still be in the early adopter phase (the first 15%).

Rogers' adoption curve:

Early adopters – the first 15% of the applicable user base

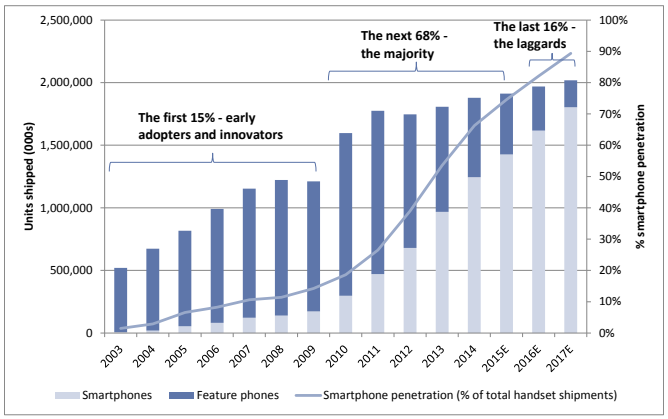
Majority – mass adoption by the next 64% of the applicable user base

Laggards – adoption by the last 16% of the applicable user base

Overall, the adoption curve for smartphones was relatively fast as smartphones represented 1% of total handset shipments in 2003 and the GS communications equipment team estimates smartphones will represent 82% of handset shipments in 2016. For smartphones, we consider the early adopter stage (the first 15%) to be from 2003-2009, the early majority (the next 34%) to be from 2010-2012, followed by late majority (the next 34%) to be from 2013-2015, with the final 16% being the laggards (2016 and on). We consider the 2007 launch of Apple's iPhone a significant accelerator of smartphone adoption as penetration began to significantly ramp after that point.

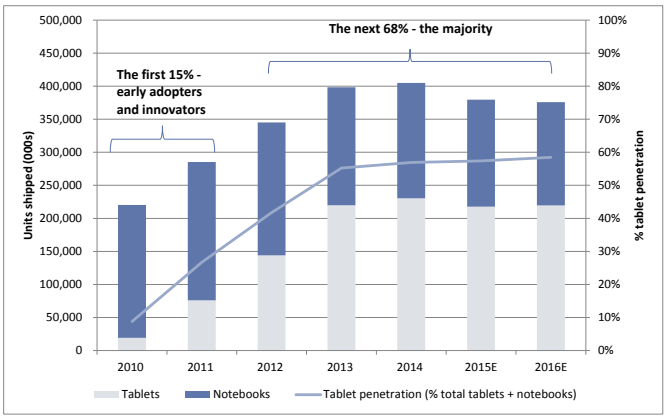
Tablets saw a quicker ramp in adoption than smartphones as the tablet was launched in 2010 and represented 27% of total tablet and notebook shipments by 2011, making its early adopter phase just two years. That said, tablets have been hovering at 50%-60% penetration since 2013 in the "late majority" phase.

Exhibit 9: Smartphone adoption curve
The early adoption was slow at first but quickly accelerated due in part to the 2007 launch of the iPhone



Source: Goldman Sachs Global Investment Research, IDC

Exhibit 10: Tablet adoption curve
Early adoption of the tablet was relatively fast, but the majority uptake has been slow as the technology and use cases evolve



Source: Goldman Sachs Global Investment Research, IDC

In comparing and contrasting the faster adoption of smartphones to the slower adoption curve of tablets, we believe one key difference is that the smartphone can be thought of as an enhanced version of the feature phone which built upon the functions of voice and text messaging and added email, internet, video, and social functionality. In a sense, the smartphone added use cases we were already familiar with from desktop computers but made that functionality completely mobile.

The tablet, on the other hand, offers a new way to do things versus the notebook given the touch screen functionality. We see tablets as more of an evolution of the notebook where the use cases of the tablet are still being defined and the technology is still evolving. In this respect, we also see VR/AR technology as an evolution in how we do things, where we could see a quick early adopter ramp but a slowing pace as the adoption curve hits the late majority.

The potential for VR/AR to become a generic computing platform

Looking back at the history of computer interface evolution, from command line, Windows, to the latest touch interface, the addressable market was broadened as the user interface became more intuitive. Twenty-five years ago, one would need to be properly trained to use a computer with command line or programming codes, but now one can use a smartphone/tablet without any training at all.

Fundamentally, virtual/augmented reality creates a new and even more intuitive way to interact with a computer. In the world of virtual/augmented reality, the controls of the computer become what we are already familiar with through gestures and graphics. VR/AR also gives us wider field of view, where the concept of virtual desktop is no longer confined by the size of a physical display screen on our desktop or in the palm of our hands. Given this attribute of ease of use and the multiple use cases across VR/AR, we see the potential for the technology to emerge from vertical specific use cases to a broader computing platform.

Summary of our hardware and software forecasts

To arrive at the VR/AR estimates, we considered the following:

1. The use cases for VR/AR and potential addressable market in terms of users
2. A volume adoption framework which considers technology enablers to reach mass adoption.
3. A pricing framework which projects how costs could decline over time as price elasticity should have an impact on end demand.

