

LECTURE 1: INTRODUCTION TO VIRTUAL REALITY

COMP 4010 - Virtual Reality

Semester 5 - 2017

Bruce Thomas, Mark Billinghurst
University of South Australia



University of
South Australia

Overview

- Introduction
- Class Overview
- What is Virtual Reality
- History of Virtual Reality

Lecturers

- **Mark Billinghurst**

- Director of the Empathic Computing Lab
- Expert in AR, 3D user interfaces
- mark.billinghurst@unisa.edu.au

- **Bruce Thomas**

- Director of the Wearable Computing Lab
- Expert in AR/VR, wearable computing
- bruce.thomas@unisa.edu.au

- **Teaching Assistants**

- Tham Piumsomboon (Unity expert)
- Theophilus Teo (AR/Unity)
- Carolin Reichherzer (VR Design)



Class Logistics

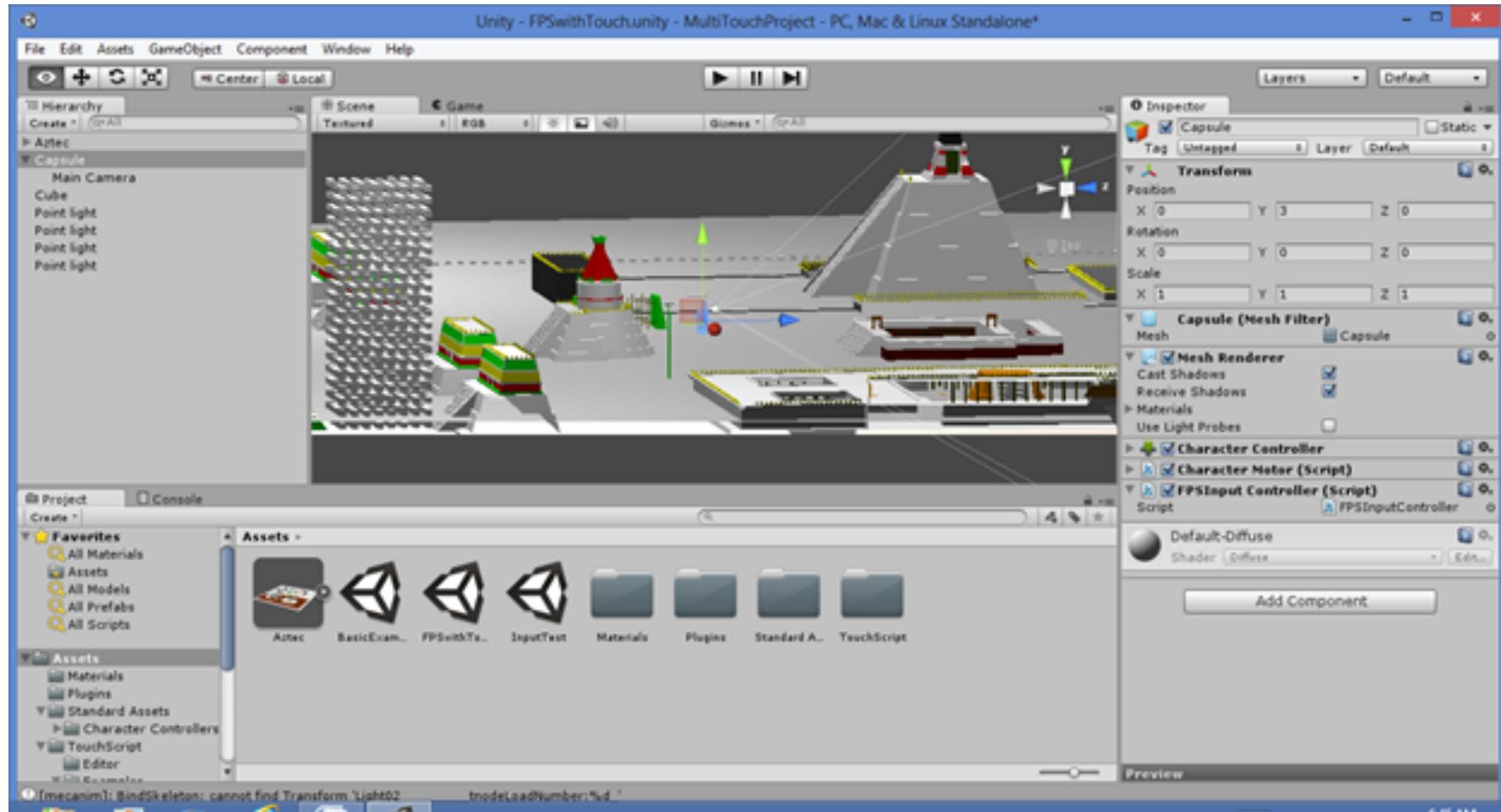
- Weekly lecture (2 hrs)
 - Thursday 11am – 1pm
 - Room F1-16
- Weekly Lab (1 hr)
 - Thursday 1-2pm
- Assessment
 - 3 projects @ 20%, 30%, 40%
 - Paper reading/class presentation @ 10%
- What you will need
 - iOS or Android phone/tablet
 - Access to laptop/PC for development

VR Lab Equipment

- **6 VR capable PCs**
 - High end graphics cards
 - Fast processors
- **3 Oculus Rift HMDs**
 - Wide Field of View display
 - Two touch controllers
- **1 HTC Vive HMD**
 - Room scale tracking
 - Two handheld controllers



Unity3D – www.unity3d.com



- Who has Unity3D Experience?

Lecture Schedule – 13 Lectures

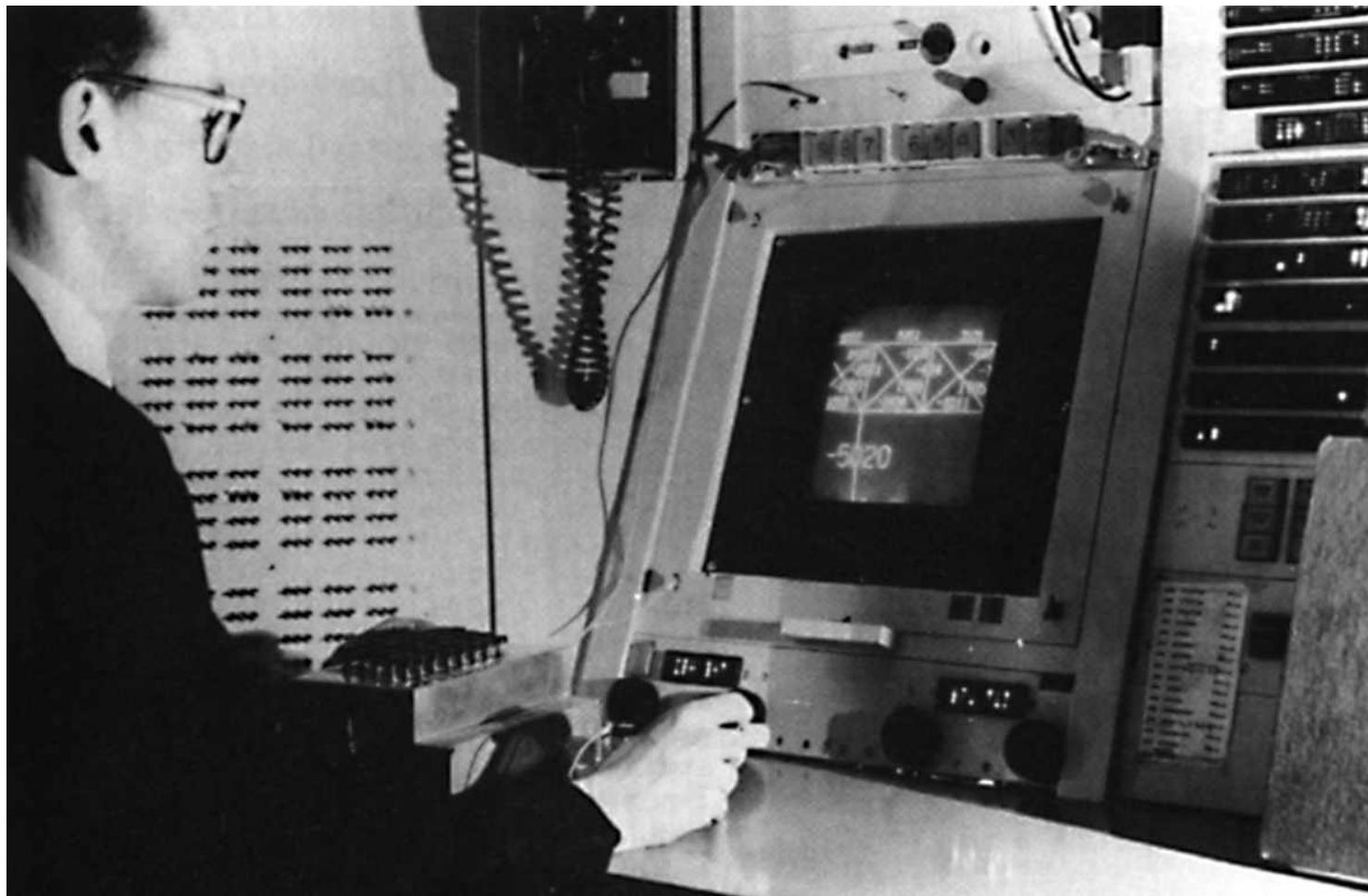
- July 27th : 1. Introduction
- Aug 3rd : 2. VR Technology Overview
- Aug 10th : 3. VR Systems
- Aug 17th : 4. 3D User Interfaces
- Aug 24th : 5. Interaction Design for VR
- Aug 31st : 6. VR Application
- Sept 7th : 7. Introduction to AR
- Sept 14th : 8. Class Presentations
- Oct 5th : 9. AR Technology
- Oct 12th : 10. AR Interface Design
- Oct 19th : 11. Mobile AR
- Oct 26th : 12. AR Applications
- Nov 2nd : 13. Research Directions

What You Will Learn

- What Augmented Reality/Virtual Reality is
- History of AR/VR
- Current AR/VR commercial market
- Different AR/VR applications
- Human perception side of VR/AR
- AR/VR technology
- 3D user interface guidelines
- How to design good AR/VR experiences
- How to build your own AR/VR applications
- Important directions for future research in AR/VR

WHAT IS VIRTUAL REALITY?

Ivan Sutherland (1963)



- Sketchpad – first interactive graphics program

Ivan Sutherland Sketchpad Demo



- <https://www.youtube.com/watch?v=DWAIp3t6SLU>

The Ultimate Display

“The ultimate display would, of course, be a room within which the computer can control the existence of matter. A chair displayed in such a room would be good enough to sit in. Handcuffs displayed in such a room would be confining, and a bullet displayed in such a room would be fatal”.

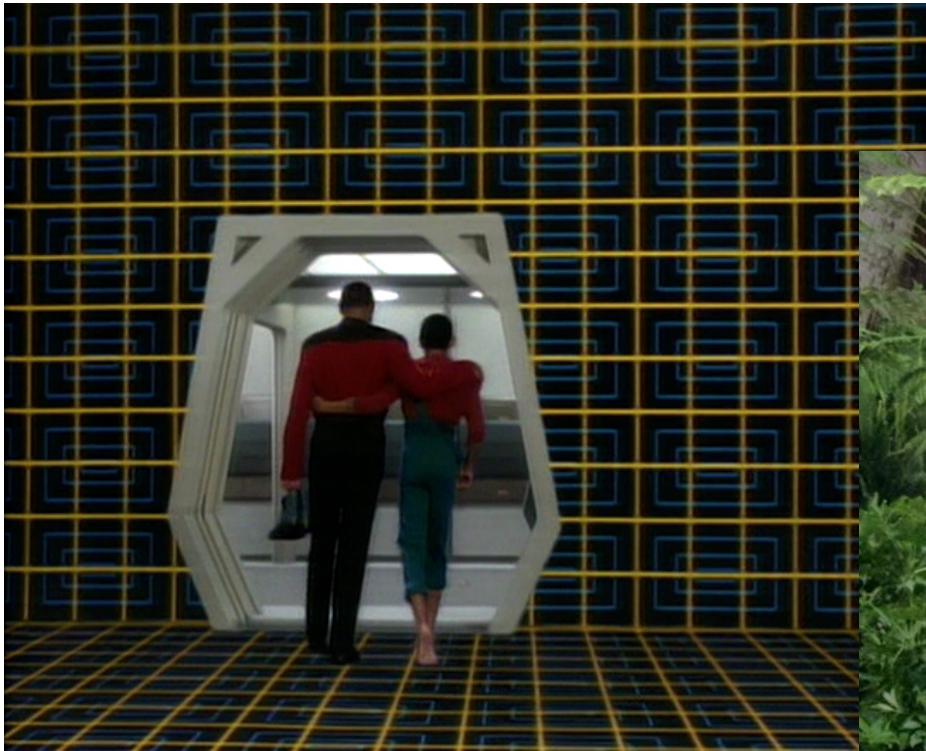
Ivan Sutherland, 1965

An Invisible Interface



“With appropriate programming such a display could literally be the Wonderland into which Alice walked.”

