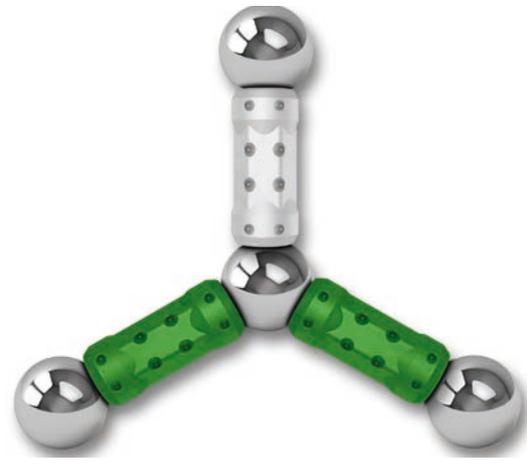


## Virtual reality: a billion dollar niche



Deloitte Global predicts that virtual reality (VR) will have its first billion dollar year in 2016, with about \$700 million in hardware sales, and the remainder from content. We estimate sales of about 2.5 million VR headsets and 10 million game copies sold.

VR is likely to have multiple applications, both consumer and enterprise, in the longer term, but in 2016 we expect the vast majority of commercial activity to focus on video games. We would expect the majority of spending on VR to be by core rather than casual gamers. This implies that while anyone with a smartphone could try out a variant of VR, the majority of VR's revenues in 2016 will likely be driven by a base of tens of millions of core gamers rather than the hundreds of millions of occasional console or PC gamers, or the billions who play casual games.

Virtual reality hardware offers visual (and sometimes audio) immersion via a head-mounted display that shows a stereo image in 3D. Sensors in the headset track the user's movements and change the user's view accordingly. A VR version of scuba diving allows you to feel as if real fish are swimming toward you. If you look up, you see a realistically rendered sky. When you glance down, you are shown the ocean floor. The sound track adjusts accordingly, enhancing the perception of being elsewhere. All other things being equal, the higher the screen resolution, and the faster the screen refresh, the more convincing the simulation<sup>134</sup>.

However the illusion remains incomplete, in that not all senses would be catered for. VR could take you into the depths of the rain forest. You could see the forest floor or look up to the canopy. But you would not feel the humidity, experience the smells or touch the vegetation.

VR content can be created using CGI (computer generated images) or filmed using special clusters of cameras that collectively capture a 360-degree field of view. In playback, the user is shown different aspects of the images captured, depending on where he or she is looking<sup>135</sup>.

As with many technologies, the notion of virtual reality is decades old, but its commercial realization has been subject to the sometimes slow pace of technological progress. Optimal VR experiences require very high resolution screens (ideally over 500 dots per inch, which have only recently become commercially available), a wide field of view and high refresh rates (ideally at least 75 frames a second<sup>136</sup>, requiring powerful processors). More processing power is also necessary so that synchronization between the user moving their head and the picture being adjusted is as near-simultaneous as possible. It is only recently that screen and processor technology have improved in terms of price and performance such that VR is commercially viable, albeit still at high price points for the full featured solution.

There are likely to be two main types of VR device in 2016: 'full feature' and 'mobile'.

The former incorporates high resolution screens and will cost about \$350-\$500 (with prices at the start of the year likely being higher), and we estimate between 1–1.75 million sales in 2016, with volumes depending heavily on the initial price<sup>137</sup>.

Full feature devices will likely be designed for use with either latest generation games consoles or PCs with advanced graphics cards (each costing about \$300) capable of driving high refresh rates: the 'average' PC is not powerful enough to support a viable VR experience.

We expect the addressable market for games consoles as of the end of 2016 to be at least 30 million units, and high-end PCs at about seven million units worldwide.

We also expect that most users of full feature VR would already own the latest generation console or a high-end PC. Otherwise, a full feature VR experience would require at least \$300 additional spending on a console or \$1,000 for a suitably equipped PC.

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We would expect the majority of spending on VR to be by core rather than casual gamers.