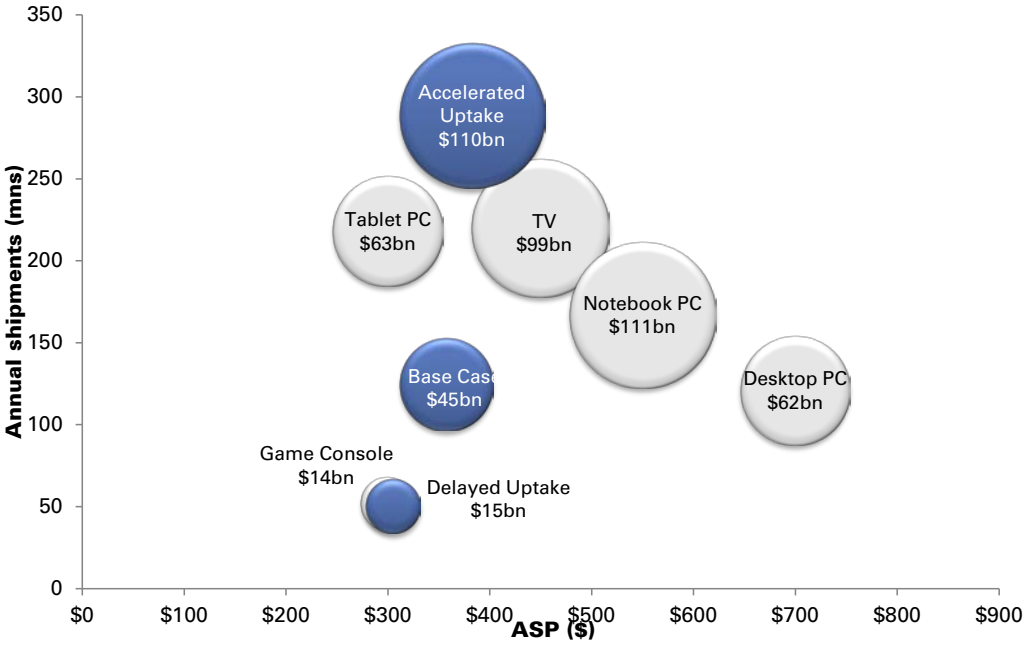
In considering the use cases and addressable markets, and marrying the volume adoption and pricing frameworks, we arrive at three outcomes in 2025 for our VR/AR hardware and software revenue TAM at $182bn, $80bn and $23bn.

Base case scenario: $80bn market ($45bn in hardware and $35bn in software)
In our base case scenario, we are assuming that HMDs gain popularity as VR/AR technology improves over time but is limited by mobility and battery life. Hence the use cases would be mostly confined to stationary mobility (i.e., living room, or office space mobility).The hardware TAM of $45bn implies a market size closer to the tablet hardware market (~$65bn) today.

"Accelerated uptake": $182bn market ($110bn in hardware, $72bn in software)
In this case, we are assuming that HMD evolves from a niche market device to a generic computing platform by 2025, as the user experience of VR/AR technology improves over time coupled with breakthroughs in cellular and battery technologies to enable true mobility. With improving VR/AR user experience combined with true mobility, we expect HMDs to proliferate from vertical markets to horizontal market adoption. Our $110bn hardware estimate represents a similar market size to what we are seeing in notebooks (~$111bn) and TV (~$99bn) today.

"Delayed uptake": $23bn market ($15bn in hardware, $8bn in software)
In this case, we are assuming that user experience of VR/AR technology improves at a slower pace due to hindrance in adoption from latency, display, safety, privacy and other issues for it to have a widespread effect. As such, we estimate that VR HMDs will primarily only succeed in the videogaming and entertainment use cases. The $15bn hardware TAM represents a market size similar to the current game console hardware market at around $14bn.

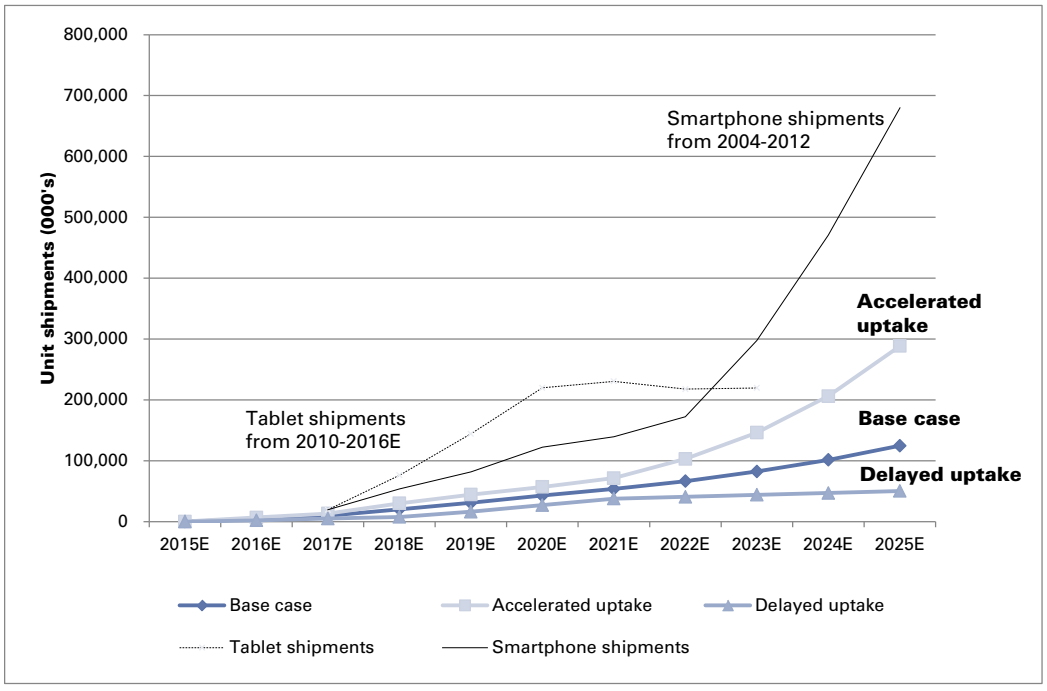
Exhibit 11: VR/AR HMD market has the potential of reach over $100bn annually by 2025



