How the Oculus Rift Works

by Bernadette Johnson

The Oculus Rift in use during E3 in Los Angeles, Calif. in June 2013.

Introduction to How the Oculus Rift Works

Virtual reality (VR) has not only been the stuff of science fiction novels and movies for decades, but it's also been an actual thing -- sort of. The first VR headsets were produced in the 1960s. At the time, the technology took up a lot of room and cost massive amounts of money. In the late 1980s to 1990s, VR became accessible to general public in arcades and other amusement venues via heavy headsets and controllers used to play rather simple games -- such as swinging a pretend sword at virtual foes, with as much accuracy as the era's computing systems could muster. The head tracking was slow, the field of vision was narrow and the graphics were low-resolution by modern standards. The experience often induced headaches and motion sickness, and it wasn't all that immersive. Still, it was a step forward in gaming and was bound to get better, but it didn't catch on at the time and the industry fizzled. The necessary technology just wasn't out yet to make it compelling to the masses.

High-end VR headsets with better resolution and response time have been developed since then, but they've remained prohibitively expensive for the home user and still tend to inhabit places like government and corporate research and training facilities. The military, automotive industry, space program and medical fields, to name a few, all use VR in one way or another, out of the view of the general populace.

But technology is ever evolving, and the small and powerful components that have made our cell phones and gaming systems so much better have now given VR technology a new lease on life by making devices like the Oculus Rift possible. It's the first of several headsets poised to bring realistic VR into the realm of possibility for the average user.

You would expect such a marvel to come from a known electronics manufacturer, but Oculus Rift had a humbler beginning. Palmer Luckey, a teenage gaming and electronics enthusiast with a passion for VR, began collecting old headsets and tinkering to try to create something that would work with modern games. Eventually he realized there was nothing viable in existence, and he'd have to make his own device from scratch.

THE HEADS OF OCULUS VR
Oculus VR quickly went from a one-man operation to a multi-million dollar company poised to corner the consumer VR market. As of this writing, it is helmed by the following executives: Palmer Luckey (Founder), Brendan Iribe (Chief Executive Officer), Michael Antonov (Chief Software Architect), John Carmack (Chief Technology Officer), Laird M. Malamed (Chief Operating Officer), Jack McCauley (Vice President Engineering), Nate Mitchell (Vice President Product) and Marshall Cline (Vice President Platform). Co-founder Andrew Scott Reisse was tragically killed in 2013 when struck by a speeding car involved in a police chase.

Opening the Rift

Luckey began working on what would become the Oculus Rift while he was in college studying journalism. He created the prototype in 2012, when he was only 19 years old. He had an idea to do a Kickstarter campaign to fund the creation of VR headset kits for maybe a few dozen devoted VR hobbyists, and he was communicating with lots of people online about it, including John Carmack, the game developer famous for creating "Doom" and "Quake" and founder of Id Software. Carmack was working on a VR project and requested a prototype. He used the Rift prototype with his own firmware to demonstrate his VR game "Doom 3 BFG" at E3 2012, and that started the hype for the Oculus Rift.

Luckey founded the company Oculus VR and enlisted the help of several industry insiders, including Brendan Iribe and Michael Antonov, cofounders of gaming UI provider Scaleform. The Kickstarter campaign commenced with a funding goal of $250,000, a goal it hit within the first day. By the end, it reached nearly 10 times that amount in pledges -- $2,437,429 total [sources: Kickstarter, Eurogamer].

The company has since gotten millions more from investors and has swelled with employees. It has partnered with Valve, Epic Games and Unity, among others, to bring high-quality and low-cost VR gaming to fruition.

As of early 2014, the Oculus Rift is currently out in a developer's kit version with the aim of encouraging the creation of content for the device before an improved consumer version goes to market. The consumer version is still in the works, and Facebook announced it was acquiring Oculus VR for $2 billion in March 2014.

The device is a lightweight virtual reality headset that blocks your view of your surroundings and fully immerses you in a virtual world. The Rift lets you step into a game, look around in any direction and see the game environment all around you rather than on a flat screen surrounded by your living room decor. And you see it in 3D. Not quite the holodeck or the matrix, but a good step in that direction.

