



北京交通大学



Human-Computer Interaction (HCI) and Virtual Reality (VR)

Welcome to the 1st course of ↑
Welcome to the 2nd course of ↑

3 weeks online → Chinese
16 weeks online → English

2nd Semester, Spring 2022

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Associate Professor

School of Software Engineering

Beijing Jiaotong University



北京交通大学



In the course, you will experience these



EUOE
6000 RMB
? AR glass

50 - 300

50 - 150

50 - 150

100 - 150

120 - 150

Pico 2499 RMB

Oculus 2799 RMB



1: price 139 VR

2: 3 weeks after offline work

In teams by 2 , Top 5 Team →



(44) 22 Teams



GPU 800 RMB
1,600 +
800 RMB
HTC VR Headset

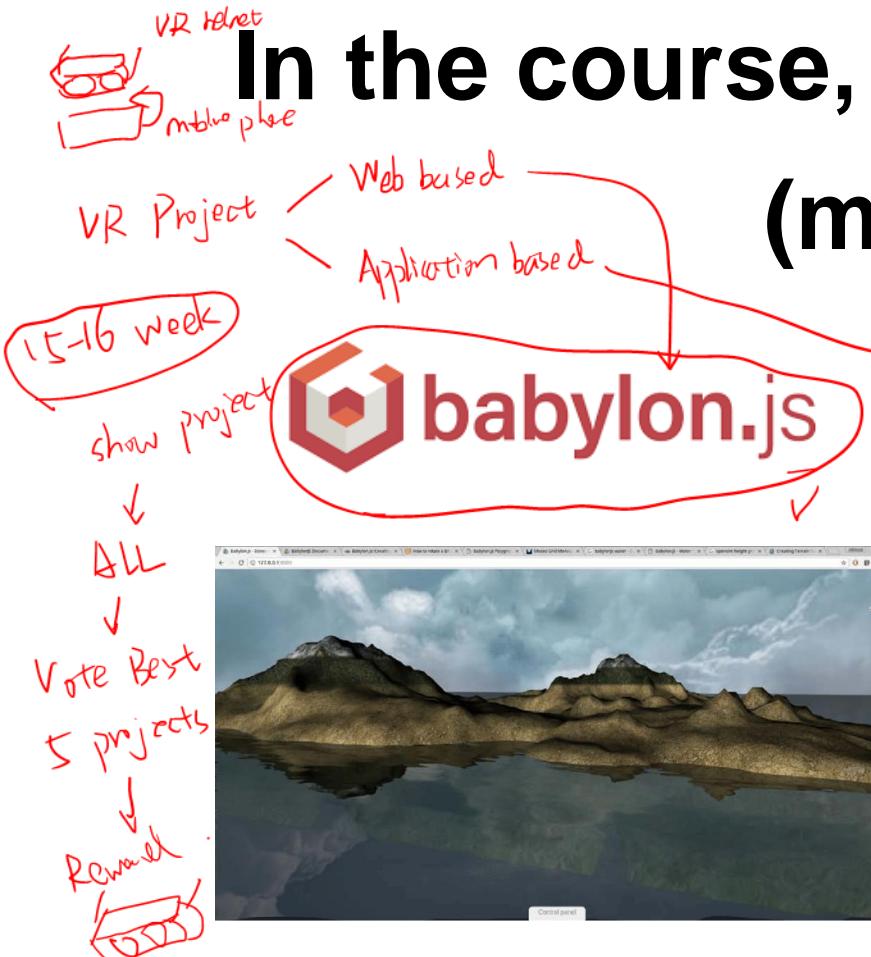
Gift
Helmet plus



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Project 2/1 Students in a Team



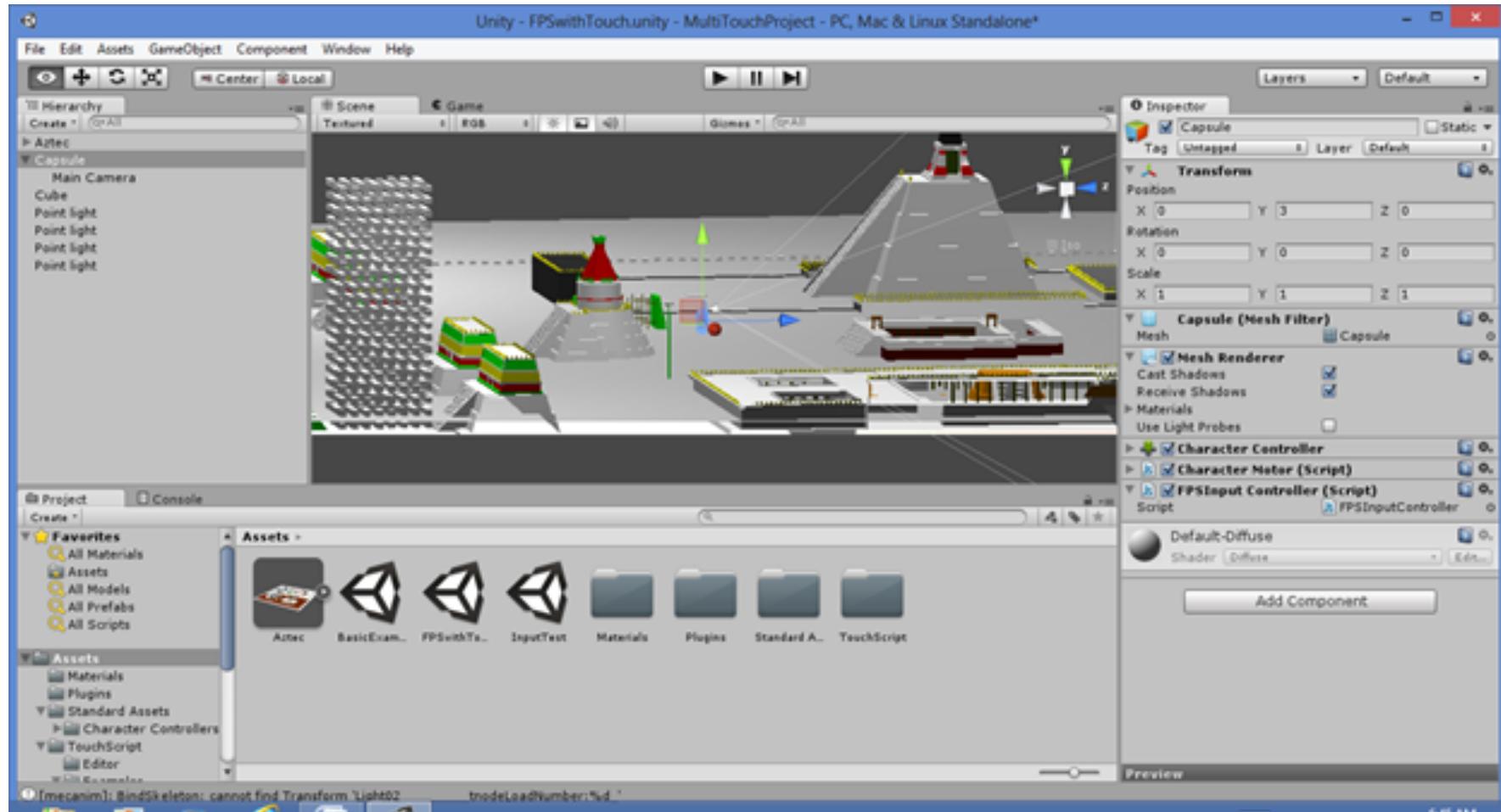
In the course, you will try these (maybe)



Overview

- Introduction ✓ → VR
- Class Overview ✓
- What is Virtual Reality ✓
- History of Virtual Reality ✓
- Introduction to Human Perception ✓

Unity3D – www.unity3d.com



- Who has Unity3D Experience?

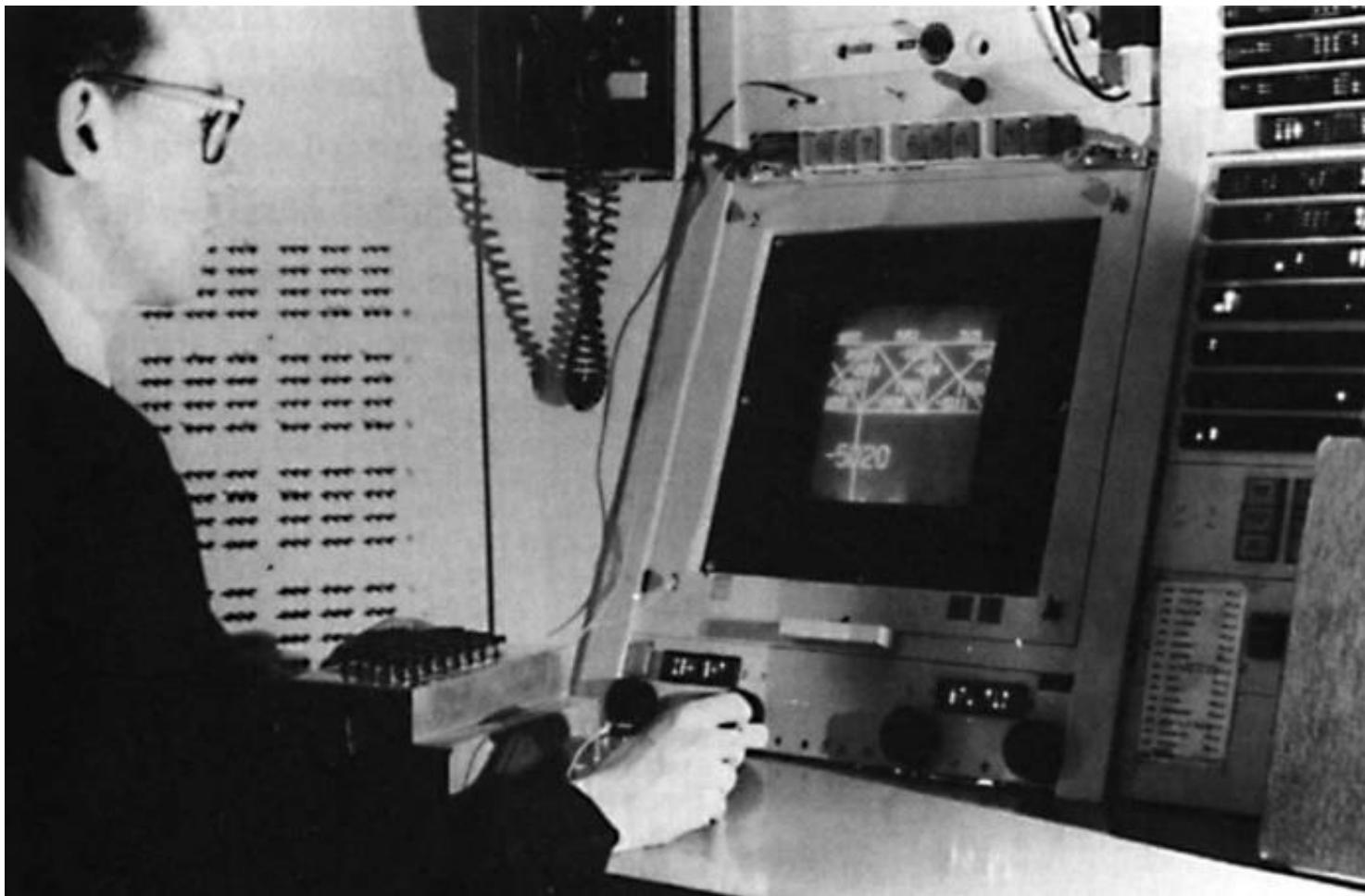
8 students
26 students

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
- https://www.youtube.com/watch?v=6orsmFndx_o&t=447s

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”.

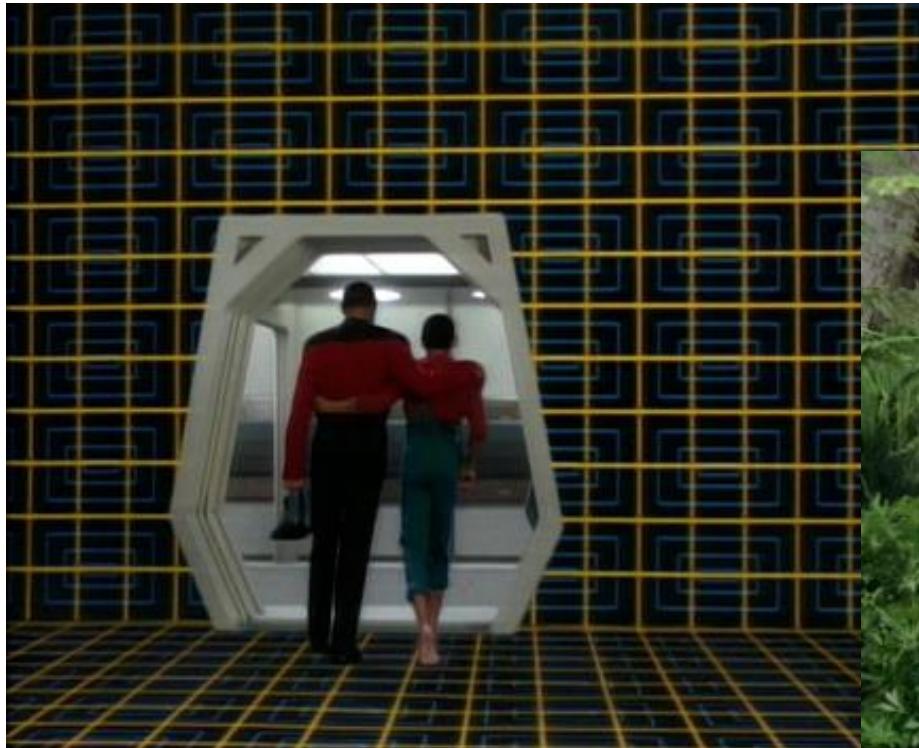
Ivan Sutherland, 1965

An Invisible Interface



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

Holodeck (1974)

