IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re *Inter Partes* Review of:	)
	)
U.S. Patent No. 10,798,509	)
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Application No.: 16/938,936	)
Filing Date: July 25, 2020	)
	)
U.S. Patent No. 11,172,316	)
Issued: Nov. 9, 2021	)
Application No.: 17/062,633	)
Filing Date: Oct. 5, 2020	)

For: **Wearable Electronic Device Displays A 3D Zone From Where Binaural Sound Emanates**

DECLARATION OF DR. GREGORY F. WELCH IN SUPPORT OF PETITIONS FOR *INTER PARTES* REVIEW OF U.S. PATENT NOS. 10,798,509 AND 11,172,316

TABLE OF CONTENTS

I. Introduction And Qualifications 1

II. Summary Of Materials Reviewed And Considered 7

III. Legal Understandings 17

IV. Overview of the ’509 Patent and ’316 Patent 21

V. Level Of Skill In The Art And Perspective Applied In This Declaration 24

VI. Claim Construction 26

VII. State of the Art 26

A. Brief History 27

B. Wearable Electronic Devices (WEDs) and Head-Mounted Displays (HMDs) 36

C. Handheld Controllers 39

D. Tracking WEDs/HMDs and Controllers 49

E. Sound Localization and Binaural Sound 59

F. Designating Sound Sources 69

G. Safety and Chaperone Systems 82

VIII. Petition Grounds and Prior Art Combinations 92

IX. The Prior Art Relied On In The Petitions 93

A. Overview Of Pedrotti (Ex.1005) 93

B. Overview Of Jang (Ex.1006) 99

C. Overview Of Begault (Ex.1007) 105

D. Overview Of McCulloch (Ex.1008) 110

E. Overview Of Flaks (Ex.1009) 116

Meta Platforms, Inc.
Exhibit 1003
Page 002

X. US Patent No. 10,798,509 120

A. Ground 1: Claims 1-14 and 17-20 Are Unpatentable Over Pedrotti In View Of Jang And Further In View Of Begault 120

1. Reasons Persons of Ordinary Skill in the Art Would Combine Pedrotti And Jang 121

2. Reasons Persons Of Ordinary Skill in the Art Would Combine Pedrotti, Jang, and Begault 126

3. Independent Claim 1 132

a. 1[pre]: "A method comprising:" 132

b. 1[a]: "dividing, with a portable electronic device (PED) held in a hand of a user, an area around the user into a zone that includes multiples sound localization points (SLPs) from where binaural sound originates to the user;" 133

c. 1[b]: "determining, with a wearable electronic device (WED) worn on a head of the user, when the user is located inside the zone;" 147

d. 1[c]: "highlighting, while the user is located in the zone and with a display of the WED, one of the multiple SLPs in the zone when the PED held in the hand of the user is pointed at the one of the multiple SLPs in the zone; and" 152

e. 1[d]: "playing, with the WED worn on the head of the user, the binaural sound that emanates from the one of the multiple SLPs in response to the one of the multiple SLPs being pointed at by the PED held in the hand of the user." 165

4. Dependent Claims 2-8 171

a. Claim 2 171

b. Claim 3 181

Meta Platforms, Inc.
Exhibit 1003
Page 003

c. Claim 4.....185

d. Claim 5.....193

e. Claim 6.....196

f. Claim 7: "The method of claim 1, wherein the zone has one of a three-dimensional (3D) shape of a cylinder and a 3D shape of a rectangle, and the user is centered in the zone." 198

g. Claim 8: "The method of claim 1 further comprising: playing, with speakers in the WED worn on the head of the user, a verbal instruction indicating the user should move back into the zone in response to the WED determining that the user moved outside the zone."....202

5. Independent Claim 9 206

a. 9[pre]: "A non-transitory computer readable storage medium storing instructions that one or more electronic devices execute as a method, the method comprising:" 206

b. 9[a]: "dividing, with a portable electronic device (PED) held in a hand of a user, an area around the user into a zone that includes sound localization points (SLPs) in empty space from where binaural sound originates to the user;" 207

c. 9[b]: "determining, with a wearable electronic device (WED) worn on a head of the user, when the user is located inside the zone;" 208

d. 9[c]: "determining, with the WED worn on the head of the user, when the user is leaving the zone; and".....208

Meta Platforms, Inc.
Exhibit 1003
Page 004

e. 9[d]: "displaying, with the WED worn on the head of the user, a three dimensional (3D) virtual image of the zone in response to the WED determining that the user is leaving the zone." 209

