INTRODUCTION TO VIRTUAL AND AUGMENTED REALITY

Lecture 1

RVAU - Realidade Virtual e Aumentada - EIC0070

2019/2020 - 1S

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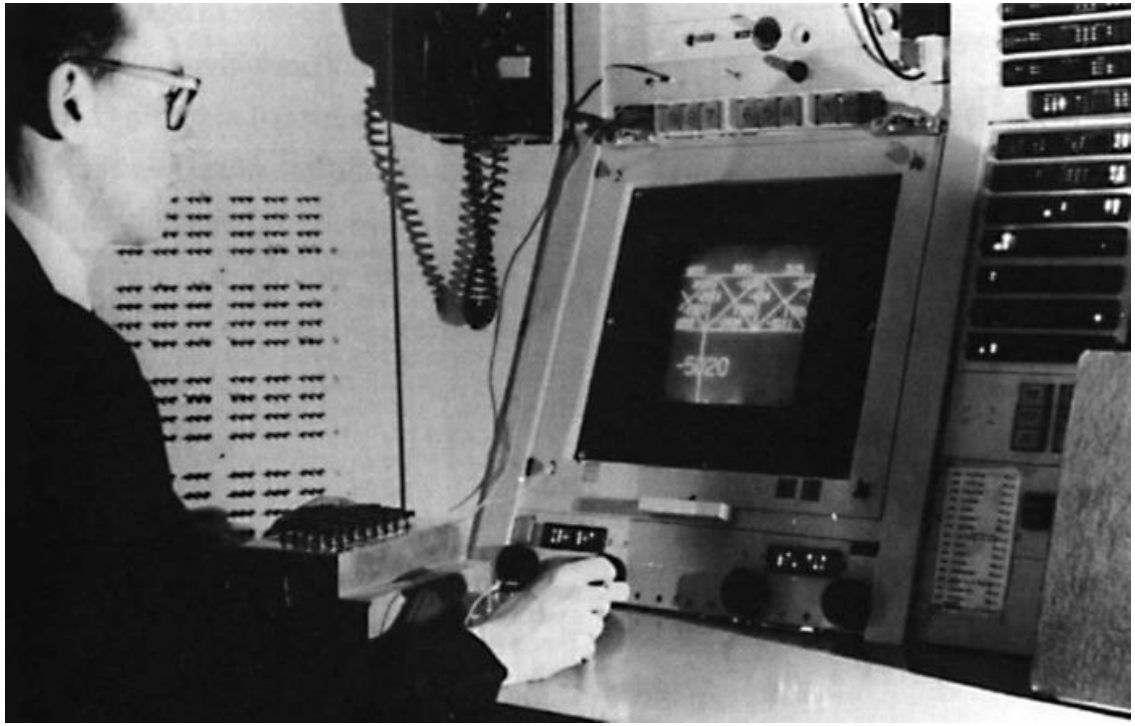
(adaptado de slides Rui Nóbrega, A. Augusto Sousa)

VIRTUAL REALITY

- Slides based on Mark Billinghurst's slideshare
  - The VR Book chapter 1

Ivan Sutherland (1963)



- Sketchpad (PhD thesis) – first interactive graphics program
- Pioneered the way for HCI
- The Graphical User Interface (GUI) was derived from the Sketchpad
- https://youtu.be/YB3saviltTI

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

Holodeck (1974)

The ultimate display in sci-fi

- First shown in Star Trek; The Animated Series

HoloDeck Video

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

Modern computers – turning point IBM-1401 (1959)

- In mid-1960s IBM-1401 type systems represented **half of the computers in the world**
- "**low-cost**" – US$2,500 rental cost (around $21,000 today)
- Mass-produced: over 12,000 units produced
- Internal architecture similar to modern computers

The Disappearing Computer

1960-70’s

1970-80’s

1980-90’s

1990-2000’s

Room

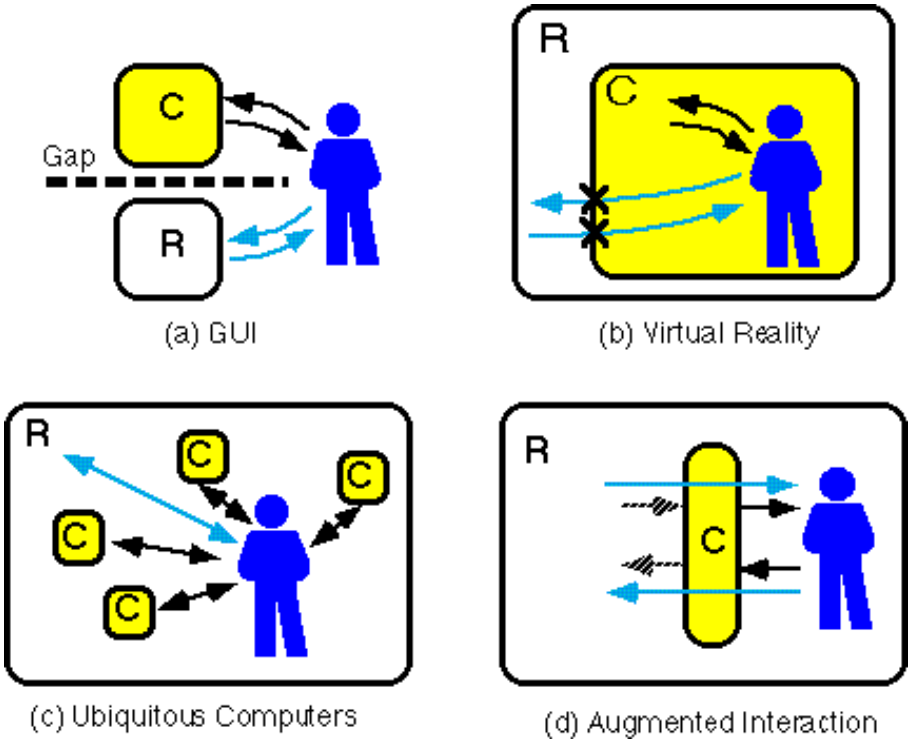
Desk

Lap

Hand

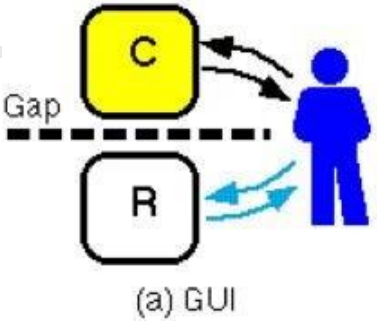
HCI Styles

Making Interfaces Invisible

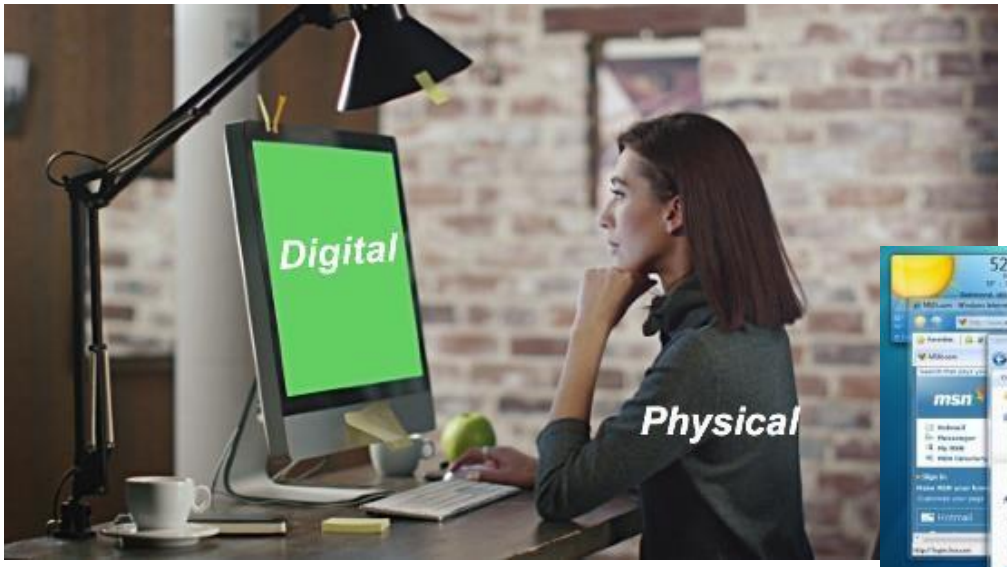


Rekimoto, J. and Nagao, K. 1995. The world through the computer: computer augmented interaction with real world environments. In *Proceedings of the 8th Annual ACM Symposium on User interface and Software Technology. UIST '*95. ACM, New York, NY, 29-36.

Graphical User Interfaces

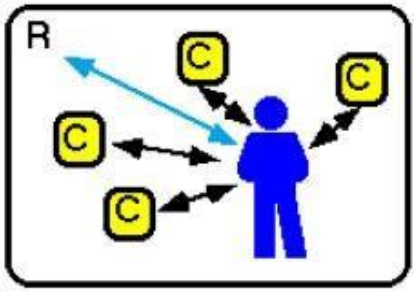


(a) GUI



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

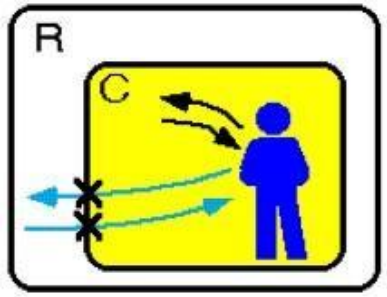
Ubiquitous Computing/IoT



(c) Ubiquitous Computers

- Embed computing and sensing in real world
  - Smart objects, sensors, etc..

Virtual Reality



(b) Virtual Reality

- Users immersed in Computer Generated environment
  - HMD, gloves, 3D graphics, body tracking

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

What is Virtual Reality?

- VR is commonly used by popular media to describe imaginary worlds that only exist in computer and our minds

- **"Virtual Reality is defined to be a computer-generated digital environment that can be experienced and interacted with as if that environment were real"**, The VR Book

Typical VR System

https://www.youtube.com/watch?v=eJCiyf8Kn9w

Many 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)

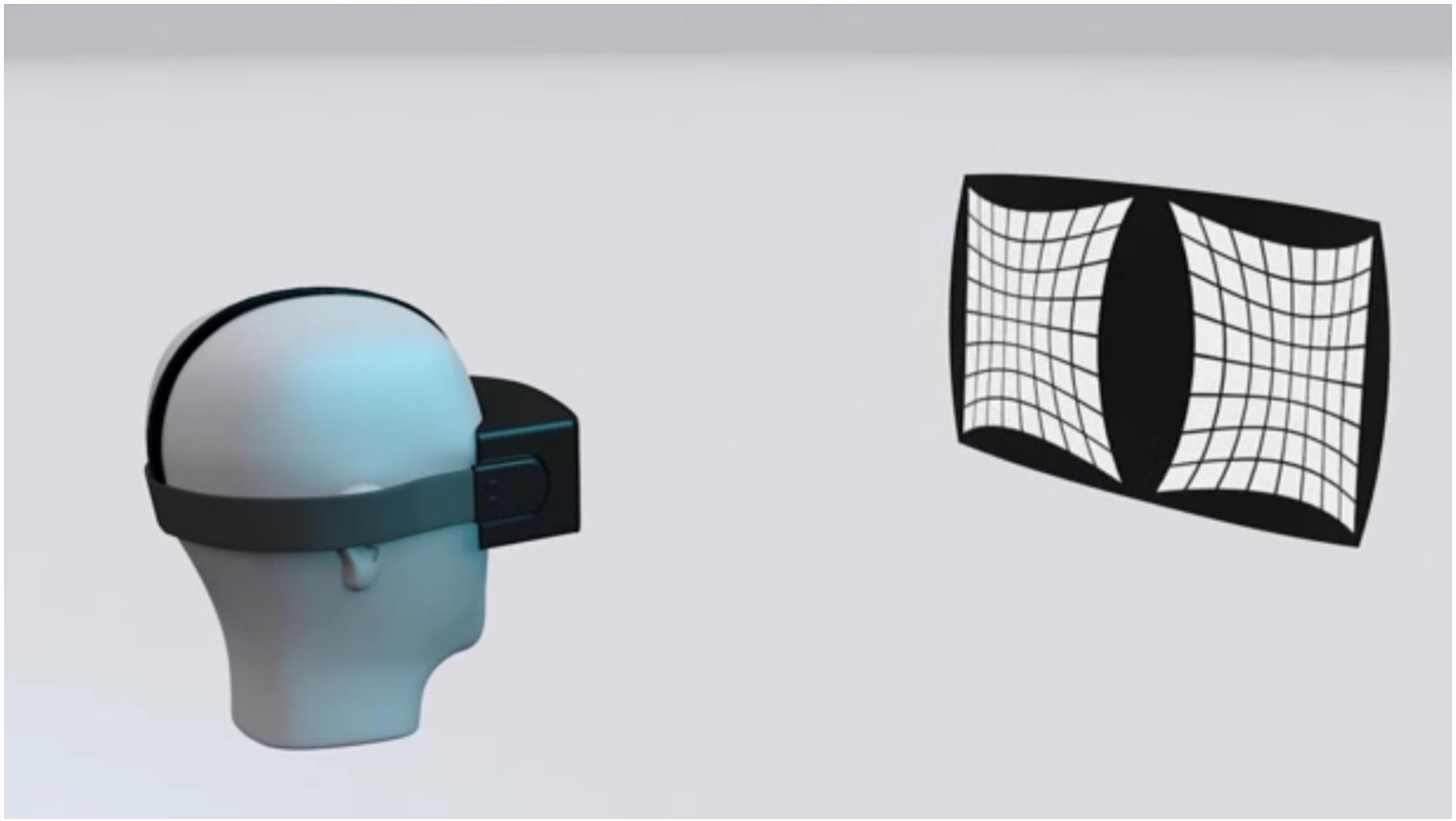
...an interactive, immersive experience generated by a computer (Pimental 1995)