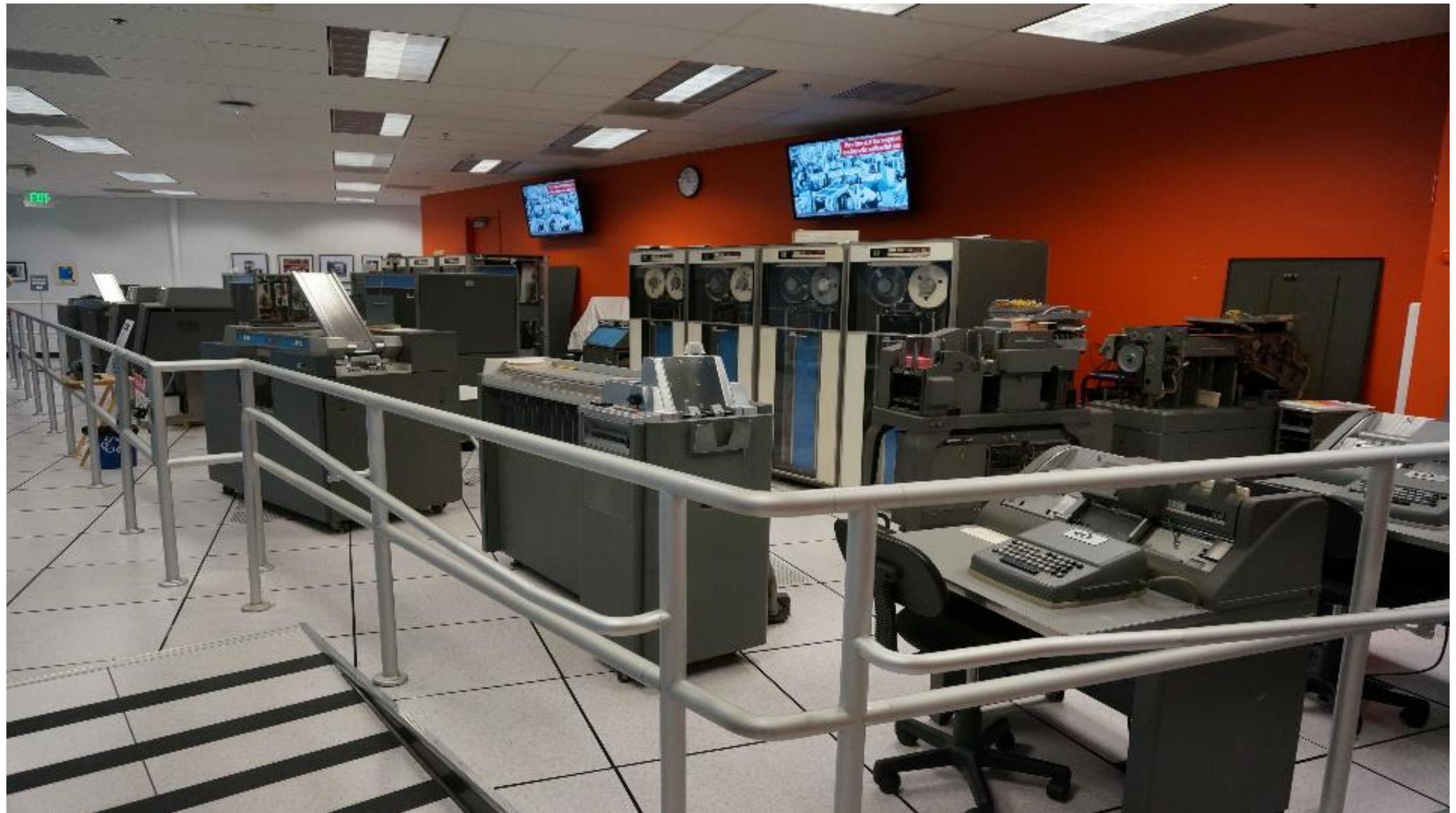


- First shown in Star Trek; The Animated Series

HoloDeck Video



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



1967 – IBM 1401 – half of the computers in the world, \$10,000/month to run

The Incredible Disappearing Computer



1960-70's



1970-80's



1980-90's



1990-2000's



Room

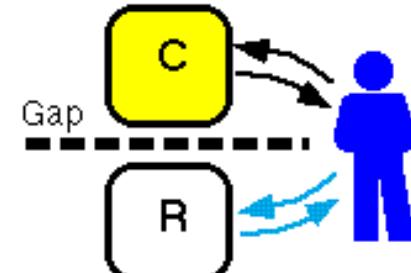
Desk

Lap

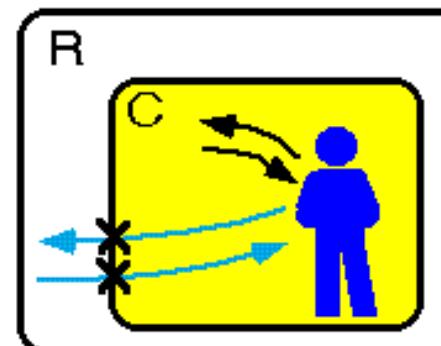
Hand

2022
↓ 10 Years
2032

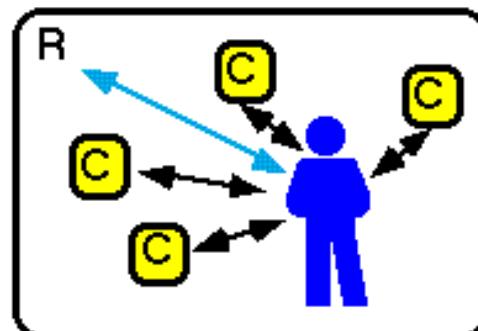
Making Interfaces Invisible



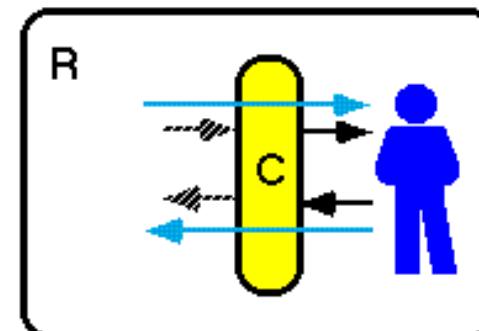
(a) GUI



(b) Virtual Reality



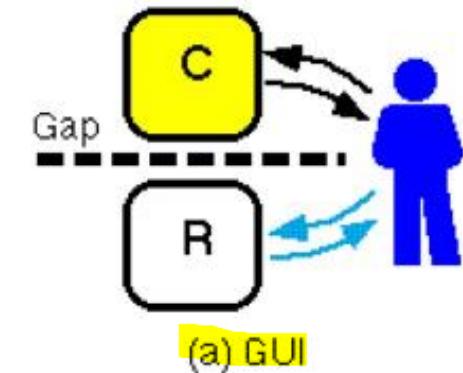
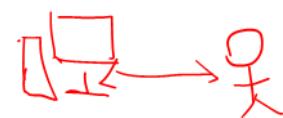
(c) Ubiquitous Computers



(d) Augmented Interaction

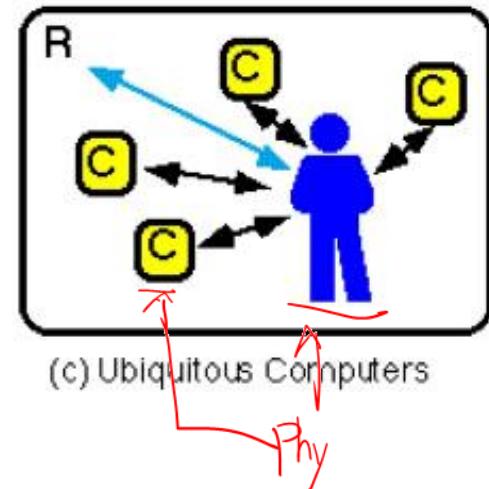
Rekimoto, J. and Nagao, K. 1995. The world through the computer: computer augmented interaction with real world environments. In *Proceedings of the 8th Annual ACM Symposium on User interface and Software Technology. UIST '95*. ACM, New York, NY, 29-36.

Graphical User Interfaces



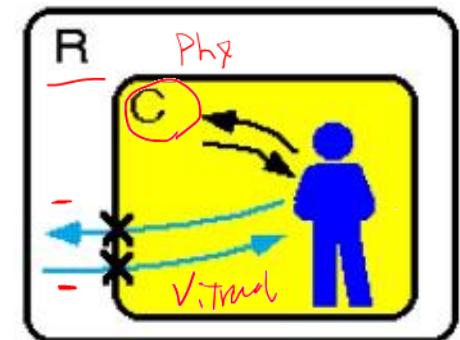
- Separation between real and digital worlds
 - WIMP (Windows, Icons, Menus, Pointer) metaphor

Ubiquitous Computing/IoT



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

Virtual Reality



(b) Virtual Reality

GUI Untergr VR.

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

What is Virtual Reality?

virtual reality

noun

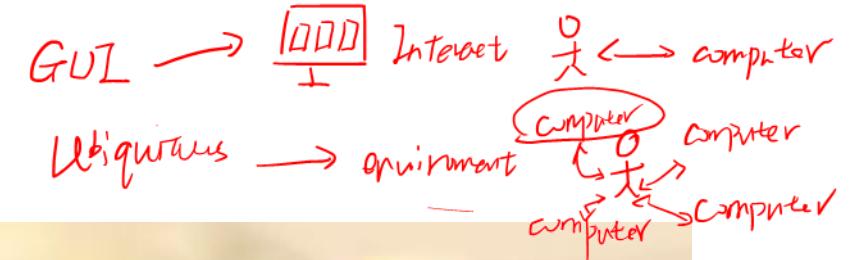
Simple Definition of VIRTUAL REALITY

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

Typical VR System



- <https://www.youtube.com/watch?v=eJCIyf8Kn9w>

Many Other Definitions

Virtual reality is... ← *Unified Def*

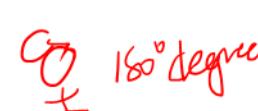
a computer technology that replicates an environment, real or imagined, and simulates a user's physical presence and environment to allow for user interaction. ([Wikipedia](#))

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](#))

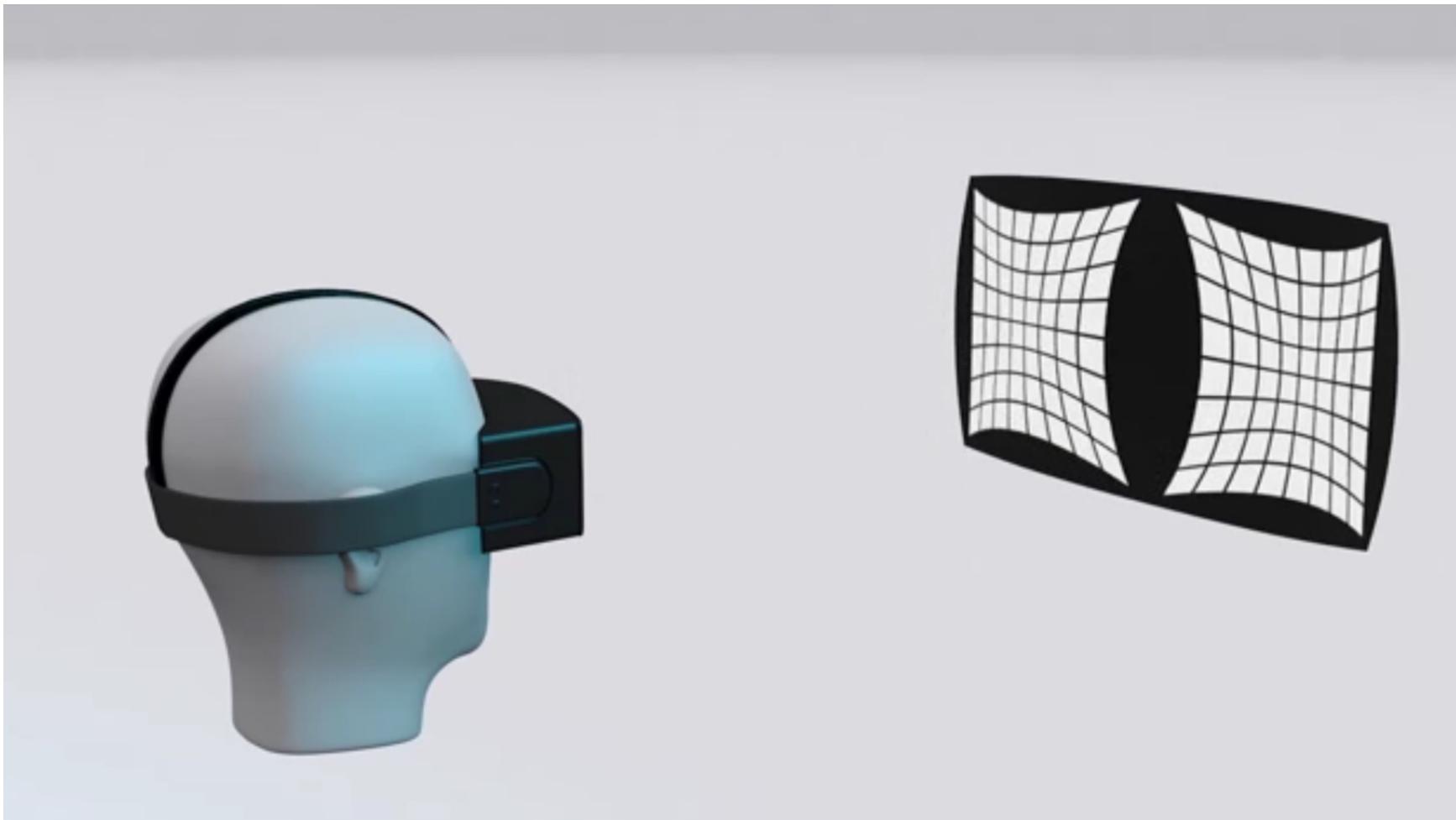
an alternate world filled with computer-generated images that respond to human movements. ([Greenbaum, 1992](#))

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



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

VR Experience

1st
VR Experience



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

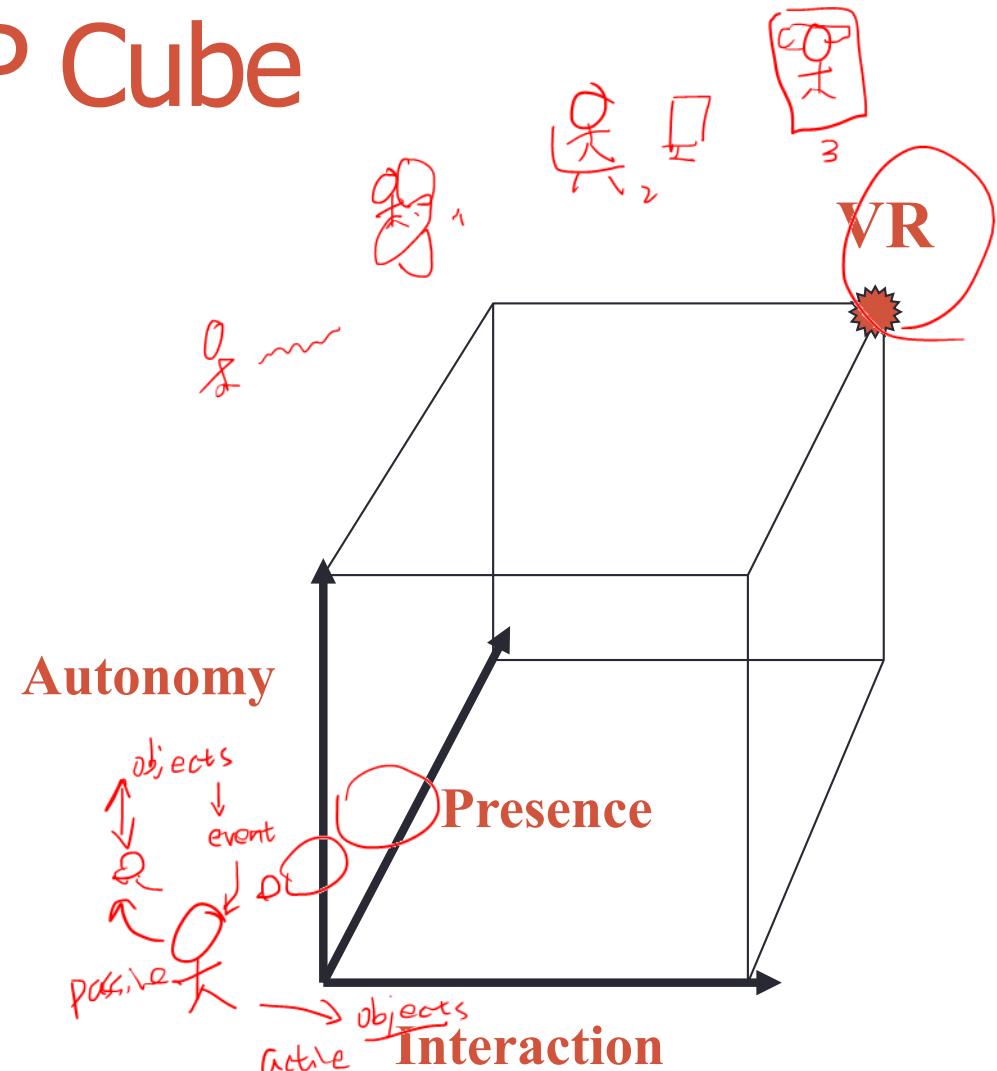
Defined in Terms of Presence

Real

- 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.