Technical Specifications: Cracking Open the Rift

The Oculus Rift Development Kit version 1.1 includes the Oculus Rift head set, which vaguely resembles a pair of black ski goggles with a rectangular box covering the front end. The kit also comes with a control box that's permanently attached to the headset via a 6-foot (1.8-meter) cable, a removable over-the-head strap for added comfort and stability, three pairs of vision lenses of different focal lengths, an HDMI cable, a USB cable, a DVI cable, an HDMI to DVI adapter and a 5-Volt switching US-standard power supply along with international power adapters. All of this comes housed in a hard case. The Oculus Rift dev kit goggles weigh less than a pound -- a mere 369

Visitors to the 2013 IFA electronics trade fair in Berlin, Germany take the Oculus Rift for a test drive.
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grams -- and the future consumer model may be even lighter.

The control box is used to hook the headset up to your computer and perform basic control functions. It includes HDMI, DVI, mini-USB and DC power connection ports, as well as five buttons for controlling contrast, brightness and power. A blue LED on top shows you whether the device is on or off.

The developer headset allows for head-tracking with 3 degrees of freedom (DOF), ultra-low latency and a field of view (FOV) of 110 degrees diagonally and 90 degrees horizontally for convincing immersion.

The Rift incorporates a flat 7-inch (17.8-centimeter) 60Hz LCD display screen with a resolution of 1280 by 800 pixels (around 720p high-def resolution). The screen is divided into 640 by 800 pixels per eye, with a 2.5-inch (64-millimeter) fixed distance between lens centers. The user views the screen through two lens cups. There are plans to make the consumer model's resolution at least 1080p, and the company has already demonstrated two 1080p prototypes (the HD and Crystal Cove models). The display inputs include DVI-D Single Link, HDMI 1.3+ and USB 2.0 Full Speed+, all fed to it through the single control box cord.

The device has a custom-built motion and orientation sensor unit with a sampling rate of up to 1000 Hz. The sensor unit includes a gyroscope, an accelerometer and a magnetometer, along with an ARM Cortex-M3 microcontroller. The data from all three sensors is combined through a process called sensor fusion to enable fast and accurate tracking of your head orientation and synchronization with what you are viewing. This allows you to turn your head in any direction and look around the virtual environment in real-time, but it doesn't allow for positional tracking.

A new prototype, dubbed Crystal Cove, debuted at CES 2014. It has a higher resolution 1080p AMOLED (active matrix organic light emitting diode) screen, lower latency, a higher refresh rate and much lower image persistence, meaning that the images you see on the screen change as quickly as you move rather than persisting on the screen long enough to cause a lot of motion blurring. Crystal Cove can also track position, rather than just orientation, with the help of IR LEDs (which look like little square white dots) all over the headset that are monitored by an external camera, giving you 6 degrees of freedom rather than just 3. You can lean toward things to get a closer look, or lean to look around corners, whereas with the developer kit you can turn your head in various directions to change the camera view, but you have to use a separate controller to handle all motion toward, away from or around things. This prototype is reportedly closer to Oculus VR's vision for the consumer version.

System Requirements

The Oculus Rift device and Software Development Kit (SDK) support Linux, Mac OS and Windows operating systems. To use the device with your computer, it must have either an HDMI port or a DVI video-out port. VGA is not supported.

There are no specific minimum system requirements, however some recommended guidelines include:

- Windows (Vista, 7 or 8)
- Mac OS 10.6 or higher
- Linux (Ubuntu 12.04 LTS)
- 2.0+ GHz processor
- 2 GB RAM
- Direct3D 10 or OpenGL 3 compatible video card

Performance should be better on a computer that can handle heavy-duty gaming. Per the SDK documentation, the Oculus team has found that a MacBook Pro Retina with an Nvidia 650M graphics card will work as a portable VR workstation.