Holodeck (1974)



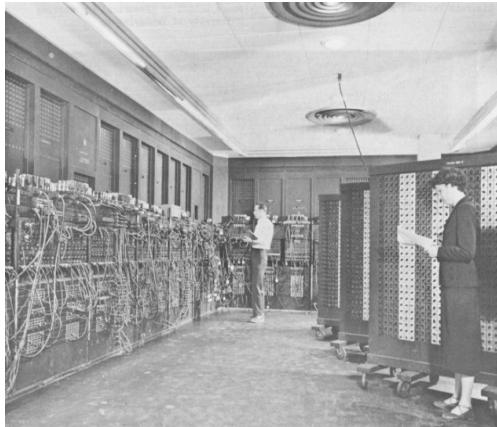
- First shown in Star Trek; The Animated Series

HoloDeck Video



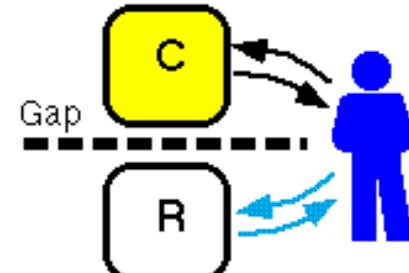
- <https://www.youtube.com/watch?v=oZwtVz7z0wM>

Trend Towards Invisible Interfaces

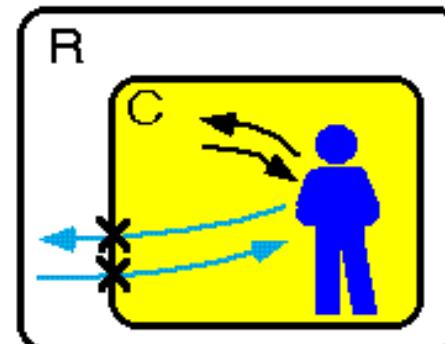


- Trend from room scale to invisible computing
- Making Computers Invisible
 - hide the computer in the real world
 - Ubiquitous Computing
 - put the user inside the computer
 - Virtual Reality

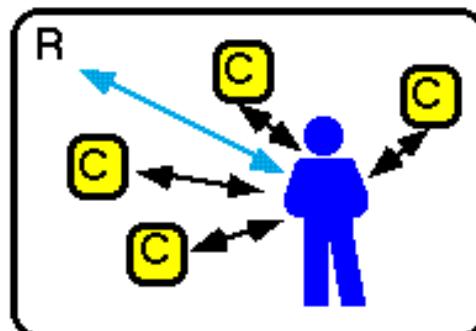
Making Interfaces Invisible



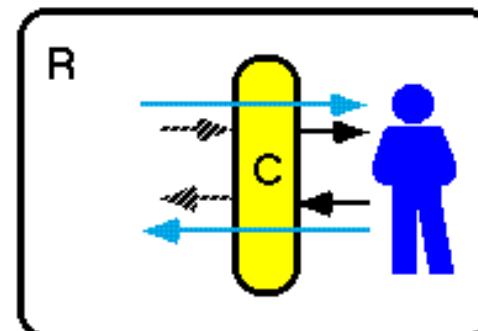
(a) GUI



(b) Virtual Reality



(c) Ubiquitous Computers



(d) Augmented Interaction

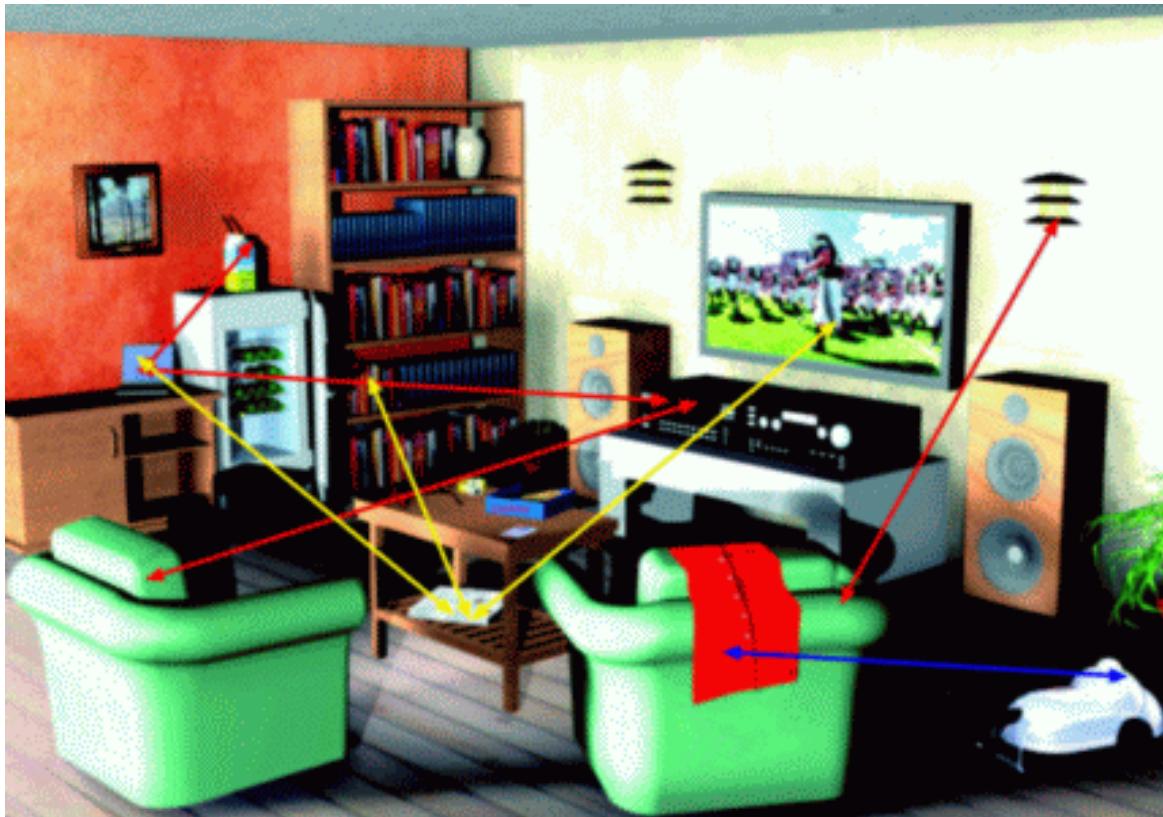
Rekimoto, J. and Nagao, K. 1995. The world through the computer: computer augmented interaction with real world environments. In *Proceedings of the 8th Annual ACM Symposium on User interface and Software Technology. UIST '95*. ACM, New York, NY, 29-36.

Graphical User Interfaces



- Separation between real and digital worlds
 - WIMP (Windows, Icons, Menus, Pointer) metaphor

Ubiquitous Computing



- Computing and sensing embedded in real world
 - Particle devices, RFID, motes, arduino, etc

Virtual Reality



- 1985...

NASA Tech Briefs

Transferring Technology to
American Industry and Government

July/August 1988
Volume 12 Number 7



NASA's Virtual Workstation Shapes A VIVED Reality

Virtual Reality



- Immersive VR
 - Head mounted display, gloves
 - Separation from the real world

What is Virtual Reality?

virtual reality

noun

Simple Definition of VIRTUAL REALITY

Popularity: Bottom 40% of words

: an artificial world that consists of images and sounds created by a computer and that is affected by the actions of a person who is experiencing it

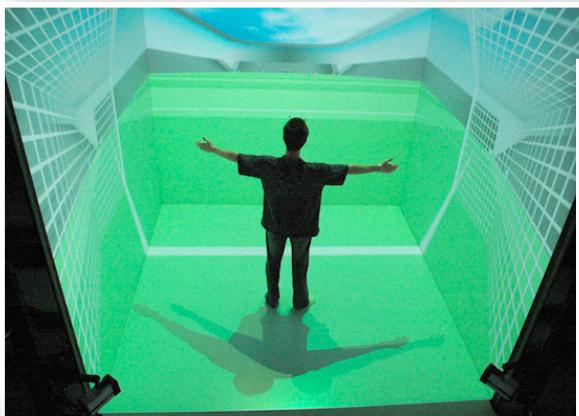
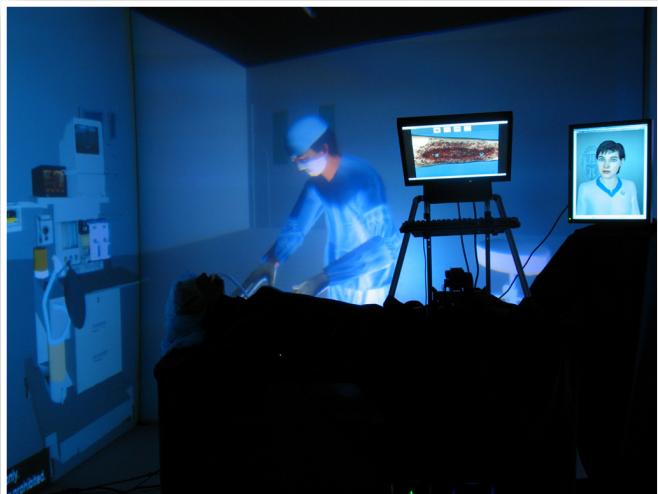
Source: Merriam-Webster's Learner's Dictionary

VR Goggles and Gloves



- <https://www.youtube.com/watch?v=Ak-Bt7IM8Jc>

Types of VR



Other Definitions

Virtual reality is..

a computer technology that replicates an environment, real or imagined, and simulates a user's physical presence and environment to allow for user interaction. (Wikipedia)

electronic simulations of environments experienced via head mounted eye goggles and wired clothing enabling the end user to interact in realistic three-dimensional situations. (Coates, 1992)

an alternate world filled with computer-generated images that respond to human movements. (Greenbaum, 1992)

an interactive, immersive experience generated by a computer (Pimental 1995)

Key Characteristics for VR

- Virtual Reality has three key characteristics
 - 3D stereoscopic display
 - Wide field of view display
 - Low latency head tracking
- When these three things are combined they provide a compelling immersive experience

Defining Characteristics



VIRTUAL REALITY

- <https://www.youtube.com/watch?v=FPcbBJbGhmk>

VR Experience



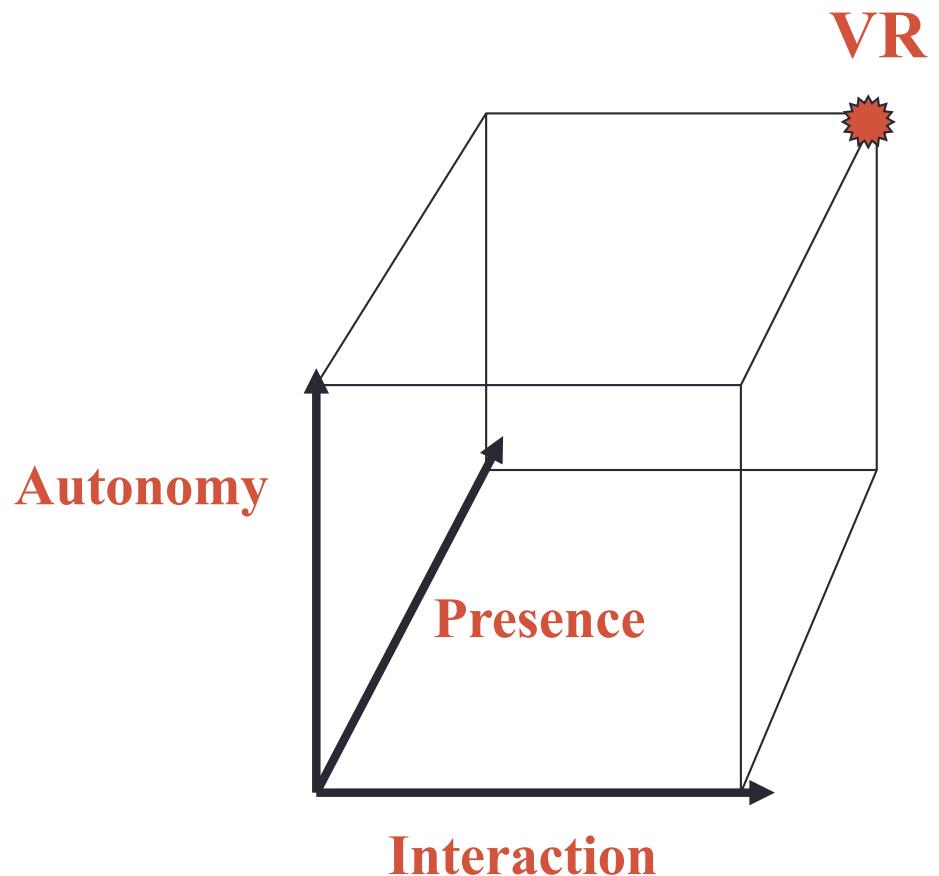
- “This is so real..”
- <https://www.youtube.com/watch?v=pAC5SeNH8jw>

Defined in Terms of Presence

- Presence is the key to defining VR in terms of experience
- Presence is defined as the sense of being in an environment
- Telepresence is defined as the experience of presence in an environment by means of a communication medium.
- A “virtual reality” is defined as a real or simulated environment in which a perceiver experiences telepresence.

David Zeltzer's AIP Cube

- **Autonomy** – User can react to events and stimuli.
- **Interaction** – User can interact with objects and environment.
- **Presence** – User feels immersed through sensory input and output channels



Zeltzer, D. (1992). Autonomy, interaction, and presence. *Presence: Teleoperators & Virtual Environments*, 1(1), 127-132.

Augmented Reality



1977 – Star Wars

Augmented Reality Definition

- Defining Characteristics [Azuma 97]
 - Combines Real and Virtual Images
 - Both can be seen at the same time
 - Interactive in real-time
 - The virtual content can be interacted with
 - Registered in 3D
 - Virtual objects appear fixed in space

Azuma, R. T. (1997). A survey of augmented reality. *Presence*, 6(4), 355-385.

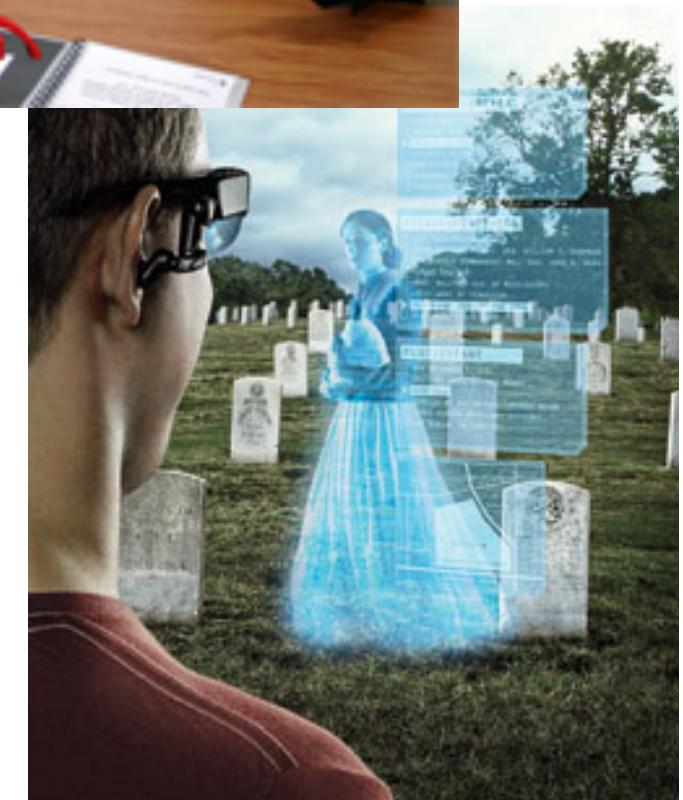
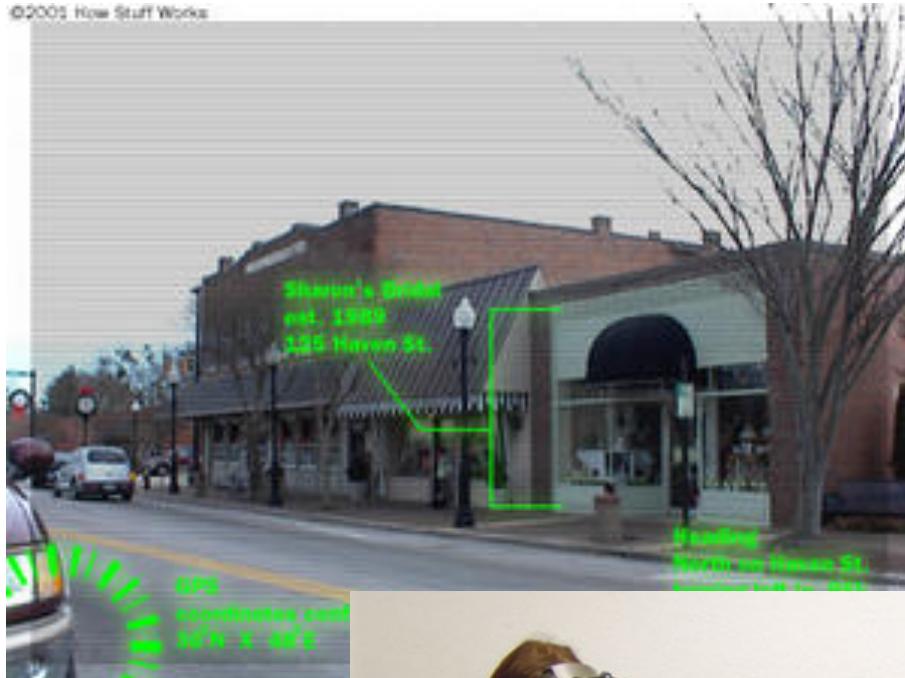
2008 - CNN