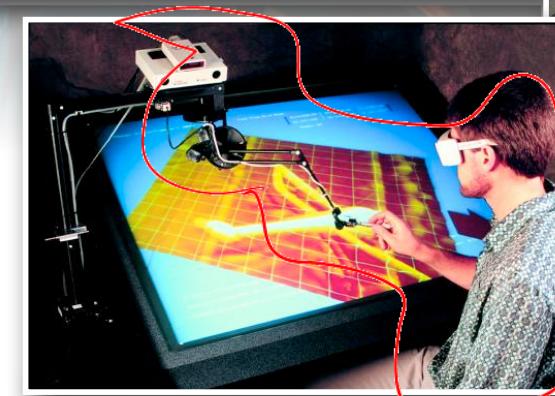
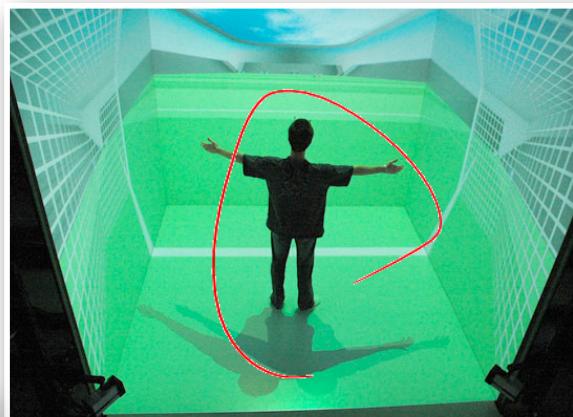
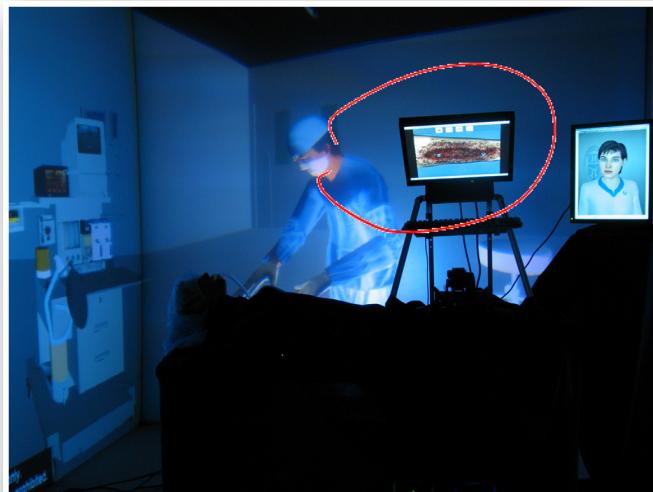
David Zeltzer's AIP Cube

- **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

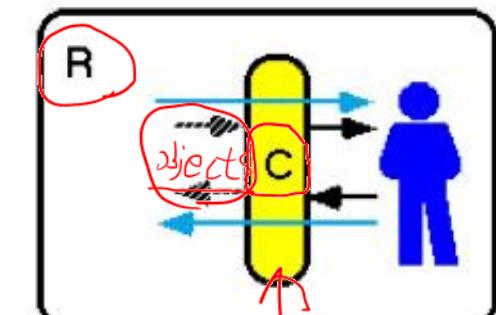
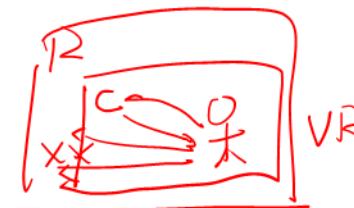


Zeltzer, D. (1992). Autonomy, interaction, and presence. *Presence: Teleoperators & Virtual Environments*, 1(1), 127-132.

Types of VR



Augmented Reality



(d) Augmented Interaction

VR
AR



- Virtual Images blended with the real world
 - See-through HMD, handheld display, viewpoint tracking, etc..

VR 1974 K. Wodeck

Augmented Reality in Science Fiction

AR



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

1977 → AR → 2008 → Wld. → 2022 → Gamified application
30 Years
14 Years
AR application popular for 1~2 years

Metaverse
Meta



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

Augmented Reality Examples



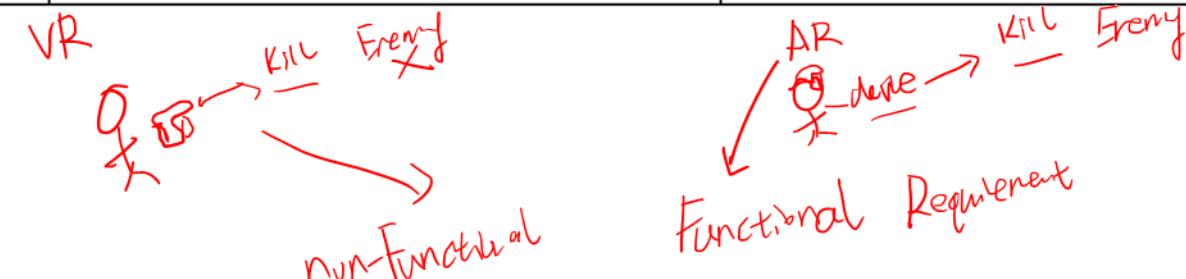
AR Colouring Example - Quiver



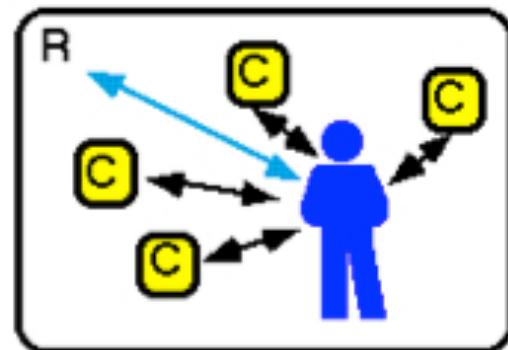
<https://www.youtube.com/watch?v=aUPMDwypBkA>

AR vs VR

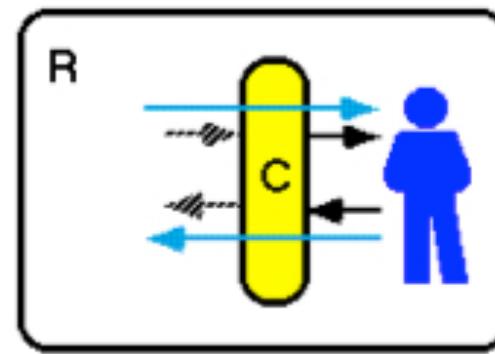
	Virtual Reality <u>Replaces Reality</u>	Augmented Reality <u>Enhances Reality</u>
<u>Scene Generation</u> ✓	Requires <u>realistic</u> <u>images</u>	Minimal <u>rendering</u> okay
<u>Display Device</u> ✓	<u>Fully immersive, wide</u> <u>field of view</u>	<u>Non-immersive, small</u> <u>field of view</u>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



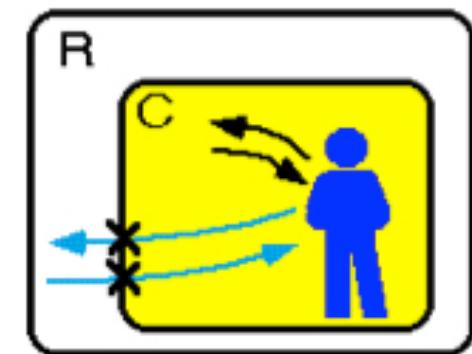
From Reality to Virtual Reality



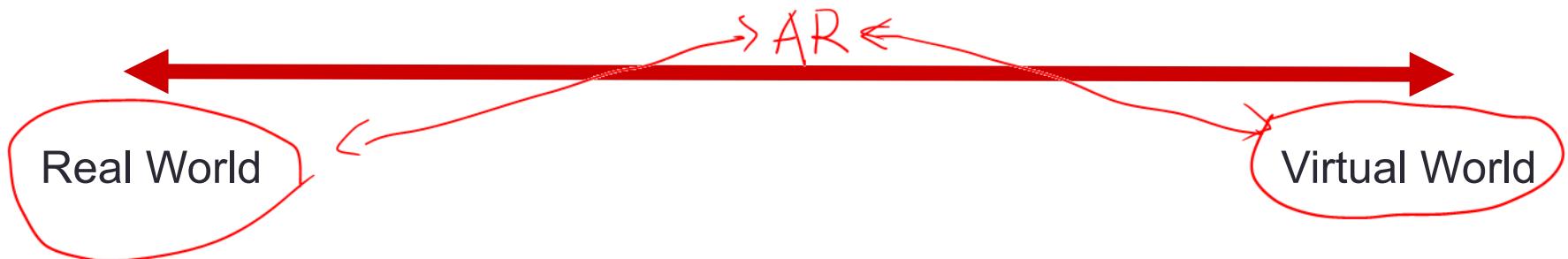
Ubiquitous Computing



Augmented Reality

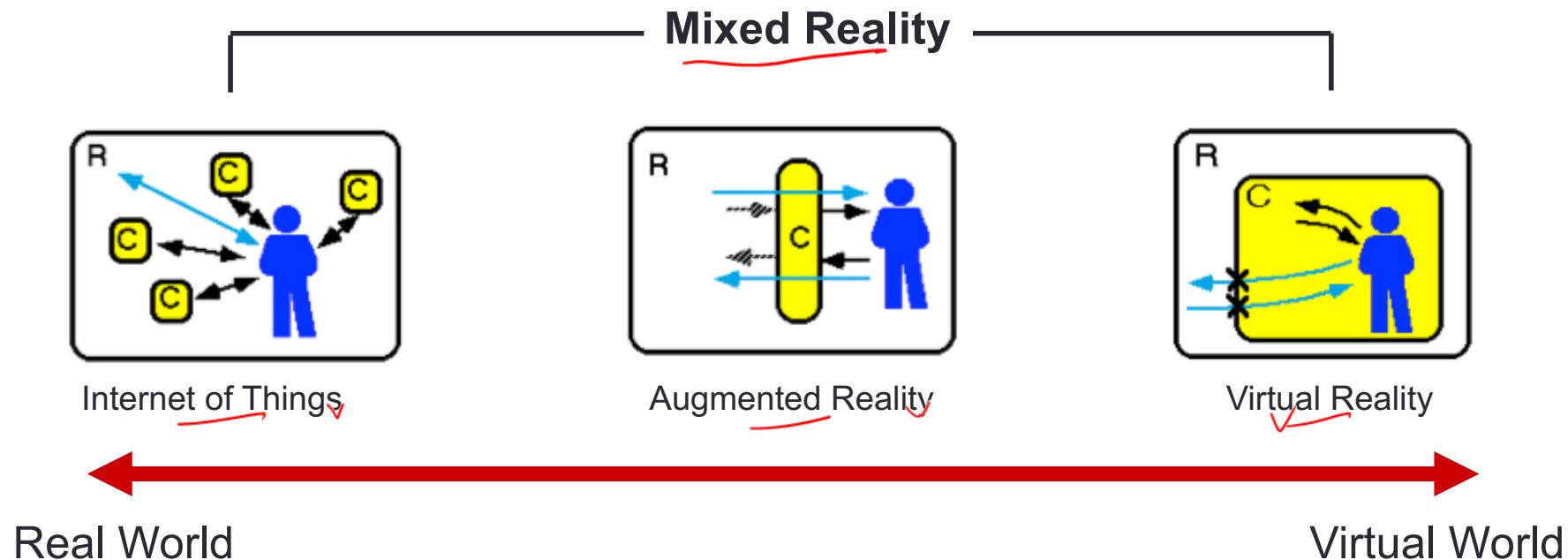


Virtual Reality



Milgram's Mixed Reality (MR) Continuum

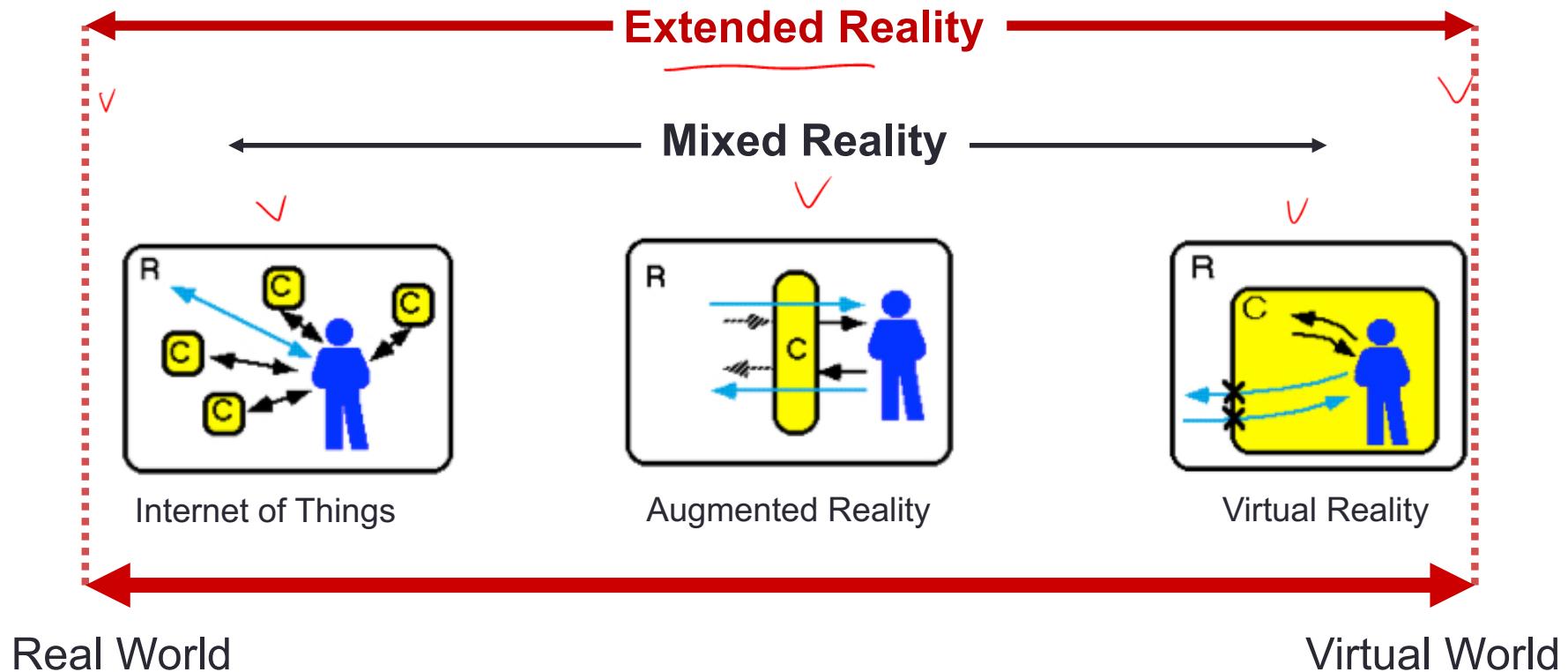
$$MR = AR + VR + IoT$$



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

P. Milgram and A. F. Kishino, (1994) A Taxonomy of Mixed Reality Visual Displays

Extended Reality (XR)