Key Characteristics for VR

- Virtual Reality has three key characteristics
  1. 3D stereoscopic display
  2. Wide field of view display
  3. Low latency head tracking

- When these three things are combined they provide a compelling immersive experience

Defining Characteristics



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

VR Experience

- “ELDERS REACT TO OCULUS RIFT”
- https://www.youtube.com/watch?v=hZ8Xj_I3aNU

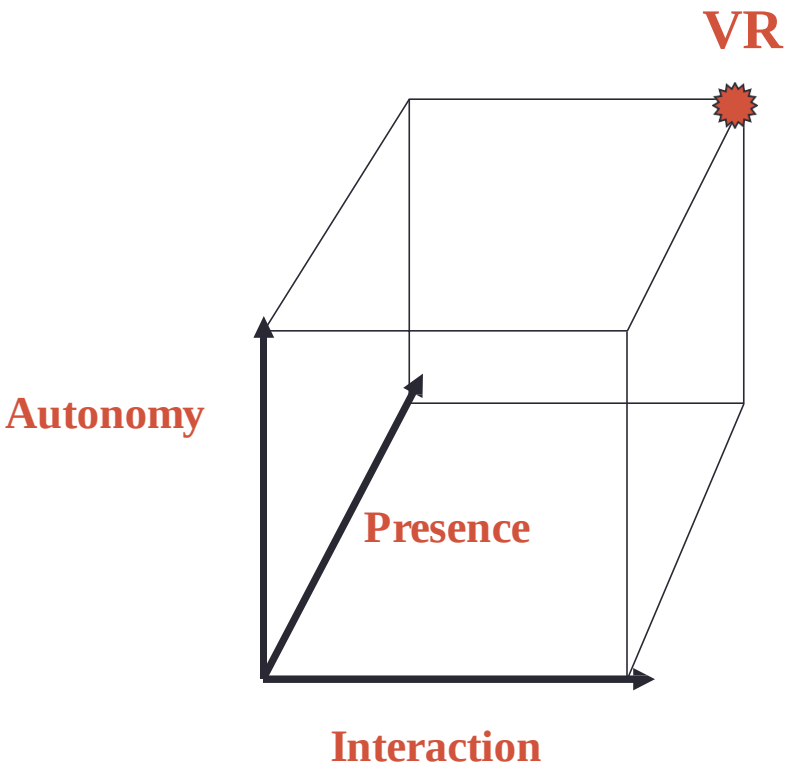
Defined in Terms of Presence

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, or sensation of being elsewhere, created by a set of technologies
- A "virtual reality" is defined as a real or simulated environment in which an observer/perceiver experiences telepresence.

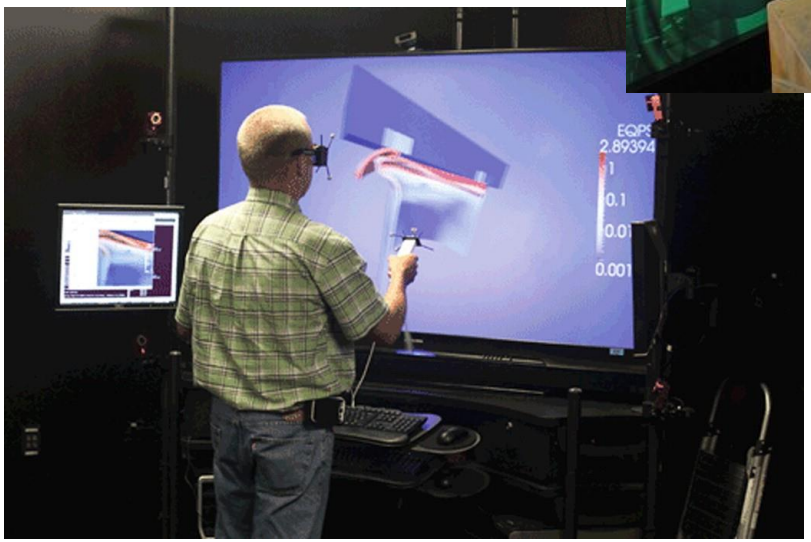
David Zeltzer's AIP Cube

- **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.

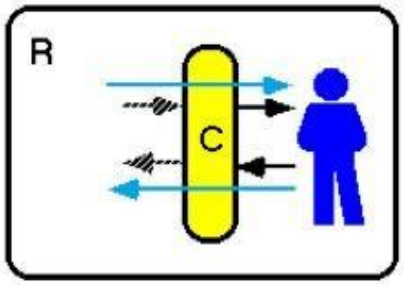
Types of VR



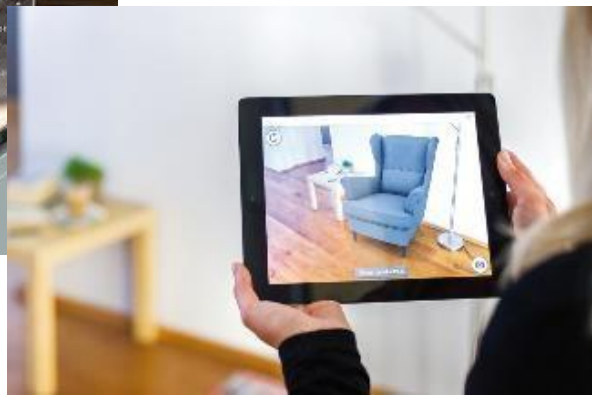
AUGMENTED REALITY

- Slides based on Mark Billinghurst's slideshare
- Azuma, A Survey of Augmented Reality - UNC Computer Science

Augmented Reality

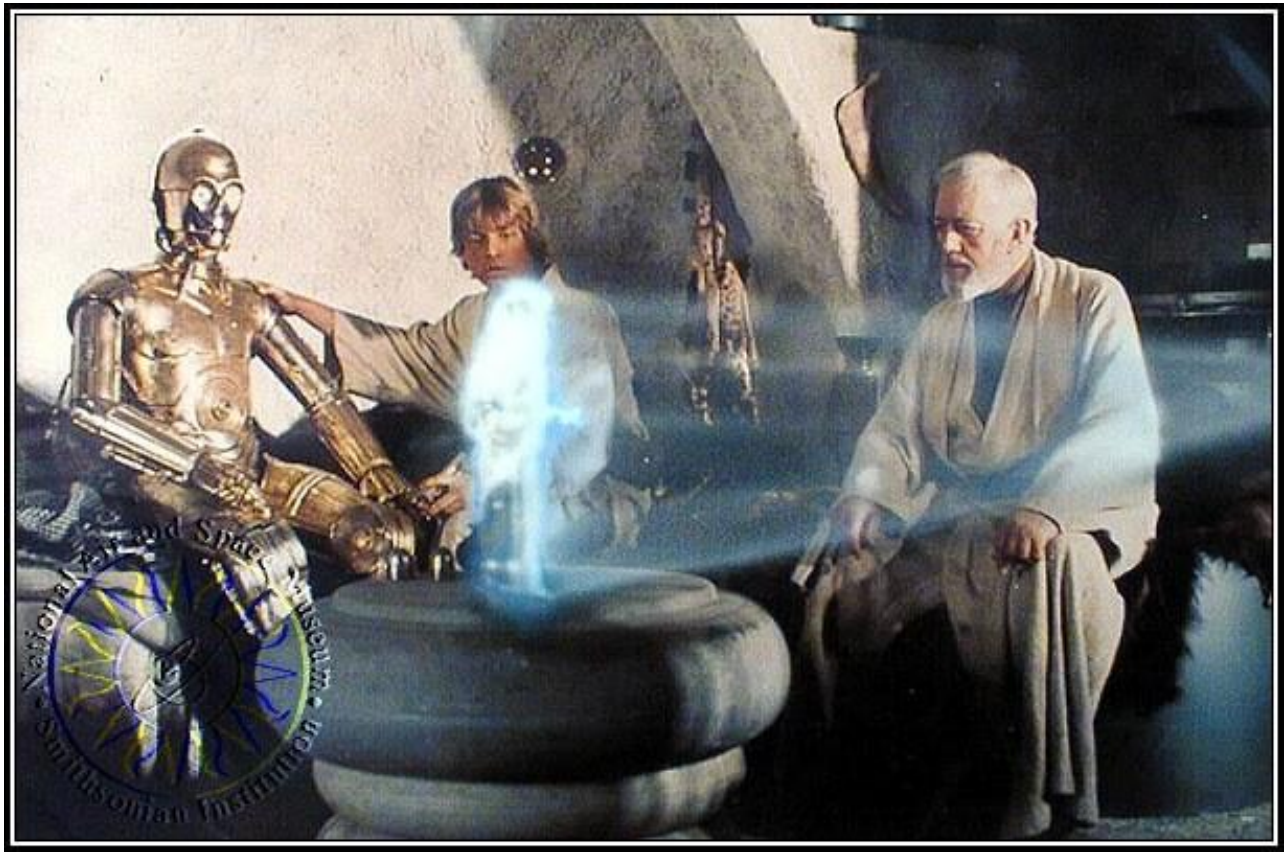


(d) Augmented Interaction



- Virtual Images blended with the real world
  - Computer screens, See-through HMDs, handheld display, glasses, etc…

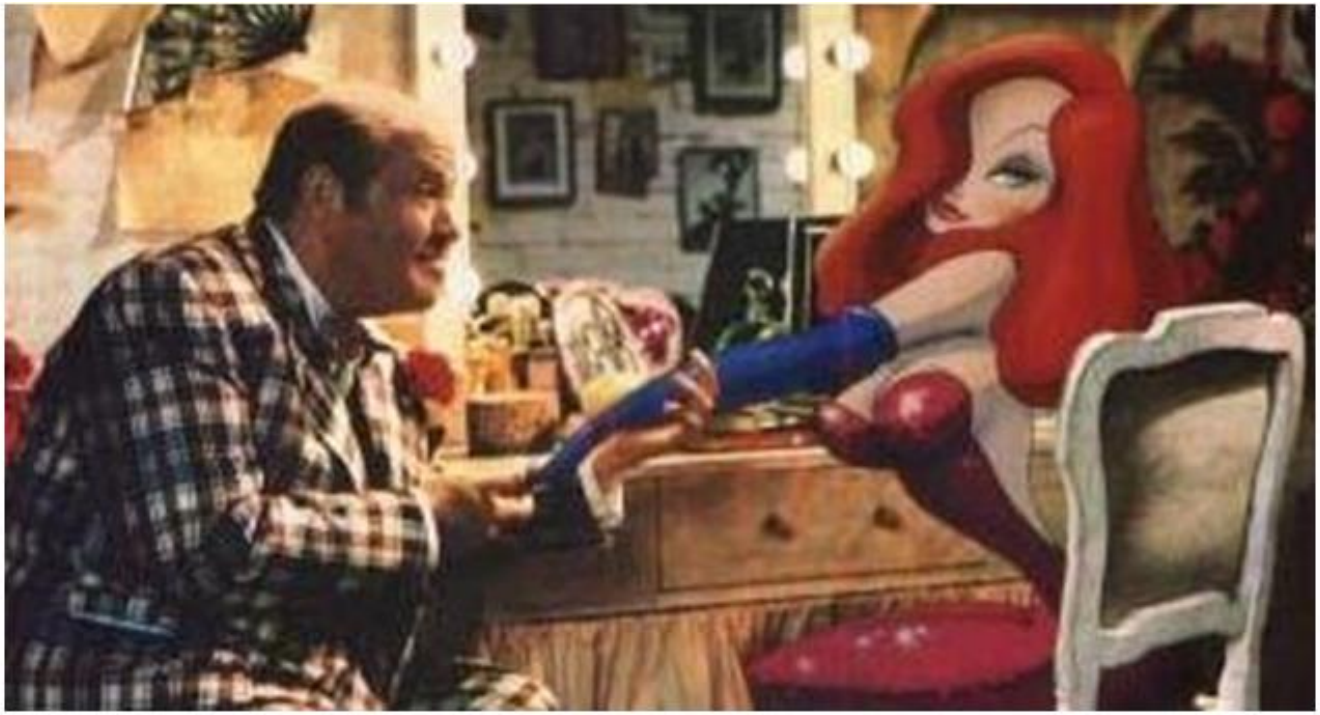
Augmented Reality in Science Fiction



1977 – Star Wars

https://youtu.be/8N_Cj3ZS9-A

Augmented Reality in Science Fiction



Screenshot from the movie"Who Framed Roger Rabbit?" blending the real character and background with computer generated cartoon characters