The SDK also includes support for some game controllers, including the Xbox 360 wired controller for Windows, the Logitech F710 Wireless Gamepad for Windows and Mac and the Sony PlayStation DUALSHOCK3 Controller for Mac.

To use the headset, you connect your computer to the control box via the USB port and one (but not both) of the video input ports (either HDMI or DVI). Then plug the power cord into the box and an electrical outlet. When all three necessary cables are connected, the screen will activate. Your computer will essentially see the Rift as another display, and you can adjust the display's settings through your computer's display control panels.

It currently only works with personal computers, but support for mobile devices is in the works, and gaming systems may be next.

Open Source Software and Hardware

The Oculus SDK is publicly available and open source, meaning that anyone can obtain, use and even modify and distribute the code. There are a few caveats spelled out in their license agreement, including that any modifications must be shared with Oculus VR, that the software may not be used to interface with other commercial VR headsets that aren't approved by Oculus VR, and that the code must be distributed in whole, not part. They can also revoke your rights to use the SDK if you create an application that causes health or safety issues.

The SDK includes C++ source code, libraries, headers, firmware, samples, tutorials and

Attendees at the 2014 International CES had the opportunity to play "EVE: Valkyrie" on the Oculus Rift.
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documentation, along with the Unreal Development Kit, Unreal Engine 4 and Unity game development software.

Some of the samples include:

- OculusRoomTiny, which displays a small room to show sensor integration and rendering.
- OculusWorldDemo, which allows you to wander through a more complex Tuscany setting.
- SensorBoxTest, which is a 3D rendered box that shows sensor fusion by tracking and displaying the Rift's rotation.

Developers can access the Oculus VR Developer Center to retrieve the latest versions of the SDK components and for online support. These resources should help greatly in developing or porting more games and other content to the Oculus Rift.

The company has also released an Oculus Latency Tester whose hardware and software are both open source. Its firmware is under the Apache 2.0 License and its schematic, board layout and enclosure are licensed under Creative Commons Attribution 4.0. You can buy the Latency Tester from the Oculus VR site, and you can use, alter or distribute any portion of the tester and its code. Or if you're a tinkerer, you can build your own using the freely available files.

Physical modification of the Oculus Rift unit itself is not recommended, however, since the company may not be able to support the modified device. But its source code is fair game.

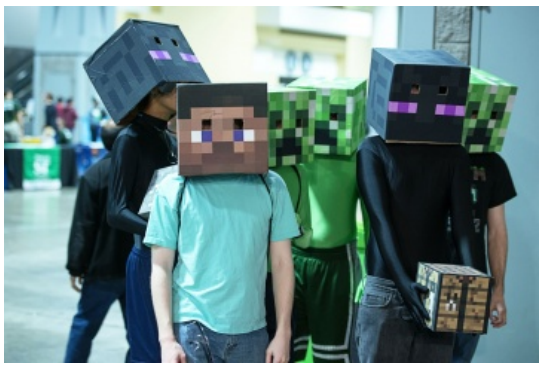
What the Rift Can Do

For some reason the Rift gets compared with Google Glass, but aside from the fact that they are both pieces of technology that you wear on your face, the two devices are entirely different animals. Google Glass is a tiny smartphone in the shape of eyeglasses with a clear rectangular see-through screen over one eye. You can see your real surroundings at all times, but you can also call up information via voice commands, and it will appear on the screen, superimposed over what's really in front of you. It's more in the realm of augmented reality than virtual reality.

The Oculus Rift, on the other hand, is true virtual reality. You are completely blocking your view of the real world and seeing a new digital, virtual world in its place. The Rift uses stereoscopic 3-D rendering, a high-resolution display, a field of view 110 degrees wide and ultra-low latency head tracking to immerse you in a virtual world that should prove to be more believable than any VR most of us have witnessed before.

The Rift achieves stereoscopic 3-D by feeding a slightly different image to each eye, which is more or less how we see in 3-D in the real world, where each eye is seeing everything from a slightly different vantage point and the differences are used to perceive depth. The110-degree field of view extends into your peripheral vision area and, in conjunction with the lenses, is intended to help immerse you into a game. The low latency means that what you see tracks with your head movements in real-time rather than being on a delay where the image has to catch up to your eyes.