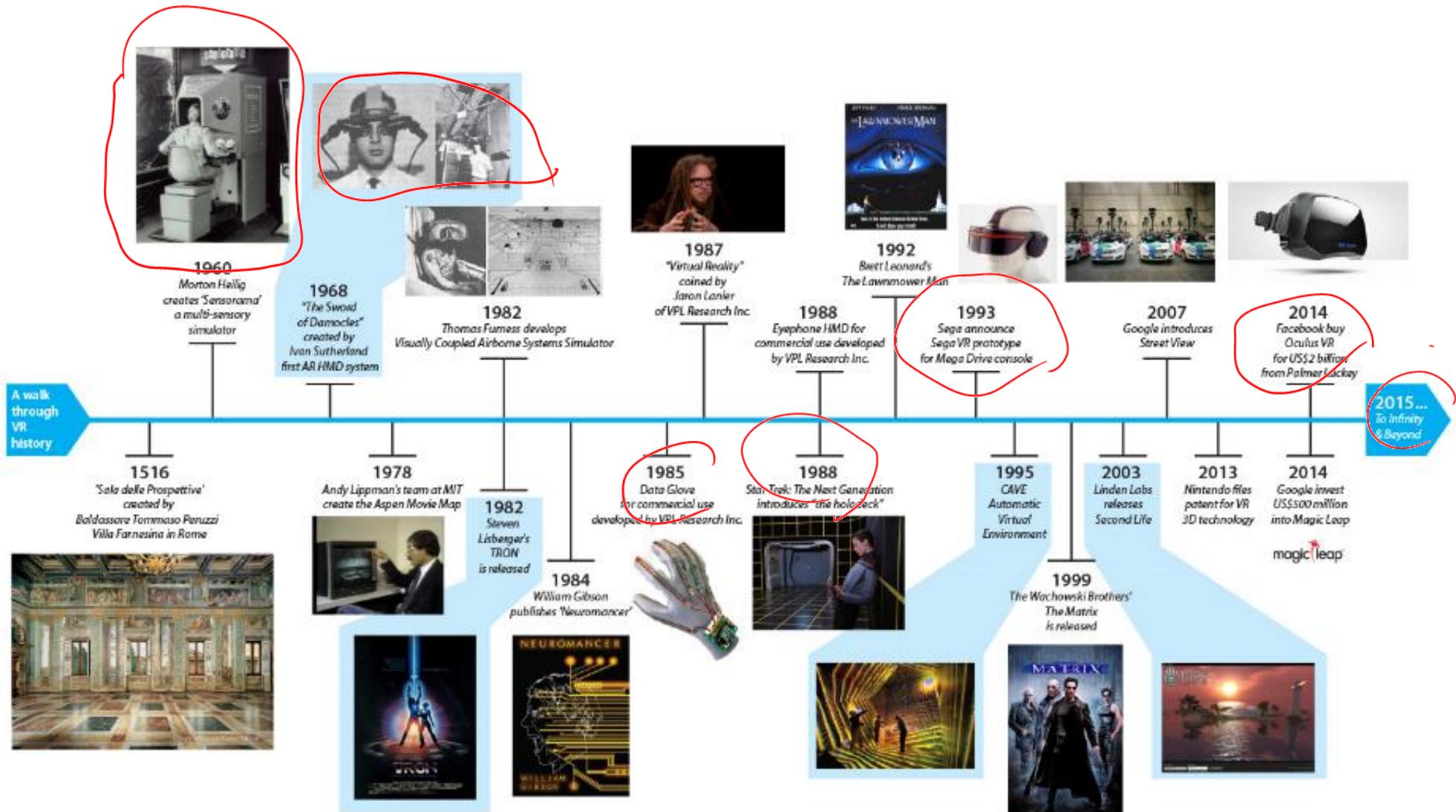


Summary

- 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



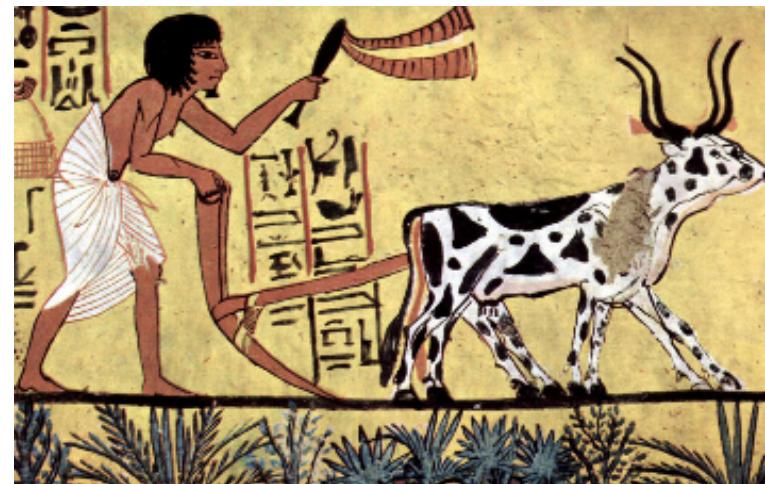
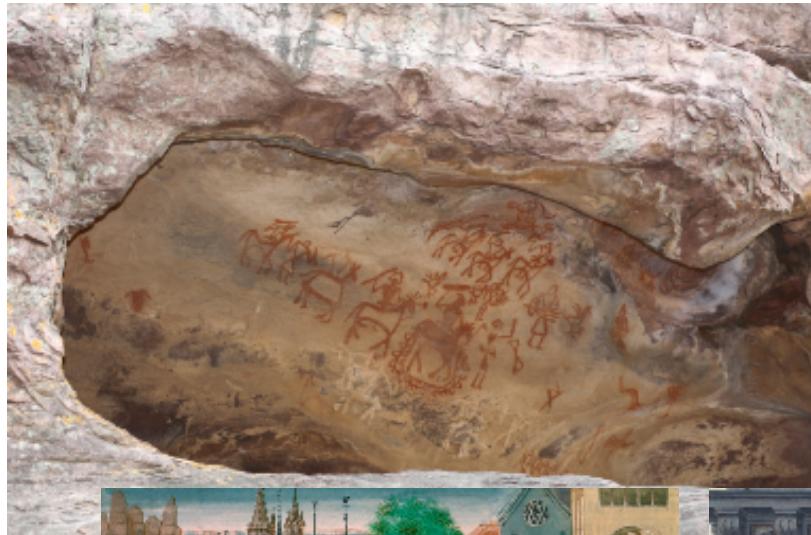
When anything new comes along, everyone, like a child discovering the world thinks that they've invented it, but you scratch a little and you find a caveman scratching on a wall is creating virtual reality in a sense.

What is new here is that more sophisticated instruments give you the power to do it more easily.

Virtual reality is dreams.

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



Brewster (1860)

Viewmaster (1939)



3D Cinema Golden Era (1950-60s)

Suggestion → 4) Chemical



4D Growth

→ 3D Cinema + interaction
(Push, hit)

5) Cinema

VR helnet



- 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



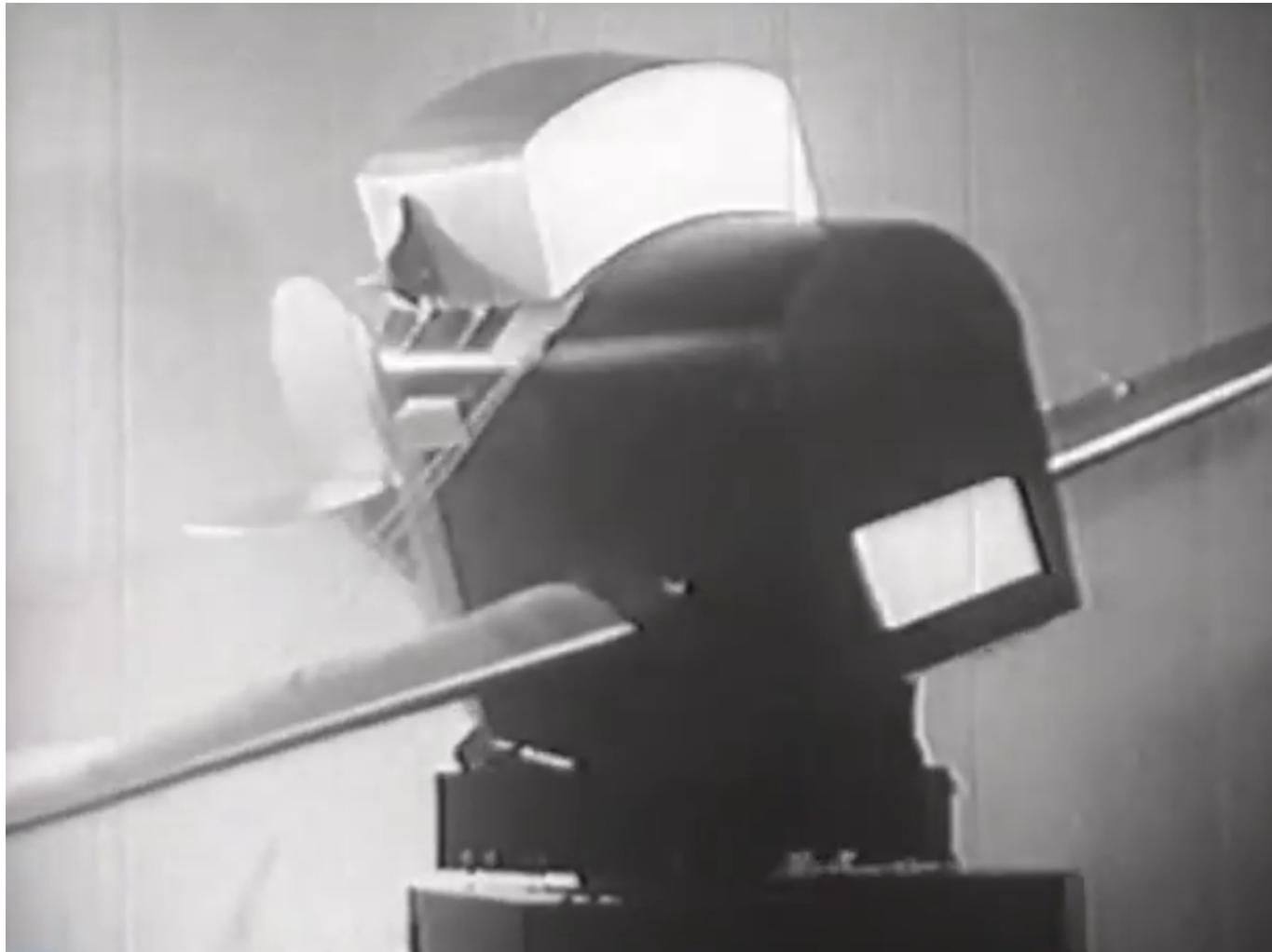
Link Trainer (1929 – 1950s)

VR
CyberSidenoss



- 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 (1940's)



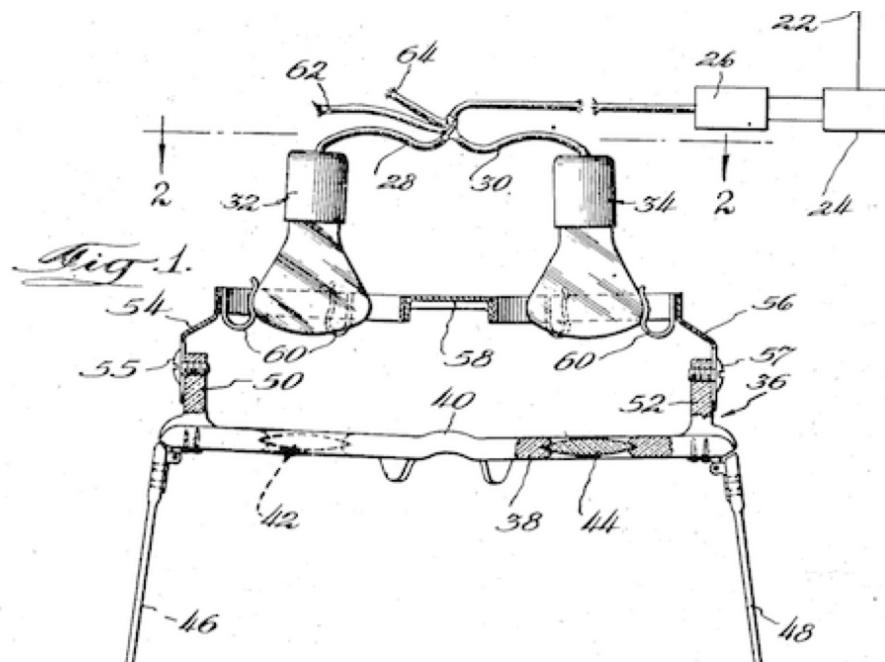
- <https://www.youtube.com/watch?v=MEKkVg9NqGM>

Sensorama (1955)

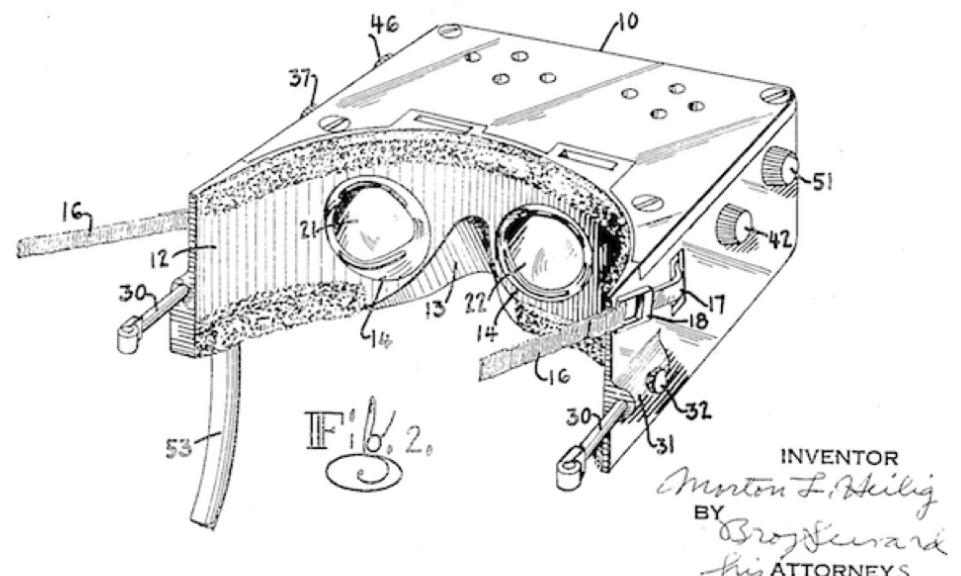
- Created by Morton Heilig
- Experience Theater
- Multi-sensory
 - Visuals
 - Sound
 - Wind
 - Vibration
 - Smell
- No financial support
 - Commercial failure