Augmented Reality in Science Fiction
Now inside the movie lore

Featuring:

- Markerless AR
- Image Processing: Real-time image-feature detection (edges and blobs perhaps)

1991 – Terminator 2

http://youtu.be/9MeaaCwBW28

Augmented Reality Definition

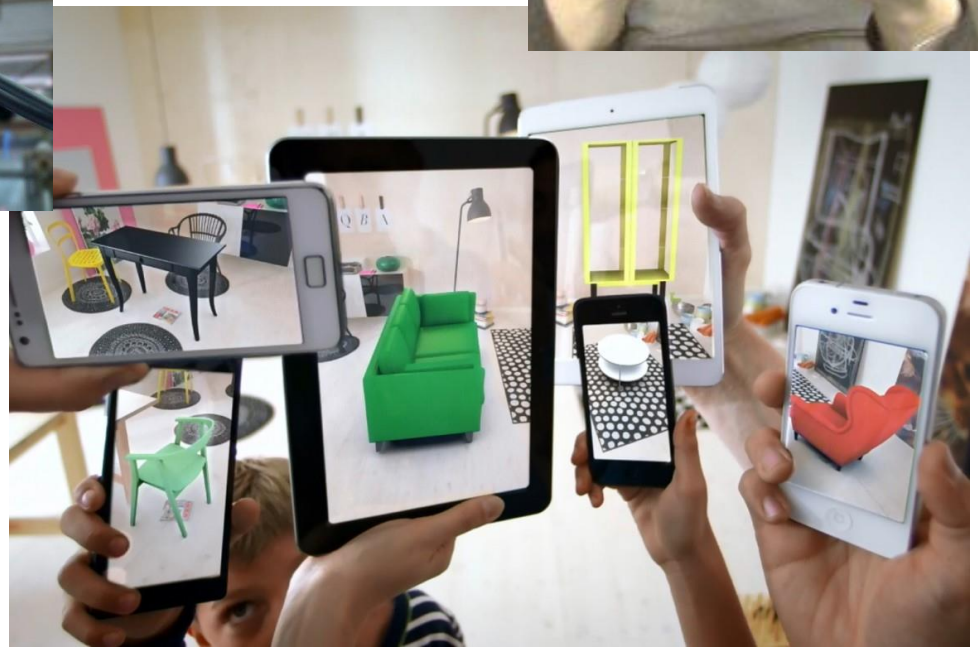
- Defining Characteristics [Azuma 97]
  - Combines Real and Virtual Images
    - Both can be seen at the same time
  - Interactive in real-time
    - The virtual content can be interacted with
  - Registered in 3D
    - Virtual objects appear fixed in space

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



AR in Marketing: Colouring Example - Quiver

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

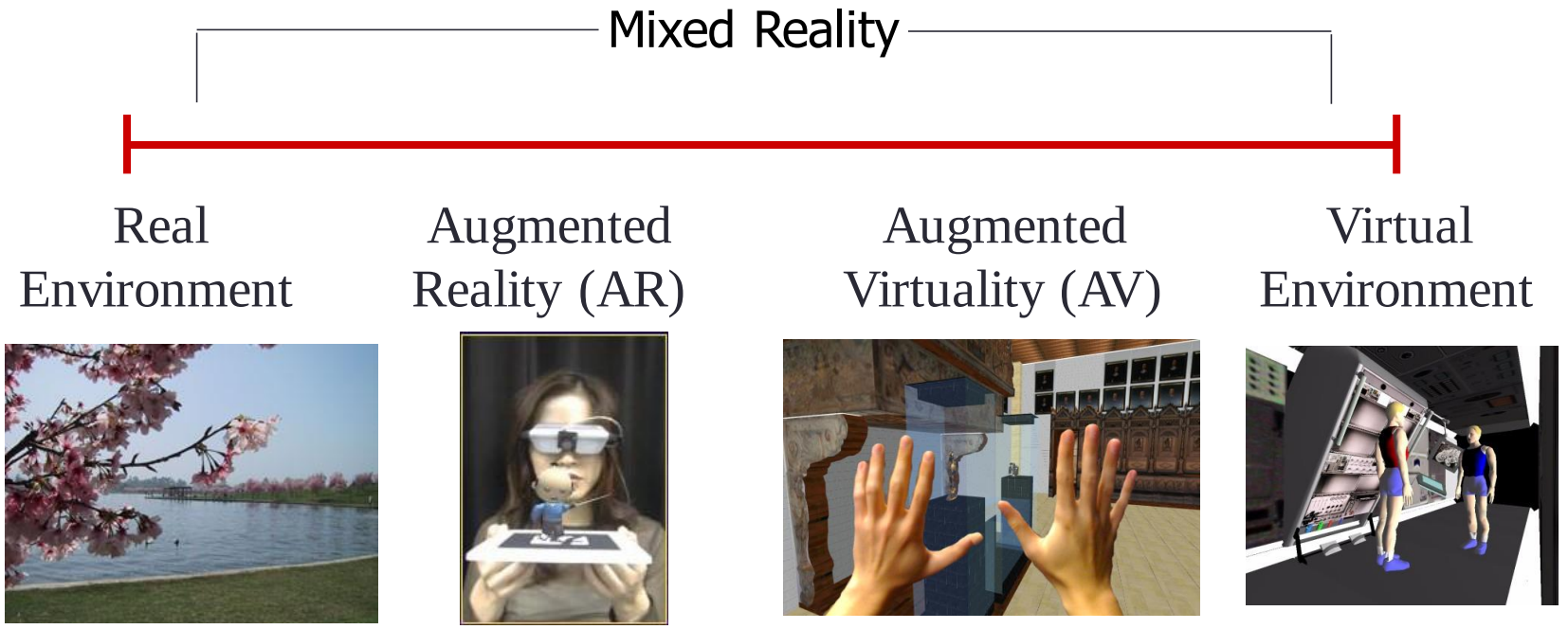
Gaming:
Pokemon GO..

AR vs VR

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

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.

VR definition angles

- 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
  - Natural User Interfaces (NUI)
  - Milgram's Mixed Reality continuum

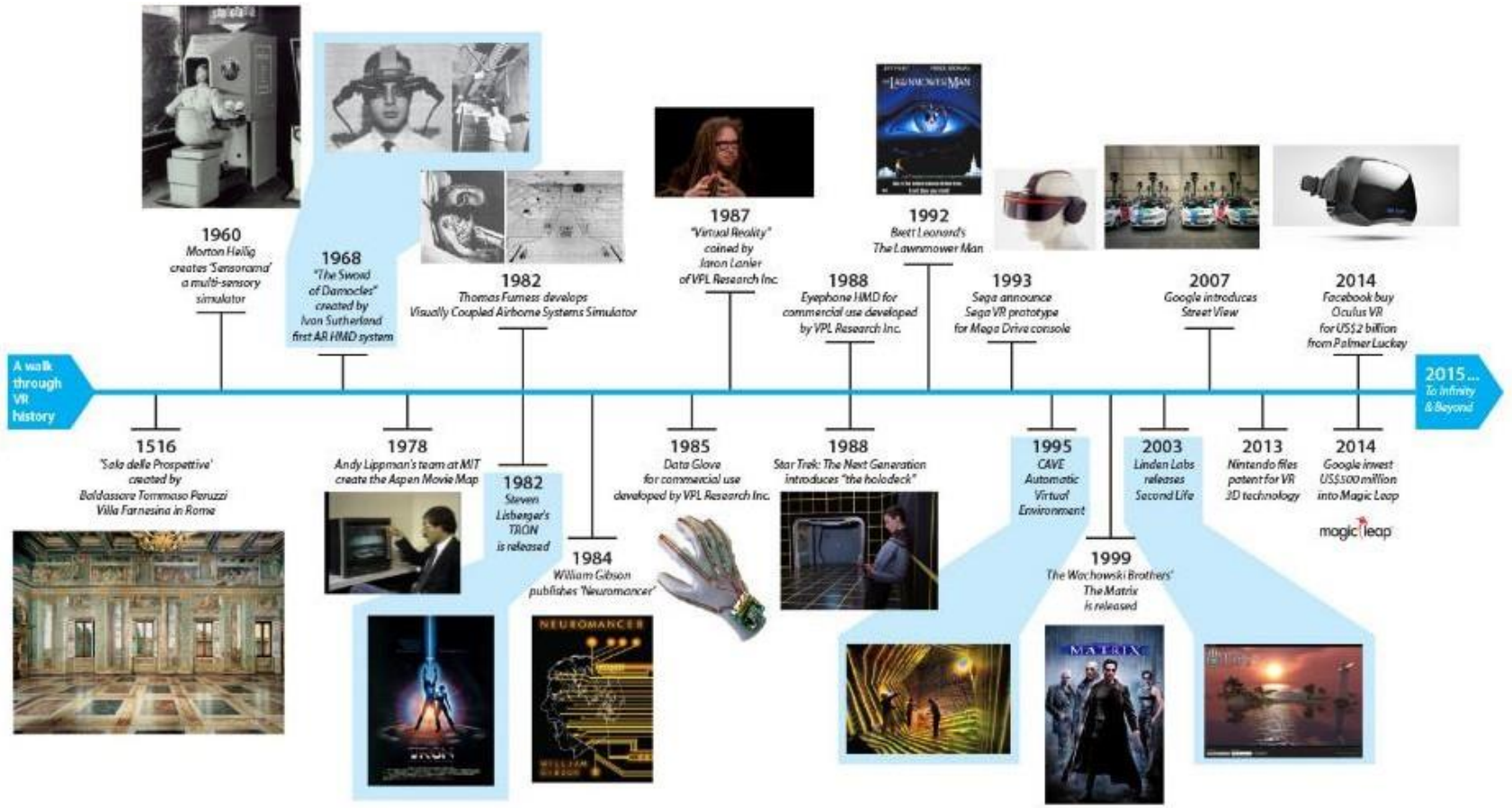
HISTORY OF VR

History of VR

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.

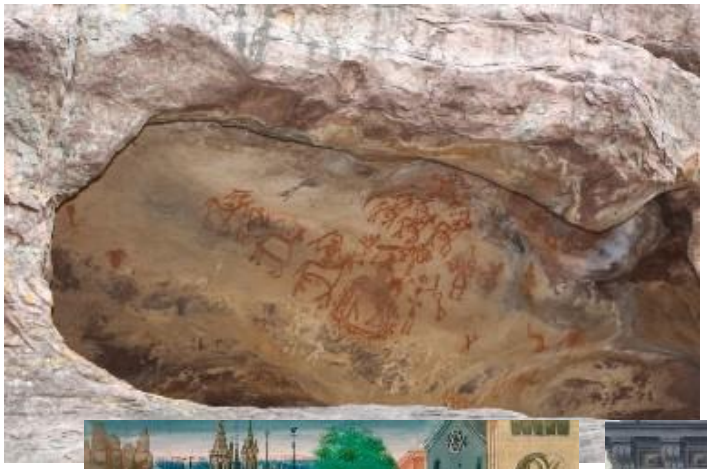
Morton Helig (Hammit 1993)

VR History Timeline



https://immersivelifeblog.files.wordpress.com/2015/04/vr_history.jpg

Early History (30,000 BC -)

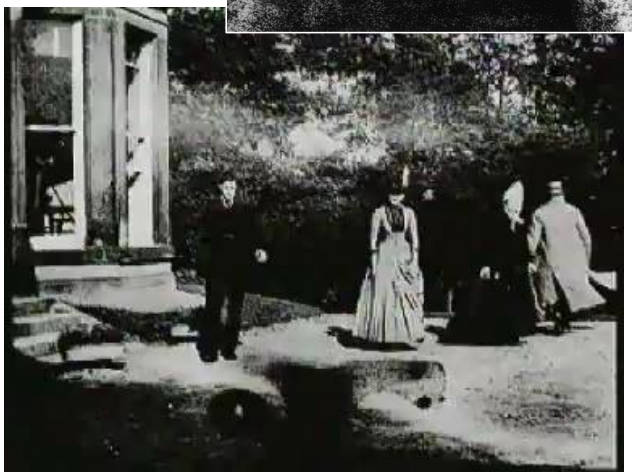





The history of VR is rooted in human's first attempts to reproduce the world around them

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)
  - The Horse In Motion (1878)
    - First Motion Picture
    - Eadweard Muybridge
  - Roundhay Garden Scene (1888)
    - First Motion Film
    - Louis Le Prince