Once you've acquired the developer's Rift and downloaded the SDK and any firmware updates from the Oculus VR site, you need to calibrate the device. This includes measuring and setting your height and your IPD (interpupillary distance, or the distance between your pupils) and running the magnetometer calibration, which involves rotating the headset as instructed. Once your device is calibrated, you can use it to test or play whatever games you find or create.



Fans of "Minecraft" will be happy to know that a VR-adaptation of the game, titled "Minecrift," is available for download on the Oculus Rift site.
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What sorts of games work with the Rift?

Although at the time of this writing the consumer version of Oculus Rift isn't out yet, there are already some games from major developers that have been created or ported to work with the device. These include:

- "Doom 3 BFG Edition" by id Software - the first Oculus-ready game.
- "Eve: Valkyrie" by CCP Games - an exclusive launch title for Oculus Rift.
- "Team Fortress 2" by Valve - a port that can be played in VR mode.
- "Half Life 2" by Valve - another port that can be played in VR mode.
- "Hawken" by Meteor Entertainment and Adhesive Games.

These may not all be available to the public in Rift-ready form, but there are non-VR versions of all but "Eve: Valkyrie" in the wild. "Doom 3 BFG Edition" was given out with the development kits purchased through the Kickstarter campaign, and "Eve: Valkyrie" has been demonstrated with the newer Rift prototypes and is slated to come out sometime in 2014.

Lots of existing games are already being adapted to work with the Rift. And there is a spot on the Oculus VR Web site here for developers to share their games, mods, demos, simulations and the like. There are more than 100 titles available on the share site already, including "Minecrift," a VR conversion of the popular game "Minecraft" (a paid copy of "Minecraft" is required for it to work); and "VR Cinema," a simulation of a movie theater within which you can actually watch videos.

Unfortunately, not just any 3-D game can be played with the device just yet. Due to the unique properties of the Rift, including its wide field of vision and head-tracking abilities, games and other applications will have to be specifically made to work with the device. The main things that have to be integrated are motion tracking and 3-D rendering along with distortion adjustment to produce the stereoscopic images (a slightly different one for each eye).

As of early 2014, around 50,000 units have been shipped [sources: Edwards, Perton]. With so many in the hands of developers, there are no doubt many games in the works. But although the Rift was designed primarily with gaming in mind, that doesn't mean that's all it will be good for. We might one day don our headsets to watch 360-degree videos, sit in virtual classrooms, view live entertainment or sporting events and move through simulated environments paired with exercise equipment for fitness.

Some higher-end players are already exploring the possibilities of the Rift. The NASA Jet Propulsion Laboratory (JPL) has experimented with an Oculus Rift in conjunction with an Xbox Kinect 2 to control a robotic arm -- a possible step toward controlling robots remotely in outer space. The JPL has also used a Rift with a Virtuix Omni treadmill and panoramic images captured by the Curiosity rover to simulate walking on Mars. A myriad of companies have reportedly already bought the developer kits for their own purposes, and there's even been talk of using them for lower-cost military training. The possible applications for a lightweight, inexpensive VR headset are truly endless.

Fighting Simulator Sickness

Even a static screen can cause eyestrain and motion sickness under certain circumstances, but VR is particularly prone to such issues. The term "simulator sickness" has been coined to describe the headaches, disorientation and nausea sometimes brought on by virtual reality and other simulation techniques. The biggest culprit is lag time between the user moving and the video image keeping up, which is mostly a hardware problem. Nonetheless, the Oculus VR team has come up with a Best Practices Guide for software developers to help prevent these problems, as well as to create enjoyable games that are well suited to VR. The document includes advice on how to best handle image rendering, user perspective, degree of stereoscopic 3-D depth, camera movement in relation to head movement, in-game speed and change of motion, placement of user interface and objects, audio, user control, visual design and other technical and design considerations.