Early HMD Patents

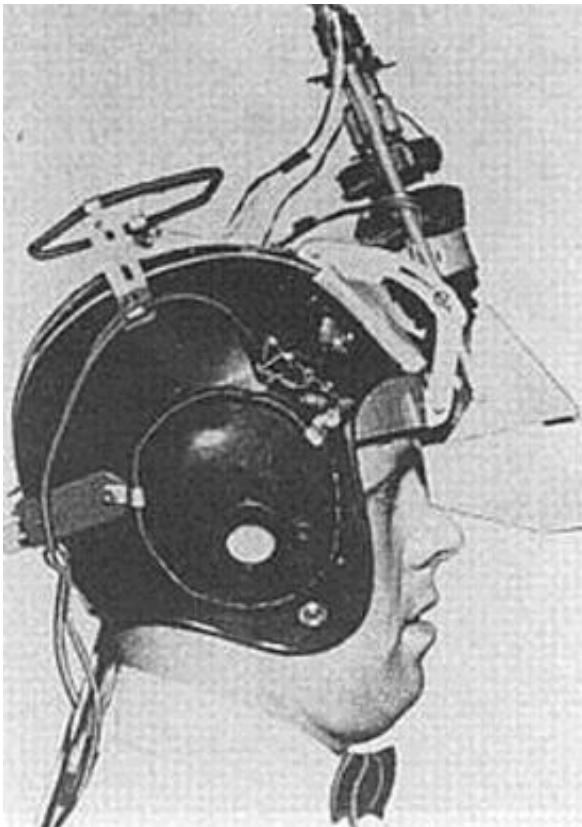


McCollum's Stereo TV HMD (1943)



Heilig's Multisensory HMD (1960)

Early HMDs (1960s)



Philco Headsight (1961)

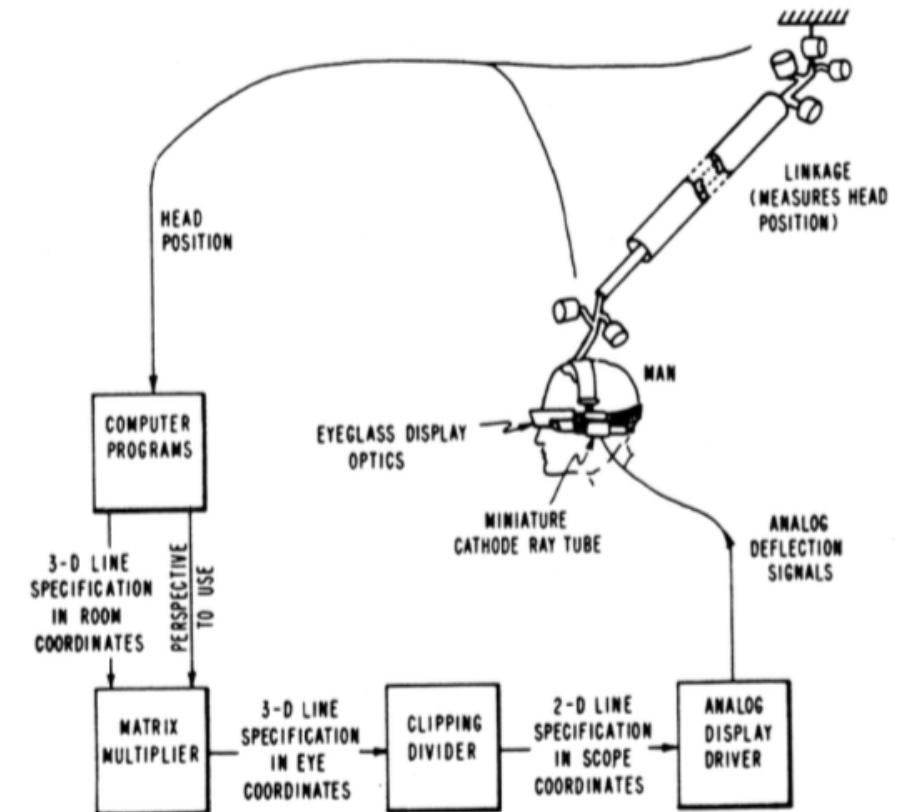
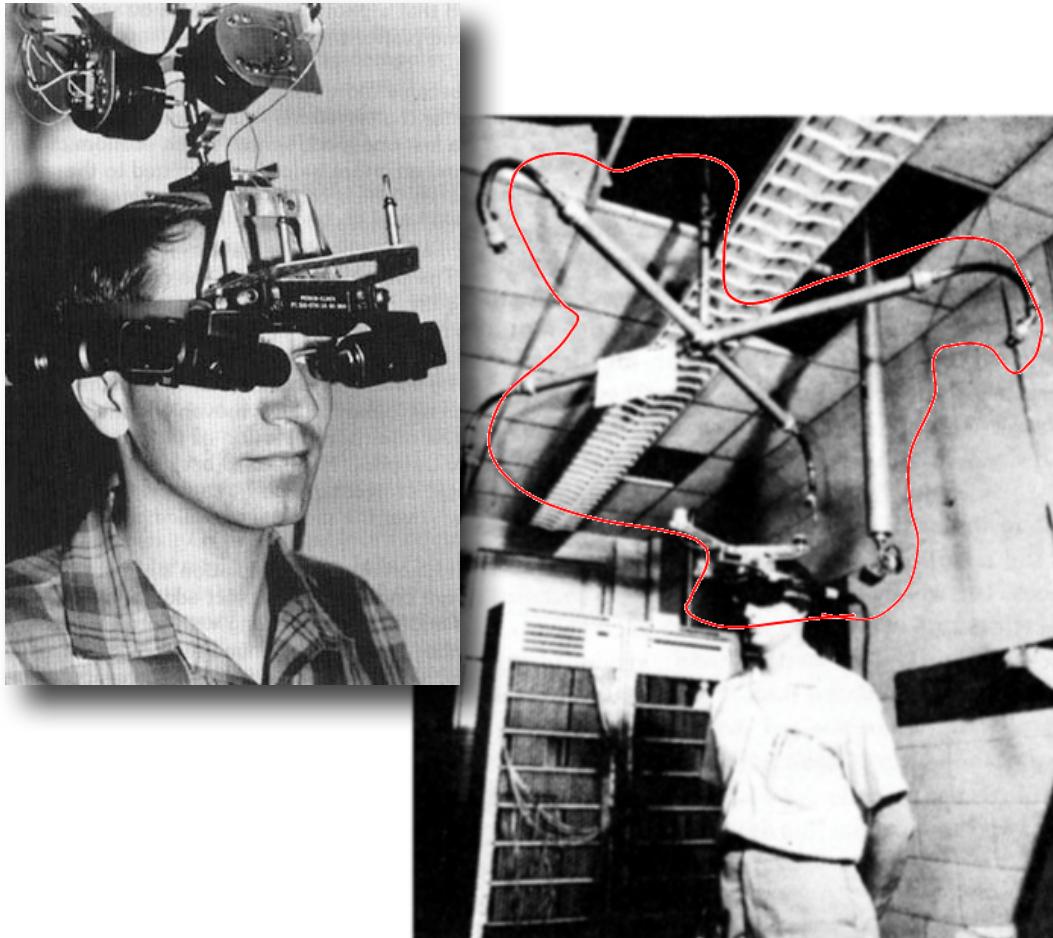


Harvard Viewer (1962)



Sutherland (1968)

Ivan Sutherland (1960s)



Ivan Sutherland's Head-Mounted Display (1968)