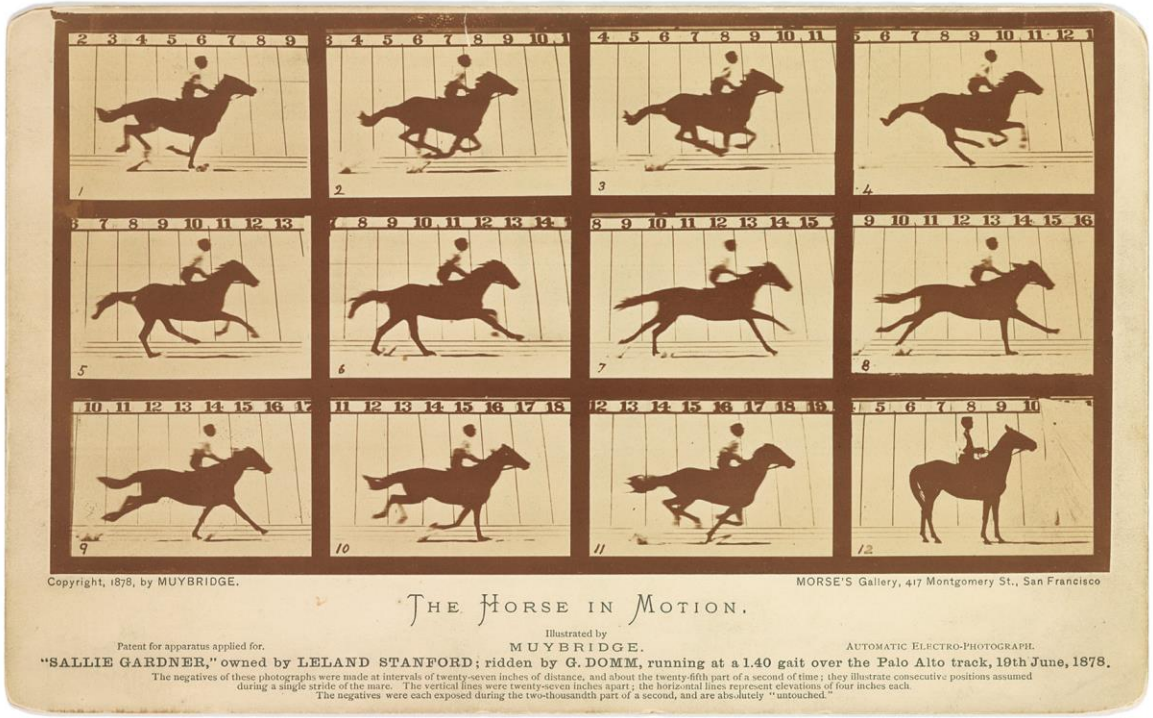


Stereo Viewers

Wheatstone (1832)

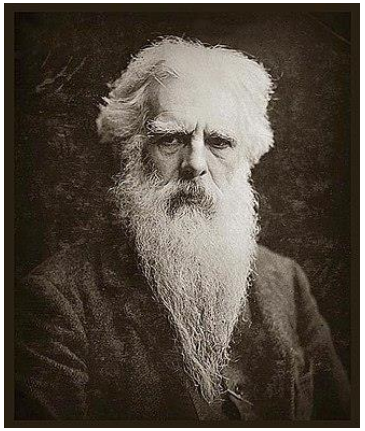
Brewster (1860)

First Motion Picture



The Horse In Motion (1878)

https://www.youtube.com/watch?v=heRuLp7CyTM



Eadweard Muybridge

Viewmaster (1939)

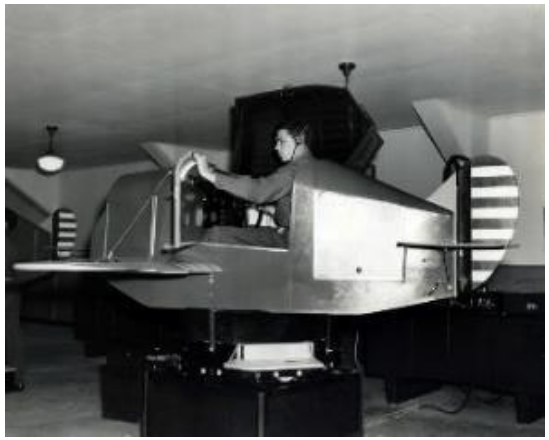
https://www.youtube.com/watch?v=f9yGKzwjomc

3D Cinema Golden Era (1950-60s)

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

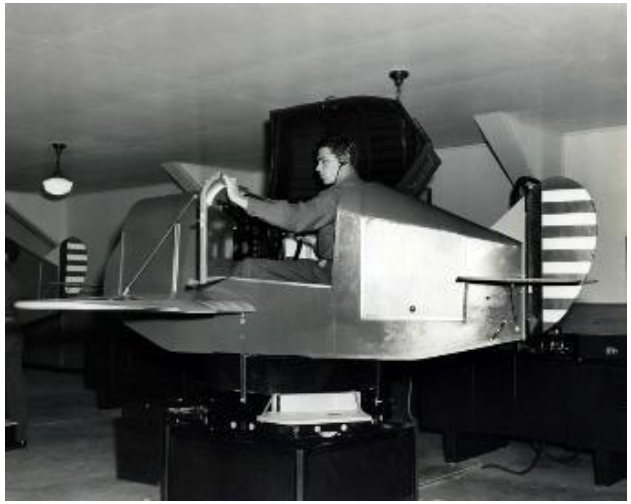
1900s – Interactive Experiences

Technological Foundations Began



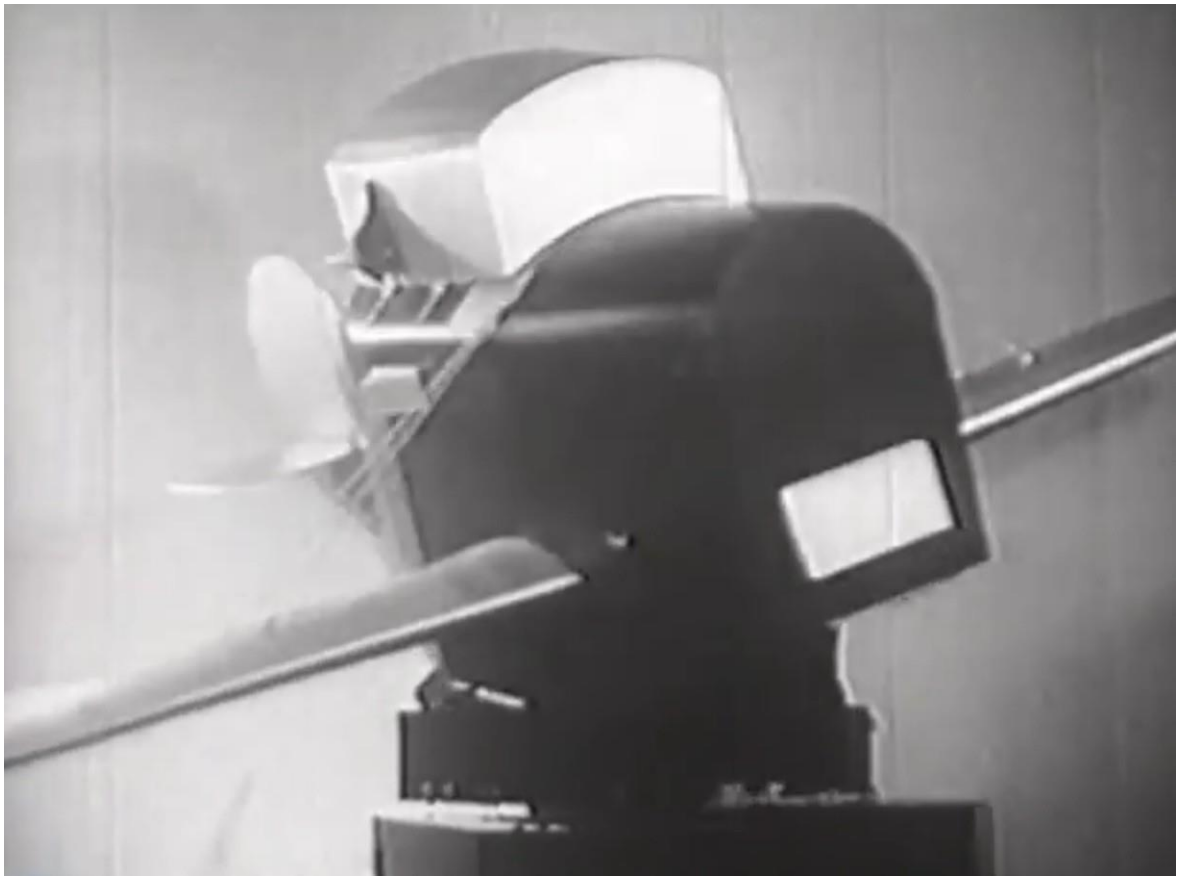
- Early Simulators (<1960s)
  - Flight simulators
  - Sensorama (1955)
- Early HMDs (1960s)
  - Philco, Ivan Sutherland
- Military + University Research (1970-80s)
  - US Airforce, NASA, MIT, UNC
- First Commercial Wave (1980-90s)
  - VPL, Virtual i-O, Division, Virtuality
  - VR Arcades, Virtual Boy

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 half a million pilots trained

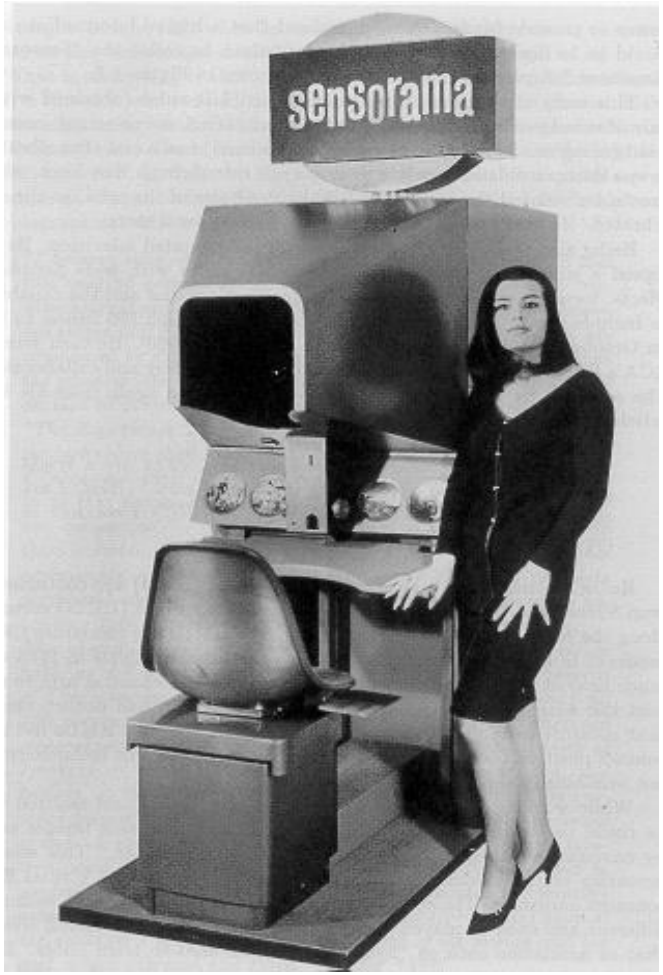
Link Trainer Video (1940's)



- https://www.youtube.com/watch?v=5kmmKj7fbnI

Sensorama (1955)

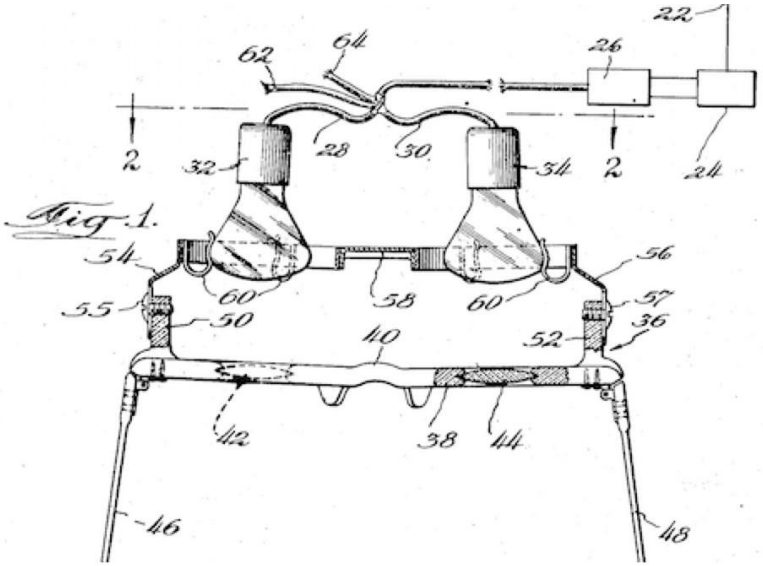
- Created by Morton Heilig
  - Experience Theater
- Multi-sensory
  - Visuals
  - Sound
  - Wind
  - Vibration
  - Smell
- No financial support
- Commercial failure