https://www.youtube.com/watch?v=v7fQ_EsMJMs

Augmented Reality Examples

©2005 How Stuff Works



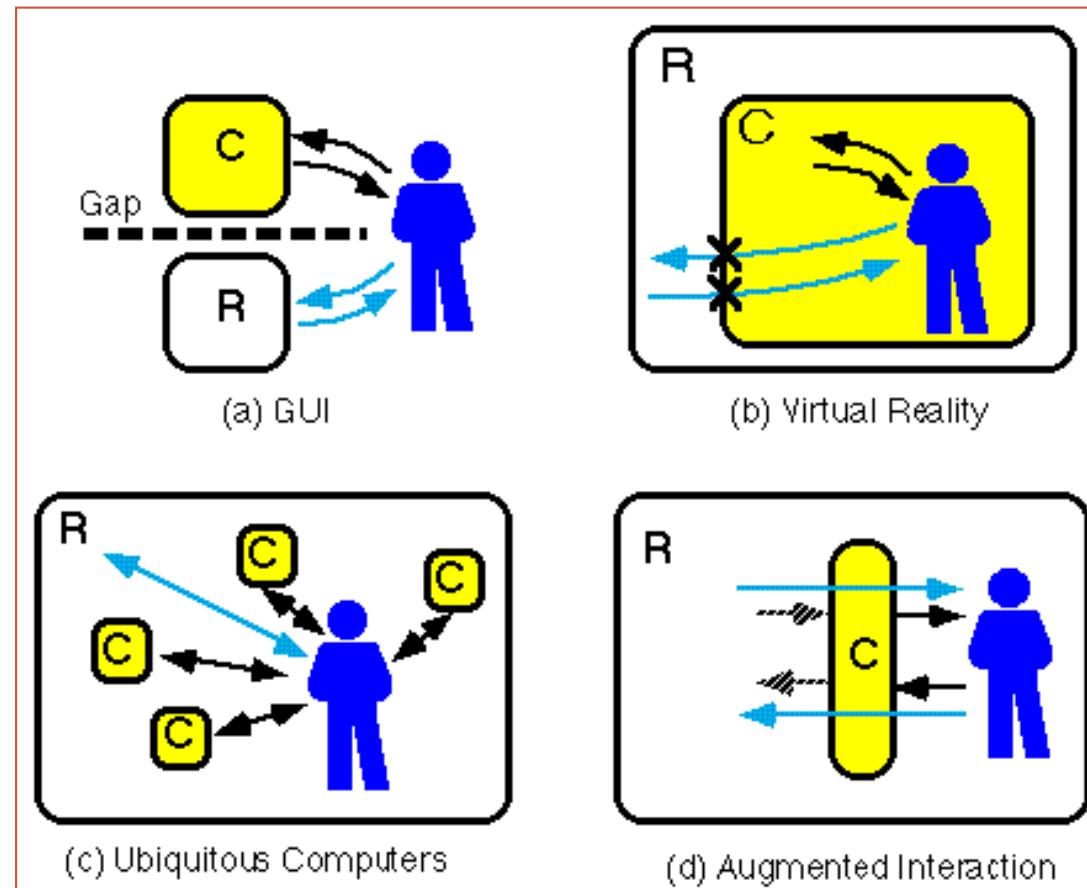
Pokemon GO..



AR vs VR

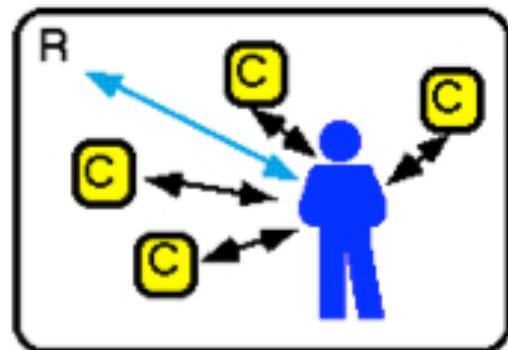
	Virtual Reality <i>Replaces Reality</i>	Augmented Reality <i>Enhances Reality</i>
<i>Scene Generation</i>	Requires realistic images	Minimal rendering okay
<i>Display Device</i>	Fully immersive, wide field of view	Non-immersive, small field of view
<i>Tracking</i>	Low to medium accuracy is okay	The highest accuracy possible

Making Interfaces Invisible

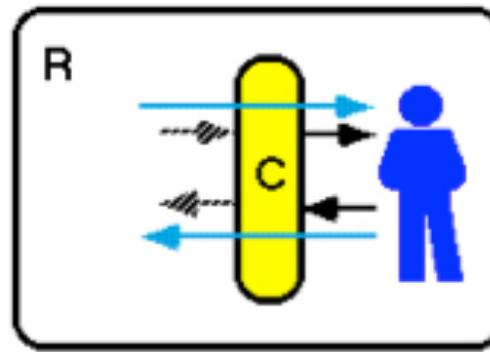


Rekimoto, J. and Nagao, K. 1995. The world through the computer: computer augmented interaction with real world environments. In *Proceedings of the 8th Annual ACM Symposium on User Interface and Software Technology. UIST '95*. ACM, New York, NY, 29-36.

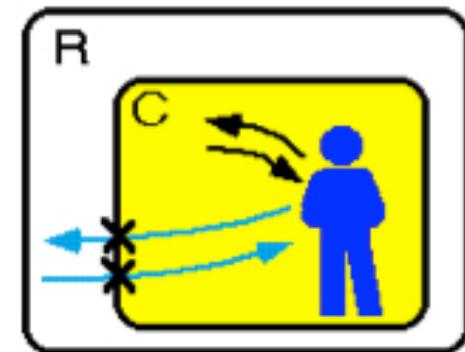
From Reality to Virtual Reality



Ubiquitous Computing



Augmented Reality

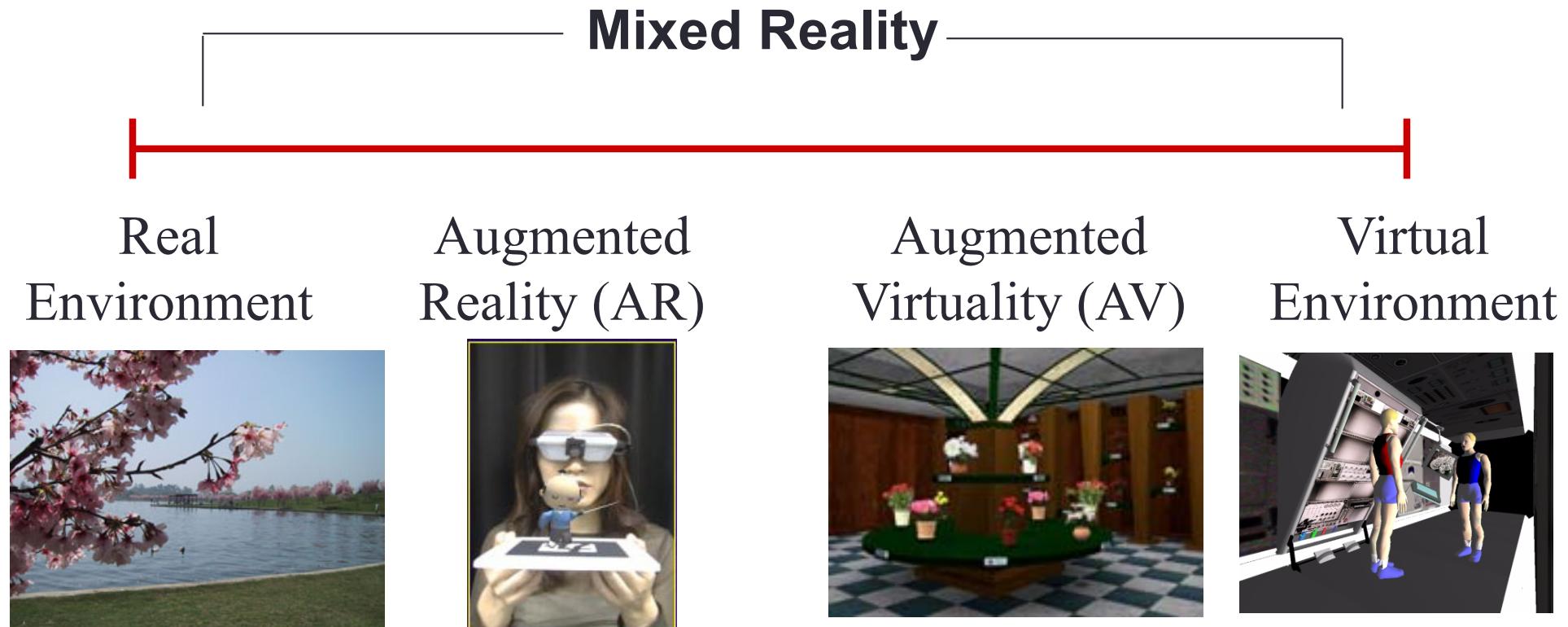


Virtual Reality



Milgram's Reality-Virtuality continuum

"...anywhere between the extrema of the *virtuality continuum*."



Reality - Virtuality (RV) Continuum

P. Milgram and A. F. Kishino, Taxonomy of Mixed Reality Visual Displays
IEICE Transactions on Information and Systems, E77-D(12), pp. 1321-1329, 1994.

Augmented Virtuality



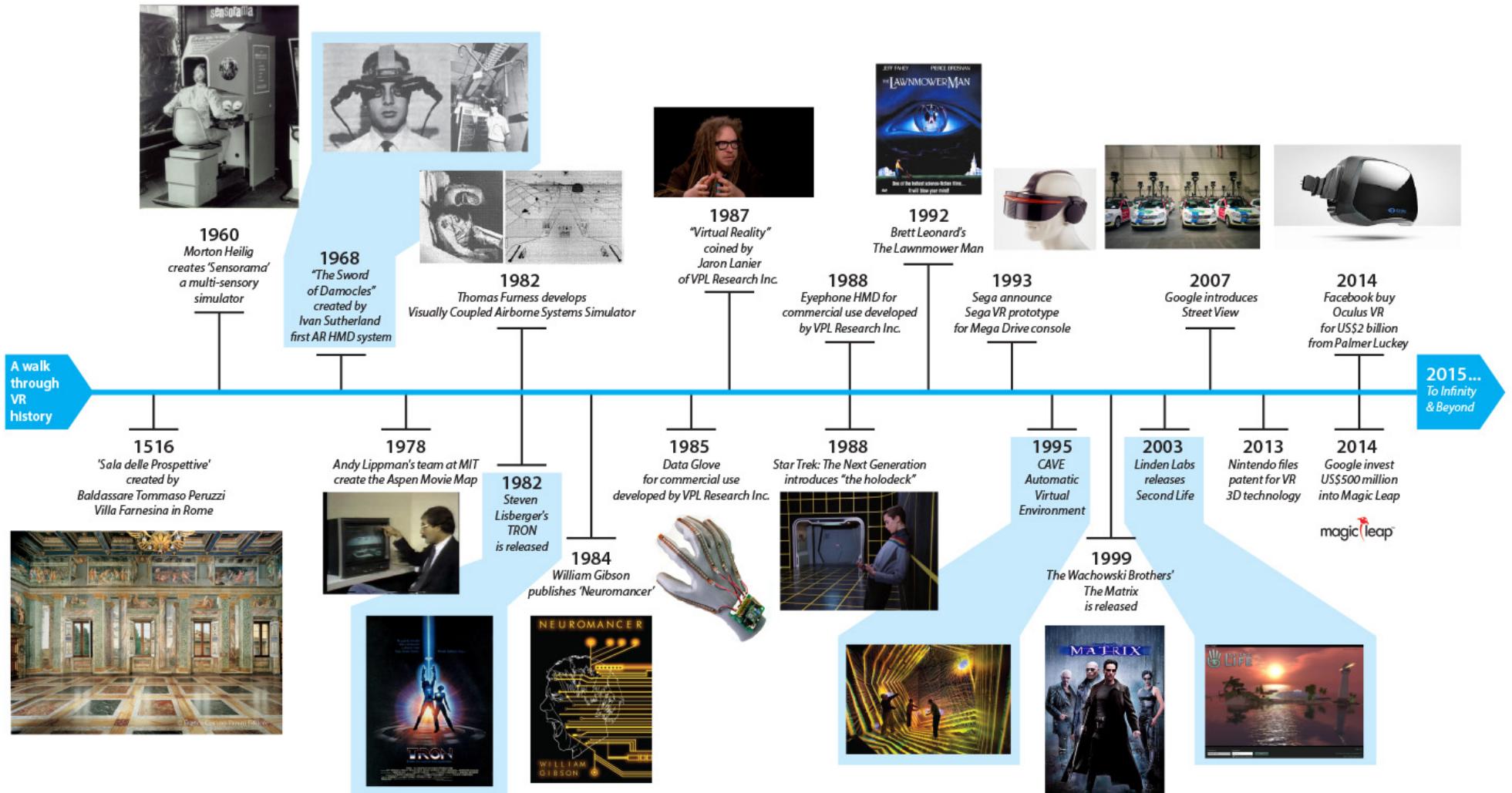
- VR with windows into the real world

Summary

- Virtual Reality can be defined in a number of ways
 - In terms of technology
 - From a Presence perspective
- VR can also be classified with other technologies
 - Invisible Interfaces
 - Milgram's Mixed Reality continuum