134. This article provides a good example of the strength of immersion that is possible with VR, see Getting sweaty with the future of Sony's virtual reality, Engadget, 11 June 2014: <http://www.engadget.com/2014/06/11/the-future-of-sony-virtual-reality-e3-morpheus/>
135. CGI provides the most realistic depth immersion while 360 videos offer more detail but less immersive pictures.
136. According to Deloitte Global research, we believe 90 frames per second (FPS) is required for a high quality VR experience; 75 (FPS) will provide a good experience on a powerful PC and 60 FPS may cause some feelings of nausea. Any fewer could cause users to feel ill-at-ease.
137. We are assuming that products will launch Q2 or later in the year, including HTC's Vive. See HTC Vive Update, HTC, 8 December 2015: <http://blog.htc.com/2015/12/htc-vive-update/>
138. For more information on treadmill for VR, see Virtuix Omni, Virtuix, as accessed on 21 December 2015: <http://www.virtuix.com/>
139. As an indicator of the number of serious games players, there are about 125 million who use Steam. See Steam has over 125 million active users, 8.9M concurrent peak, VG247, 24 February 2015: <http://www.vg247.com/2015/02/24/steam-has-over-125-million-active-users-8-9m-concurrent-peak/>
140. For more information on gaming accessories and price, see PC gaming hardware, Amazon, as accessed on 21 December 2015: [http://www.amazon.ca/ref=s9\\_acc\\_bw\\_ct\\_Computer\\_ct\\_4\\_h?rh=videogames,n:356952011&ie=UTF8&pf\\_rd\\_m=A3DWYK6Y9EEQ85pf\\_rd\\_s=merchandised-search-5&pf\\_rd\\_t=189PH7K5CJM5533RY05pf\\_rd\\_l=1018pf\\_rd\\_p=2253574542&pf\\_rd\\_i=1235983011](http://www.amazon.ca/ref=s9_acc_bw_ct_Computer_ct_4_h?rh=videogames,n:356952011&ie=UTF8&pf_rd_m=A3DWYK6Y9EEQ85pf_rd_s=merchandised-search-5&pf_rd_t=189PH7K5CJM5533RY05pf_rd_l=1018pf_rd_p=2253574542&pf_rd_i=1235983011)
141. One of the biggest giveaways was of a million units by the New York Times in late 2015. See New York Times Gives Away One Million Virtual Reality Viewers for New App, Variety, 20 October 2015: <http://variety.com/2015/digital/news/nyt-vr-virtual-reality-cardboard-new-york-times-1201622150/>
142. For example, see Best Google Cardboard apps: Top games and demos for your mobile VR headset, Wareable, 26 November 2015: <http://www.wareable.com/google/the-best-google-cardboard-apps;the-best-virtual-reality-apps-for-iphone-compatible-with-google-cardboard-applesider,1August2015:> <http://applesider.com/articles/15/08/02/the-best-virtual-reality-apps-for-iphone-compatible-with-google-cardboard>
143. For more information, see HULU DIVES INTO VIRTUAL REALITY, Hulu, 24 September 2015: <http://blog.hulu.com/2015/09/24/huluvirtualreality/>
144. As of end-2015, a few professional VR cameras had launched. For example, see Nokia announces OZO virtual reality camera for professional content creators, Nokia, 29 July 2015: <http://company.nokia.com/en/news/press-releases/2015/07/29/nokia-announces-ozo-virtual-reality-camera-for-professional-content-creators>
145. For more information, see Interview: VR movie pioneer on the challenges and future of virtual reality filmmaking, PCWorld, 9 April 2014: <http://www.pcworld.com/article/2141202/interview-vr-movie-pioneer-on-the-challenges-and-future-of-virtual-reality-filmmaking.html>
146. For more information, see Eye, 360 Designs, as accessed on 21 December 2015: <http://360designs.io/eye/>
147. DigitalVR develops virtual reality platform for architects, Prolific North, 29 October 2015: <http://www.prolificnorth.co.uk/2015/10/digitalvr-develops-virtual-reality-platform-for-architects/>
148. How this 150-year-old company uses virtual reality, Fortune, 25 August 2015: <http://fortune.com/2015/08/25/mccarthy-construction-vr/>
149. See 8 Amazing Uses for VR Beyond Gaming, PCMagazine, as accessed on 21 December 2015: <http://uk.pcmag.com/wearable-tech/29151/gallery/8-amazing-uses-for-vr-beyond-gaming?p=4>
150. Virtual Reality in Healthcare: Where's The Innovation?, TechCrunch, 16 September 2015: <http://techcrunch.com/2015/09/16/virtual-reality-in-healthcare-where-the-innovation/>

Some VR owners may purchase additional accessories, ranging from controllers to treadmills whose base plate moves in alignment with the view being seen. The floor would tilt, for example, if you were walking uphill<sup>138</sup>.

There are hundreds of millions of gamers on consoles and PCs, and many of them buy hardware accessories to improve their game play<sup>139</sup>. However, the vast majority of the top selling peripherals are \$30-50<sup>140</sup>. Only a minority of these gamers may want to spend over \$300 on additional equipment such as graphics cards, liquid cooling for processors or other special devices.