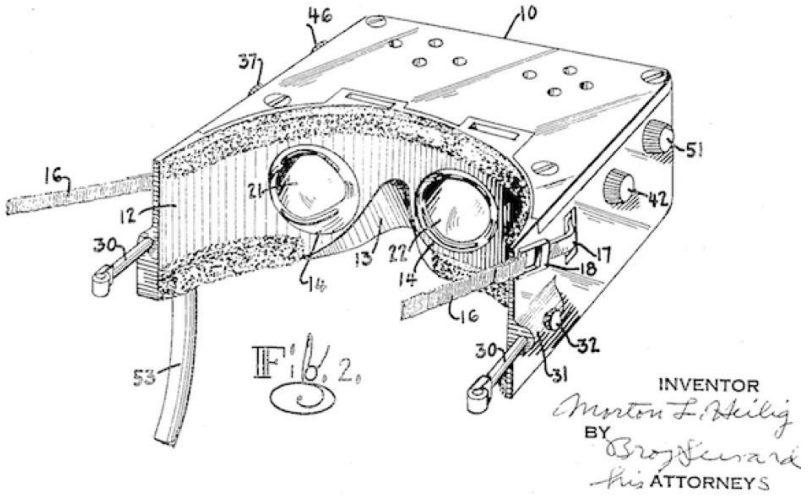
Sensorama Video

- https://www.youtube.com/watch?v=vSINEBZNCks

Early HMD Patents



McCollum's Stereo TV HMD (1943)



Heilig's Multisensory HMD (1960)

Early HMDs (1960s)

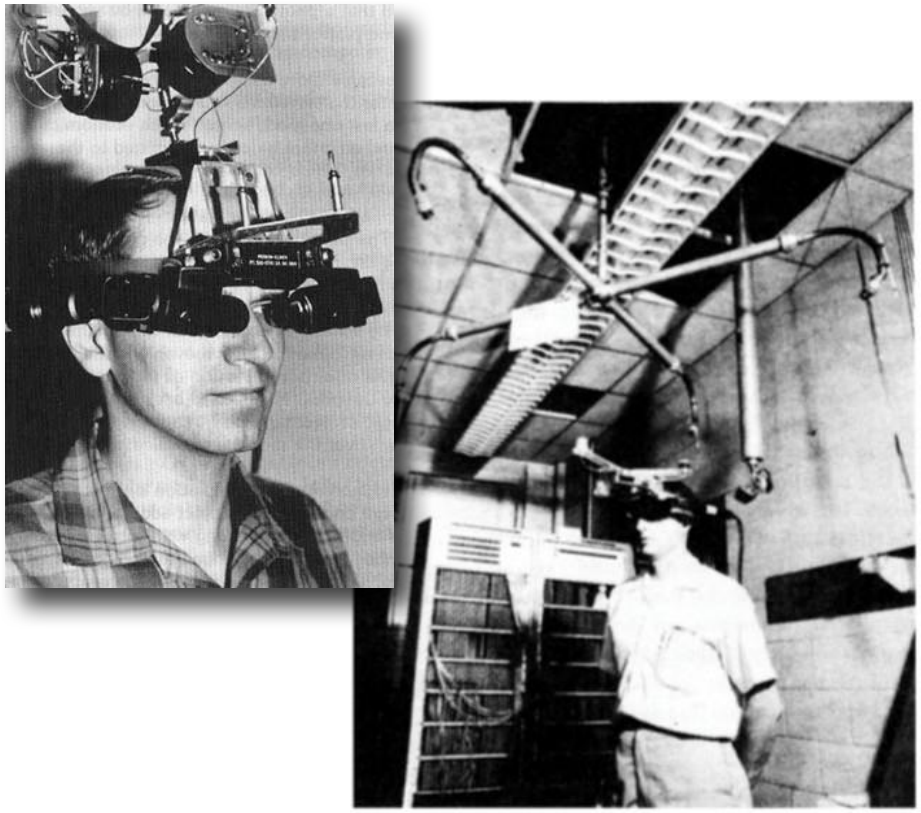
Philco Headsight (1961)

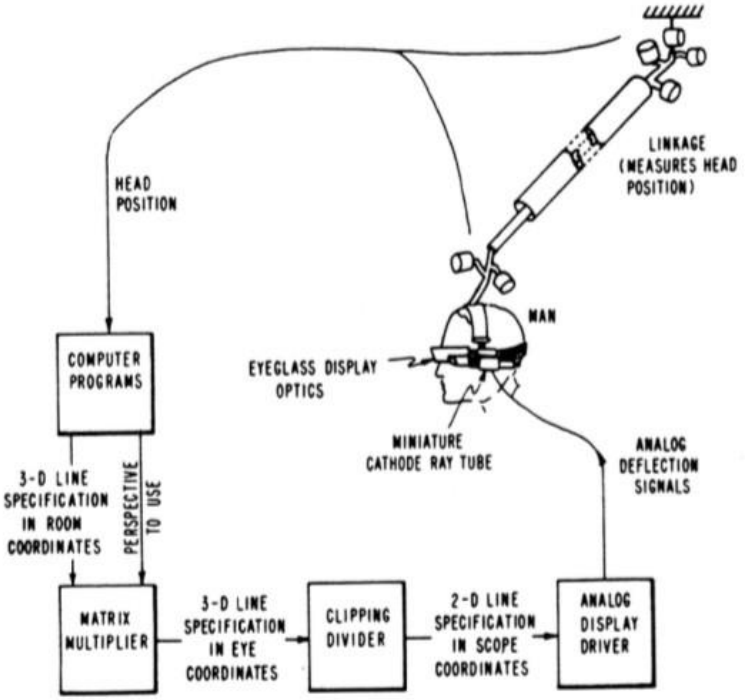
Sword of Damocles - Sutherland (1968)

- No computer generated graphics
- Magnetic head tracking
- A video telepresence solution?
  - Remote video with a CRT

- First HMD with head tracking and computer generated images

Ivan Sutherland (1960s)





Ivan Sutherland's Head-Mounted Display (1968)

The Sword of Damocles

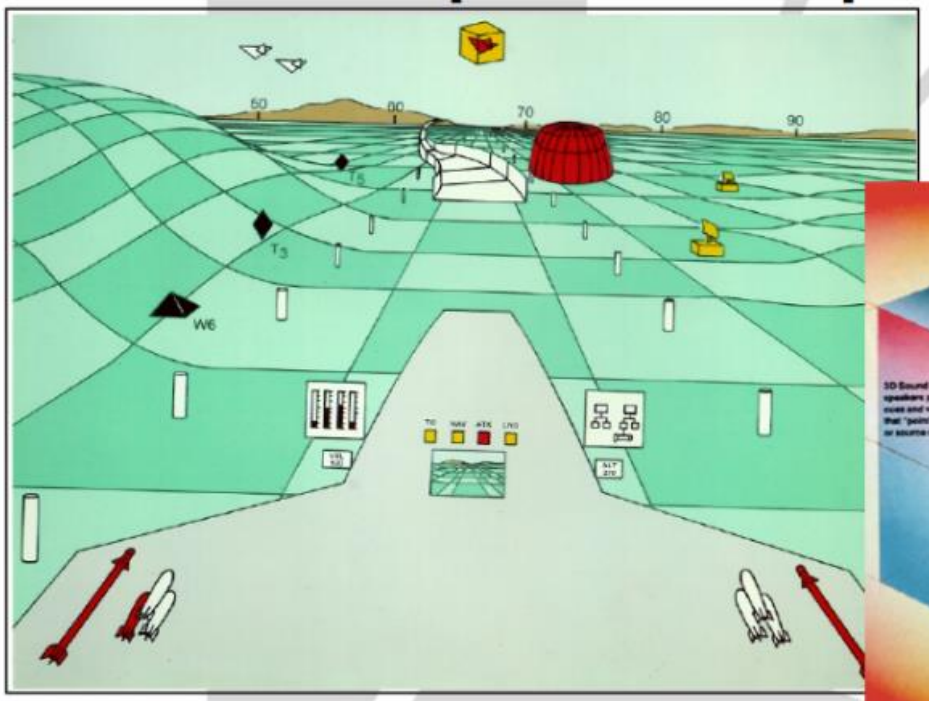
Sutherland Display – First HMD

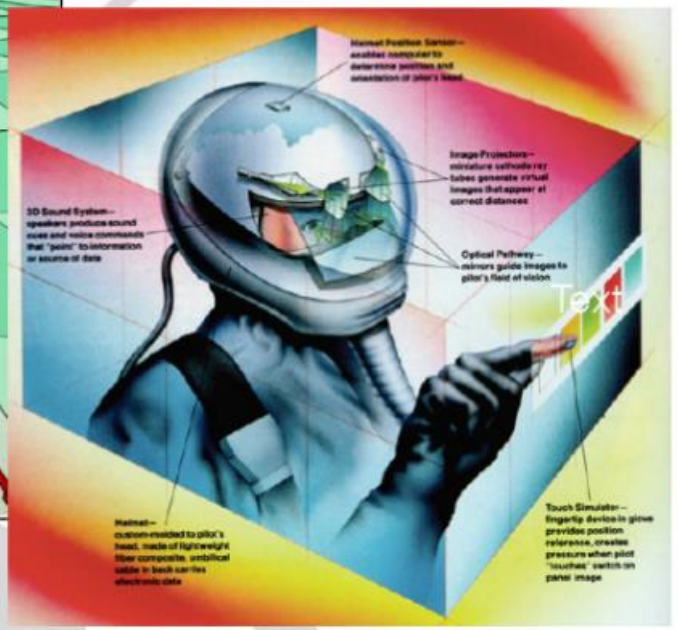
https://www.youtube.com/watch?v=NtwZXGprxag

Super Cockpit (1965-80's)

- From the US Airforce Research Program
  - Wright Patterson Air Force Base
- Created by **Tom Furness** III
  - A VR Pioneer
- Multisensory
  - Visual, 3D audio
  - Tactile recognition (gloves)
  - Speech-recognition
  - Tried to address the pilot information overload
  - Flight controls and tasks were too complicated
- Research only
  - big system, but perhaps too ambitious

The Super Cockpit (1980's)



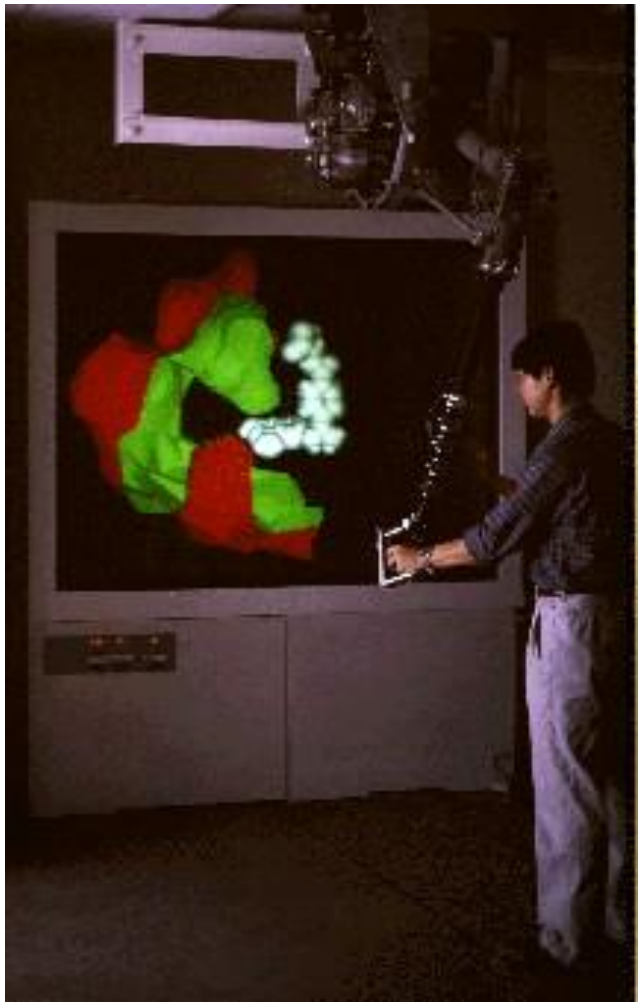


- Furness - USAF

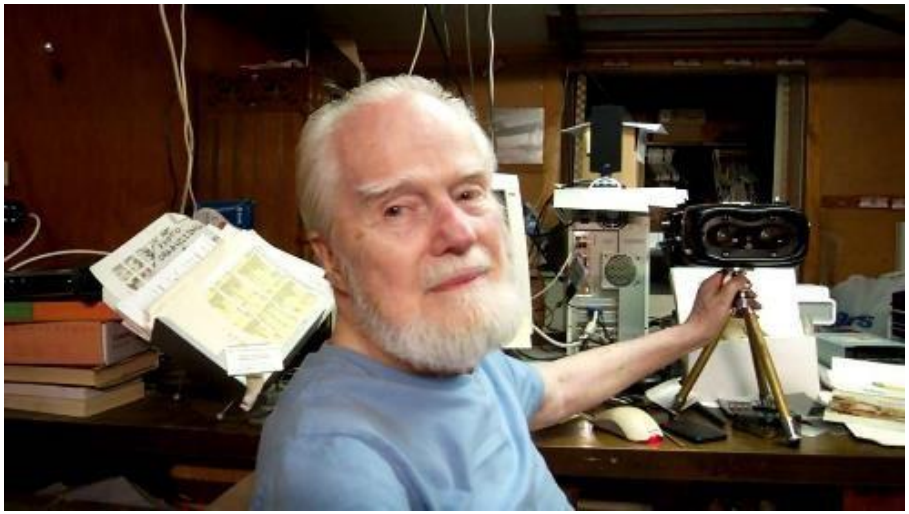
Furness, T. A. (1986, September). The super cockpit and its human factors challenges. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 30, No. 1, pp. 48-52). SAGE Publications.