HISTORY OF VR

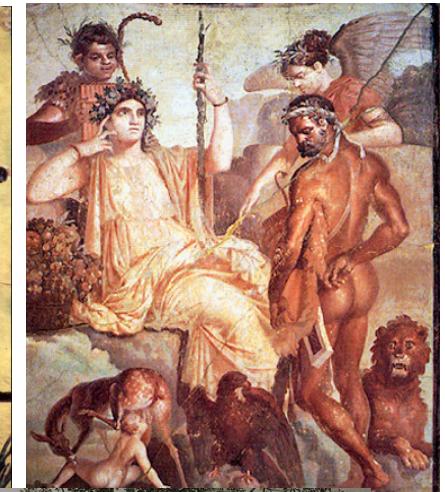
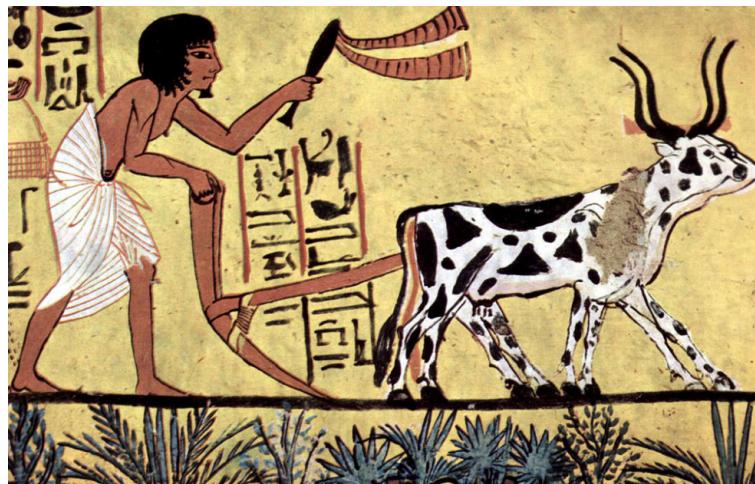
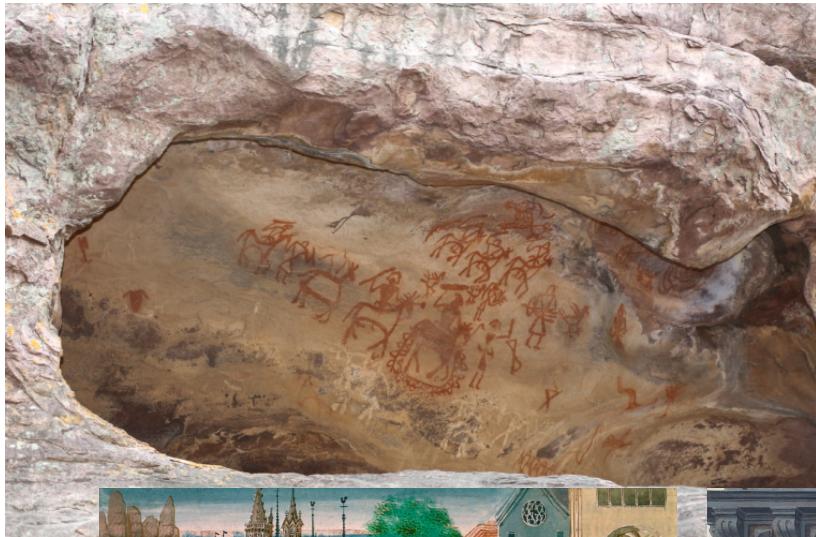
VR History Timeline



When anything new comes along, everyone, like a child discovering the world thinks that they've invented it, but you scratch a little and you find a caveman scratching on a wall is creating virtual reality in a sense.

Morton Helig (Hammit 1993)

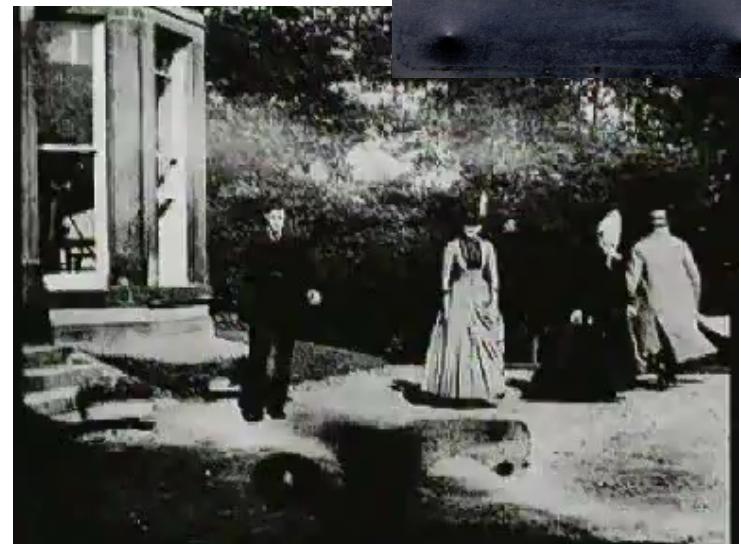
Early History (30,000 BC -)



The history of VR is rooted in human's first attempts to reproduce the world around them

1800's – Capturing Reality

- **Panoramas (1790s)**
 - Immersive paintings
- **Photography (1820-30s)**
 - Oldest surviving photo (Niépce, 1826)
- **Stereo imagery (1830s)**
 - Wheatstone (1832)
 - Brewster (1851)
- **Movies (1870s)**
 - Muybridge (1878)
 - Roundhay Garden Scene (1888)



Stereo Viewers



Wheatstone (1832)



Brewster (1860)

Viewmaster (1939)



3D Cinema Golden Era (1950-60s)



Another Famous... **FIRST FROM U-I!**

FIRST with WIDE-VISION SCREEN and STEREOFONIC SOUND... on "THUNDER BAY" at the LOEW'S STATE, N.Y. • MAY 20th

NOW Universal-International brings

THE FIRST 3-D PICTURE ON THE GIANT WIDE-VISION SCREEN WITH STEREOFONIC SOUND!
at the RKO HILLSTREET and PANTAGES Theatres, Los Angeles, May 27th

THE FIRST 3-D SCIENCE-FICTION STORY
THE FIRST ALL 3-D PROGRAM WITH
THE FIRST 3-D MUSICAL FEATURETTE

NAT 'KING' COLE
Singing "Praised"
RUSS MORGAN'S Orchestra & **Sexual Revue**

IT CAME FROM OUTER SPACE IN 3-DIMENSION

SINCE THE DAWN OF TIME... man has never seen such sights... nor trembled before such terror!

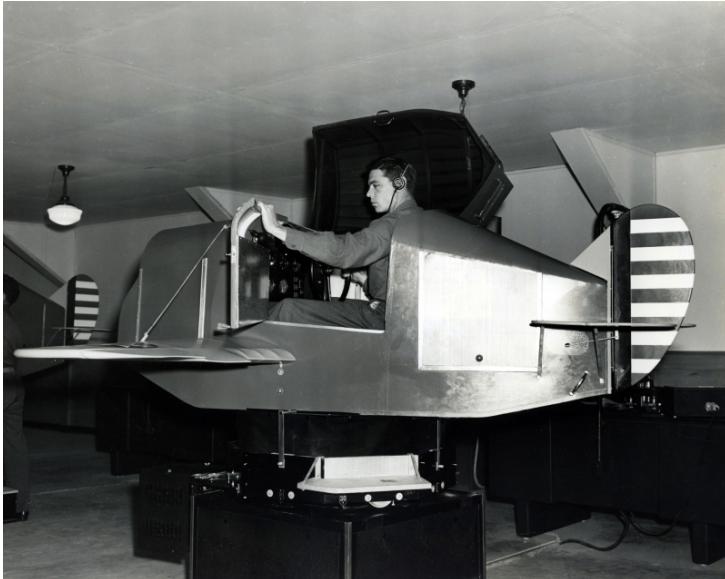
starring RICHARD CARLSON · BARBARA RUSH
with CHARLES DRAKE · RUSSELL JOHNSON · KATHLEEN RUGGLES · JOE SAWYER
Directed by JACK JARRELL · Screenplay by RARRY ESSEX · Story by RAY BRADBURY · Produced by WILLIAM ALLARD
A UNIVERSAL INTERNATIONAL PICTURE

- Polarized 3D projection or anaglyph (red/blue)

1900s – Interactive Experiences

- Early Simulators (<1960s)
 - Flight simulation
 - Sensorama (1955)
- Early HMDs (1960s)
 - Philco, Ivan Sutherland
- Military + University Research (1970-80s)
 - US Airforce, NASA, MIT, UNC
- First Commercial Wave (1980-90s)
 - VPL, Virtual i-O, Division, Virtuality
 - VR Arcades, Virtual Boy

Link Trainer (1929 – 1950s)



- Flight Simulator Training
 - Full six degree of freedom rotation
 - Force feedback and motion control
 - Simulated instruments
 - Modeling common flight conditions
- Over 500,000 pilots trained

Link Trainer Video (1966)



- <https://www.youtube.com/watch?v=MEKkVg9NqGM>

Sensorama (1955)

- Created by Morton Heilig
- Experience Theater
- Multi-sensory
 - Visuals
 - Sound
 - Wind
 - Vibration
 - Smell
- No financial support
 - Commercial failure

