Upcoming Deadlines

Sunday, May 9: Project 2 late deadline
Monday, May 10: Discussion Project 3
Sunday, May 16: Project 3 due
Monday, May 17: Discussion Project 4
Sunday, May 23: Project 3 late deadline
App Presentations

Anders Johnson
  ◦ Engage

Dillon Handal
  ◦ Tea For God
Oculus DK1 Kickstarter in 2012

Launch video:
Oculus Rift DK1

Funded through Kickstarter with $2.4M
Released March 2013
Single LCD display with 1280 x 800 pixels
110 degrees FOV
60 Hz refresh rate
Head orientation tracking only (3 DOF)
  ◦ Fast, custom IMU
No tracked controllers available
Inertial Measurement Unit (IMU)

Measures
- gravitational force
- angular rate
- magnetic field (optional)

Consists of
- 3 accelerometers
- 3 gyroscopes
- magnetometer

IMUs also used in
- aircraft, spacecraft, satellites
- smart phones
- fitness trackers
- remote controls
- game controllers
Oculus Rift DK2

Released July 2014

Single OLED display (same as Samsung Galaxy Note 3)

1920 x 1080 pixels

Field of view: 95 x 105 degrees

75 Hz refresh rate

Same IMU as DK1

6 DOF tracking with IMU and camera for head location tracking

No tracked controllers available
Sony Playstation VR

Released October 13, 2016
Sold for Play Station 4
Single OLED display
960 x 1080 pixels per eye
100 degrees field of view
90 or 120 Hz refresh rate
Fixed IPD
Headphone jack
Innovative head strap
External camera for tracking
6 DOF tracking with visible light in different colors
Uses Sony Move controllers
HTC Vive

Released April 5, 2016

2 OLED displays

1200 x 1080 pixels per eye

110 x 113 degrees field of view

90 Hz refresh rate

Adjustable eye distance (IPD)

Integrated camera

Headphone jack

Includes two controllers

6 DOF tracking with 2 Lighthouses
Oculus Rift CV1

Released March 28, 2016
2 OLED displays
1200 x 1080 pixels per eye
94 x 93 degrees field of view
90 Hz refresh rate
Adjustable eye distance (IPD)
Integrated headphones
Infrared LEDs on HMD and controllers
6 DOF tracking with infrared cameras ("sensors")
Oculus Rift CV1 Teardown
Oculus Rift: Ear Phones
Face Foam
Infrared LEDs
Separate lens/display assemblies
CV1 Lens

Asymmetric

Hybrid Fresnel lens

Focus varies along vertical axis of lens

→ Push lens higher or lower to focus
Lenses: DK2 vs. CV1

Circular vs. Asymmetric
Microsoft Mixed Reality

First devices released October 17, 2017

Virtual Reality HMDs
  ◦ No augmented reality, despite the name

Specifications by Microsoft

Dual 6 DOF controllers with infrared LEDs

Inside-out 6 DOF HMD tracking with two cameras

HMDs built by:
  ◦ Samsung, Dell, HP, Lenovo, Acer, Asus
HTC Vive Pro

- Released April 5, 2018
- Built-in stereo cameras for AR
- 1440 x 1600 pixels per eye
- 90Hz refresh rate
- 110 degrees FOV
- Integrated headphones
- New design with sizing dial
- 2 cameras
- Tracking space up to 10 x 10 meters with new Lighthouses 2.0 (released April 23, 2018)
Oculus Rift S

Release date: May 21, 2019

LCD display

1280 x 1440 pixels per eye

80 Hz refresh rate

Internal speakers + headphone jack
Valve Index

Release date: July 1, 2019

1440 x 1600 pixels per eye

LCD display

120 Hz refresh rate (144 Hz experimental mode)

Integrated speakers

Lighthouse base stations 2.0

New Index (“Knuckle”) controllers: sense finger positions, allow open hands
Vive Cosmos

Released October 2019

Inside-out tracking with 6 cameras

Price: $700

1440 x 1700 pixels per eye

90Hz refresh rate

110 degrees FOV

Built-in stereo headphones

Adjustable IPD

Includes controllers
HP Reverb G2

Released November 2020
Windows Mixed Reality headset
2160 x 2160 pixels per eye
114 degrees field of view
90 Hz refresh rate
6 DOF inside out tracking
Same controllers as other Mixed Reality systems
Oculus Quest 2