Haptic and Force Feedback Systems (1967 –80's)

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

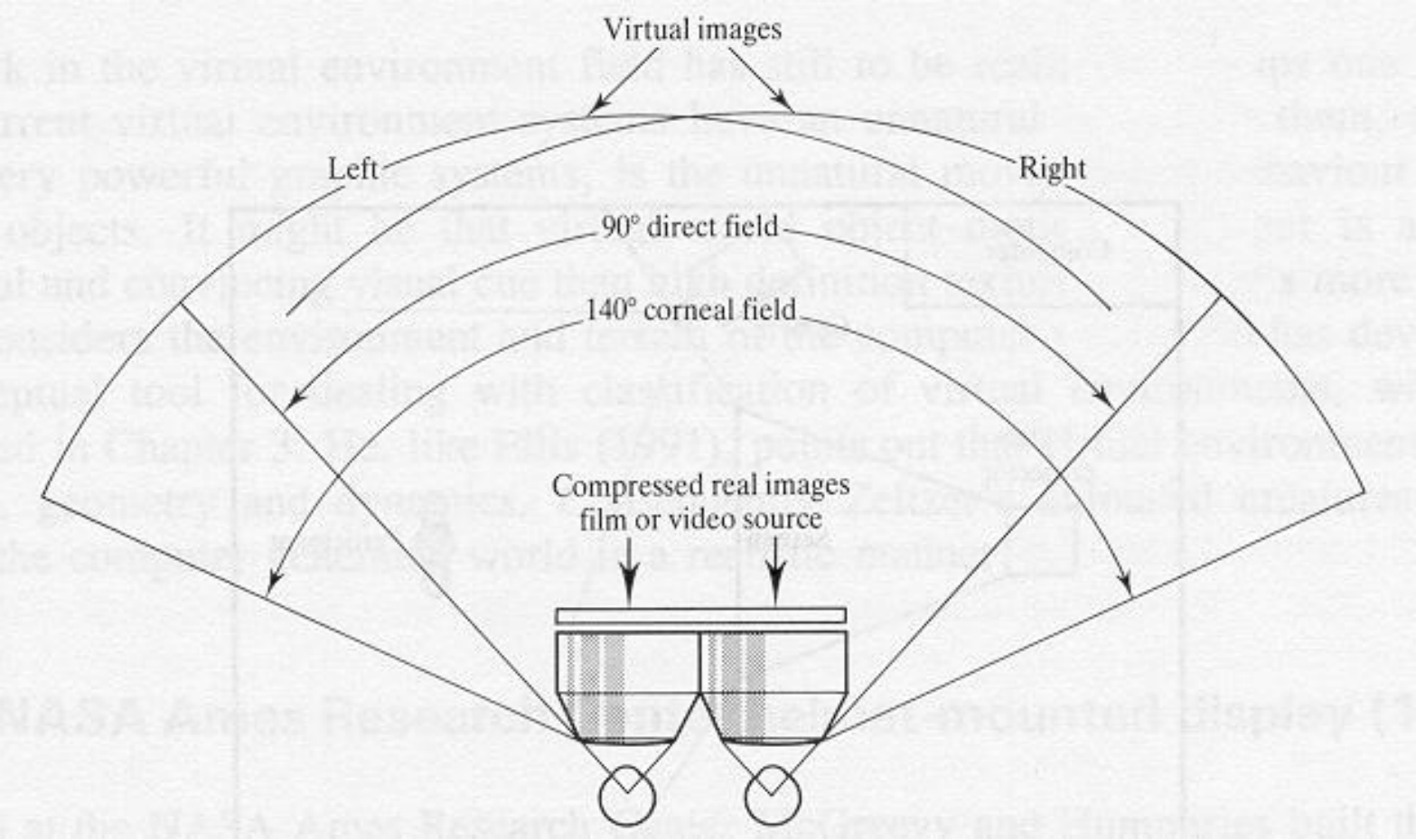


LEEP Optics (1979)



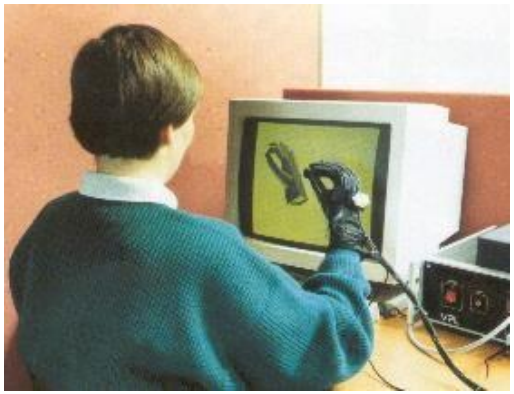
- Large Expanse, Extra Perspective Optics
  - Developed by Eric Howlett
- Lens design for extremely wide field of view
  - High resolution in centre, lower resolution in periphery
  - 90º direct FOV, 140º corneal FOV
- Used as basis for most VR HMDs today

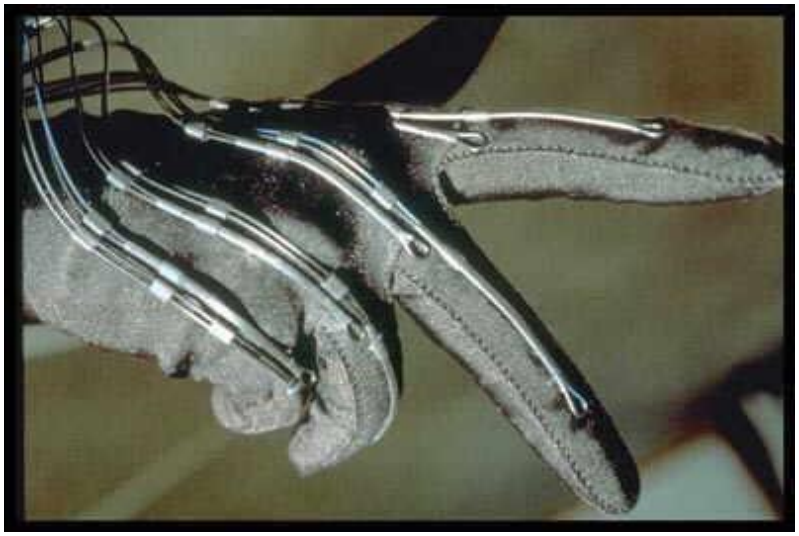
LEEP Optics Design



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)





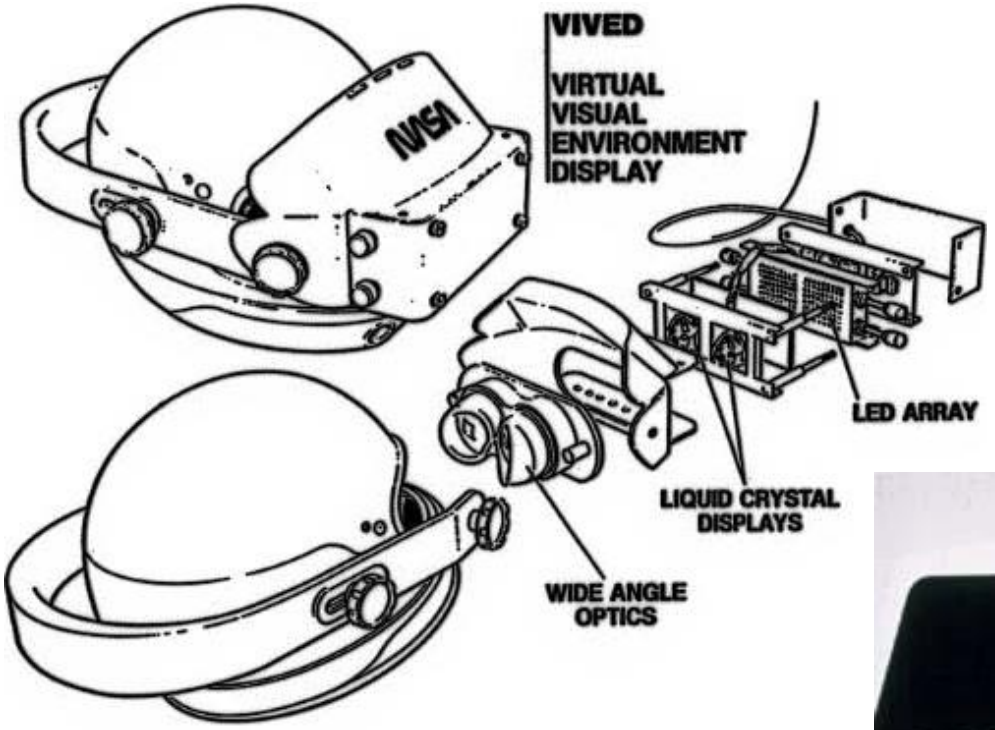
VPL DataGlove Demo

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

NASA VIEW/VIVED(1981-86)

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

Virtual Interface Environment Workstation (VIEW)



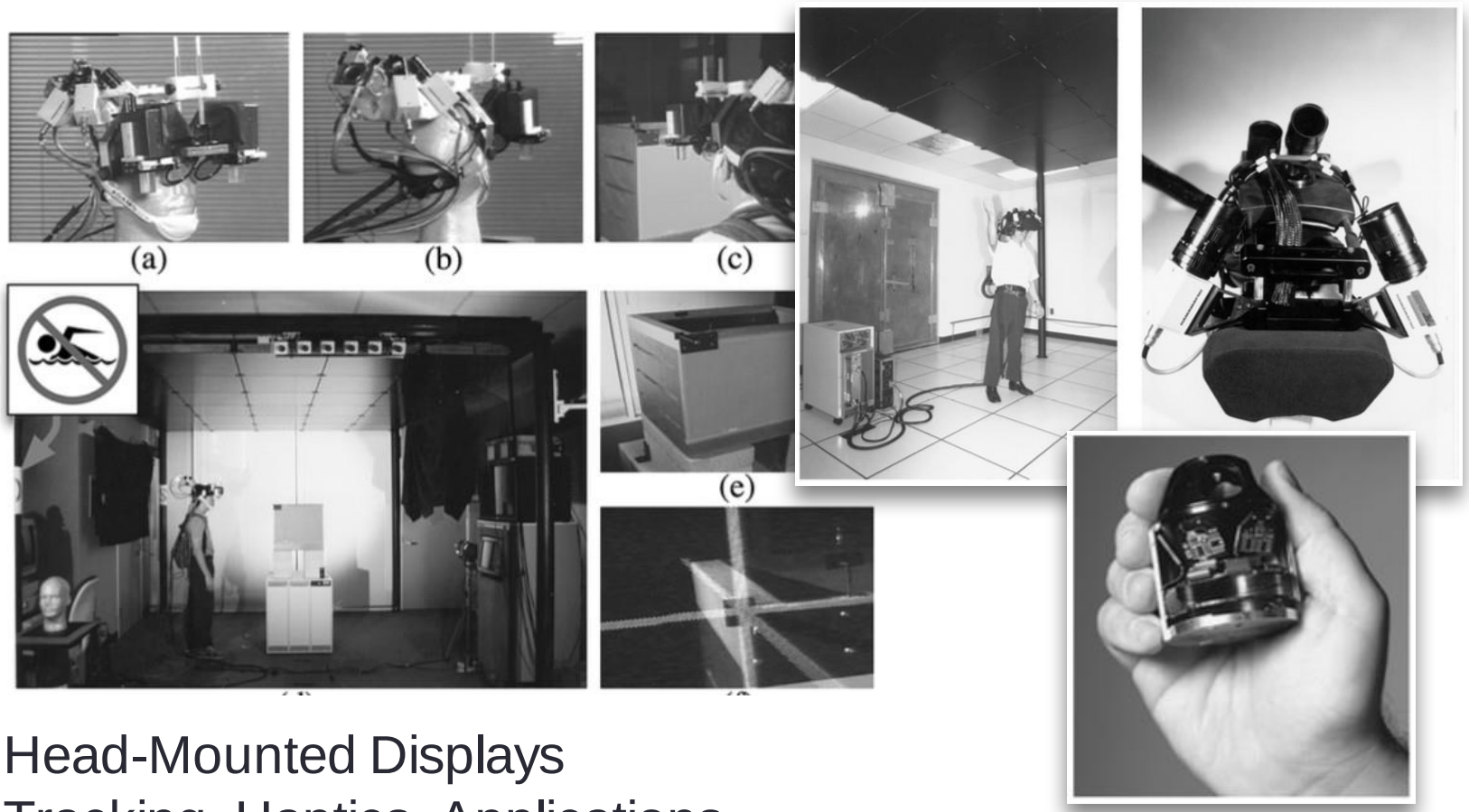
- Motorbike helmet + LEEP

Commercial Era

VPL Research and Products (1985 –1999)