Source: Goldman Sachs Global Investment Research, IDC

The following chart lays out our base case, accelerated uptake case, and delayed uptake case for VR/AR shipments and overlays the adoption curve for smartphones (starting in 2004) and tablets (starting in 2010).

Exhibit 12: Our VR/AR shipment assumptions vs. the smartphone and tablet ramps



Source: Goldman Sachs Global Investment Research, Gartner for tablet shipment data

Use cases and software market detail

We believe VR and AR have the potential to not only create new markets but also disrupt existing ones. We've identified 9 use cases for VR/AR technology which we see currently emerging: videogames, live events, video entertainment, retail, real estate, education, healthcare, engineering, and military.

For each of these use cases, we assess the following:

1) The potential market reach in terms of users
2) The current challenges to execute on this use case
3) The existing revenue pool that VR/AR adoption could disrupt
4) Revenue drivers and estimate the software/subscription revenue potential through 2025

The following exhibit summarizes our software estimates by use case and key data points to gauge the market.

Exhibit 13: Our base case user and software revenue assumptions

	Current market size	Datapoints on the population that could use VR/AR	2020 Base case assumptions		2025 Base case assumptions	
	The market VR/AR is playing into	*To gauge the magnitude, the population that VR/AR could sell into*	**Users**	**Software revenue**	**Users**	**Software revenue**
Videogames	$106bn videogame market	~230mn installed base of video game consoles ~150mn PC gamers in developed markets	70mn	$6.9bn	216mn	$11.6bn
Live events	$44bn in live sports ticketing revenue	~715mn viewers of World Cup ~160mn viewers of the Super Bowl ~92mn ESPN subscribers	28mn	$0.8bn	95mn	$4.1bn
Video entertainment	$50bn online video TAM	~450mn household online video addressable market	24mn	$0.8bn	79mn	$3.2bn
Real estate	$107bn total real estate commission market in US, Japan, UK, and Germany	1.4mn real estate agents in US, Japan, UK, and Germany	0.2mn	$0.8bn	0.3mn	$2.6bn
Retail	$3bn in ecommerce software market (impacting $1.5tr ecommerce market)	1bn+ online shoppers In-store shoppers	9.5mn	$0.5bn	31.5mn	$1.6bn
Education	Education software market: $5bn for K-12, $7bn for higher education	~200mn primary and secondary students in developed markets In US, ~50mn K-12 and ~20mn college students	7mn	$0.3bn	15mn	$0.7bn
Healthcare	$16bn patient monitoring devices market	~8mn physicians and EMTs in developed markets In US, ~800k physicians and 240k EMTs	0.8mn	$1.2bn	3.4mn	$5.1bn
Engineering	$20bn engineering software market	~6mn engineers in US, Europe and Japan ~2.4mn engineers/technicians in the US	1.0mn	$1.5bn	3.2mn	$4.7bn
Military	$9bn defense industry training and simulation market	~6.9mn military personnel in "high income countries" (World Bank) ~1.3mn US military personnel	Assuming proprietary HMDs	$0.5bn	Assuming proprietary HMDs	$1.4bn
Total			**95mn**	**$13.1bn**	**315mn**	**$35.0bn**

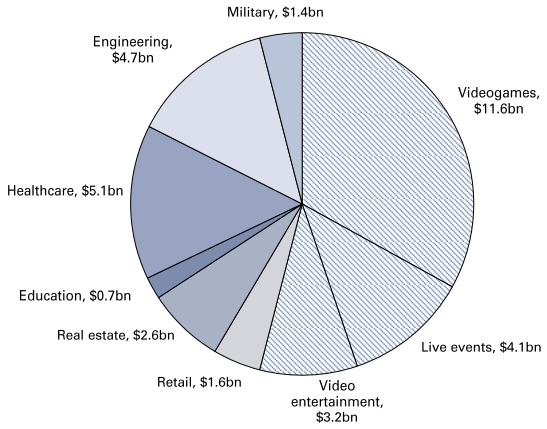
Source: Goldman Sachs Global Investment Research/ Data point stats from: Gartner, IDC, World Bank, US Bureau of Labor Statistics, National Center for Education Statistics, Nielsen, FIFA, American Medical Association, Research and Markets, National Association of Realtors, OC&C Strategy Consultants, the Japan Ministry of Land, Infrastructure, Transport and Tourism, the Land Institute of Japan, Borrell Associates, CAE, Eurostat, and Statistics Japan.