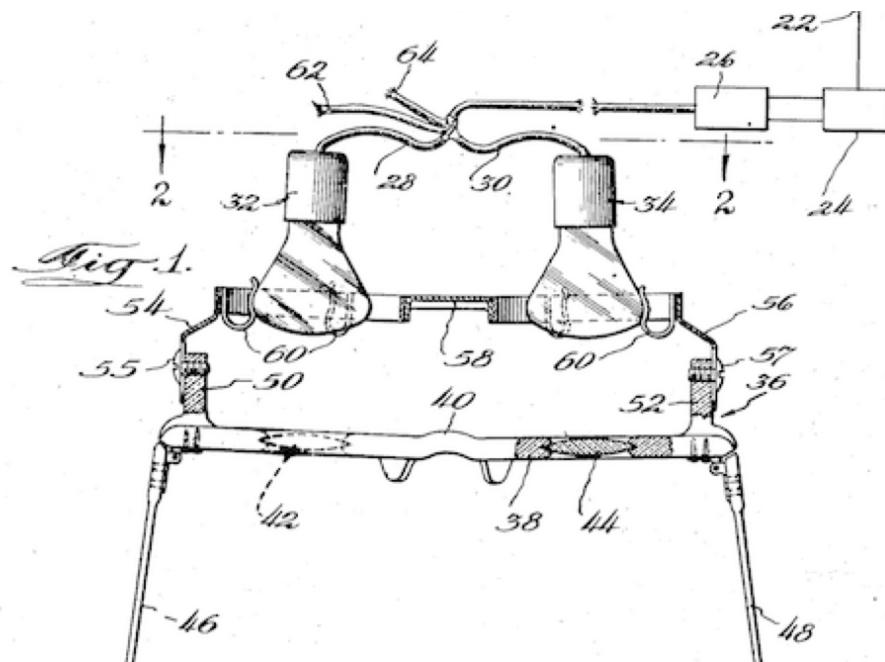


Sensorama Video

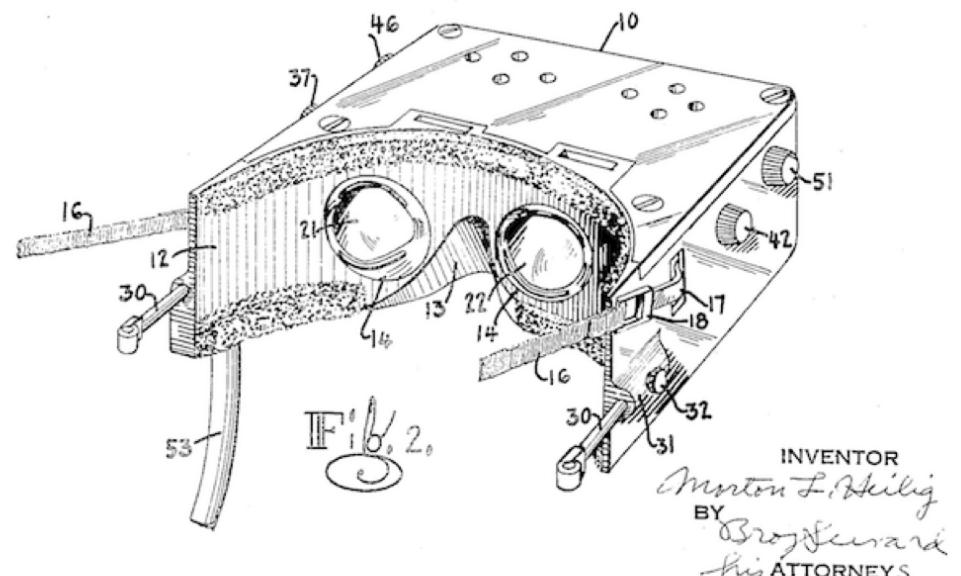


- <https://www.youtube.com/watch?v=vSINEBZNCKs>

Early HMD Patents

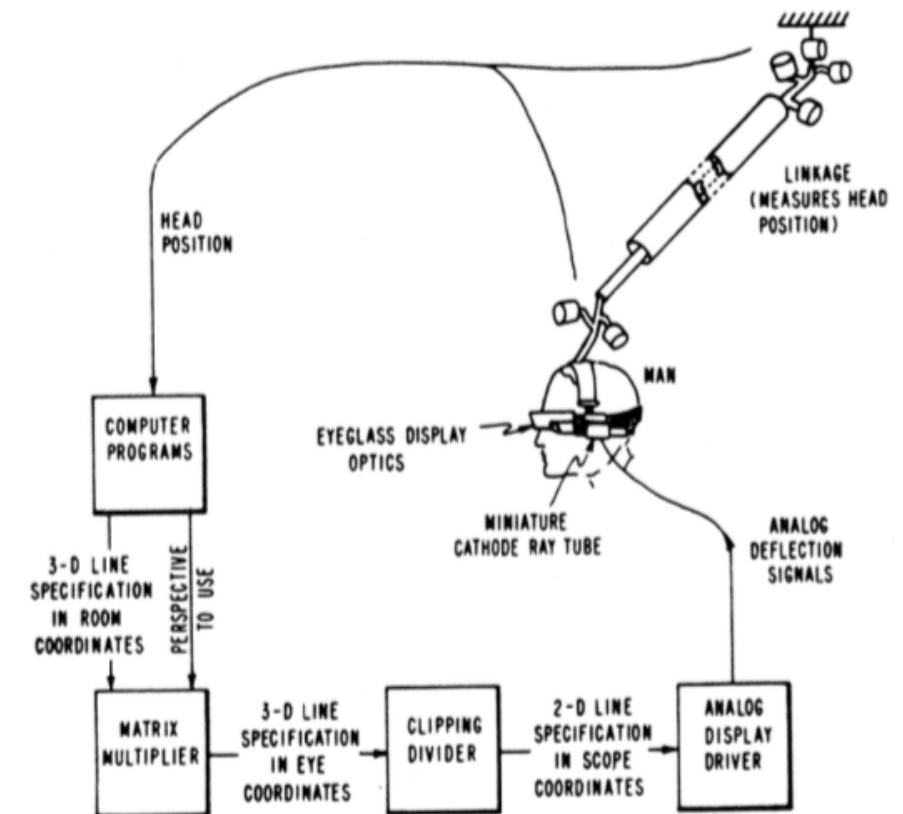
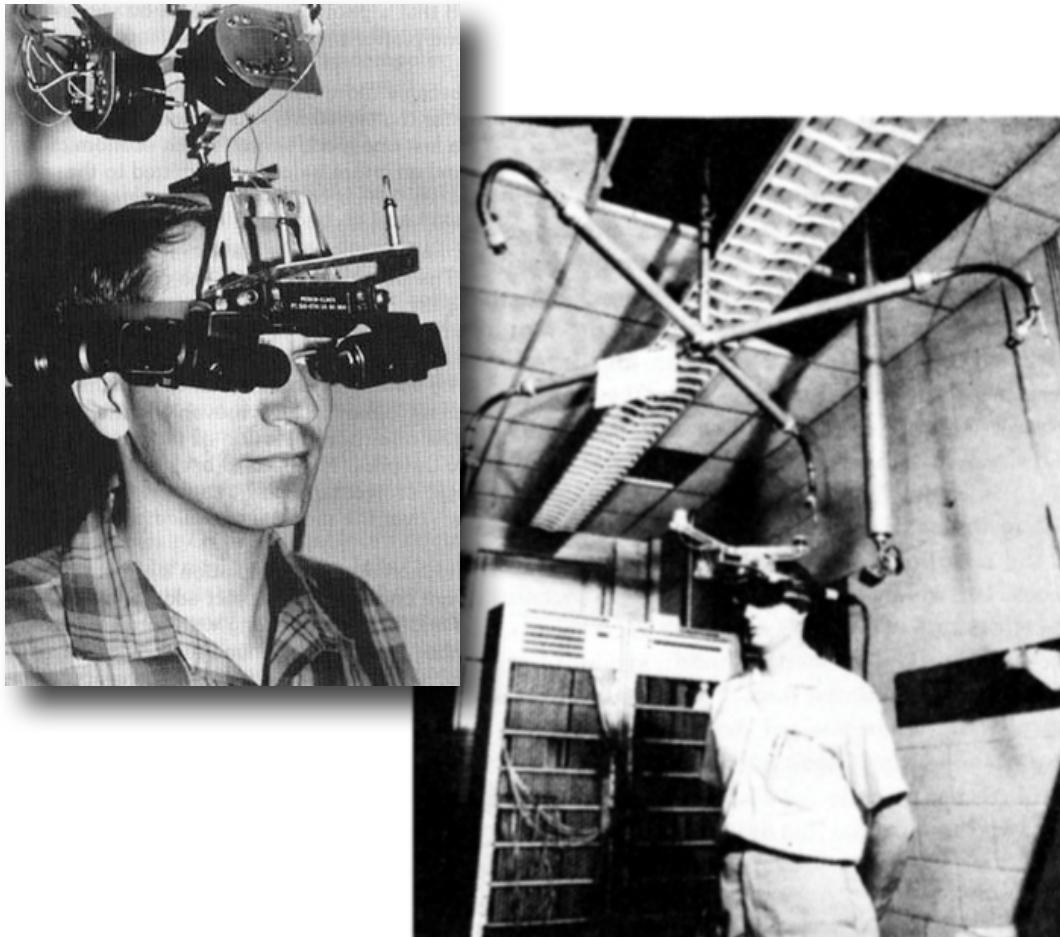


McCollum's Stereo TV HMD (1943)



Heilig's Multisensory HMD (1960)

Ivan Sutherland (1960s)



Ivan Sutherland's Head-Mounted Display (1968)

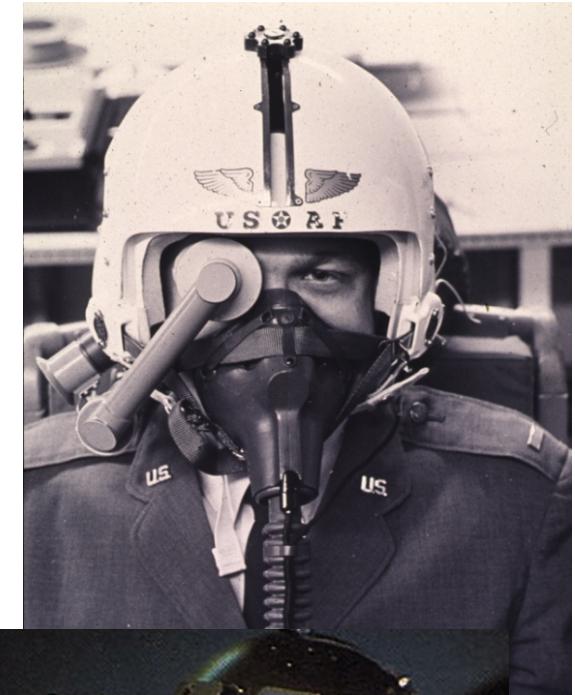
Sutherland Display



<https://www.youtube.com/watch?v=eeVKAIYqKtg>

Super Cockpit (1965-80's)

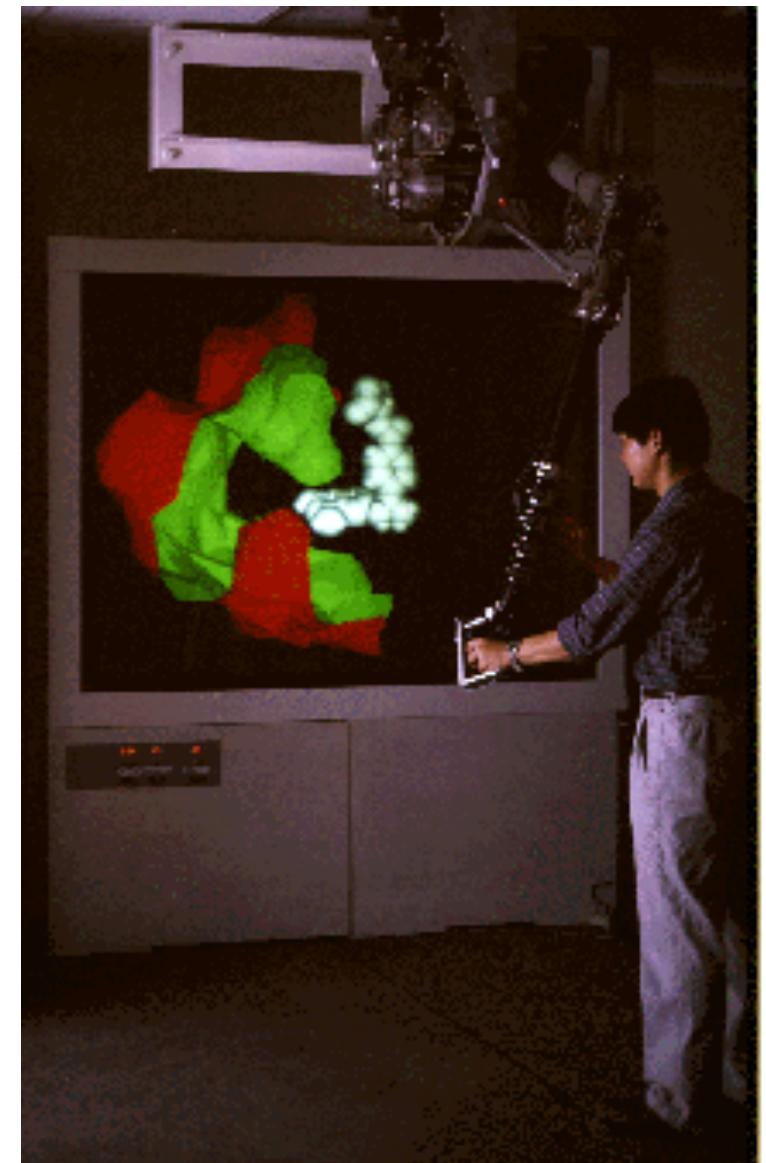
- US Airforce Research Program
 - Wright Patterson Air Force Base
- Tom Furness III
- Multisensory
 - Visual, auditory, tactile
 - Head, eye, speech, and hand input
- Addressing pilot information overload
 - Flight controls and tasks too complicated
- Research only
 - big system, not safe for ejecting



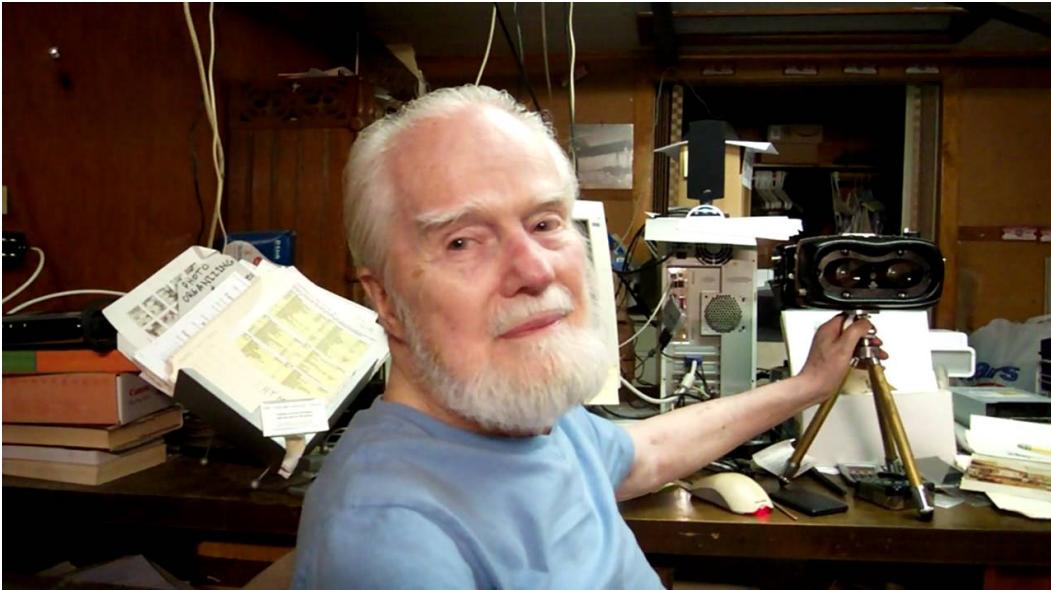


UNC Haptic Systems (1967 – 80's)

- Haptic/kinesthetic display system
 - 6D force fields of molecular structures
- Progression
 - Grope I, simple fields, particle feedback
 - Grope II, 1978, children's building blocks
 - Grope III, late 80's, Remote Manipulator
- Sarcos arm

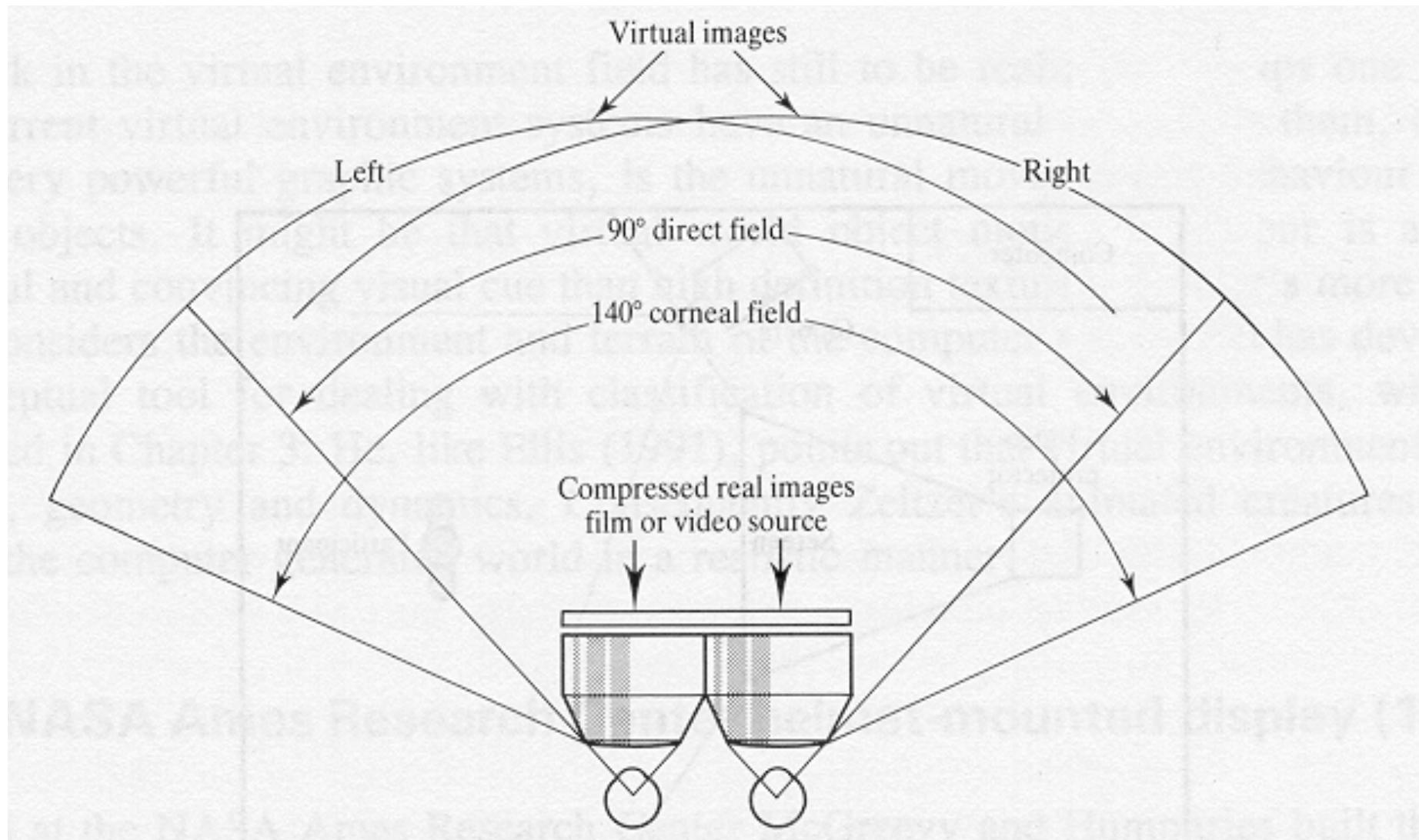


LEEP Optics (1979)