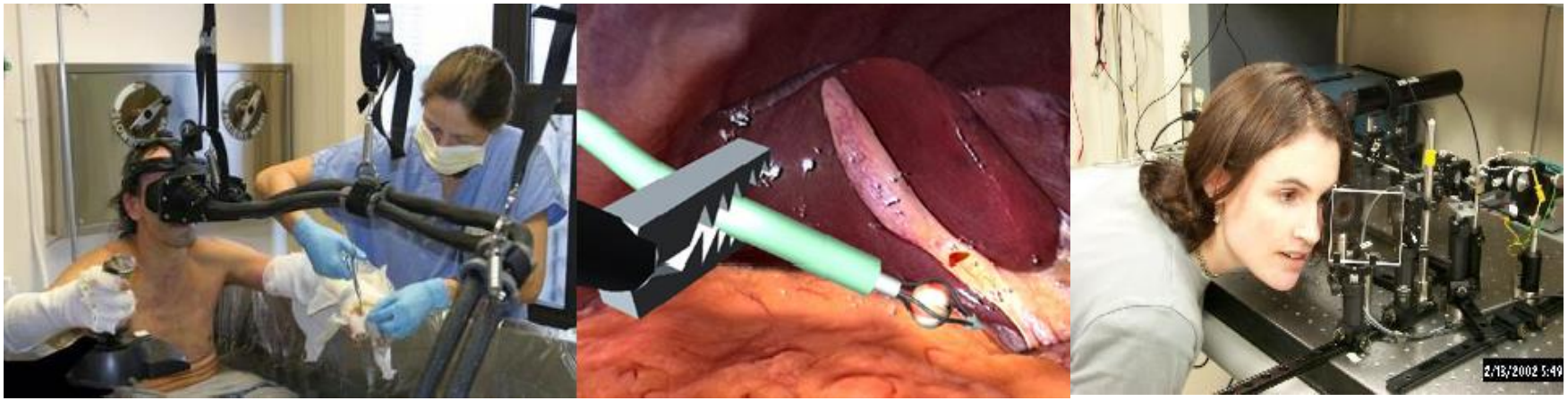
- First Commercial VR Company
  - Jaron Lanier, Jean-Jacques Grimaud
- **Provided complete systems**
  - Displays, software, gloves, etc..
  - DataGlove, EyePhone, AudioSphere

To follow:
The University of North Carolina at Chapel Hill (1980s-)



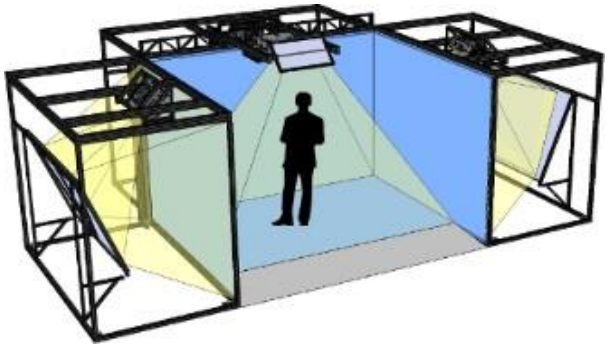
Head-Mounted Displays
Tracking, Haptics, Applications

To follow:
University of Washington (1989 -)



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

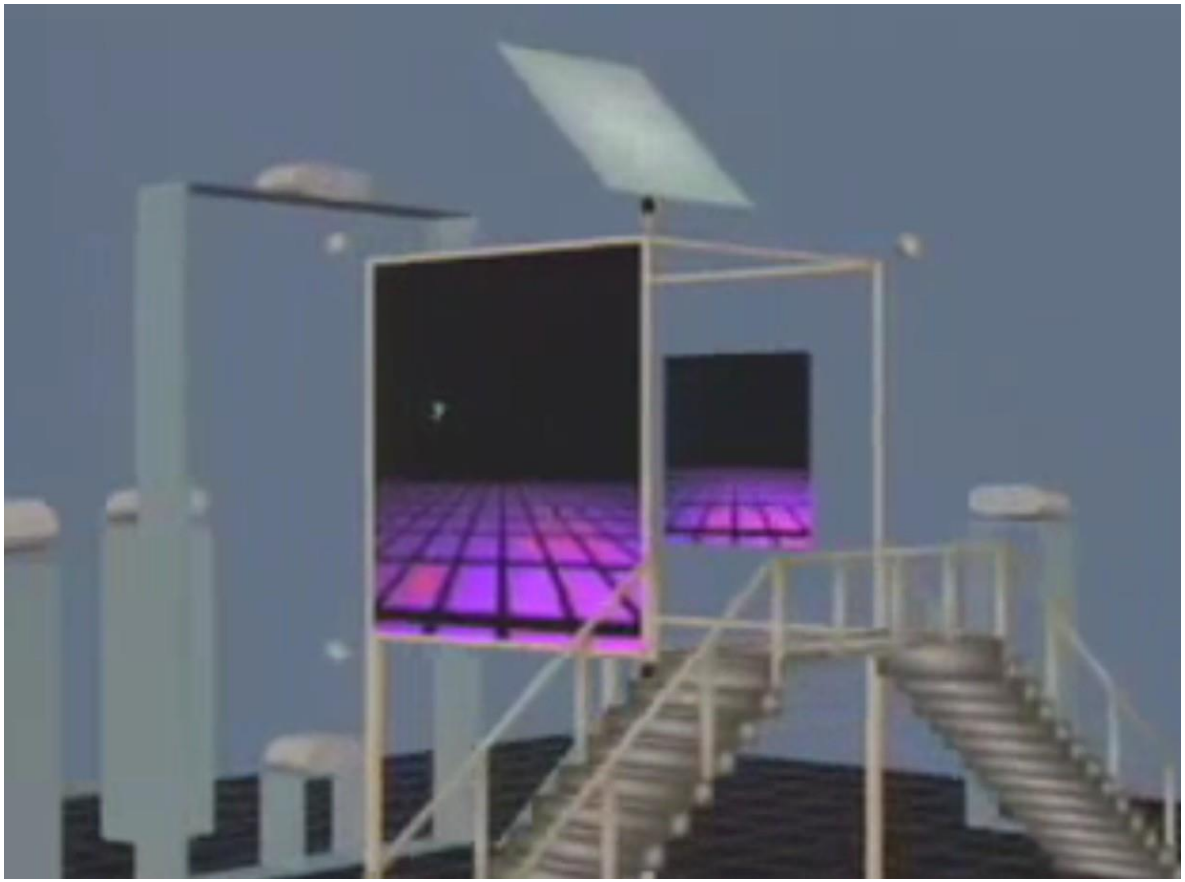
CAVE (1992)
University of Illinois Chicago



- 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.

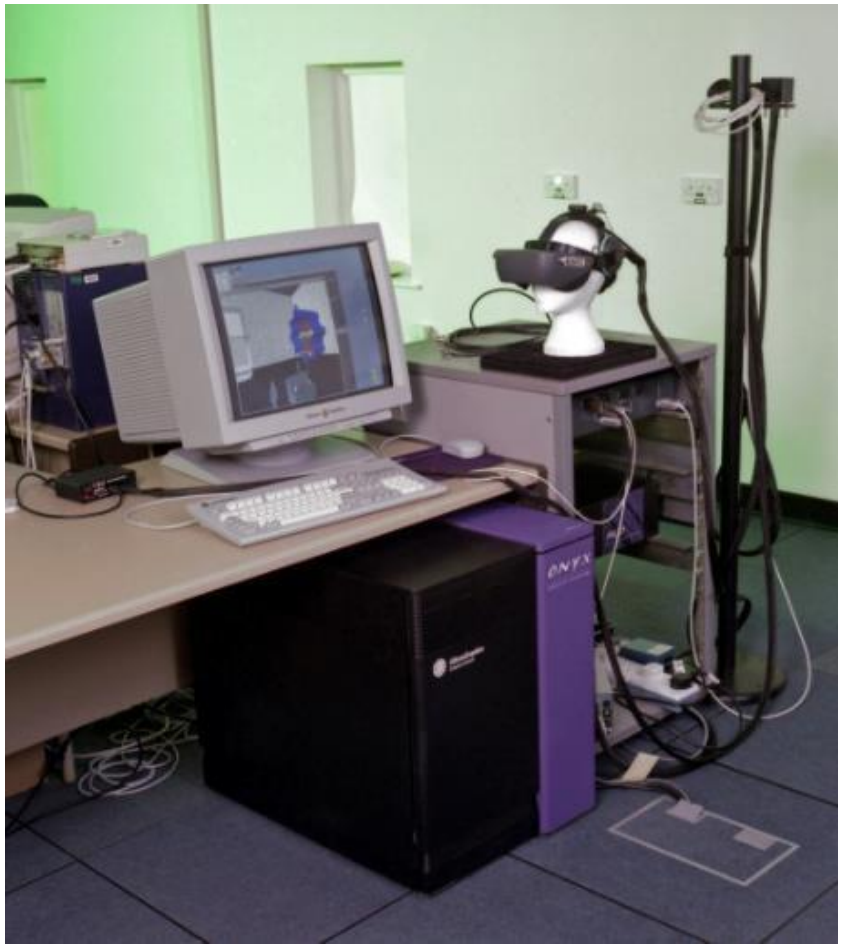
CAVE Demo Video



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

Desktop VR - 1995

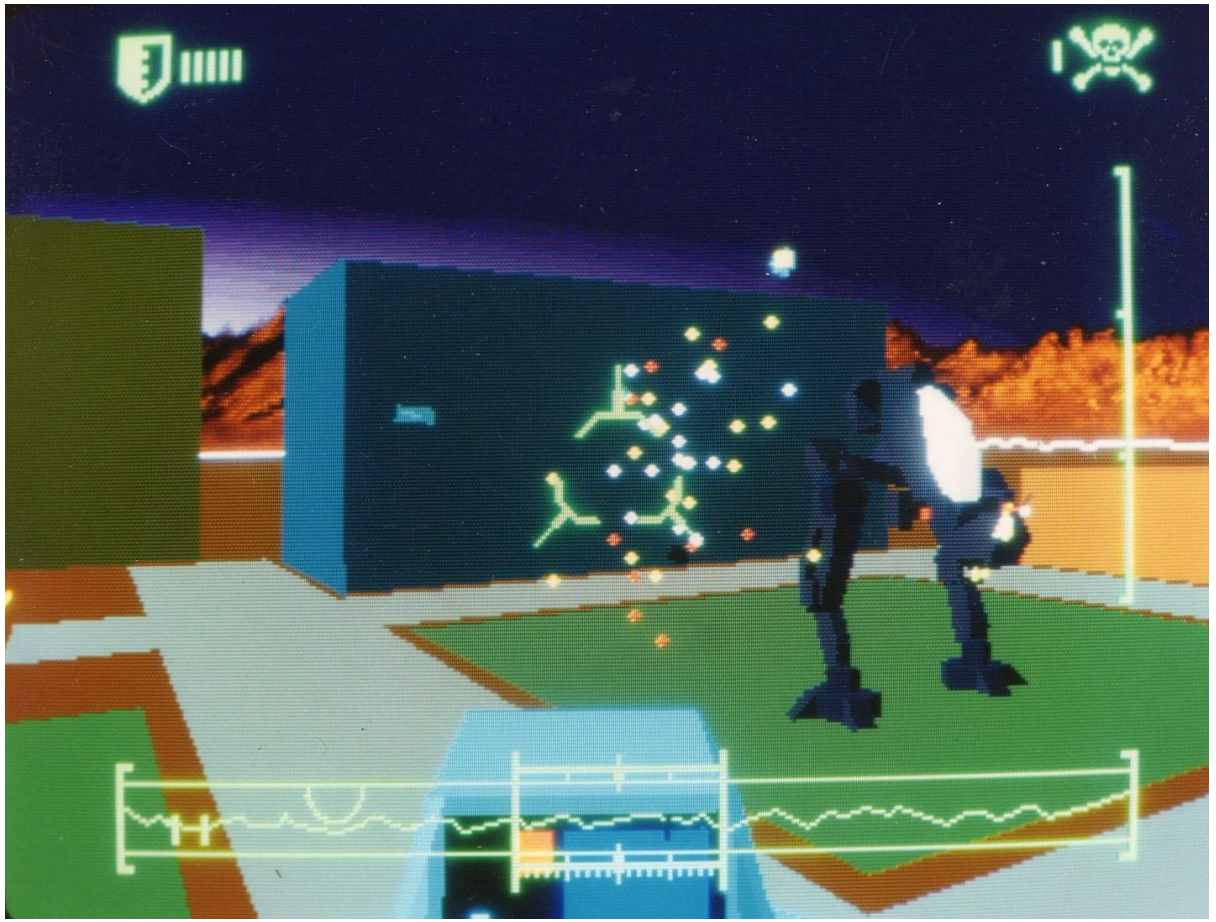
- Expensive - $150,000+
- 2 million polys/sec
- VGA HMD – 30 Hz
- Magnetic tracking