We believe VR devices will have multiple use cases similar to smartphones that serve the functions of voice communication, texting, email, video, internet browsing, and social platforms. In our view, consumers will be able to use a single VR device to play videogames, watch video programming and live events, and shop. That said, we believe the business use cases will likely use separate devices given that specialized software will be required along with potential enterprise security concerns.

A software market driven by both consumer and enterprise

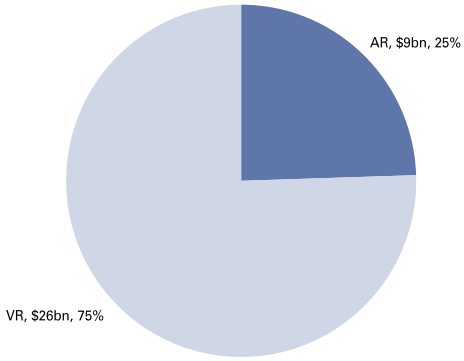
We note that of our 9 use cases, videogames, live events, and video entertainment are the only 3 that are entirely driven by the consumer and make up ~60% of our total VR/AR revenue assumptions for 2025. The remaining ~40% is driven by enterprise and public sector spend with the largest revenue generating use cases in engineering, healthcare, and real estate.

Exhibit 14: Our 2025 VR/AR estimates by use case
Consumer-driven use cases in videogames, live events and video driving ~60% of software spend with the remainder from enterprise and public sector



Source: Goldman Sachs Global Investment Research.

Exhibit 15: Our 2025 software estimates by VR and AR
VR use cases driving 75% of our software estimate; as AR technology matures we expect more enterprise use cases to emerge



Source: Goldman Sachs Global Investment Research.

As mentioned, we see use cases that are specific to VR, use cases that are specific to AR, and some cases where the two overlap. Our research indicates that AR technology still needs to mature, especially in display technology and the real-time processing and calibration of real-world physical environment. As AR technology matures, we see stronger enterprise use cases emerging especially considering AR enables you to see your physical environment whereas VR completely blocks it.

The chicken-and-egg dilemma

Before diving into the individual use cases, we note that a key challenge for videogame and entertainment VR use cases is a chicken-and-egg problem where content makers (e.g., videogame publishers, filmmakers) are hesitant to develop VR content without an installed base and consumers are reluctant to buy the technology without content to experience. That said, we see Google, Facebook, Sony and Microsoft trying to solve for this issue on both sides of the equation. On the installed base side, Google has already distributed 2mn Google Cardboard viewers (1mn provided for free via the New York Times) and Oculus is innovating with HMDs with Rift being the first major PC-based device coming to market. In terms of content, Facebook and YouTube have enabled 360-degree videos viewable in VR, and Oculus is creating its own video content with Oculus Story Studio which plans to release 20 VR videogames in 2016, and expects 100 games to be available in total by year-end.

VIDEOGAMES
$11.6 billion (2025E base case)
216 million users

- First consumer market to develop
- Current games cannot be ported to VR/AR platform
- New franchise costs are high, but decline with subsequent versions

VR technology heightens the videogame experience by completely immersing a user in a virtual world while AR technology can turn your physical world into a videogame canvas. We see VR videogames as the first consumer market to develop as we see both the hardware and software further along in development (relative to our other highlighted use cases and to AR gaming) as well as the gamer community eagerly awaiting the technology.

The potential user base

We estimate an installed base of ~230mn gaming consoles and ~150mn PC gamers. Our console estimate is based on the installed base of Xbox, PlayStation, and Wii. We believe hardcore gamers (defined as people that play over 15 hours of games per week) will be the first to adopt VR gaming and note that IDC estimates that roughly 30% of PS4 and Xbox One users fall into this category. As for PC gamers, we estimate ~700mn worldwide and ~150mn in developed countries. Given that Oculus will require a high-end PC, we assume that PC gamers in developed countries would be more likely to adopt.

The challenges

One of the key challenges is that current videogames cannot simply be ported to a VR/AR platform. Given our conversations with large videogame publishers like EA Sports and Activision, a new videogame franchise can cost up to ~$75-$100mn to create while subsequent versions of the game can cost as little as ~$10mn. Without a strong installed base of VR hardware devices, videogame publishers are cautious to make investments in new VR game franchises as they can't be certain of the addressable market. That said, we note the gaming industry can quickly shift with IDC estimating that the mobile gaming market grew to $35bn in 2015, surpassing the console market for the first time. Further, Oculus said in September 2015 that it had 200k developers registered to create games on the VR platform.