Release date: Oct 13, 2020

Standalone VR HMD
  ◦ Inside-out 6 DOF tracking

LCD display
1832 x 1920 pixels per eye
90 Hz refresh rate
90 degrees FOV
Adjustable IPD (3 settings)
Qualcomm Snapdragon XR2
Built-in headphones
Includes 2 controllers
Issues with VR HMDs

High-End (PC-Based) VR:
- Most drivers for Windows only, Mac and Linux lacking support
- User can get tangled up in cables (except for wireless HMDs)
- Cumbersome camera calibration (even with inside-out systems)

Low-End (Smart Phone-Based) VR:
- Most apps only have orientation tracking
  - Position tracking possible with Apple’s ARKit and Google’s ARCore, but rarely used for VR
- Hand-held controllers not standardized and usually not supported

Both:
- More powerful GPUs needed for more visual realism
- Most VR HMDs don’t allow view of environment
- Wearing an HMD is socially awkward (looks weird, can’t see other people)
- AR is coming, but technology lagging behind VR
<table>
<thead>
<tr>
<th>DEVICE</th>
<th>FOV</th>
<th>REFRESH RATE</th>
<th>TRACKING TECHNOLOGY</th>
<th>PLATFORM SUPPORT</th>
<th>PRICE (USD)</th>
<th>DISPLAY DETAILS</th>
<th>RESOLUTION PER EYE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Google Cardboard</td>
<td>~90</td>
<td>60Hz</td>
<td>X</td>
<td>G</td>
<td>$15</td>
<td>HEADSET</td>
<td>540x480</td>
</tr>
<tr>
<td>Switch LABO</td>
<td>~90</td>
<td>60Hz</td>
<td>X</td>
<td>CONSOLE</td>
<td>$299</td>
<td>LCD</td>
<td>640x480</td>
</tr>
<tr>
<td>Playstation VR</td>
<td>100</td>
<td>120Hz</td>
<td>X</td>
<td>X</td>
<td>$39</td>
<td>HEADSET</td>
<td>960x1080</td>
</tr>
<tr>
<td>Oculus Rift S</td>
<td>90</td>
<td>80Hz</td>
<td>X</td>
<td>LCD</td>
<td>$349</td>
<td>HEADSET</td>
<td>1280x1440</td>
</tr>
<tr>
<td>Asus HC102</td>
<td>95</td>
<td>90Hz</td>
<td>X</td>
<td>OLED</td>
<td>$399</td>
<td>HEADSET</td>
<td>1440x1440</td>
</tr>
<tr>
<td>Lenovo Explorer</td>
<td>110</td>
<td>90Hz</td>
<td>X</td>
<td>LCD</td>
<td>$400</td>
<td>HEADSET</td>
<td>1440x1440</td>
</tr>
<tr>
<td>Dell Visor</td>
<td>110</td>
<td>90Hz</td>
<td>X</td>
<td>LED</td>
<td>$450</td>
<td>HEADSET</td>
<td>1440x1440</td>
</tr>
<tr>
<td>Oculus Quest 2</td>
<td>89</td>
<td>120Hz</td>
<td>X</td>
<td>LCD</td>
<td>$299</td>
<td>HEADSET</td>
<td>1832x1920</td>
</tr>
<tr>
<td>Oculus Quest</td>
<td>94</td>
<td>72Hz</td>
<td>X</td>
<td>OLED</td>
<td>$399</td>
<td>HEADSET</td>
<td>1600x1440</td>
</tr>
<tr>
<td>Odyssey+</td>
<td>110</td>
<td>90Hz</td>
<td>X</td>
<td>AMOLED PENTILE</td>
<td>$499</td>
<td>HEADSET</td>
<td>1440x1400</td>
</tr>
<tr>
<td>HP Reverb G1</td>
<td>114</td>
<td>90Hz</td>
<td>X</td>
<td>LCD</td>
<td>$599</td>
<td>HEADSET</td>
<td>2160x2160</td>
</tr>
<tr>
<td>HP Reverb G2</td>
<td>115</td>
<td>90Hz</td>
<td>X</td>
<td>LCD INDEX LENSES</td>
<td>$599</td>
<td>HEADSET</td>
<td>2160x2160</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DEVICE</th>
<th>FOV</th>
<th>REFRESH RATE</th>
<th>TRACKING TECHNOLOGY</th>
<th>PLATFORM SUPPORT</th>
<th>PRICE (USD)</th>
<th>DISPLAY DETAILS</th>
<th>RESOLUTION PER EYE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vive Cosmos</td>
<td>110</td>
<td>90Hz</td>