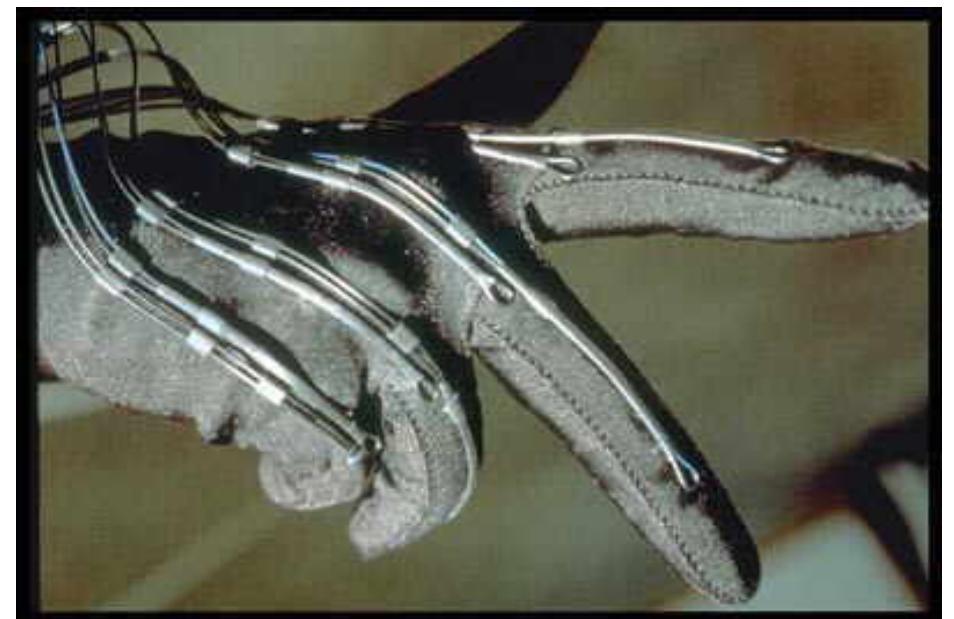
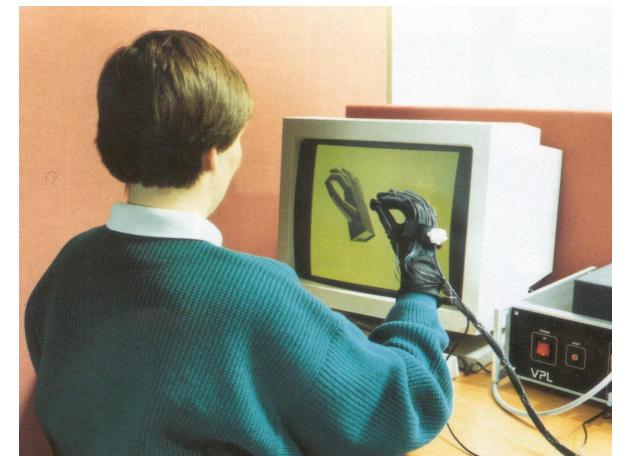
- Large Expanse, Extra Perspective optics
 - Developed by Eric Howlett
- Lens design for extremely wide field of view
 - High resolution in centre, lower resolution in periphery
 - 90° direct FOV, 140° corneal FOV
- Used as basis for most VR HMDs

LEEP Optics Design



The Data Glove (1981-82)

- Precursor, Sayre Glove
 - Univ. of Illinois, 1977
- Thomas Zimmerman (1982)
- Fiber optic bend sensors
 - Detecting finger bending
- Commercialized by VPL
 - Mattel PowerGlove (1989)



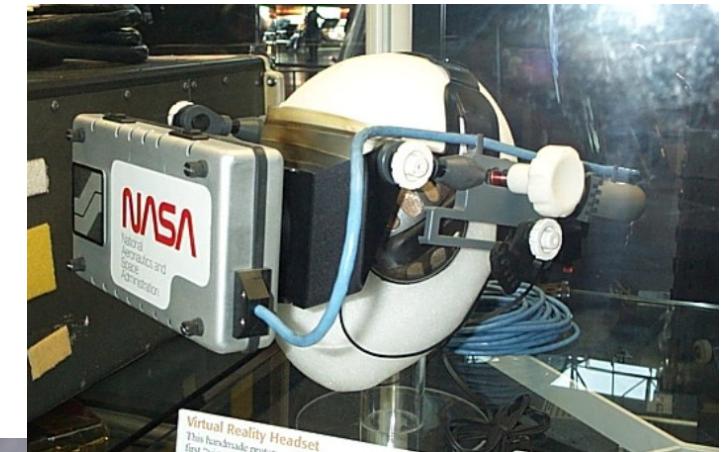
VPL DataGlove Demo



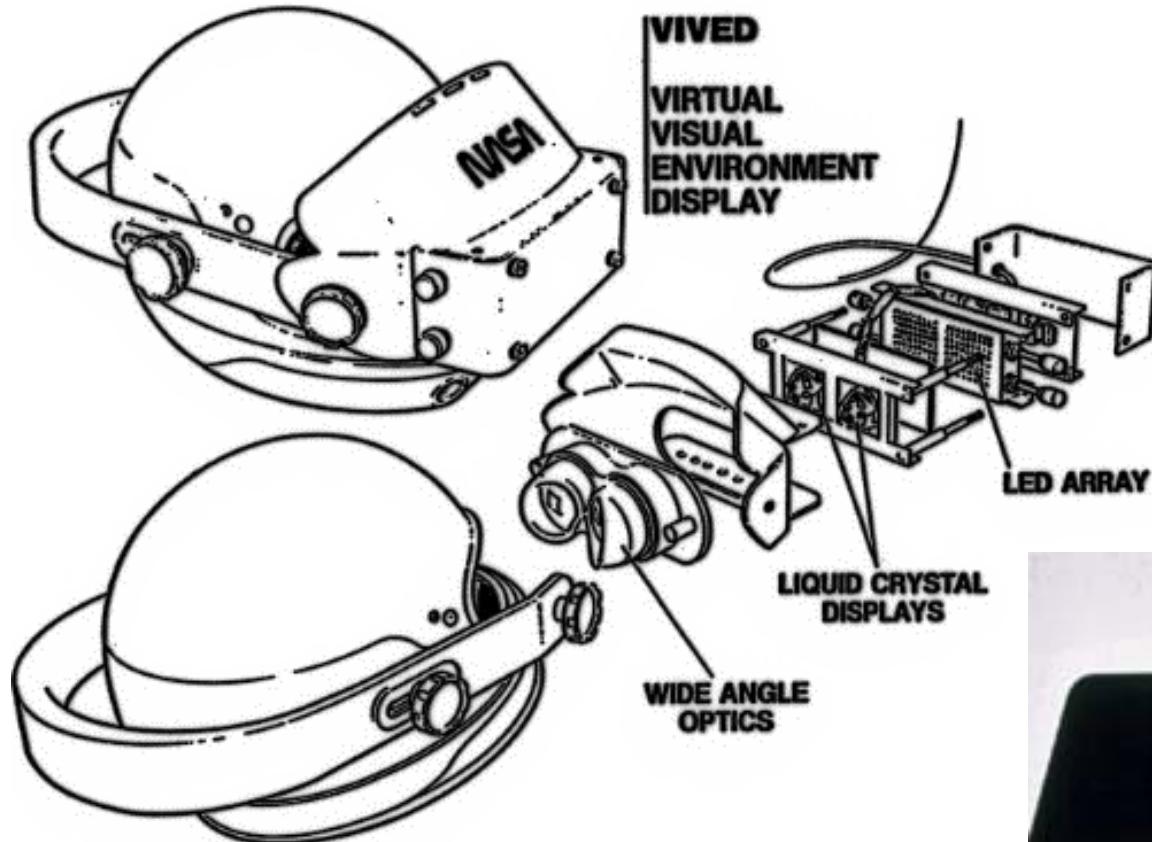
- <https://www.youtube.com/watch?v=fs3AhNr5o6o>

NASA VIEW/VIVED (1981-86)

- Early HMD (McGreevy Humphries)
 - LCD “Watchman” displays
- VIEW (Scott Fisher)
 - Polhemus tracker
 - LEEP-based HMD
 - 3D audio (Convolutron)
 - DataGlove gesture input
 - Simple graphics

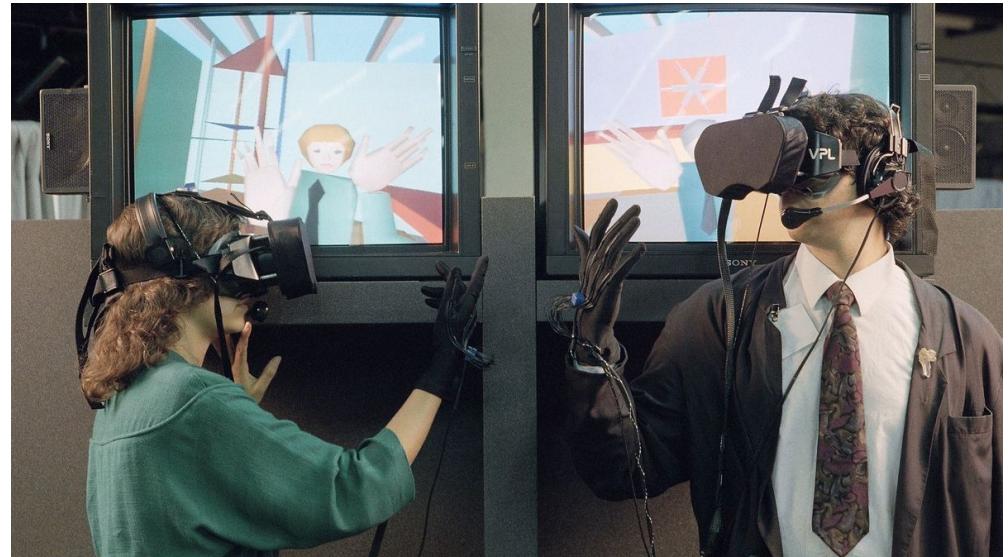


Virtual Interface Environment Workstation



- Motorbike helmet + LEEP

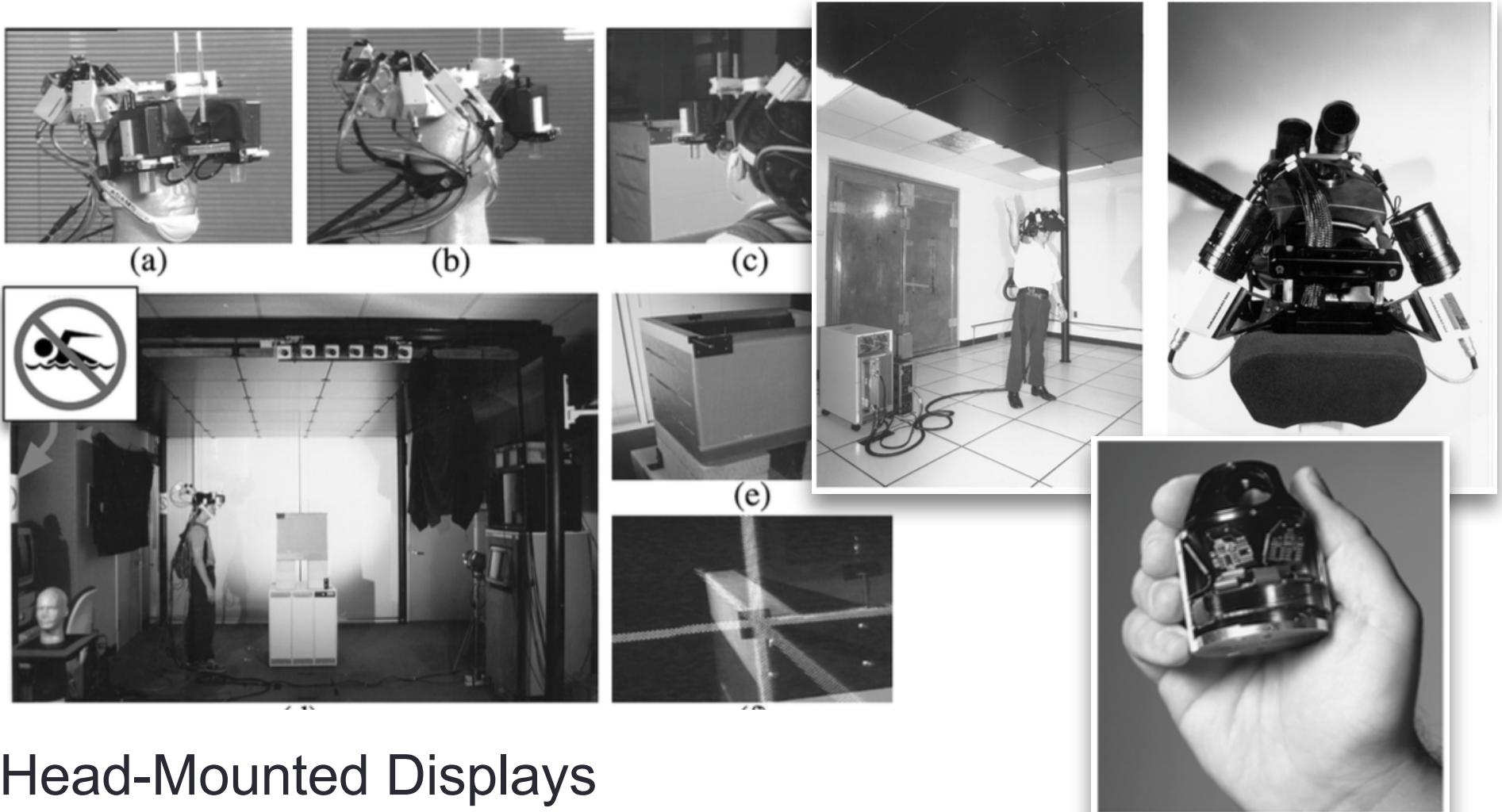
VPL Research (1985 – 1999)



- First Commercial VR Company
 - Jaron Lanier, Jean-Jacques Grimaud
- Provided complete systems
 - Displays, software, gloves, etc
 - DataGlove, EyePhone, AudioSphere