The market disrupted

IDC estimates the total videogame market at $106bn for 2015. We see the potential for VR/AR to be a disruptive force in this market, while also growing the overall market size by attracting new users and increasing the videogame attach rate per user.

Sizing the revenue opportunity

Our base case, estimates $6.9bn in VR videogame revenue in 2020 and $11.6bn in 2025. To illustrate VR's potential in the videogame software market, we consider the number of VR gamers, the number of games an average user will buy each year, and the cost that can be charged per game.

- **Gamers**: Our base case assumes there are 70mn VR gamers in 2020 (which would represent 30% of the current 230mn console installed base) and 216mn VR gamers in 2025.
- **# of games bought per user**: In our analysis, we assume VR gamers on average purchase 2.5 games a year then trend down towards 1.0 game per year, which are similar metrics we estimate for Xbox and PlayStation.
- **Price per game**: We believe that VR games will come with pricing in line with current 2D games and assume an initial average price of $60 for a VR game.

LIVE EVENTS

$4.1 billion (2025E base case)
95 million users

- Examples include sports, concerts and world affairs
- Gaining VR broadcast rights is a challenge
- Headsets also limit the amount of social interaction possible during streaming

One of the key VR use cases we see emerging is the streaming of live events (like sports, concerts, world affairs) which solves the problem of limited seating at events and makes events essentially available to anyone and anywhere. Radio once solved this problem with an audio experience, TV currently solves this problem with a 2D viewing experience, and VR has the potential to be the new format in which people watch and experience live events.

Watching an event in VR will essentially make a user feel like they're physically attending the event with the best seat in the house. We see this opportunity initially applying to sports, but also going beyond and note that CNN streamed the first US Democratic presidential debate in VR which was watched across 121 countries.

The potential user base

We try to gauge the user base opportunity for live events in VR through TV viewership and subscriber statistics:

- **715mn people watched the 2006 World Cup final match** according to FIFA
- **160mn people watched the 2015 Super Bowl** according to Nielsen
- **There are ~92mn ESPN subscribers** according to Nielsen

Further, HBO and Showtime reported that 4.4mn people subscribed to the Mayweather vs Pacquiao boxing match for a $100 fee. While some of these are single events, we're highlighting that sports events have mass worldwide appeal. The events that could be broadcast in VR go beyond sports to concerts and events of world interest like the wedding of Prince Charles and Lady Diana which drew 750mn viewers.

The challenges

One of the key challenges with VR live events is gaining the rights to broadcast the content. The NFL has TV contracts with Fox, NBC, and CBS but it's not entirely clear whether or not virtual reality broadcasts fall under these contracts. Another challenge is on the user adoption side as many people watch live events as a social activity and wearing a virtual reality headset would limit interaction. In this respect, we expect much of the entertainment on virtual reality to be consumed individually.

The market disrupted

PwC estimates $44bn in gate revenue for sporting events in CY15, with the global sports market at $145bn when also including $35bn in media rights revenue, $45bn in sponsorships, and $20bn in merchandising. We don't expect VR to cannibalize gate revenue as we always expect demand to see events in person. In fact, we believe VR has the potential to create new revenue pools in the form of new ticketing and subscription fees charged to sports fans that want to watch events in VR but can't attend the event live. Further, media rights revenue is likely to be expanded as the likes of the NBA and FIFA will have more outlets to license to.

Sizing the revenue opportunity

Our base case assumptions lead to $750mn in revenue in 2020 and $4.1bn in 2025. To size the market, we consider the number of VR users for this use case, the number of events watched a year, and the price per event.

- **Users**: We believe live events will be a popular use case for VR users and estimate 30% penetration of our base-case installed base which equates to 28mn users in 2020 and 95mn in 2025.
- **Events per year**: We estimate that users initially watch 2 events per year, but that slowly increases as more content becomes available to nearly 4 events in 2025. We see this as low with 82 NBA games per season (for each 30 teams), 162 MLB games (for each of the 30 teams), and major sporting events each having playoff and championship games with broad appeal, in addition to the wide range of non-sporting events.

- **Price per event**: Finally, we assume an initial price point of $10 per event, which is a steep discount to an NBA ticket costing $50 on average and events like the Mayweather vs Pacquiao fight costing $100 per TV viewer (and grossing over $300mn in revenue for HBO and Showtime).

VIDEO ENTERTAINMENT

$3.2 billion (2025E base case)
79 million users

- Similar to videogames, existing films cannot be ported over
- VR is creating a new medium for entertainment
- A challenge is the availability of new content without a large installed base

We see VR creating a new form of movie and TV entertainment. Instead of watching a movie on two dimensional screens, users can be completely immersed in the film.

The potential user base

While we see VR as a new form of content, we expect it to appeal to the masses and see a potential user base similar to online video today, which our GS Internet Team estimates as having an addressable market of 462mn households. We believe in the long-run, VR video content is addressing a similar market.