The guide suggests a few baselines for comfort, like a simulated walking speed of 4.5 feet (1.4 meters) per second, a minimum frame rate of 60 frames per second (fps), an ideal latency of 20 milliseconds or less and virtual placement of static objects no closer than 1.6 feet (50 centimeters) away from the user. There are also references in the guide to specific Oculus VR software features like distortion shaders, predictive tracking and the Oculus head model that developers can use to improve gamer comfort without having to reinvent the wheel.

It suggests performing user testing with outside users to make sure the game (or other application) is comfortable for a variety of people, not just developers accustomed to the content. The guide also advises developers to include optional user settings, including the ability to change speed, acceleration size, field of view and the effect of collisions, as well as inclusion of a monoscopic display mode that makes the image the same for both eyes (which is supposed to decrease simulator sickness).

Although it's a danger when running around in any virtual world, in part due to the disconnect between what your mind is seeing and what your body is doing, sound design can help decrease the likelihood of simulator sickness. The new Crystal Cove prototype's greatly reduced motion blurring should reduce the possibility of motion sickness still further. There's even some evidence that you can just get used to VR and not get as sick as your experience with it increases.

The Oculus VR team claims that viewing through the Rift may be a little better than staring at a standard flat screen when it comes to eyestrain, since it makes your eyes focus in the distance, which is their natural resting position.

Attendees playing "EVE: Valkyrie" at the Intel booth at the 2014 International CES in Las Vegas, Nevada.

Reviews, Availability and Possibilities

Early impressions of the developer model have been largely positive. Many people think the Rift is incredibly cool, including one early adopter's 90-year-old grandmother [source: Kooser]. It has been called a game changer for, well, gaming.

There have been the expected complaints about nausea and dizziness, and some concern about using glasses with the Rift. You can actually use the headset with most eyeglasses, depending upon their size and shape. To accommodate glasses, you adjust the distance of the lenses to your face by turning two screws on either side of the headset -- the closer the better so that you're getting the maximum field of view. Using it with glasses is not recommended, however, due to the risk of scratching your eyeglass lenses and the certainty of reducing your field of view. They do recommend swapping out the Rift's lenses to see if any of them will work for you without glasses. The longest set (A) was made for people with 20/20 or farsighted vision, the mid-length set (B) was made for people with moderate nearsightedness and the shortest set (C) was made for people with more severe nearsightedness. The Oculus team is planning to make the consumer version a little more eyeglasses-friendly.

Positive reactions to the newer Crystal Cove prototype have been even more effusive due to the higher resolution, reduced motion blurring and positional tracking. Both iterations of the device received Best of CES accolades in 2013 and 2014 respectively.

As of early 2014, you can purchase the developer version directly from the Oculus VR site for $300, but the release date and price point for the consumer version have yet to be officially announced. But with so many dev kits and even better prototypes out there, hopefully -- especially with the financial backing of Facebook -- the wait won't be long for VR fun in our living rooms.

Lots More Information

Author's Note: How the Oculus Rift Works
I have been longing for virtual reality since "Tron," the "Star Trek: The Next Generation" holodeck, "The Lawnmower Man" and "The Matrix" (the horror aspects of all but one of those aside). It's not like I haven't experienced virtual reality. I've done my fair share of simulator rides, and tried the headset arcade games once or twice,

but I remember it being expensive, extremely low resolution, imprecise and not all that immersive.

As it always does, technology has improved by leaps and bounds, graphics have gotten better, and now with the Oculus Rift, it sounds like more enjoyable and believable VR is within our grasp. It's still not the holodeck, but I can't wait to try out the 1080p consumer model whenever it becomes available.

And I might just break down and get the developer model in the near future. I am, after all, a developer (although I haven't yet delved into game development). Or I could just build stuff in "Minecraft" like I do now in regular 2-D "Minecraft." Constructing random castles, shearing sheep and taming ocelots and wolves may be even more satisfying in 3-D VR. Although running face first into a creeper in an immersive reality might be the stuff of nightmares.

Related Links

- How Virtual Reality Works
- Who invented virtual reality technology?
- Who popularized the term "virtual reality"?

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