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

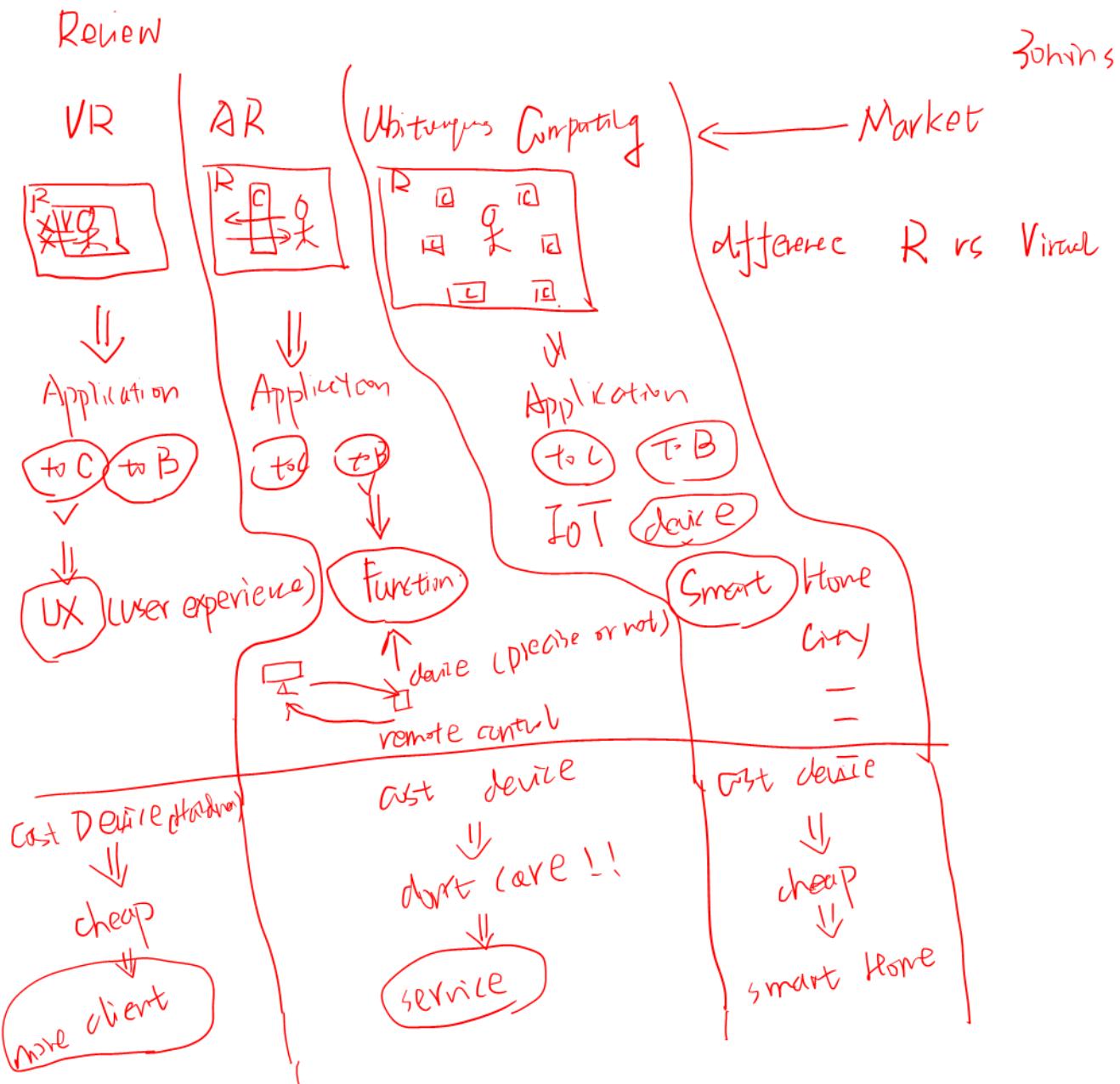
- Addressing pilot information overload

- Flight controls and tasks too complicated

- Research only

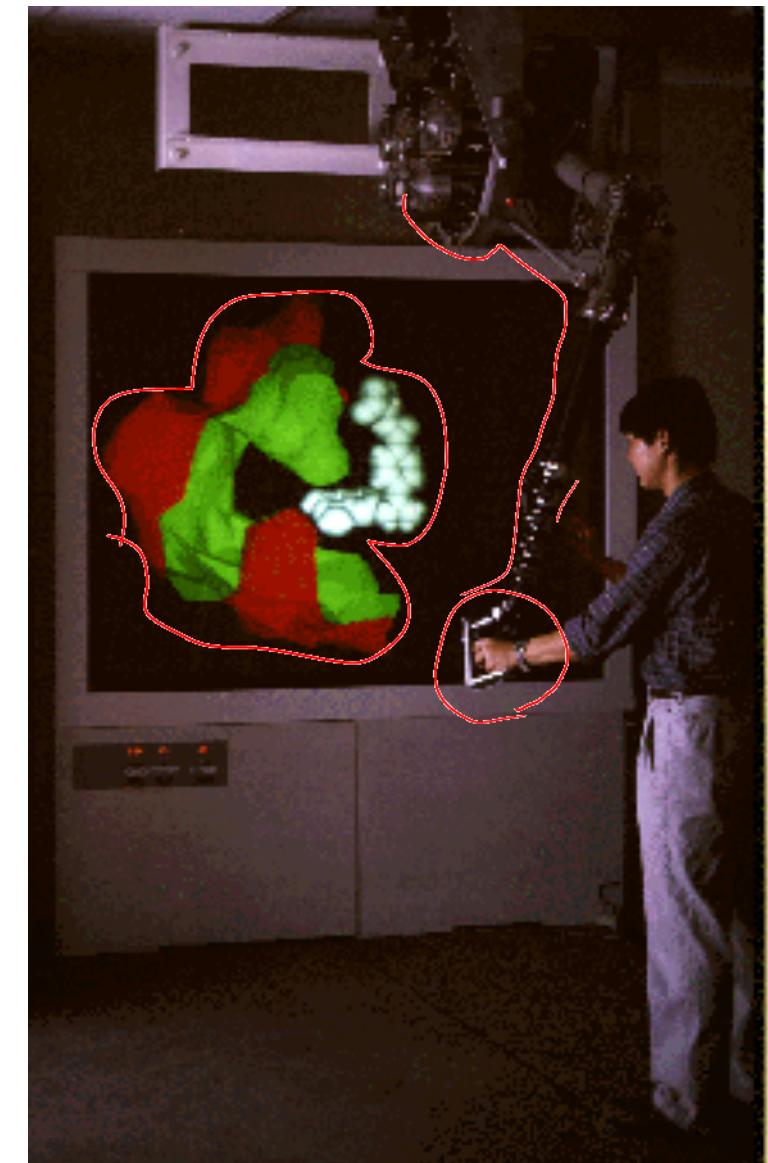
- big system, not safe for ejecting





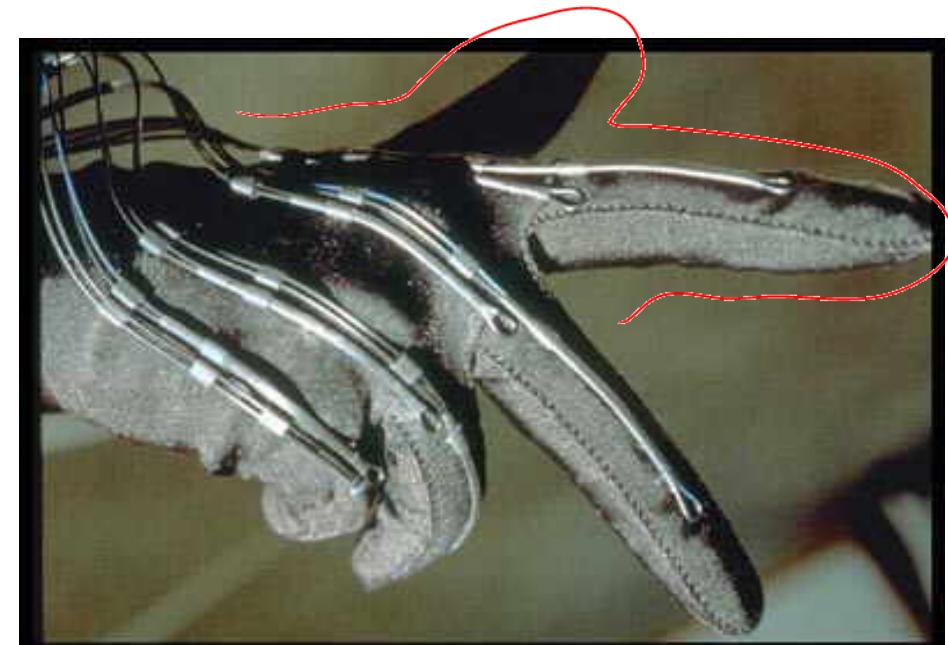
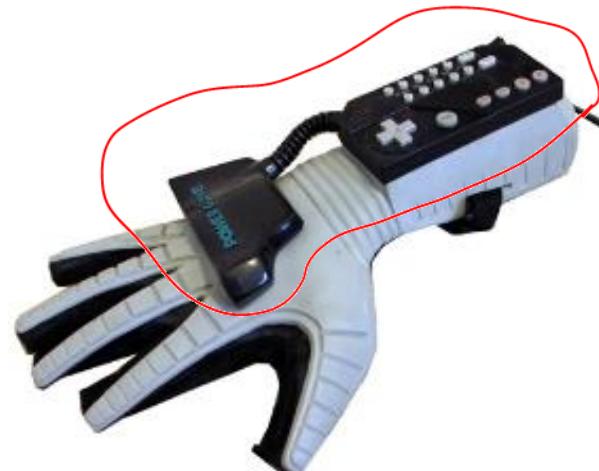
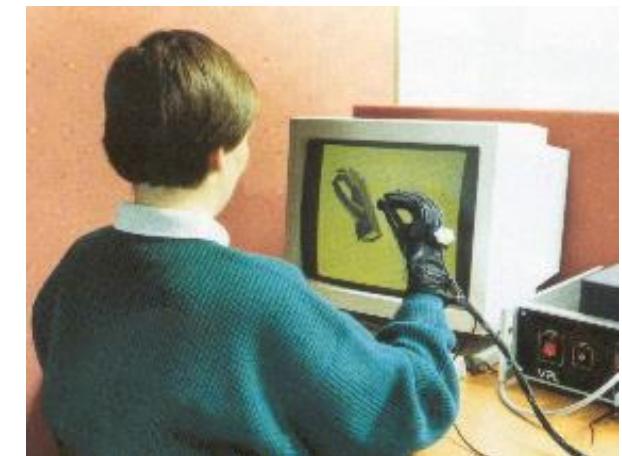
UNC Haptic Systems (1967 – 80's)

- 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

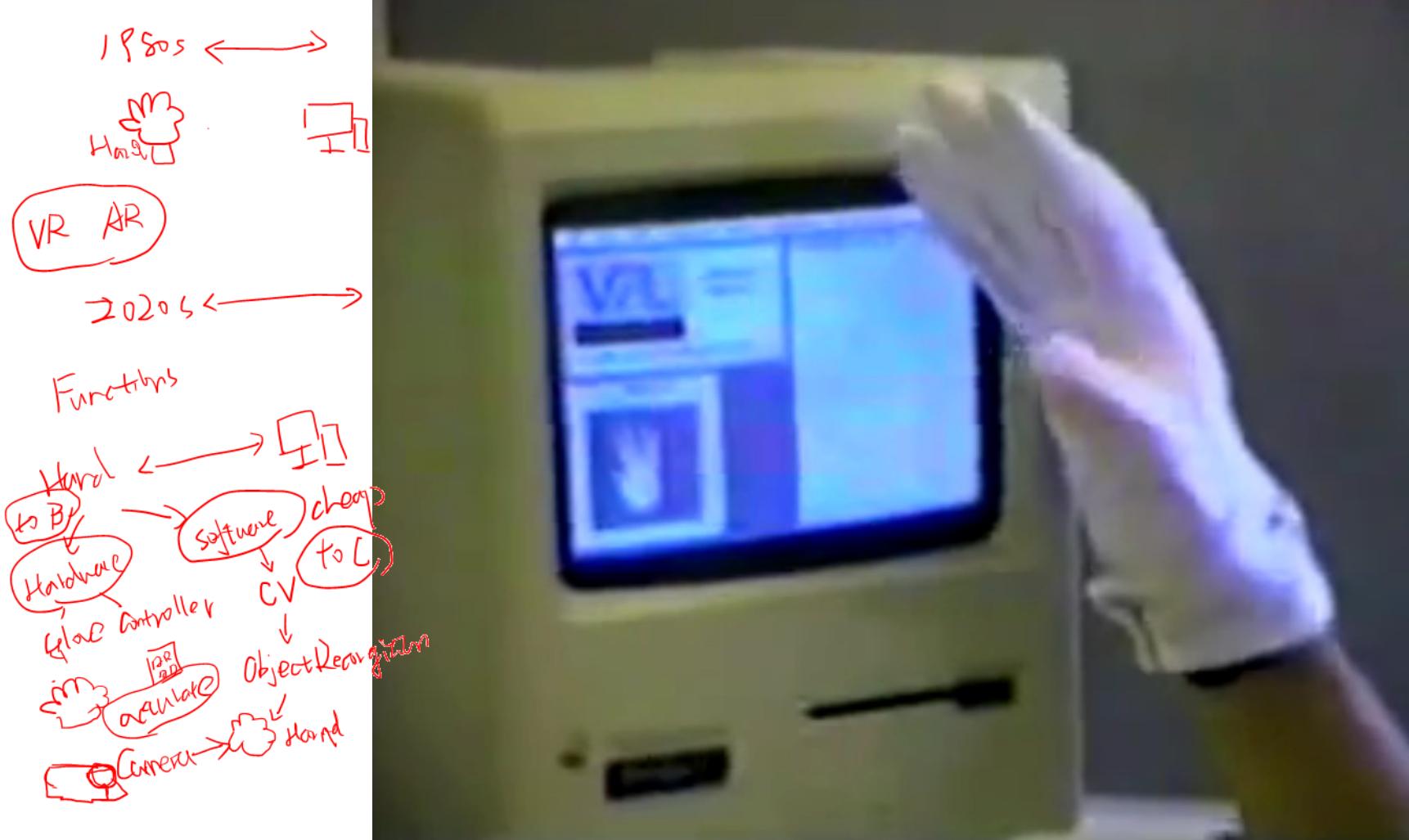


The Data Glove (1981-82)

- 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

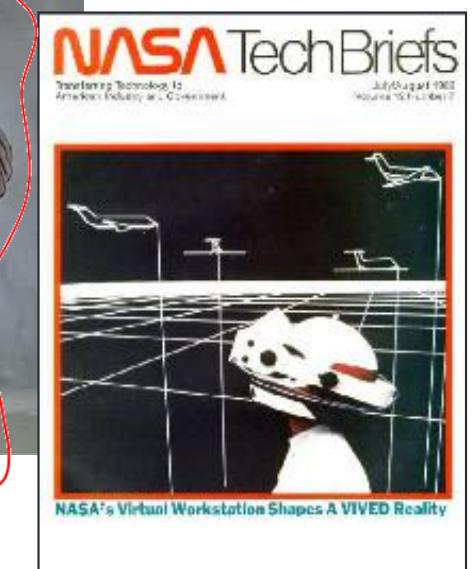


- <https://www.youtube.com/watch?v=fs3AhNr5o6o>

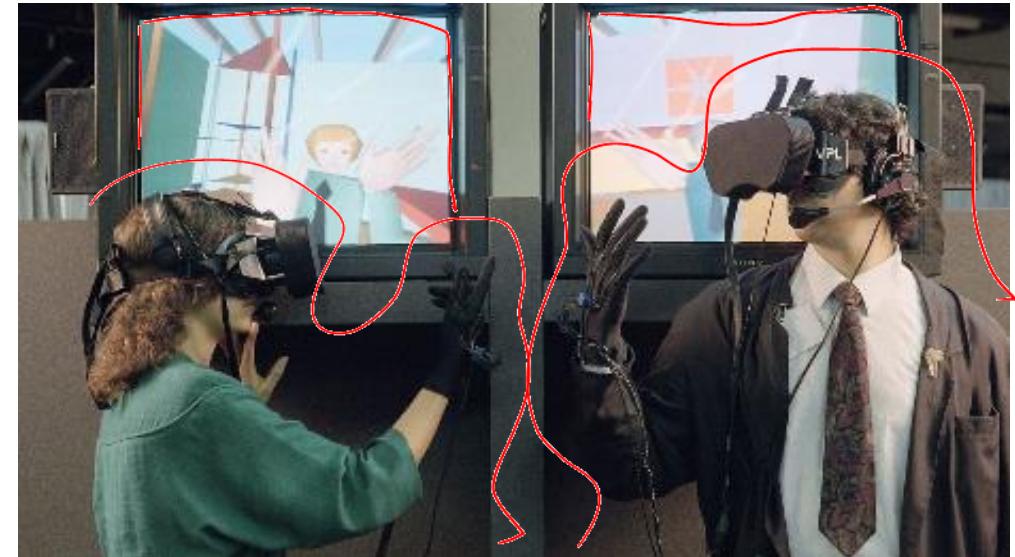
NASA VIEW/VIVED (1981-86)

- Early HMD (McGreevy Humphries)
 - LCD "Watchman" displays
- VIEW (Scott Fisher)
 - Polhemus tracker
 - Wide FOV HMD
 - Field of View*
 - 3D audio (Convolutron)
 - DataGlove gesture input
 - Simple graphics

1986
~~21 years~~
36 years



VPL Research (1985 – 1999)

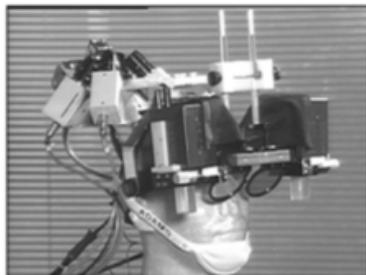


- First Commercial VR Company
 - Jaron Lanier, Jean-Jacques Grimaud
- Provided complete systems
 - Displays, software, gloves, etc
 - DataGlove, EyePhone, AudioSphere



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

UNC



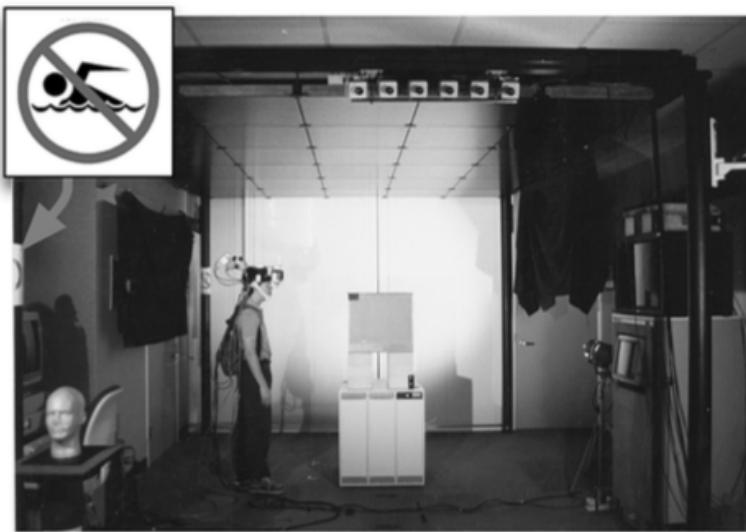
(a)



(b)



(c)



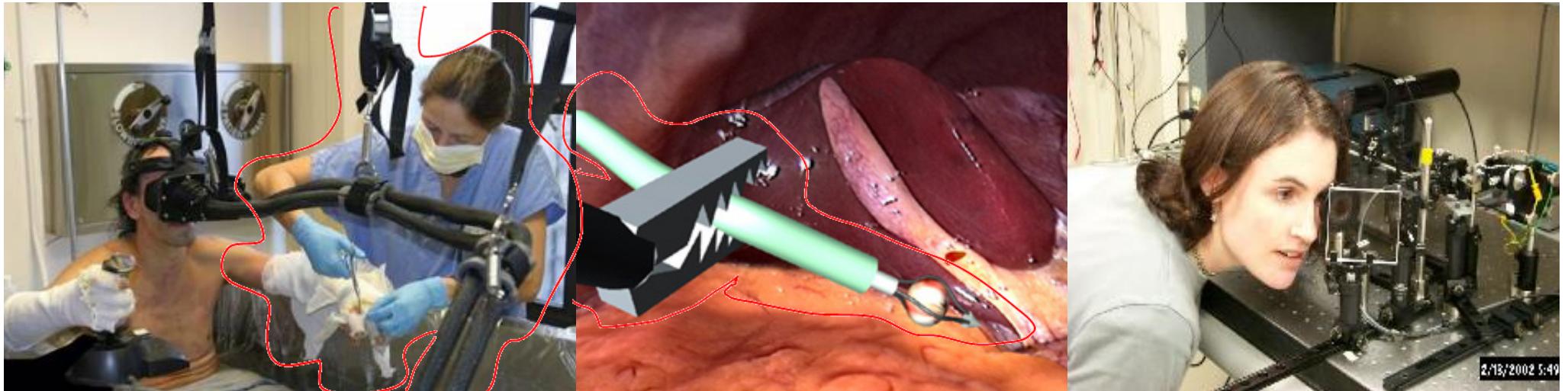
(e)



Head-Mounted Displays
Tracking, Haptics, Applications

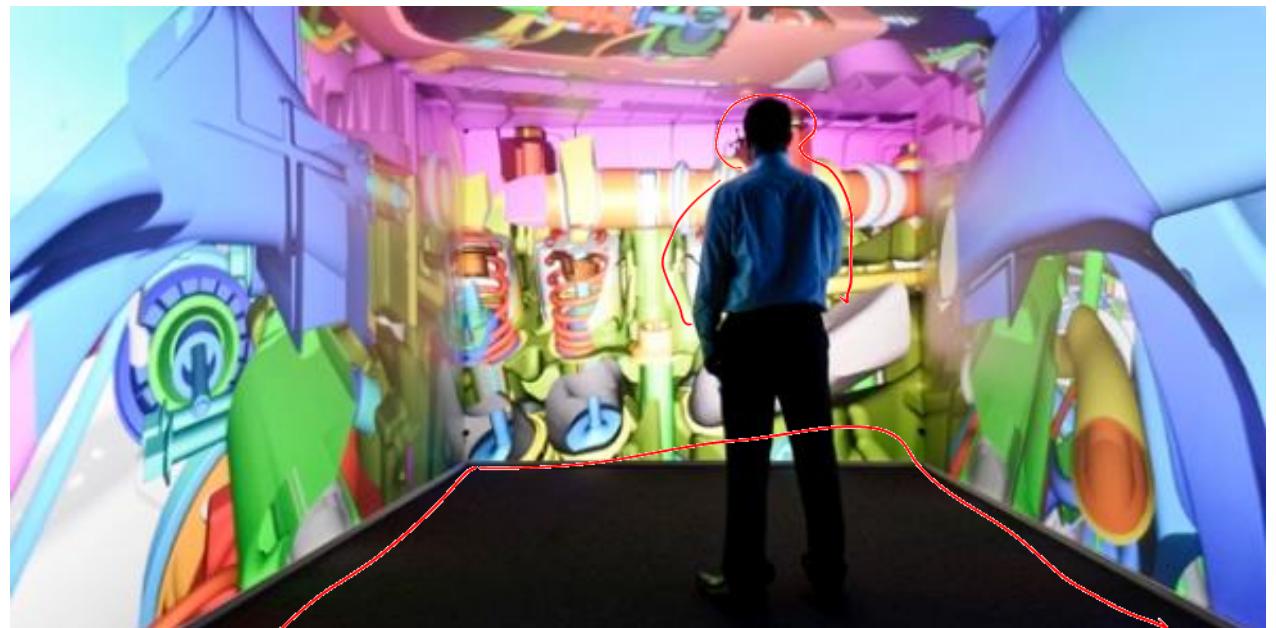
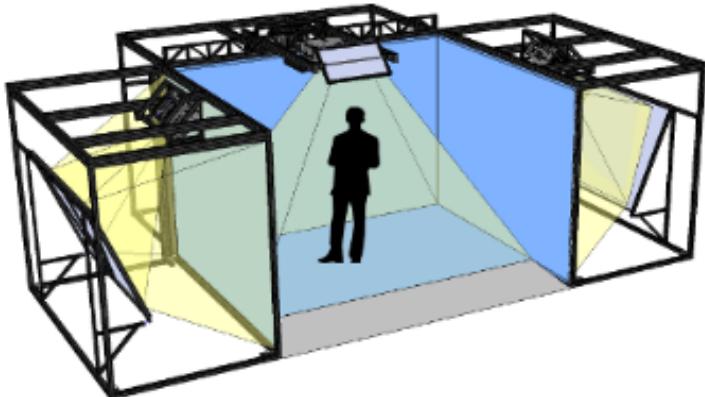
VR & AR \Rightarrow Medical