The challenges

Similar to videogames, creating content is a key challenge for virtual reality video entertainment. To gain the full VR experience, movies must be filmed with a 360-degree camera which means current films cannot simply be ported over. VR is essentially a new storytelling format that will require different writing and producing techniques than traditional movies and TV. In this regard, the cost to produce VR video entertainment is difficult to predict. We actually see the potential for the costs around camera work to be lower in VR as a 360-degree camera reduces the need for multiple cameras and editing work that is typical with 2D video. That said, similar to the challenges with videogames, Hollywood needs to be convinced of the opportunity in VR movies to begin making the investment.

The market disrupted

We see VR video disrupting the online movie and TV market.

Sizing the revenue opportunity

Our base case assumptions lead to $750mn in revenue in 2020 and $3.2bn in 2025. To size the market, we consider the number of VR users for this use case and the annual spend these users would pay for VR content.

- **Users**: We believe video will be a popular use case for VR and estimate 25% penetration of the installed base of headsets which equates to 24mn users in 2020 and 79mn in 2025.

  Annual spend per user: As VR video content is still in the phase of gaining user adoption and acceptance, we see content being free in the early years but then generating subscription revenue that is supplementary to 2D video packages as we don't expect VR video to be a replacement. In this sense, we consider the additional fee consumers would pay for an enhanced video experience and note that IMAX movies come at a 45% premium to a 2D movie ticket. Further, we note that when Netflix initially started offering Blu Ray, the company charged a ~25% premium to standard DVD packages and we view the step to VR video as an incrementally greater experience. For our VR annual subscription ARPU we use a premium to the current online video ARPU, implying that a VR video subscription is incremental to a standard streaming video package. This equates to a VR subscription ARPU of $32 which we apply starting in 2017 and growing 5% annually starting in 2020.

RETAIL

$1.6 billion (2025E base case)
32 million users

- Emerging use cases in home improvement, apparel and auto industries
- Key challenge is developing realistic, easy-to-use software
- We anticipate VR/AR will be used for higher-end purchases

Ecommerce is a $1.5tr market today and represents 6% of all retail spending worldwide. While not frequently discussed, we believe high-end portions of the market that have been challenging for the internet to penetrate can be revolutionized due to the adoption of VR and AR technology.

- Home Improvement store Lowe's has a "Holoroom" at 6 of its stores where shoppers can configure kitchens and bathrooms and view their designs with Oculus devices.
- Microsoft and Volvo announced a partnership and have performed a demo where HoloLens can be used by consumers to configure cars at a dealership.
- There is also an apparel shopping use case, where consumers could use VR/AR to see how clothes look on them without physically trying them on.

The challenges

The key challenge is developing software that works with VR/AR devices for these specific commerce use cases. Whether you're envisioning a remodeled kitchen, a new car, how certain pieces of furniture might look in your home, or how clothes look on you, the experience needs to be easy for the consumer to use and be realistic.

The potential user base

We use the 1bn online shoppers (according to Internet Retailer) as a gauge. In the long-run, we see the shopping use case for VR/AR to be available to any shopper.

The market disrupted

We consider the $3bn ecommerce software market as the main revenue pool VR/AR software will play into, as this market is comprised of tech investments that retailers make to serve their customers. We see VR/AR disrupting retail markets where companies can garner a competitive advantage by using the technology and as such have the ability to increase share of their existing market. We see an opportunity for this in the near-term with the $180bn home improvement market (Bureau of Economic Analysis) and the $260bn apparel market (Euromonitor). Further, we see the potential for VR/AR to reduce the need for in-store displays and possible erode the value of a physical store.

Sizing the revenue opportunity

Our base case assumptions lead to $500mn in VR retail software revenue in 2020 and $1.6bn in 2025. We see VR/AR as a technology that retailers will have to invest in to serve their customers and keep ahead of their competition. Ecommerce software companies like Demandware charge their customers on a revenue/share basis where Demandware gets 1-2% of the sales that run through its platform. We believe VR/AR sales could operate in a similar model. To estimate the market size, we consider the number of users (assuming just 1 transaction per year), and the average size of transaction (assuming a 1% take rate).

- **Users**: On our base case, we're assuming just 5% of the VR/AR installed base engages in VR shopping.
- **Average transaction size**: We assume an average transaction size of $5k as we believe VR will be used for higher-end purchases, but this is still a steep discount to the average cost to remodel a kitchen at $19k (HomeAdvisor) and the average new car cost of $34k (Kelley Blue Book).

These assumptions imply $158bn in 2025 of consumer sales transacted through VR/AR versus $1.5tr in ecommerce revenue today. For the retail use case of VR/AR, we're less focused on the software revenue opportunity and instead focus on the disruption potentially caused in retail markets the technology can serve.

REAL ESTATE
$2.6 billion (2025E base case)
300,000 users

- VR to draw spend from $107bn commissions market (US, Japan, Germany, UK)
- Sotheby's is already experimenting with VR
- Rate of capture for VR content a key challenge to broader adoption

We see the potential for VR to drive consumer purchasing in real estate and note that Sotheby's is experimenting with VR to show homes to prospective buyers. We see shifts like VR changing the industry as companies emerge to go after a portion of the commission dollars on these transactions.