<td>X</td>
<td>LCD RGB</td>
<td>$699</td>
<td>HEADSET FULL KIT</td>
<td>1440x1700</td>
</tr>
<tr>
<td>HTC Vive Focus</td>
<td>110</td>
<td>75Hz</td>
<td>X</td>
<td>AMOLED PENTILE</td>
<td>$799</td>
<td>HEADSET FULL KIT</td>
<td>1440x1600</td>
</tr>
<tr>
<td>Cosmos Elite</td>
<td>110</td>
<td>90Hz</td>
<td>X</td>
<td>LCD RGB</td>
<td>$549</td>
<td>HEADSET FULL KIT</td>
<td>1440x1700</td>
</tr>
<tr>
<td>Pimax 8K</td>
<td>170</td>
<td>80Hz</td>
<td>X</td>
<td>LCD RGB</td>
<td>$499</td>
<td>HEADSET FULL KIT</td>
<td>3840x2160</td>
</tr>
<tr>
<td>Valve Index</td>
<td>130</td>
<td>144Hz</td>
<td>X</td>
<td>LCD RGB</td>
<td>$999</td>
<td>HEADSET FULL KIT</td>
<td>1440x1600</td>
</tr>
<tr>
<td>HTC Vive Pro</td>
<td>110</td>
<td>90Hz</td>
<td>X</td>
<td>AMOLED PENTILE</td>
<td>$799</td>
<td>HEADSET FULL KIT</td>
<td>1440x1600</td>
</tr>
<tr>
<td>Pimax 8K</td>
<td>170</td>
<td>80Hz</td>
<td>X</td>
<td>LCD RGB</td>
<td>$1299</td>
<td>HEADSET FULL KIT</td>
<td>3840x2160</td>
</tr>
<tr>
<td>Pimax 8K Plus</td>
<td>170</td>
<td>144Hz</td>
<td>X</td>
<td>OLED PENTILE</td>
<td>$899</td>
<td>HEADSET FULL KIT</td>
<td>2560x1440</td>
</tr>
<tr>
<td>StarVR ONE</td>
<td>210</td>
<td>90Hz</td>
<td>X</td>
<td>AMOLED RGB TOBII EYE</td>
<td>$3200</td>
<td>HEADSET FULL KIT</td>
<td>1830x1464</td>
</tr>
<tr>
<td>HTC Vive</td>
<td>110</td>
<td>90Hz</td>
<td>X</td>
<td>AMOLED PENTILE</td>
<td>$1080</td>
<td>HEADSET FULL KIT</td>
<td>1080x1200</td>
</tr>
<tr>
<td>Oculus CV1</td>
<td>94</td>
<td>90Hz</td>
<td>X</td>
<td>OLED PENTILE</td>
<td>$1080</td>
<td>HEADSET FULL KIT</td>
<td>1080x1200</td>
</tr>
<tr>
<td>Virtual Boy</td>
<td>~30</td>
<td>50Hz</td>
<td>X</td>
<td>LED</td>
<td>$384</td>
<td>HEADSET</td>
<td>384x224</td>
</tr>
</tbody>
</table>

Disclaimers:
- Field of view depends highly on the screen size and eye relief (eye to lens distance).
- All FOVs listed are the horizontal specifications.
- All specifications listed are from the “Comparison of virtual reality headsets” Wiki Article.
PenTile Displays

A display technology from Samsung that uses clusters of **five** (penta) **subpixels**. Originally developed by Clairvoyante, PenTile uses fewer subpixels, and subsequently less power, for the total number of pixels on screen than the conventional RGB subpixel method. [Wikipedia]
AMOLED Displays

AMOLED = Active-Matrix Organic Light-Emitting Diode

AMOLED screens don’t need a backlight, as each pixel is able to produce its own light when it needs to. This makes blacks look amazing when viewing a picture or video, because the pixels do not have to provide light at all, rather than LCD displays where the backlight bleeds through and you get a dark grey color where there should be black.

AMOLED drawbacks:

- more expensive to produce
- not as sharp as LCD displays when looking up close
  - AMOLED uses a different subpixel arrangement than LCD displays, which makes individual pixels more noticeable (see picture)
HMD Sales Forecast

FORECAST: Global VR Headset Shipments
By Category

- Smartphone-powered headsets
- PC-powered Headsets
- Game console-powered headsets

Source: BI Intelligence Estimates