6. Dependent Claims 10-14.....210

a. Claim 10.....210

b. Claim 11: "The non-transitory computer readable storage medium of claim 9 in which the method further comprises: highlighting, while the user is located in the zone and with a display of the WED, a virtual image at one of the SLPs in the zone when the PED held in the hand of the user is pointed at the one of the multiple SLPs in the zone."....212

c. Claim 12: "The non-transitory computer readable storage medium of claim 9, wherein the 3D virtual image of the zone is shaped as a cylinder with the user being centered in the cylinder, and the WED is one of a head mounted display and electronic glasses." 213

d. Claim 13: "The non-transitory computer readable storage medium of claim 9, wherein the 3D virtual image of the zone is shaped as a rectangle with the user being centered in the rectangle, and the WED is one of a head mounted display and electronic glasses." 213

e. Claim 14: "The non-transitory computer readable storage medium of claim 9 in which the method further comprises: playing, with the WED worn on the head of the user, a verbal instruction indicating the user should move back into the zone in response to the WED determining that the user moved outside the zone."....214

7. Independent Claim 17 215

Meta Platforms, Inc.
Exhibit 1003
Page 005

a. 17[pre]: "The electronic system comprising:" 215

b. 17[a]: "a portable electronic device (PED) held in a hand of a user that divides an area around the user into a three-dimensional (3D) zone that includes sound localization points (SLPs) in empty space from where binaural sound originates to the user; and" 215

c. 17[b]: "a wearable electronic device (WED) that is worn on a head of the user," 216

d. 17[c]: "wirelessly communicates with the PED," 216

e. 17[d]: "includes speakers that play the binaural sound to the user that emanates from the SLPs in empty space," 217

f. 17[e]: "includes one or more sensors that sense when the PED leaves the zone," 217

g. 17[f]: "and includes a display that displays a 3D virtual image of the zone in response to sensing that the PED leaves the zone," 218

h. 17[g]: "wherein the display displays the 3D virtual image of the zone to warn the user that the user is leaving the zone." 218

8. Dependent Claims 18-20 219

a. Claim 18: "The electronic system of claim 17, wherein the display of the WED highlights a virtual image at one of the SLPs in response to the WED determining that the PED is pointing to the one of the SLPs." 219

Meta Platforms, Inc.
Exhibit 1003
Page 006

b. Claim 19: "The electronic system of claim 17, wherein the WED tracks a location of the user with respect to the SLPs, and automatically display a virtual image at a location of one of the SLPs in response to determining that the user is proximate to the location of the one of the SLPs."....220

c. Claim 20: "The electronic system of claim 17, wherein the speakers in the WED play the binaural sound that emanates from one of the SLPs in empty space in response to the WED determining that the PED is pointed to the one of the SLPs in empty space."....222

B. Ground 2: Claims 1-14 and 17-20 Are Unpatentable Over McCulloch In View Of Pedrotti, And Further In View Of Flaks....223

1. Reasons Persons Of Ordinary Skill In The Art Would Combine McCulloch and Pedrotti....223

2. Reasons Persons Of Ordinary Skill In The Art Would Combine McCulloch, Pedrotti, And Flaks....232

3. Independent Claim 1....234

a. 1[pre]: "A method comprising:"....234

b. 1[a]: "dividing, with a portable electronic device (PED) held in a hand of a user, an area around the user into a zone that includes multiples sound localization points (SLPs) from where binaural sound originates to the user;"....235

c. 1[b]: "determining, with a wearable electronic device (WED) worn on a head of the user, when the user is located inside the zone;"....250

d. 1[c]: "highlighting, while the user is located in the zone and with a display of the WED, one of the multiple SLPs in the zone when the PED held in the hand of the user is pointed at the one of the multiple SLPs in the zone; and"....254

Meta Platforms, Inc.
Exhibit 1003
Page 007

e. 1[d]: "playing, with the WED worn on the head of the user, the binaural sound that emanates from the one of the multiple SLPs in response to the one of the multiple SLPs being pointed at by the PED held in the hand of the user." 261

4. Dependent Claims 2-8 263

a. Claim 2 263

b. Claim 3 268

c. Claim 4 271

d. Claim 5 275

e. Claim 6 285

f. Claim 7: "The method of claim 1, wherein the zone has one of a three-dimensional (3D) shape of a cylinder and a 3D shape of a rectangle, and the user is centered in the zone." 288

g. Claim 8: "The method of claim 1 further comprising: playing, with speakers in the WED worn on the head of the user, a verbal instruction indicating the user should move back into the zone in response to the WED determining that the user moved outside the zone." 288

5. Independent Claim 9 290

a. 9[pre]: "A non-transitory computer readable storage medium storing instructions that one or more electronic devices execute as a method, the method comprising:" 290

b. 9[a]: "dividing, with a portable electronic device (PED) held in a hand of a user, an area around the user into a zone that includes sound localization points (SLPs) in empty space from where binaural sound originates to the user;" 290