The potential user base

We see a potential user base of 1.4mn registered real estate agents. Real estate is a market where the lines between consumer use and business use begin to blur:

- Real estate agents will want VR devices for the prospective clients to use.
- Homebuyers would want their own devices to be able to view homes without an agent.

In terms of the addressable user base, we focus on countries that have large online real estate classifieds markets including the US, Japan, Germany, and the UK. There are 1.2mn registered real estate agents in the US, 123k in Japan, 32k in Germany, and 22k in the UK according to data from the National Association of Realtors (NAR), OC&C Strategy Consultants, and the Japan Ministry of Land, Infrastructure, Transport and Tourism.

The challenges

The key challenge for the real estate use case is that VR content for homes must be captured with a 360-degree camera which can be costly and labor-intensive.

The market disrupted

We estimate an aggregate real estate commissions market of $107bn using our data sources for registered real estate agents as well as data from Borrell Associates and the Land Institute of Japan, with $52bn in the US, $38bn in Japan, $9bn in the UK, and $8bn in Germany. For the US commission pool, 53% ($27bn) is retained for profit, 17% ($9bn) goes to marketing, and 30% ($16bn) goes to the brokerage. We believe VR technology could draw spend from either the marketing budget or brokerage budget.

Sizing the revenue opportunity

Our base case assumptions lead to $750mn in revenue in 2020 and $2.6bn in 2025. To size the market, we consider the number of agents using VR as a selling tool and the potential average annual spend. We believe the value proposition of a VR home listing ad can significantly outweigh that of an online ad. For 2020, we estimate 130k real estate agents using VR to show homes with an annual spend of $5,000 which we believe can grow 10% annually. In light of a $107bn real estate commission market and given that VR has the potential to change the business model, we see these estimates as conservative.

HEALTHCARE

$5.1 billion (2025E base case)
3.4 million users

- VR/AR has potential to treat phobias and aid in medical procedures
- Can also aid in day-to-day tasks as a hands-free device
- Data privacy and software development could limit uptake

We see several use cases for VR/AR technology in healthcare: 1) as a tool to aid doctors in medical procedures and day-to-day tasks, 2) for physical therapy and to treat phobias like fear of heights, and 3) to increase access to doctors through virtual visits.

1. When Google Glass was first introduced, Google offered select hospitals Glass devices to test the product. During these trials, surgeons used Google Glass for a range of functions, like projecting CT scans and MRIs on to the field of vision as he or she would operate, scanning bar codes to gain basic medical information about the patient, and alerting the doctor with lab results.
2. In the therapy use case, VR can treat patients with anxiety disorders (such as PTSD) or phobias. These virtual worlds can create artificial, controlled stimuli in order to habituate the patient to those environments that cause anxiety. VR can also be used to rehabilitate patients, such as amputees.
3. We also see an opportunity for VR/AR to increase consumer access to doctors. Doctors are already conducting video-based visits and VR can enhance that experience.

The potential user base

We estimate there are ~8mn physicians and EMTs globally that could use VR/AR technology according to data from the Organisation of Economic Co-operation and Development (OECD), the America Medical Association (AMA) and US Bureau of Labor Statistics. In the US, there are ~1.5mn medical professionals which could serve as the addressable user base of VR/AR, with ~740k specialty physicians, ~500k primary care physicians, and 240k EMTs.

The challenges

In speaking with doctors about Google Glass, privacy was a concern as data transmitted to the device was not encrypted and violated HIPAA regulations. Additionally, for specialty physician use cases the software required would need to be complex and precise.

The market disrupted

We see VR/AR applications in healthcare disrupting a $16bn market for patient monitoring devices according to Research and Markets.

Sizing the revenue opportunity

Our base case estimates $1.2bn in revenue in 2020 and $5.1bn in 2025. While the number of doctors that could potentially use VR/AR devices is relatively small when compared to the consumer market, we believe the bigger market opportunity will be in specialized software versus the hardware sold. While it's difficult to gauge how much VR/AR software will cost for specialized medical use, we note that specialized computer-aided design (CAD) software for architects and engineers can range from $1,000-$5,000 per year and use this as a comp as we see specialized medical software also requiring a high-degree of precision. In our base case, we estimate that 800k EMTs and physicians use VR/AR technology in 2020 and 3.4mn in 2025 at an assumed subscription software cost of $1,500.

EDUCATION

$700 million (2025E base case)
15 million users

- Use cases span K-12, higher education
- Strapped education budgets could limit uptake

We believe VR/AR technology has the potential to be a standard tool in education and could revolutionize the way in which students are taught for both the K-12 segment and higher education (college and beyond). Teachers can use VR/AR as a way for students to interact with objects in a 3D environment. For example, students can learn about the solar system or a historical event by interacting with those virtual worlds. Google is offering Cardboard to schools for free and has already developed over 100 "virtual field trips." We're also seeing traction of virtual reality at the higher end of the market with medical schools experimenting with AR.

The potential user base

There are 200mn primary and secondary students in the developed countries according to the World Bank. In the US, there are 50mn K-12 students and 20mn college students, according to the National Center for Education.

The challenges

New educational content can be difficult to create, especially as students move from preliminary schooling to higher education.