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

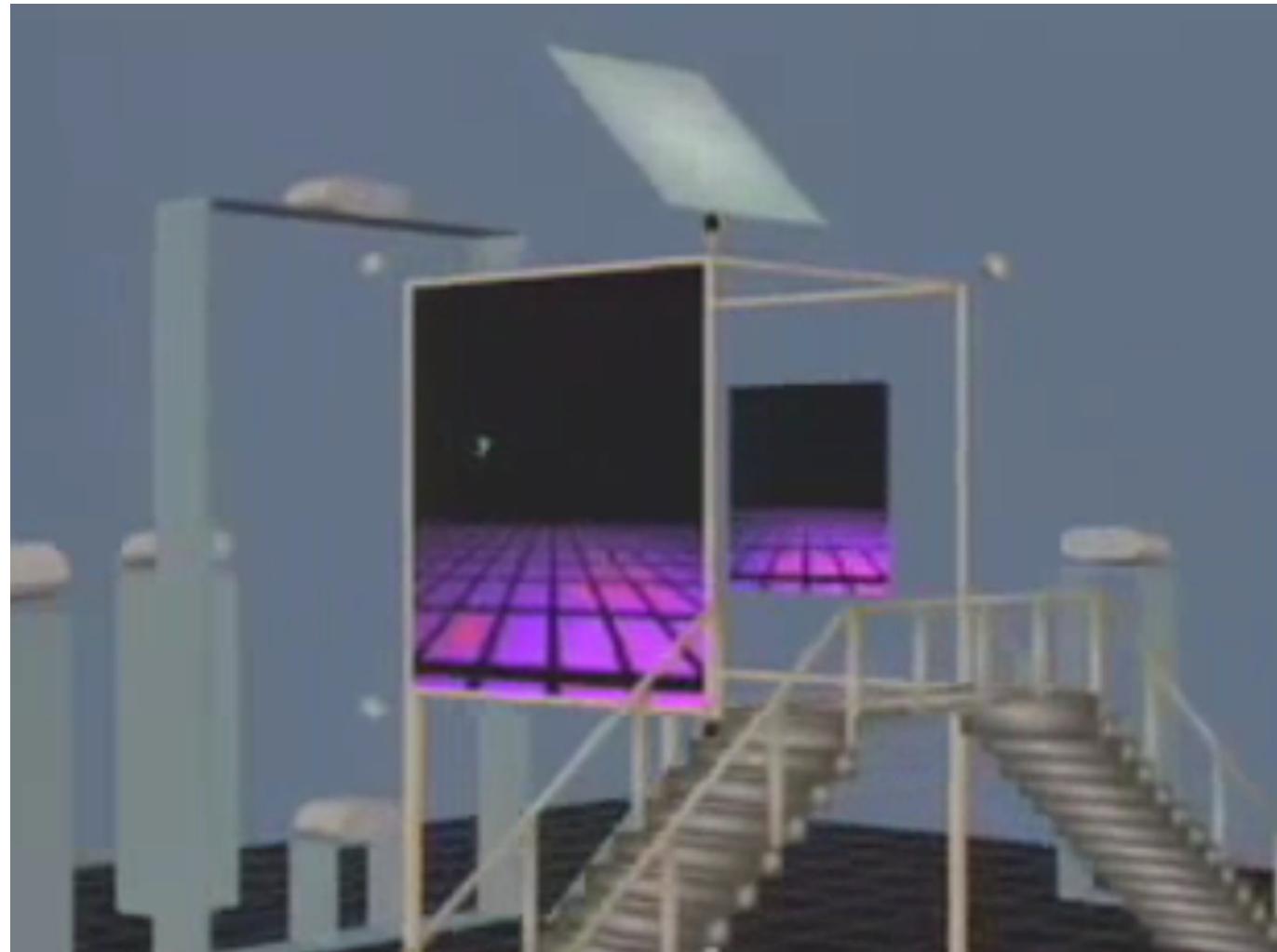
CAVE (1992)



- 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



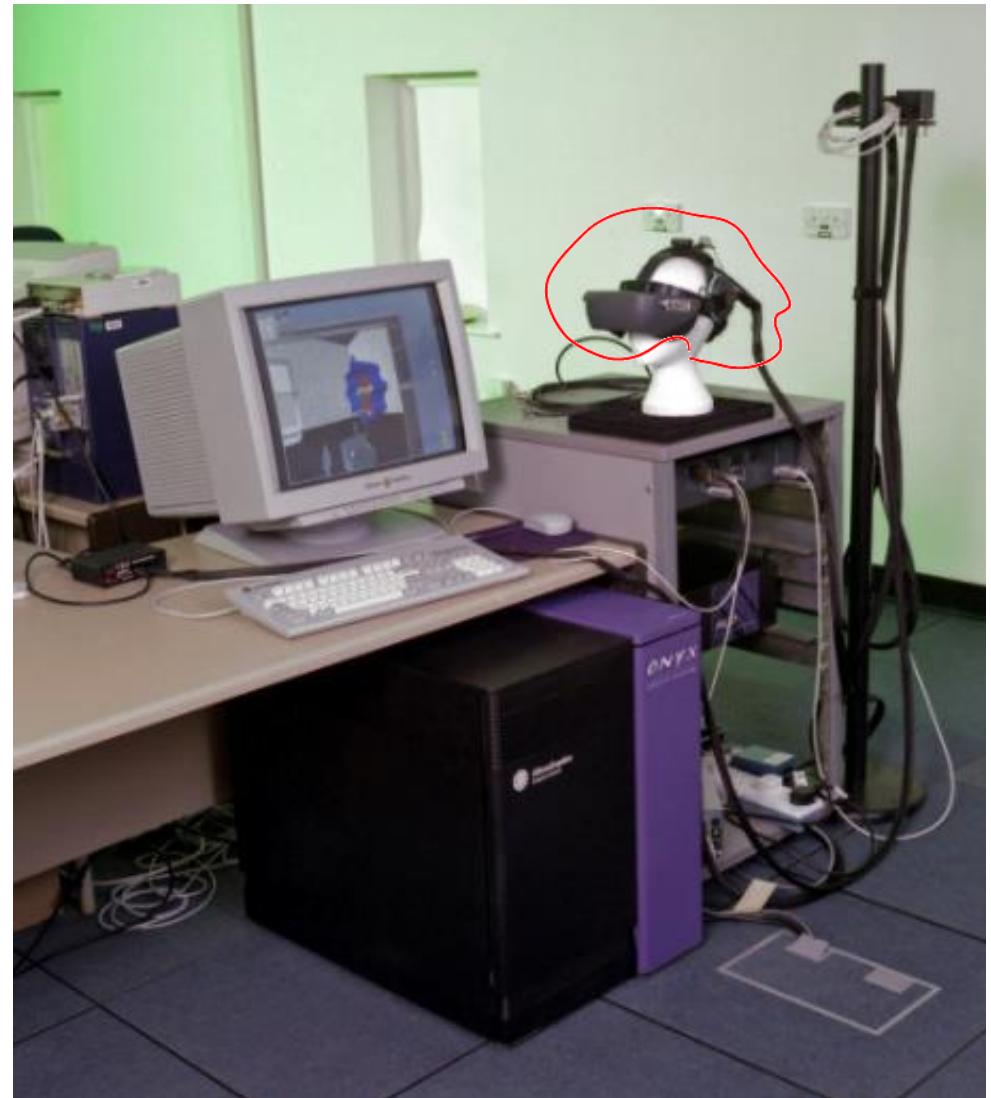
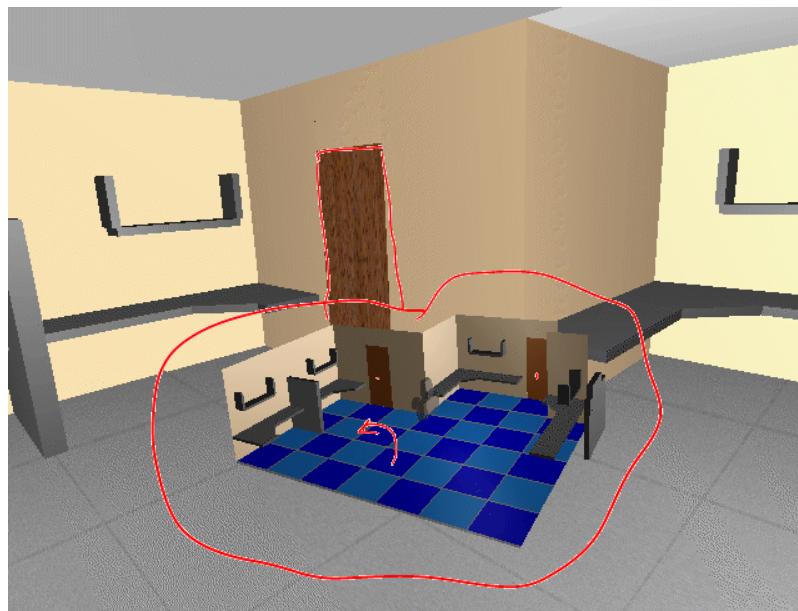
VR Helmet X
3D glass

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

Desktop VR - 1995

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

Vision
IDac



Rise of Commercial VR Companies

↑ VR
UIS BJ TU
707 ← SSE

• W Industries/Virtuality (1985 - 97)

1986
1st Burst of VR
23 years

2019
2nd Burst of VR
20 years

at which year
we will use VR
everywhere?

Game (3A)
VR device
mobile phone

XR device
OPO (one x)
AR glass

cheaper
Hardware

10 years
20 years
Devices don't

- Location based entertainment
- Virtuality VR Arcades

Google

2009
2020 ~ 2019 (series)

Facebook
↓
Meta

apple

5 years
Netaverse
Meta workplace
Horizon

2021.10 3D Web



Update

PPT Slides

HCI & VR

25 min

17:35 → 18:10

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

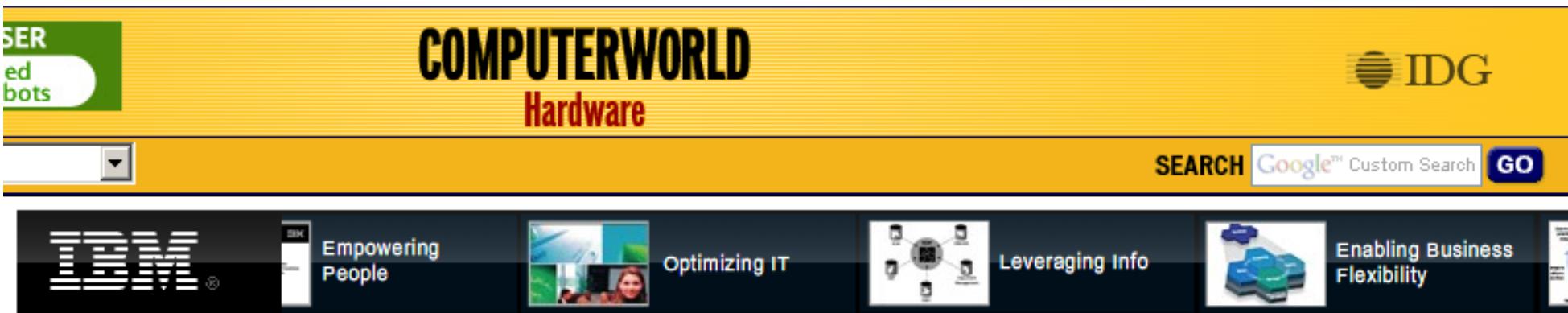


Dactyl Nightmare

Game
Content 1998
App Good Graphic
Game v fun & x Graphic
Content Function
VR Most important app/Game



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



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 ▾](#)

1996
2007
2019

- April 2007 ComputerWorld
 - 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° FOV



The Oculus Kickstarter Video

Handicar
↓
↓ twice 23 yrs
VR
↓
↓ today
wrg way ~ 40
↓
better
BJ FD
↓
SSE
↓
VZS
↓
VR (1)



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

Desktop VR in 2016

↳ *HTC Vive*

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

Pico → Helmet

3DoF
6DoF

\$180 → Current Desktop

\$360 → Oculus → Desktop



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>

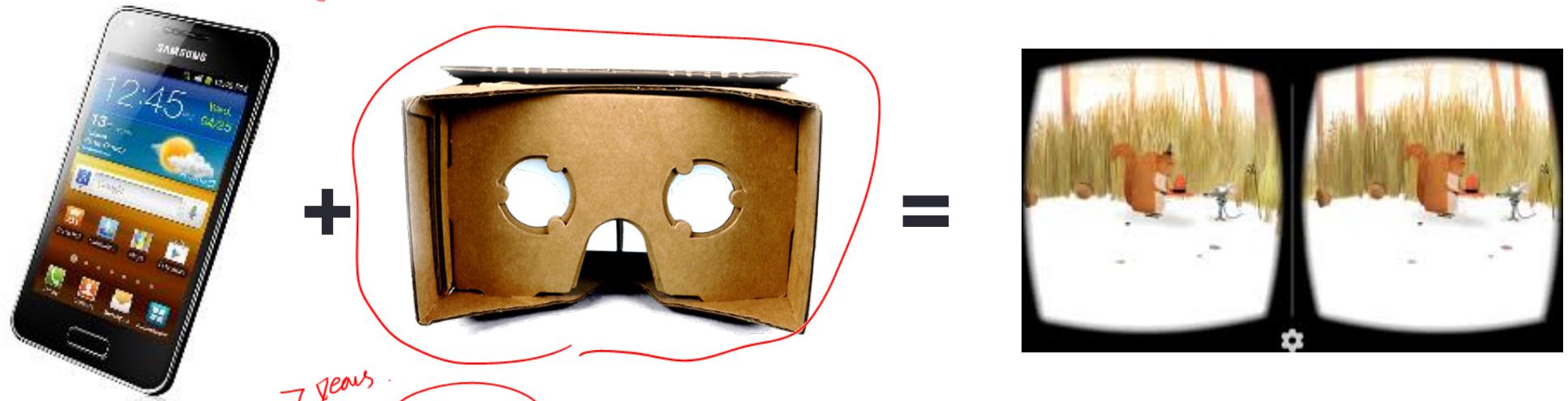
VR2GO (2013)