Rise of Commercial VR Companies

- Virtual Boy (1995 – 1996)
  - Nintendo's console
- W Industries/Virtuality (1985 - 97)
  - Location based entertainment
- Virtuality VR Arcades
  - Division (1989 – 1998)
- Virtual i-O (1993 -1997)
  - Inexpensive gamer HMDs
- Sense8 (1990 - 1998)
  - WorldToolKit, WorldUp
- VR authoring tools

Virtuality VR (1992)
Game: Exorex



- https://www.youtube.com/watch?v=1Qe4suqGZmU

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

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^{o} FOV

The Oculus Kickstarter Video

- https://www.youtube.com/watch?v=hxptk8P15TI

Desktop VR in 2016

- Graphics Desktop
  - $1500 USD
  - >4 Billion poly/sec
- $600 HMD
  - 1080x1200, 90Hz
- Optical tracking
  - Room scale

2016 - Rise of Consumer HMDs

Oculus Rift

HTC/Valve Vive

Playstation VR

HTC Vive

- Room scale tracking
- Gesture input devices

Example Vive App – Tilt Brush

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

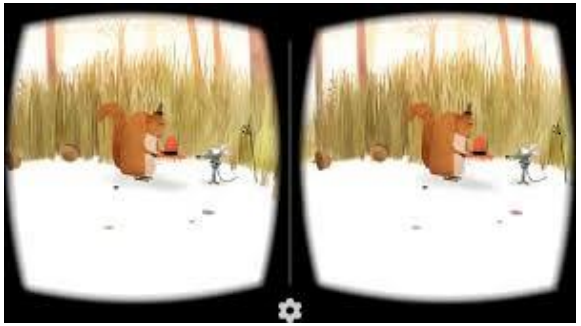
VR2GO (2013)

- 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

+

=

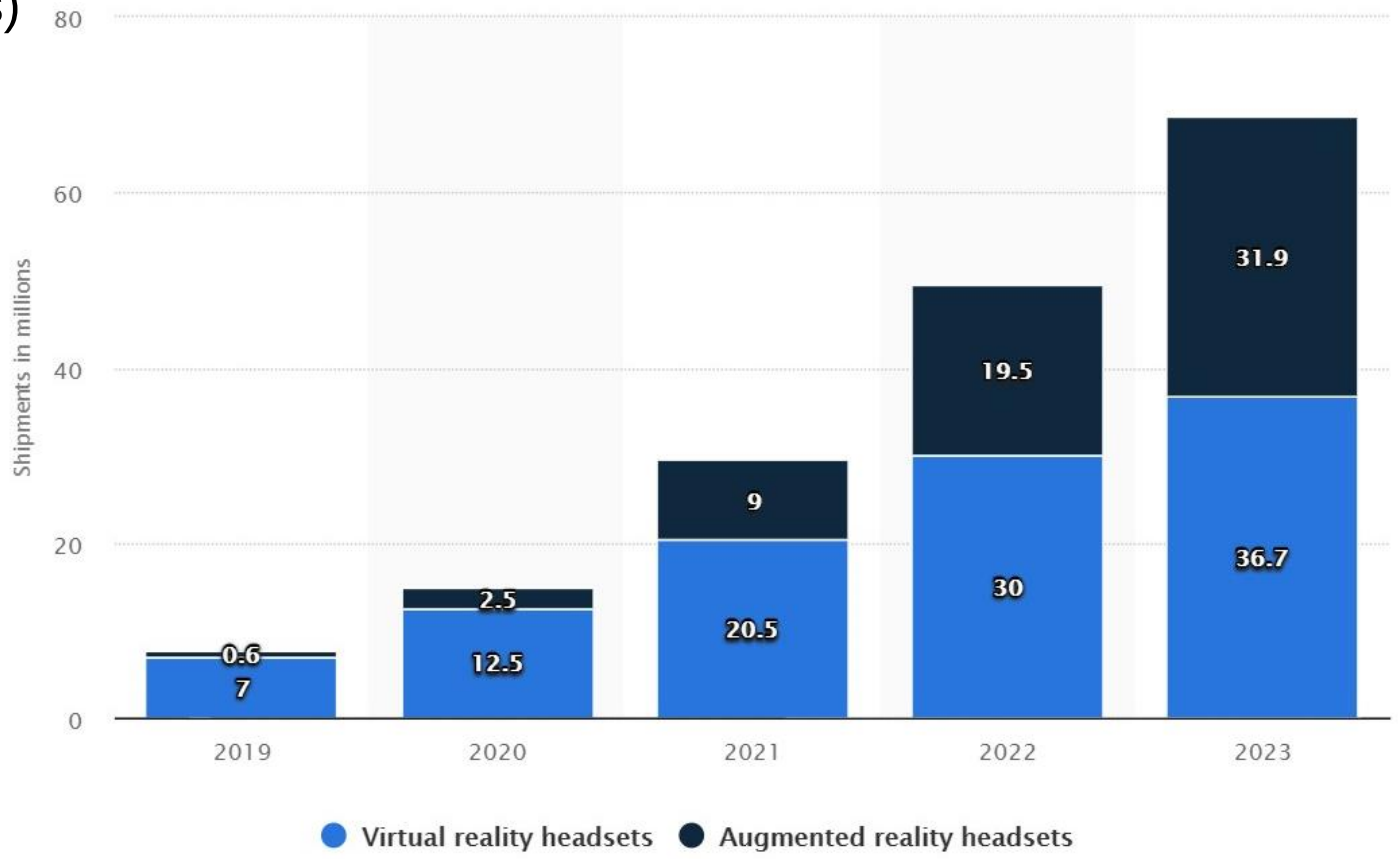


- Released 2014
  - From Google 20% side project incentive
- >5 million shipped/given away
- Easy to use developer tools

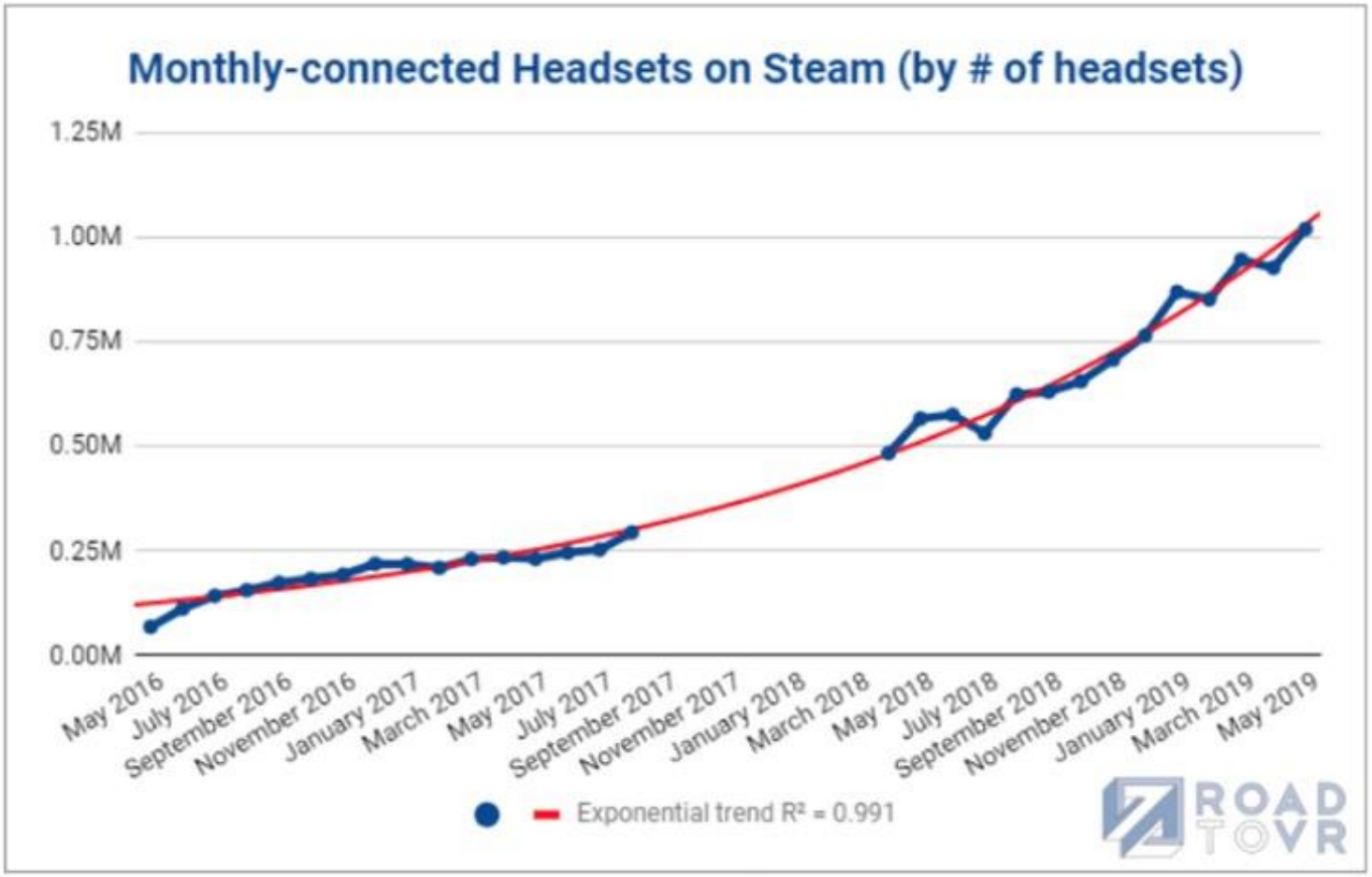
Multiple Mobile VR Viewers Available

Projected HMD Sales

Forecast unit shipments of AR and VR headsets from 2019 to 2023 (in millions)

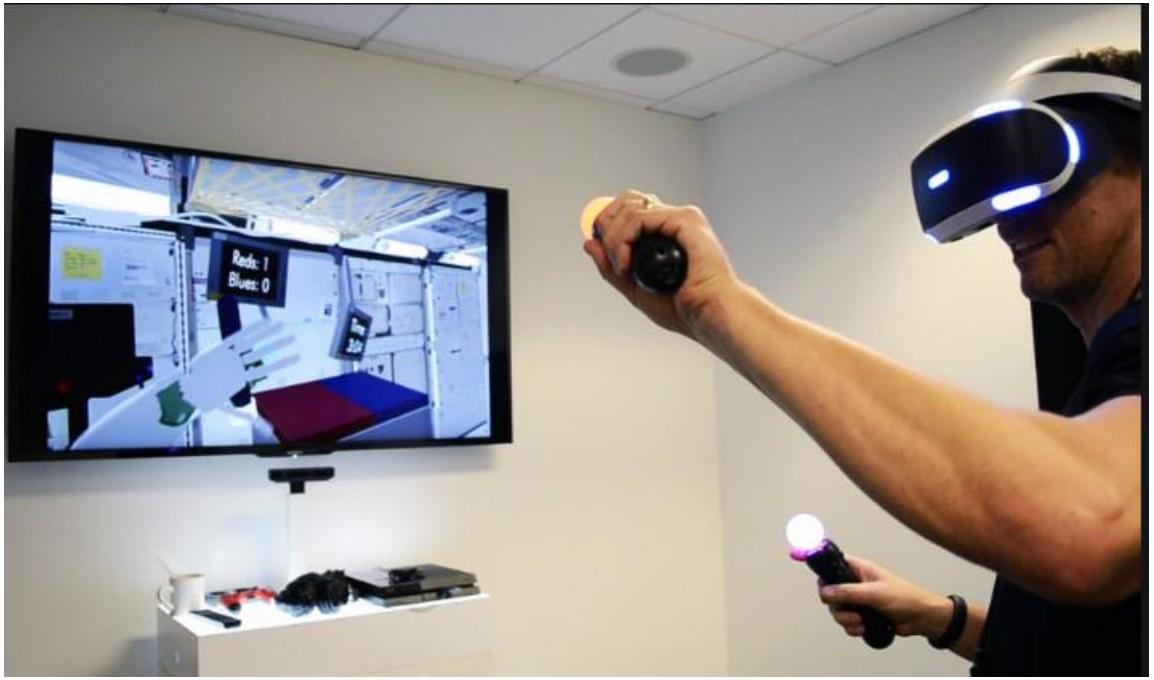


Market size – PC Steam



Data gap from seven months of data misreported by Valve

Market size – Playstation VR



As of March 3, 2019, **PlayStation VR** has sold-through **over 4.2 million units** worldwide.

THE VR FUND H2 2017 VR INDUSTRY LANDSCAPE

Why 2020s won't be like the 1990s

- 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: <u>Focus on User Experience and Natural User Interfaces (NUI)</u>**

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, portable HMDs
  - Large commercial investment, Significant installed user base