The market disrupted

Gartner sizes the global education software market at ~$12bn for 2015, consisting of the K-12 education software market at $5.2bn and the higher education (college and beyond) software market at $6.6bn.

Sizing the revenue opportunity

We assume $300mn in educational software revenue in 2020 and $700mn in 2025. While we believe in the impact that VR/AR could have in education, we're being conservative in our assumptions and estimate that it would take 5 years to sell 8mn VR/AR units. Further, we believe that VR/AR will first take shape in the K-12 market as more of an interactive tool and believe that graduate educational VR/AR software in subjects like medicine and engineering could be given away for free to get users accustomed to the software as this is a typical marketing strategy for engineering software vendors.

After this initial phase, we're estimating the average annual cost of educational software per K-12 student of $50. While we believe VR can revolutionize education, we don't expect full curriculums to be taught in VR at this point and acknowledge the education budgets are strapped as it is. We don't see education as a material revenue generator, but greater benefits in growing adoption as students become accustomed to the VR/AR technology.

MILITARY

$1.4 billion (2025E base case)
700,000 users

- US military has been using VR technology for training for several years
- Potential use cases include flight and battle simulation, medic training
- "Fidelity" cited as a main challenge to adoption

The US military has been using virtual reality for training purposes since at least 2012 with proprietary hardware and software. Examples of simulations currently used include flight simulations, battlefield simulations, and medic training. These simulations help soldiers train for dangerous settings in a more cost effective manner than traditional approaches.

The potential user base

According to the World Bank, there are ~6.9mn military personnel in "high-income" countries. In the US, there are about 475k personnel in the US Army, 320k in the Airforce, 330k in the Navy, and 185k in the Marines.

The challenges

A survey conducted by the Government Business Council (GBC) in 2014 notes that the main challenge with simulation training was "fidelity", implying that simulations did not feel real enough.

The market disrupted

The global military simulation and training market is estimated to be $9.3bn according to CAE, a military contractor. Of this budget, $3.8bn is allocated to flight simulation which saves costs versus training on actual fighter jets; indeed, the US Airforce is expected to save $1.7bn from FY12-16 (~$400mn annually) by using flight simulators according to GBC. That said, while flight simulation is driving cost savings, the list price of a full-flight air simulator is still over $10mn. If some portions of flight simulation training can be replaced with VR hardware and software, the incremental cost savings could be material. Flight simulation is just one example of how VR could drive cost savings in the military and we see battlefield simulations and medic training as other potential opportunities.

Sizing the revenue opportunity

Our base case estimates $500mn in software revenue in 2020 and $1.4bn in 2025. We believe the number of VR/AR headsets that the military purchases could be widespread, but believe these are likely to be proprietary headsets that are only for sale to the military, similar to night vision goggles and as such we're not incorporating these unit sales into our forecast at this time. To size the VR/AR software market, we believe we are being conservative in our assumptions to take small portions of the global $9.3bn military simulation and training budgets. For 2025, we assume 15% of the military simulation and training spend can go toward VR which equates to $1.4bn. To test the reasonableness of this assumption, we note that this would imply 700k users (vs 6.9mn military personnel in "high income" countries) at an annual VR software cost of $2,000.

ENGINEERING

$4.7 billion (2025E base case)
3.2 million users

- Potential to disrupt the computer-aided design and manufacturing markets
- Allows engineers to test scenarios and designs before products are made
- Challenges to adoption include software development, learning curve

We see VR/AR technology disrupting both the computer-aided manufacturing (CAM) and computer-aided design (CAD) markets. In product manufacturing, VR/AR can enable engineers to test scenarios and designs before the products are made, driving productivity and cutting down on the cost of wasted materials. According to Forbes, Ford has been using virtual technology to design cars since 2000.

The potential user base

We estimate 6mn engineers in the US, Europe and Japan according to data from the US Bureau of Labor, Eurostat, and Statistics Japan.

The challenges

While large automotive companies might have the resources to develop their own VR software, not all engineers have this access. Engineering software needs to be developed by specific industry and there could be a learning ramp to use the software and adjust engineering techniques.

The market disrupted

The global engineering software market is $20bn in 2015 according to Research and Markets.

Sizing the revenue opportunity

We estimate $1.5bn in software revenue in 2020 and $4.7bn in 2025. To size the market, we consider the number of engineers that could use VR/AR and the annual subscription cost of the software.

- **Users**: In our base case, we estimate that 1mn engineers use VR/AR technology in 2020 and 3.2mn in 2025.
- **Annual subscription fee**: As mentioned, computer-aided design (CAD) software for architects and engineers can range from $1,000-$5,000 per year and we use this as a comp for VR engineering software, which we conservatively assume costs $1,500.

Disclosure Appendix

Reg AC

We, Heather Bellini, CFA, Wei Chen, Masaru Sugiyama, Marcus Shin, Shateel Alam and Daiki Takayama, hereby certify that all of the views expressed in this report accurately reflect our personal views about the subject company or companies and its or their securities. We also certify that no part of our compensation was, is or will be, directly or indirectly, related to the specific recommendations or views expressed in this report.

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