HTC
Oculus
Sony



- 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



2018 – Self Contained VR



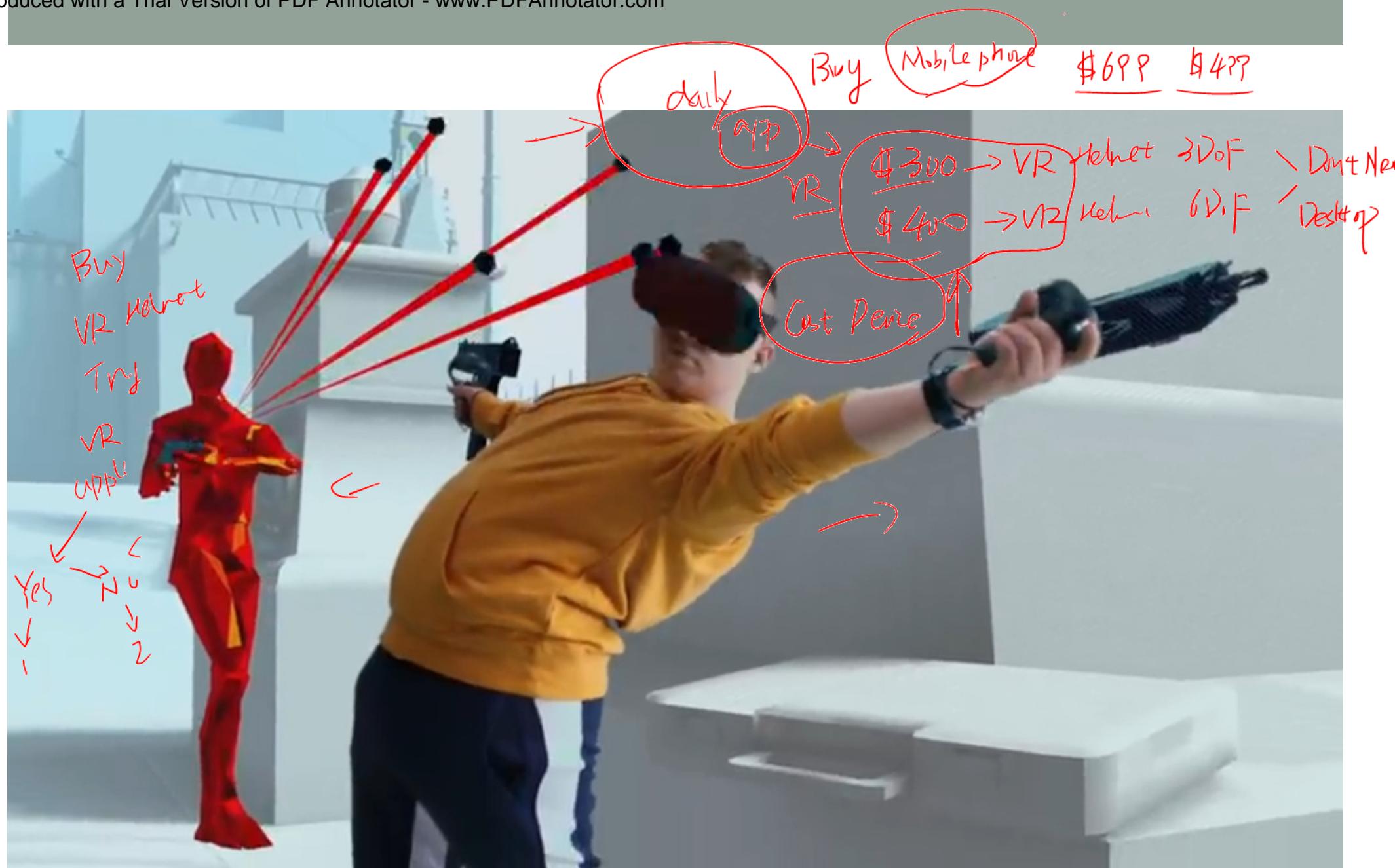
Vive Focus



VR Helmet

Oculus Quest

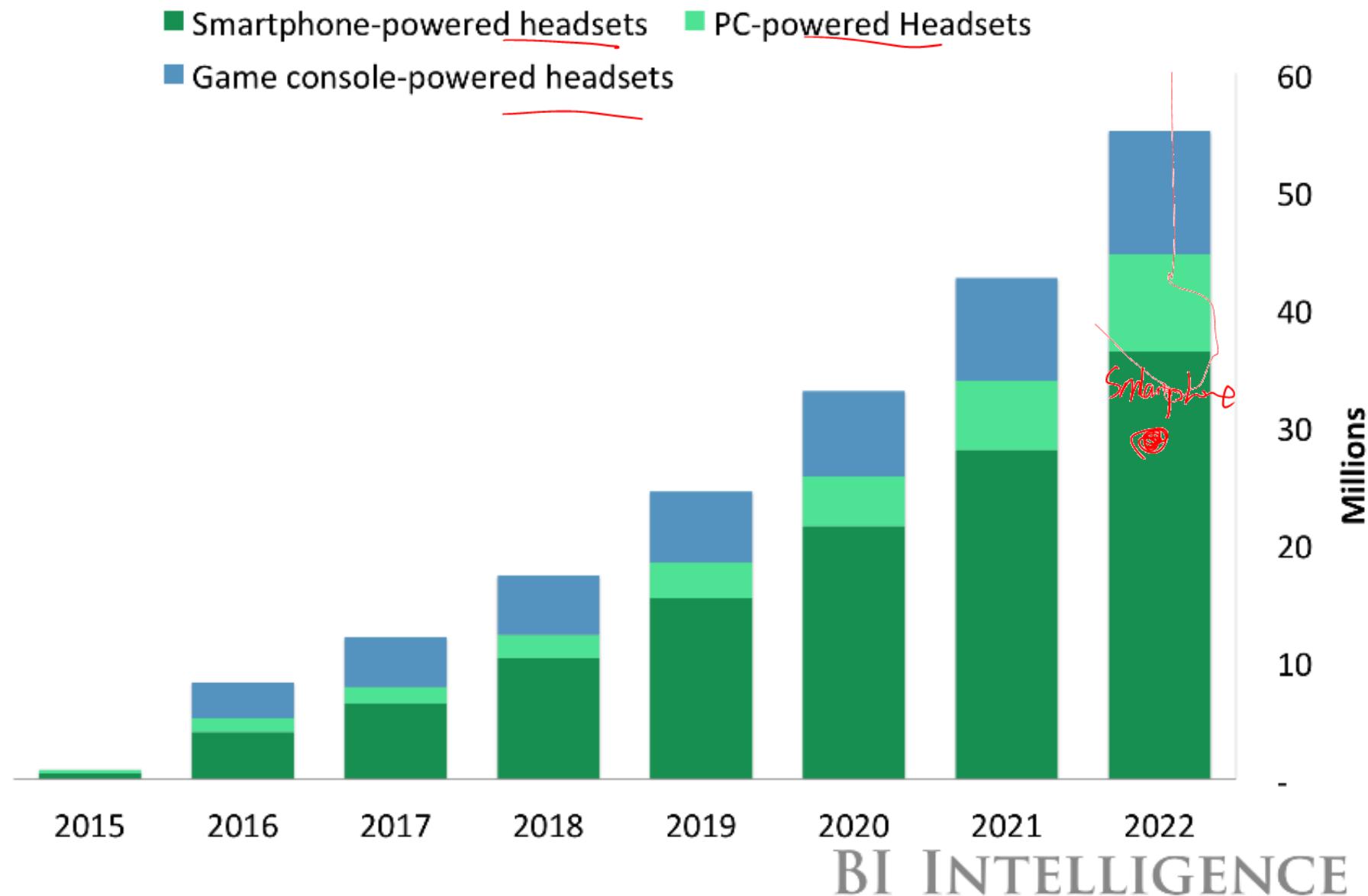
- Untethered VR, self contained in one device
 - Inside out 6 DOF tracking
 - 1-2 handheld controllers
 - Mobile graphics and processing



- <https://www.youtube.com/watch?v=Di7dlhUFsbw>

FORECAST: Global VR Headset Shipments

By Category



Source: BI Intelligence Estimates

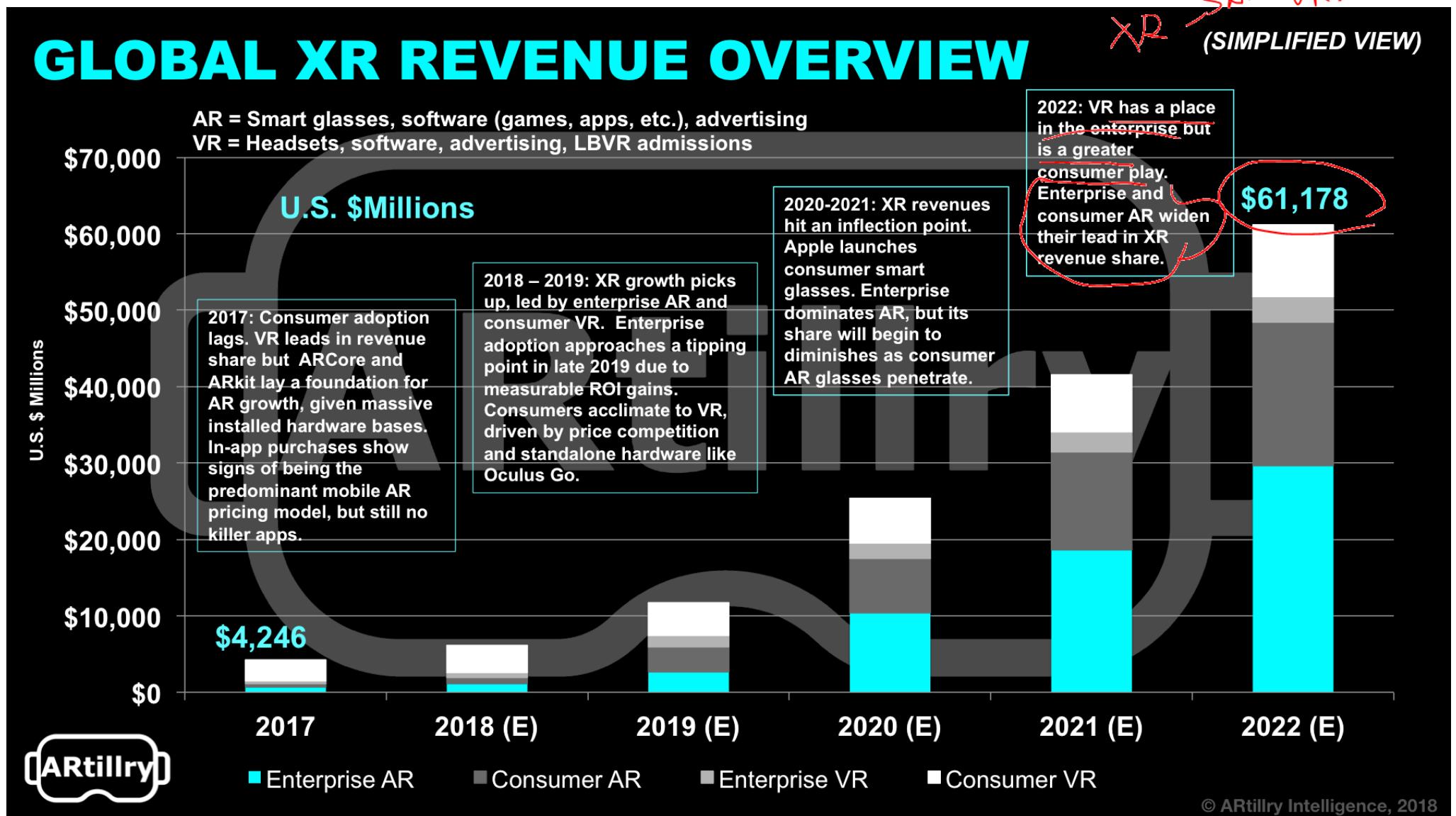
Large Commercial Market

AR/VR/XR Leaders*

* Includes funded/exited startups and selected corporates

Advertising/marketing				Art/design				Business				Distribution			
Real Vision	AdsReality	Criteo	Aarki	LIME	Oment	IMMERSAL	MIXED PLACE	gravity sketch	Mindesk	iris	artomatix	cluster.	VIRTUALITICS	ConstructVR	Wevr
PRSONAS	Zenith	TAG GROUP	retinad	Advair	blippar.	PLATTAR	AUGMENT	immersv	VIRE	Xperiel	zappar			Sketchfab	UNIVERSIL
eCommerce				Education				Enterprise				Entertainment			
amazon	Alibaba.com	IKEA	houzz	CAPACITY	GROKSTYLE	Spaceview	wayfair	hexa	tylko	ARR	AVANTIS	enovate	carevrum	SERIOUS LABS	MADISON
Imagine	STRIVR	VPS	Lenqiy	DISCOVER LABS	BOULEVARD	OSGENIC	VSPACE	DYNAMIS	LABSTER	UPASKILL	immerse.io	MURE	FAIR	SCOPES	Jacnic
VIVDWORKS	InContext	aisle411	tylko												
Games				Medical				Health/fitness				Kids			
B-Dreams	playful	playfun	ZEEV	echo pixel	AIRA	appliedVR	ALUMEDIX	BILUCID	BPSIOUS	FOV	Virtual Reality	Scandy	360 VR	ALCHEMY VR	Pixelbug
VRSTUDIOS	TWO BIT CIRCUS	hyperverse		LEVEL EX	marion	orosim	CVILOG	ECHOLOGIC	FEARLESS	ENTRYPOINT	YOU VISIT	LUCID	MATTERPORT	LUNA	The Wave VR
NEWS	PERIPHERALS														
Location based				Medical				Music				Kids			
VRstudios	Two Bit Circus	Hyperverse		AIRA	AppliedVR	Alimedix	Bilucid	Bpsious	Melody						
VRC				Echopixel	Level Ex	Marion	Orosim	CviLog	Echologic	Entrypoint	You Visit	Lucid	Matterport	Luna	The Wave VR
News				Peripherals				Music				Kids			
87870.com	UPLOAD	VIQVR	here	LIGHTFORM	POLARANT	FACETRONICS	HAPTICS	YOGI	KINTR	FOV	Virtual Reality	Scandy	360 VR	ALCHEMY VR	Pixelbug
HAMMER & TUSK	LEAP	MYO	LIGHTFORM												
Productivity				Smartglasses				Solutions/services				Navigation			
CLEVR	FlirtAR	PLUTO	evertoon	NEOS	HOLODIA	FIRSTVISION	BAGEL LABS	Seene	BAGEL LABS	Pixelbug	Spotscale	DoubleMe	DIVERSE	FISHBOWL VR	Sketchbox
Social				Sports				Tech				Solutions/services			
CLEVR															
Travel/transport				Utilities				VR headset				Navigation			
ZeroLight	STARFEE	timelopper	GAMAR	BAGEL LABS	JANUSVR	Vizor	bigscreen	Seene	PRIMITIVE	HASHPLAY	alcatel	LG	ARCHOS	Vuzix	Facebook

Market Size



Why 2019 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 1996
 - Too expensive, bad user experience, poor technology, etc
- We are now in second commercial wave 2019 → VR
 - Better experience, Affordable hardware
 - Large commercial investment, Significant installed user base