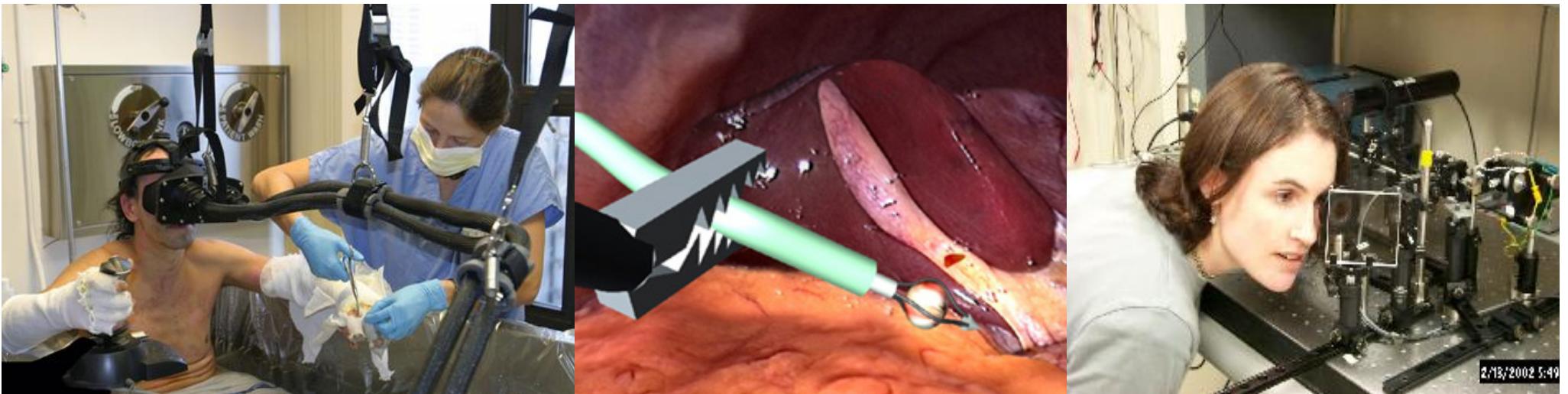


The University of North Carolina at Chapel Hill (1980s-1990s)



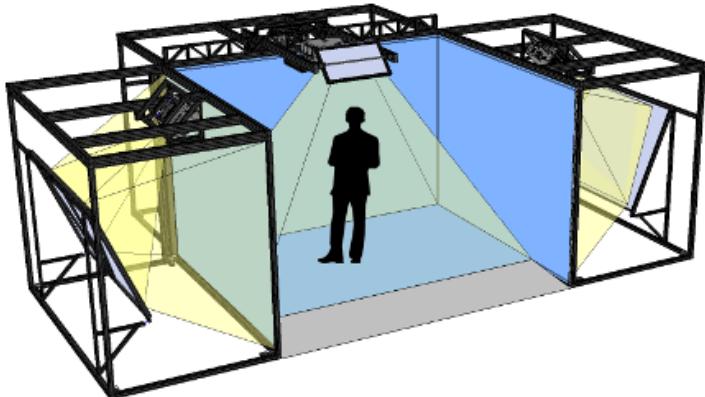
Head-Mounted Displays
Tracking, Haptics, Applications

University of Washington (1989 -)



- Human Interface Technology Laboratory (HIT Lab)
 - Founded by Tom Furness III
- Many AR/VR Innovations
 - Virtual Retinal Display
 - ARToolKit AR Tracking library
 - GreenSpace shared VR experience
 - VR and pain care
 - VR and Education

CAVE (1992)



- Projection VR system
 - 3-6 wall stereo projection, viewpoint tracking
 - Developed at EVL, University of Illinois Chicago
- Commercialized by Mechdyne Corporation(1996)

C. Cruz-Neira, D. J. Sandin, T. A. DeFanti, R. V. Kenyon and J. C. Hart. "The CAVE: Audio Visual Experience Automatic Virtual Environment", *Communications of the ACM*, vol. 35(6), 1992, pp. 64–72.

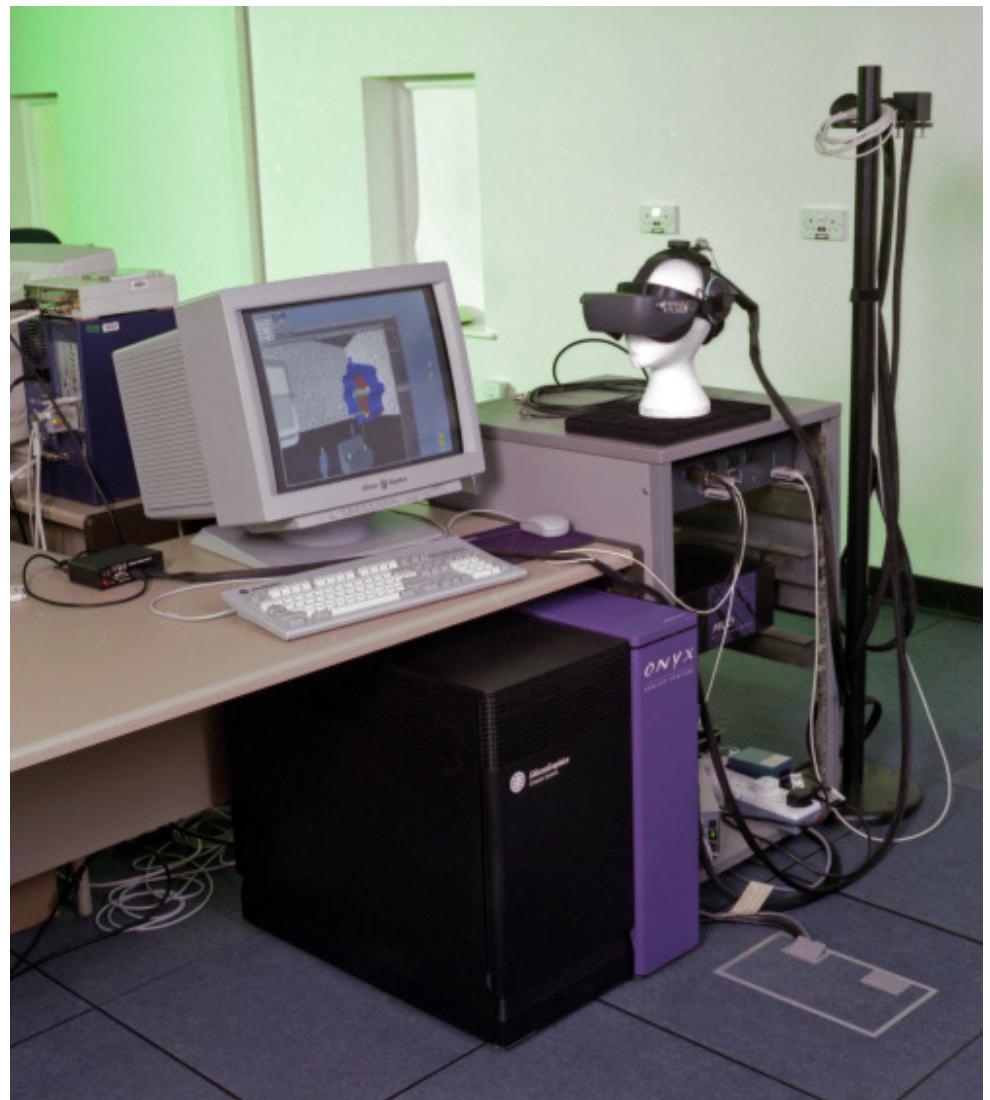
CAVE Demo Video



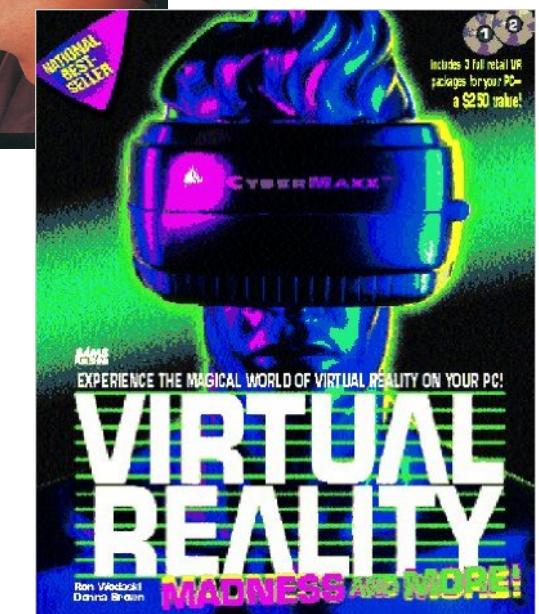
- <https://www.youtube.com/watch?v=aKL0urEdtPU>

Desktop VR - 1995

- Expensive - \$150,000+
- 2 million polys/sec
- VGA HMD – 30 Hz
- Magnetic tracking

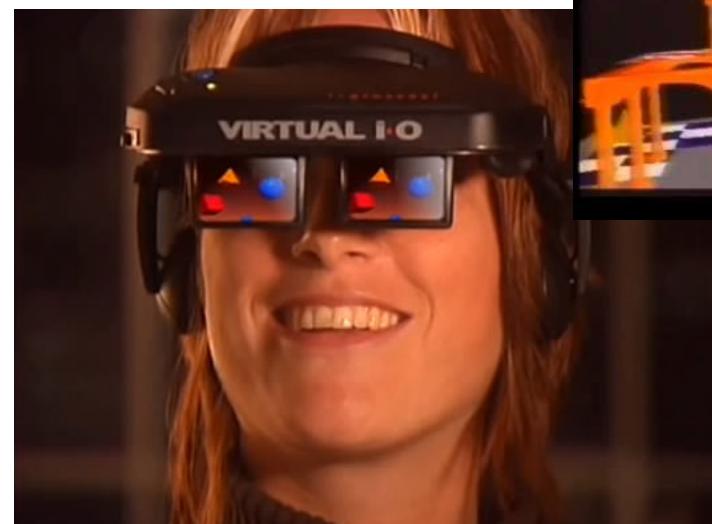


Virtual Reality was HOT! .. In 1995..



Rise of Commercial VR Companies

- W Industries/Virtuality (1985 - 97)
 - Location based entertainment
 - Virtuality VR Arcades
- Division (1989 – 1998)
 - Turn key VR systems
 - Visual programming tools
- Virtual i-O (1993 -1997)
 - Inexpensive gamer HMDs
- Sense8 (1990 - 1998)
 - WorldToolKit, WorldUp
 - VR authoring tools



Dactyl Nightmare



- <https://www.youtube.com/watch?v=L60wgPuuDpE>

Over view of VR in the 1990's

Architecture and Virtual Reality
Part 1: VR History

M.Arch Thesis: University of Toronto
Daniel Voshart 2014

vrch.ca

<https://www.youtube.com/watch?v=tdAaU0CRHng&t=119s>

df1990-540

DOCTOR FUN presents 1990



Virtual Reality Spreadsheets

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GO



Empowering
People



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Leveraging Info



Enabling Business
Flexibility

Don't Believe the Hype: The 21 Biggest Technology Flops

We fondly recall 21 overpromoted products and technologies that utterly failed to live up to their hype -- and we give you a chance to choose the biggest flop of all.

David Haskin [Today's Top Stories ▾](#) or [Other Hardware Stories ▾](#)

- April 2007 ComputerWorld
 - VR Voted 7th on list of 21 biggest technology flops
 - MS Bob #1

Lessons Learned

- **Don't believe the hype**
 - Not everything is better in VR
- **Many factors determine technology acceptance**
 - Human Centered Design/Design for users
- **Need to move from Demo to Production**
 - Profitable niche markets first
- **Follow the money**
 - Target industries with money

VR Second Wave (2010 -)

- Palmer Luckey
 - HMD hacker
 - Mixed Reality Lab (MxR) intern
- Oculus Rift (2011 -)
 - 2012 - \$2.4 million kickstarter
 - 2014 - \$2B acquisition FaceBook
 - \$350 USD, 110° FOV



The Oculus Kickstarter Video



- <https://www.youtube.com/watch?v=aNSYscbxFAw>

Desktop VR in 2016

- **Graphics Desktop**
 - \$1,500 USD
 - >4 Billion poly/sec
- **\$600 HMD**
 - 1080x1200, 90Hz
- **Optical tracking**
 - Room scale



2016 - Rise of Consumer HMDs



Oculus Rift



HTC/Valve Vive



Sony Morpheus

HTC Vive



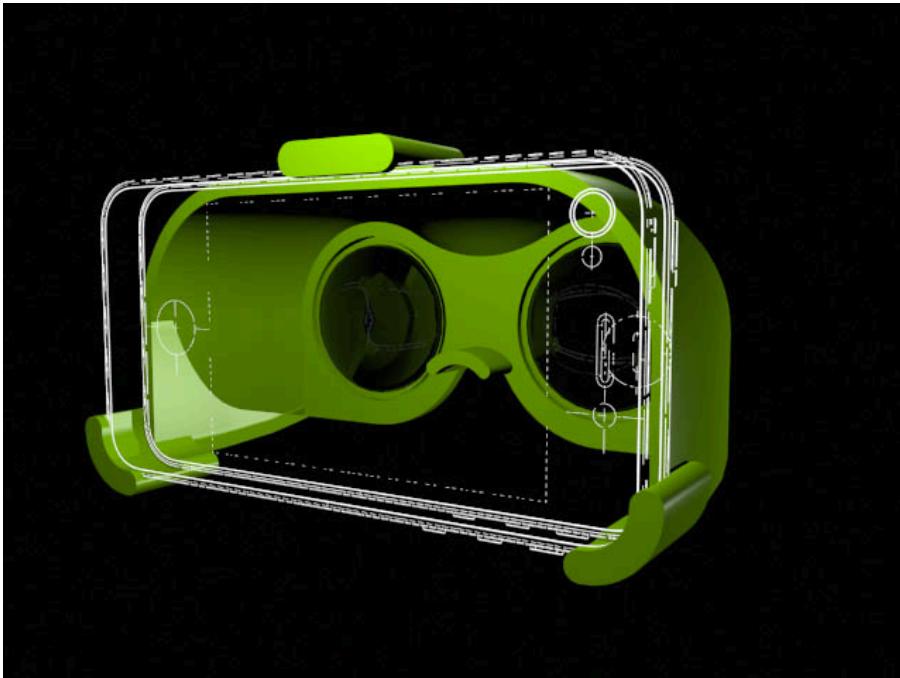
- Room scale tracking
- Gesture input devices