'Mobile VR' incorporates a high-end smartphone's screen into a special case, enabling the headset to fit more-or-less snugly on the user's head. This is likely to cost from about \$100, and we forecast that at least half a million units will be sold in 2016. Mobile VR requires smartphones with large, high resolution screens, ideally with greater than 400 pixels per inch (PPI) resolution, which is higher than that for the average premium smartphone. We expect that VR-ready smartphones will cost from \$750 and up but that most purchasers of mobile VR will already be owners of a suitable device.

Both types of VR would provide a high quality VR experience, with the caliber of full feature VR being noticeably superior, at least in 2016 and out to 2020. The processor and pixel density requirements require a lot of power, with plug in power being ideal. A smartphone being used for VR may exhaust its battery after half an hour. Mobile VR will rely on accelerometers for tracking and lacks positional tracking, which may cause a little lag. Furthermore, the field of vision in full feature VR should be slightly superior, at about 100 degrees or wider, while a smartphone tends to offer a field of 96 degrees at most.

VR can be experienced with lower specification PCs, consoles or smartphone, but the quality degrades accordingly. A normal PC would deliver lower screen refresh rates, lessening the efficacy of the simulation. The images shown may lag the pace of a turning head, in turn causing a feeling of nausea, as the image presented would not be what the brain expects. One can also use standard resolution smartphones, but you would likely see pixelated, less convincing images. A smartphone screen that is pixel free at normal viewing distances (10 cm) is likely to appear pixelated when a mere 1-2 cm away from the eye. Smartphone vendors are unlikely to over-specify pixel density unless they can monetize it. Also, mobile graphics chips have to get powerful enough to cope with such high resolutions.

VR cardboard kits are also available. These have the virtue of being low cost, often less than \$10 and frequently given away<sup>141</sup>. But they can be fragile as they are self-assembled and because of the material. Low cost variants lack features such as nose supports, causing discomfort with prolonged use. Most of them lack the strap to attach it to your head and require a person to hold it in their hands; this in turn eliminates the motion sickness caused by slow phone refresh rates, but reduces the immersion that the user is experiencing.

As for VR content, we would expect most revenue generated to come from games sales, with titles sold at between \$5 and \$40, generating over \$300 million. Many of the apps created for smartphones are likely to be available for under \$10 or free, with the latter serving primarily as marketing tools<sup>142</sup>.

We do not expect VR to be used to any great extent in television or movies in 2016. A key reason for VR's minimal impact on TV and movies this year is that little VR content exists, with a fundamental constraint being the lack of broadcast grade or even hobbyist cameras capable of capturing VR content. VR apps will be available, but we expect these typically to offer a view of a virtualized living room which includes a virtual television set, displaying regular TV programs in 2D<sup>143</sup>.

By the start of 2016, we anticipate a small range of suitable cameras may have been launched onto the market, but the cost of purchasing or renting professional grade devices may initially be prohibitive for many projects<sup>144</sup>.

Furthermore, as was the case with 3D filming for television, there is likely to be a learning curve in determining best practices for shooting for VR<sup>145</sup>. Regular filming places the set in front of the camera, and the production crew to the rear and out of shot. VR filming may require the crew to disappear entirely, which may complicate the directing of the shots. For VR sports, it is not yet certain where best to place the camera: placing it in the center of a field and in the mid-point of the action would likely constrain players' movements.

There are also likely to be challenges in post-production, one of which will be simply how to store the image files. One production level camera features 42 cameras capable of 4K resolution. This captures a gigapixel image (about 500 times the size of a standard smartphone image), and shoots at 30 frames a second<sup>146</sup>.

One subsequent challenge of capturing images at this level of resolution will be determining how to store, transmit and edit the files.

VR offers viewers a choice of point of view (POV); some viewers may prefer the director to choose the best viewing angle for them. The first DVDs offered the option of multiple angles, with the viewer choosing the perspective, as a differentiator to video cassettes, but this option was rapidly dropped due to low consumer interest.