Example Vive App – Tilt Brush



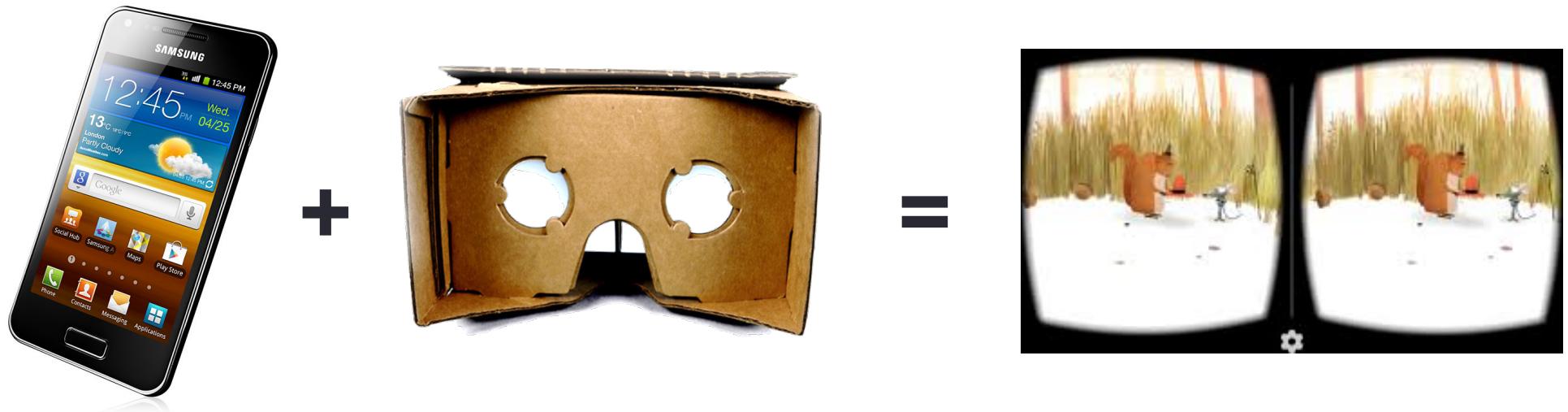
- <https://www.youtube.com/watch?v=ijukZmYFX-0>

VR2GO (2013)



- MxR Lab
 - 3D print VR viewer for mobiles
 - Open source hardware + software
 - <http://projects.ict.usc.edu/mxr/diy/vr2go/>
- Early Mobile VR viewer

Google Cardboard



- Released 2014 (Google 20% project)
- >5 million shipped/given away
- Easy to use developer tools



Multiple Mobile VR Viewers Available



Gartner Hype Cycle (2016)



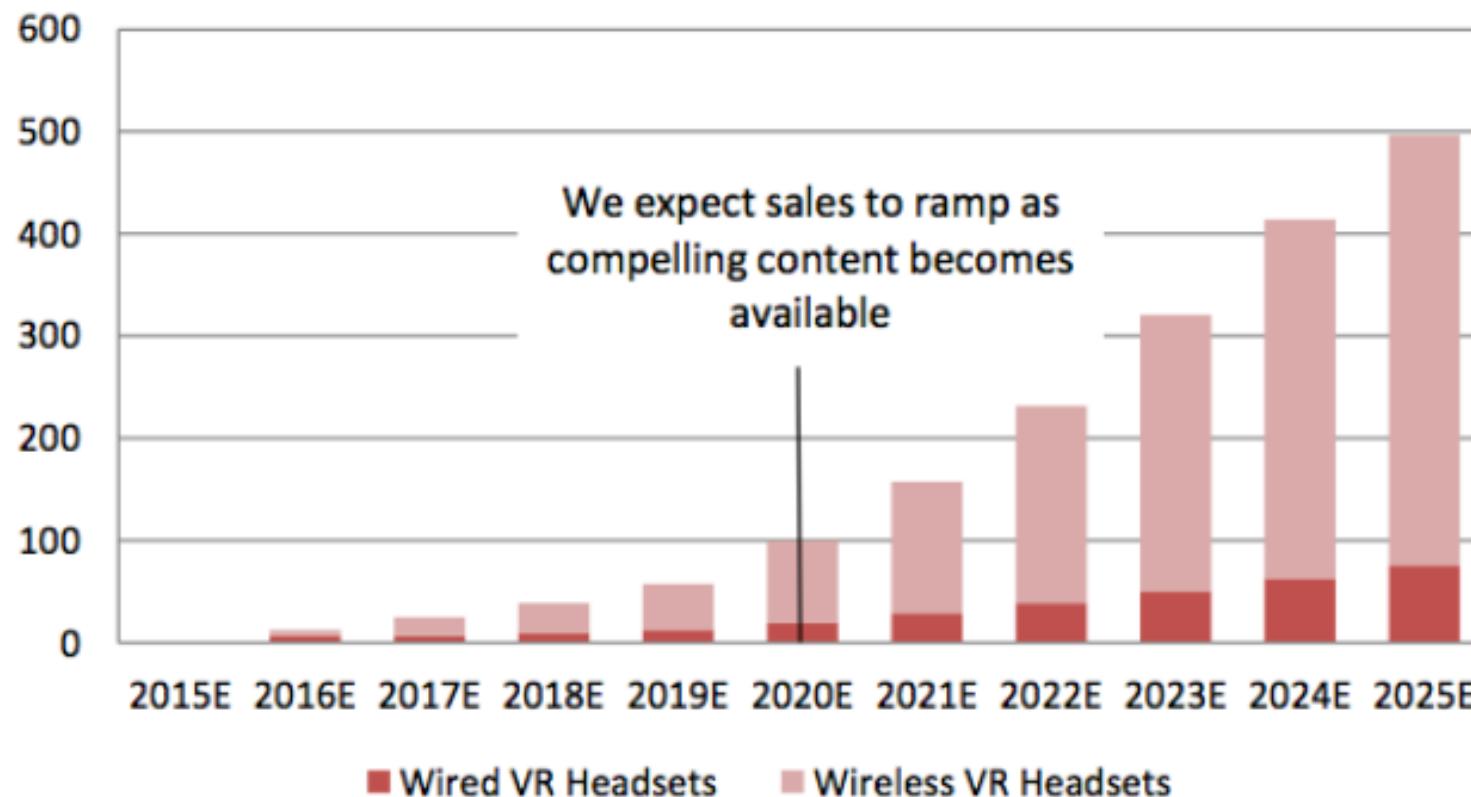
Gartner Hype Cycle (2016)



Projected HMD Sales

VIRTUAL REALITY HEADSET SALES

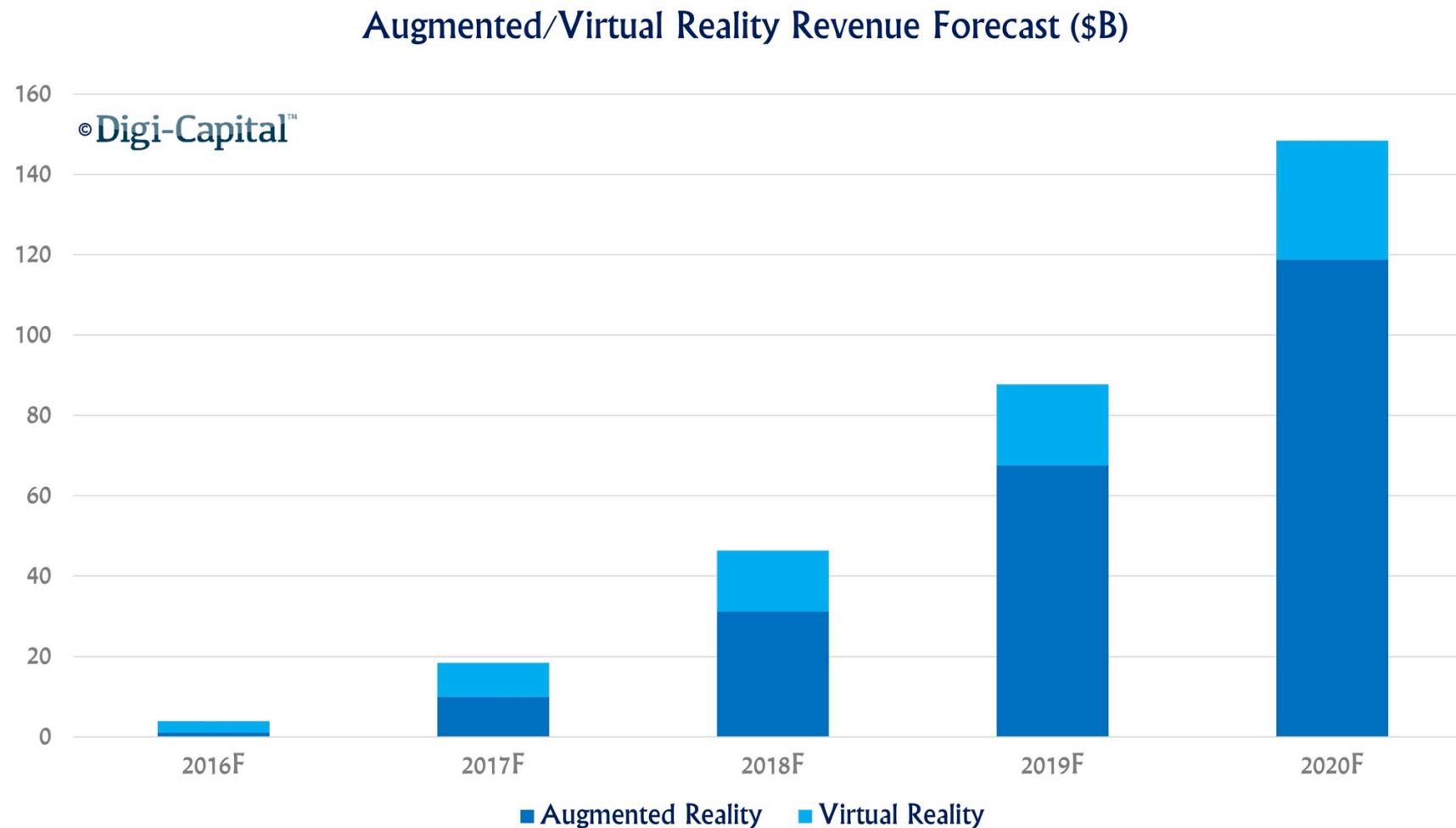
(In Millions)



Source: Piper Jaffray estimates

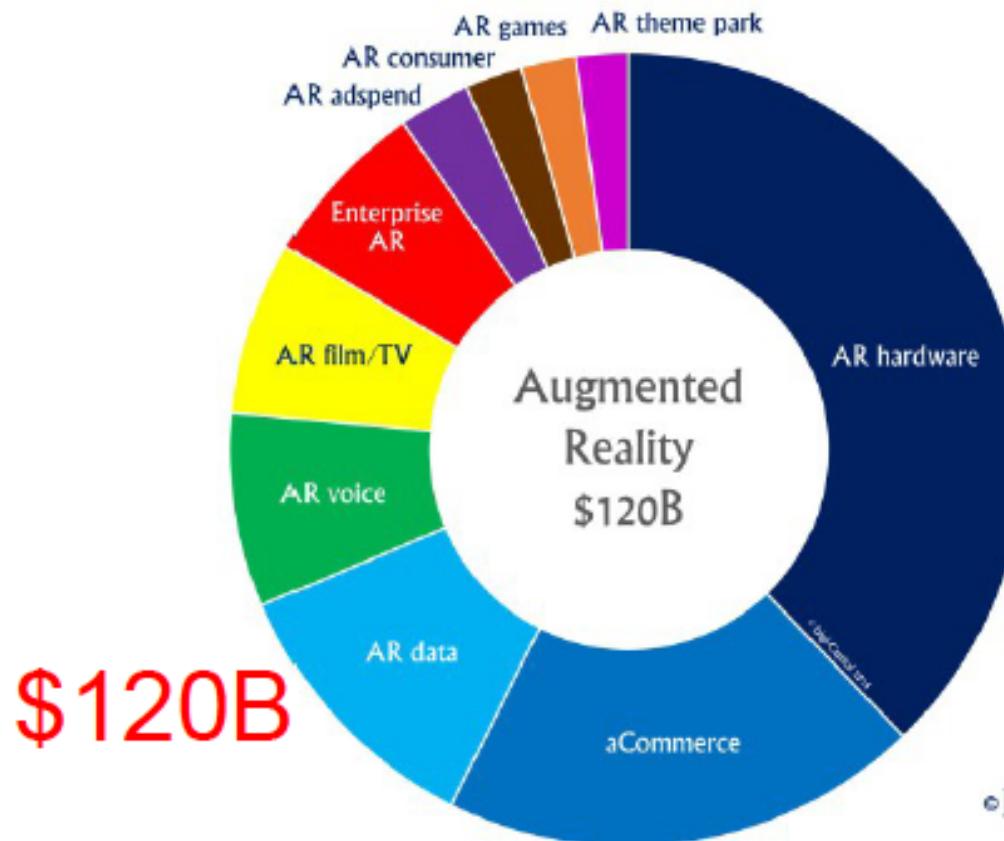
Source: PiperJaffray, Next Mega Tech Theme is Virtual Reality, May, 2015

Market Size



AR / VR Market Size

Augmented/Virtual Reality Revenue Share 2020F



Augmented And Virtual Reality To Hit \$150 Billion,
Disrupting Mobile By 2020, Digi-capital, 4/15

THE VR FUND 2016 VR INDUSTRY LANDSCAPE v1.1

APPLICATIONS/CONTENT ▲

LOCATION BASED	SPORTS/LIVE EVENTS	SOCIAL	GAMES	ENTERTAINMENT	ENTERPRISE	HEALTHCARE	EDUCATION
TOURISM	SPORTS TRAINING	SOCIAL MEDIA				JOURNALISM	

INFRASTRUCTURE TOOLS/PLATFORM ▲

DISTRIBUTION (APPS/VIDEO)	3D TOOLS (ENGINES/AUDIO)	REALITY CAPTURE (360 VIDEO/NEXT GEN)

HMD (TETHERED/MOBILE) ▲

INPUT (HAND/EYE/WEARABLE/OMNI TREADMILLS/HAPTICS)

Why 2017 won't be like 1996

- It's not just VR anymore
- Huge amount of investment
- Inexpensive hardware platforms
- Easy to use content creation tools
- New devices for input and output
- Proven use cases – no more Hype!
- Most important: Focus on User Experience

Conclusion

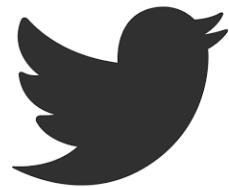
- Virtual Reality has a long history
 - > 50 years of HMDs, simulators
- Key elements for VR were in place by early 1990's
 - Displays, tracking, input, graphics
 - Strong support from military, government, universities
- First commercial wave failed in late 1990's
 - Too expensive, bad user experience, poor technology, etc
- We are now in second commercial wave
 - Better experience, Affordable hardware
 - Large commercial investment, Significant installed user base
- Will Virtual Reality be a commercial success this time?



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