151. See How Virtual Reality Can Help Hotels Compete With Airbnb, Hospitality Net, 28 October 2015: <http://www.hospitalitynet.org/news/4072363.html>
152. See 8 Amazing Uses for VR Beyond Gaming, PCMagazine, as accessed on 21 December 2015: <http://uk.pcmag.com/wearable-tech/29151/gallery/8-amazing-uses-for-vr-beyond-gaming?p=5>
153. Link Trainer, Wikipedia, as accessed on 21 December 2015: [https://en.wikipedia.org/wiki/Link\\_Trainer](https://en.wikipedia.org/wiki/Link_Trainer)
154. New head mounted display for use in military training, Gizmag, 17 July 2007: <http://www.gizmag.com/go/7645/>
155. Facebook's Zuckerberg: Virtual reality will have slow ramp, ZDNet, 5 November 2015: <http://www.zdnet.com/article/facebook-zuckerberg-virtual-reality-will-have-slow-ramp/>
156. How Oculus and Cardboard Are Going to Rock the Travel Industry, Bloomberg, 19 June 2015: <http://www.bloomberg.com/news/articles/2015-06-19/how-oculus-and-cardboard-are-going-to-rock-the-travel-industry>
157. See Mark Zuckerberg: Virtual Reality is the Future of Travel, Yahoo, 17 April 2015: <https://www.yahoo.com/travel/mark-zuckerberg-virtual-reality-is-the-future-of-116646911427.html>

As for enterprise adoption of VR, we expect 2016 will be a year of experimentation, with a range of companies dabbling with using VR for sales and marketing purposes. These activities are likely to be commercially insignificant this year. For example:

- Some architects are using VR to create interactive visualizations of construction projects in place of 3D models, or fly-through video<sup>147</sup>. This approach can enable clients to make changes before work starts<sup>148</sup>.
- Emergency response workers have used VR to practice how to respond to faults with nuclear reactors<sup>149</sup>.
- There are multiple applications for healthcare, with training and education of staff and members of the public being among the most prevalent<sup>150</sup>.

- Hotels can provide VR guides to properties<sup>151</sup>. For guests at a property, a VR headset could act as a virtual concierge, showing guests places they could visit.

- As well as teaching via a virtual classroom, VR can additionally be used to provide digitized tours to prospective students<sup>152</sup>.
- VR will likely continue to be used in the military where simulators have long been commonplace (see side bar: Simulators and the military).

We congratulate VR on what we expect will be its first billion dollar year, and we forecast rising revenues in coming years: it is possible that the industry will generate tens of billions of revenues in the medium term<sup>155</sup>. What appears certain however is that VR's potential is unlikely to be reached imminently; as with all emerging technologies patience is required.

### Simulators and the military

Simulators have been used for flight training as it is much safer and cheaper to learn how to fly in difficult conditions on the ground than in the air. Early simulators were wooden boxes mounted on a Universal Joint and driven by organ bellows in 1930, but were critical to training<sup>153</sup>. By the 1990s, full flight simulators were more mechanically sophisticated and incorporated large, high resolution screens that projected virtual scenes for the pilots-in-training. These cost millions of dollars, and in some cases less expensive solutions were sufficient. By 2007 helmets incorporating projected dual screen images a few inches from the user's eyes were being used for training, both for flight simulation and land combat training<sup>154</sup>.

## Bottom Line

Virtual reality is a fantastic innovation which can demonstrate the cutting edge of what technology is capable of today. VR's capability is likely to improve further still over the years as processors improve, screen resolution increases yet further, and content creators learn how to create for the format.

That said, as can happen with emerging technologies, there is considerable hype about the impact of VR in the near-term. Any company that is considering VR in any regard should have a careful look at the likely addressable market. Enthusiastic reactions to VR at trade fairs or at industry conferences, based on a few minutes of usage, may not convert into mass market demand. Those who attend trade shows may not be representative of the overall population, and those who are willing to line up for hours to try a new VR headset are likely to be even less representative. Furthermore, not all of those who are willing to line up for a free trial may be willing to spend \$300-500 of their own money when the devices become commercially available.

Any company considering marketing via VR imagery should consider the cost of making this content available to consumers. For example travel companies wanting to create VR brochures should assess how much filming and playback in VR may cost relative to current marketing approaches<sup>156</sup>. They should also assess the cost associated with acquiring the hardware needed to display these materials.

Recent breakthrough technologies that required consumers to wear something on their face have not proven to be mass market successes. While VR headsets may sell better than smart glasses or 3D TV glasses, also consider that using the technology may require a set of behavioral changes (the most apparent of which is wearing a large headset) that the majority of people do not want to make. For some people the immersion that VR causes may overwhelm rather than liberate. And wearing a padded headset for a prolonged period of time may cause the user's face to get hot and/or sweaty.

But the dream of being able to teleport anywhere just by donning a pair of goggles might prove enough for some to continue using VR on a daily basis<sup>157</sup>. The ambition to deliver on this dream is likely to keep many companies investing in the goal of making VR a commercial and virtual reality.

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As for enterprise adoption of VR, we expect 2016 will be a year of experimentation, with a range of companies dabbling with using VR for sales and marketing purposes.

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