Meta Platforms, Inc.
Exhibit 1003
Page 008

c. 9[b]: "determining, with a wearable electronic device (WED) worn on a head of the user, when the user is located inside the zone;" 291

d. 9[c]: "determining, with the WED worn on the head of the user, when the user is leaving the zone; and".....292

e. 9[d]: "displaying, with the WED worn on the head of the user, a three dimensional (3D) virtual image of the zone in response to the WED determining that the user is leaving the zone."....292

6. Dependent Claims 10-14.....292

a. Claim 10.....293

b. Claim 11: "The non-transitory computer readable storage medium of claim 9 in which the method further comprises: highlighting, while the user is located in the zone and with a display of the WED, a virtual image at one of the SLPs in the zone when the PED held in the hand of the user is pointed at the one of the multiple SLPs in the zone."....295

c. Claim 12: "The non-transitory computer readable storage medium of claim 9, wherein the 3D virtual image of the zone is shaped as a cylinder with the user being centered in the cylinder, and the WED is one of a head mounted display and electronic glasses." 295

d. Claim 13: "The non-transitory computer readable storage medium of claim 9, wherein the 3D virtual image of the zone is shaped as a rectangle with the user being centered in the rectangle, and the WED is one of a head mounted display and electronic glasses." 296

Meta Platforms, Inc.
Exhibit 1003
Page 009

e. Claim 14: "The non-transitory computer readable storage medium of claim 9 in which the method further comprises: playing, with the WED worn on the head of the user, a verbal instruction indicating the user should move back into the zone in response to the WED determining that the user moved outside the zone."....296

7. Independent Claim 17....297

a. 17[pre]: "The electronic system comprising:"....297

b. 17[a]: "a portable electronic device (PED) held in a hand of a user that divides an area around the user into a three-dimensional (3D) zone that includes sound localization points (SLPs) in empty space from where binaural sound originates to the user; and"....297

c. 17[b]: "a wearable electronic device (WED) that is worn on a head of the user,"....297

d. 17[c]: "wirelessly communicates with the PED,"....298

e. 17[d]: "includes speakers that play the binaural sound to the user that emanates from the SLPs in empty space,"....298

f. 17[e]: "includes one or more sensors that sense when the PED leaves the zone,"....298

g. 17[f]: "and includes a display that displays a 3D virtual image of the zone in response to sensing that the PED leaves the zone,"....298

h. 17[g]: "wherein the display displays the 3D virtual image of the zone to warn the user that the user is leaving the zone."....299

8. Dependent Claims 18-20....299

Meta Platforms, Inc.
Exhibit 1003
Page 010

a. Claim 18: "The electronic system of claim 17, wherein the display of the WED highlights a virtual image at one of the SLPs in response to the WED determining that the PED is pointing to the one of the SLPs." 300

b. Claim 19: "The electronic system of claim 17, wherein the WED tracks a location of the user with respect to the SLPs, and automatically display a virtual image at a location of one of the SLPs in response to determining that the user is proximate to the location of the one of the SLPs." 300

c. Claim 20: "The electronic system of claim 17, wherein the speakers in the WED play the binaural sound that emanates from one of the SLPs in empty space in response to the WED determining that the PED is pointed to the one of the SLPs in empty space." 302

XI. US Patent No. 11,172,316 303

A. Ground 1: Claims 1-20 Are Unpatentable Over Pedrotti In View Of Jang, And Further In View Of Begault 303

1. Independent Claim 1 303

a. 1[pre]: "A method comprising:" 303

b. 1[a]: "dividing, with a portable electronic device (PED) held in a hand of a user, an area around the user into a zone that extends around the user and that includes a sound localization point (SLP) from where binaural sound in empty space originates to the user;" 304

c. 1[b]: "playing, with speakers in a wearable electronic device (WED) worn on a head of the user, the binaural sound that originates from the SLP in empty space;" 318

Meta Platforms, Inc.
Exhibit 1003
Page 011

d. 1[c]: "tracking, with one or more sensors in the WED worn on the head of the user, the PED to determine when the PED held in the hand of the user is moving outside the zone that extends around the user; and" 323

e. 1[d]: "displaying, with the WED worn on the head of the user a virtual reality (VR) image that shows the zone in response to the WED determining that the PED is moving outside the zone." 331

2. Dependent Claims 2-8 334

a. Claim 2 334

b. Claim 3: "The method of claim 1 further comprising: displaying, with the WED worn on the head of the user, the VR image that shows a size and a shape of the zone in response to the WED determining that the PED is moving outside the zone." 349

c. Claim 4 350

d. Claim 5 357

e. Claim 6 360

f. Claim 7: "The method of claim 1, wherein the zone has one of a three-dimensional (3D) shape of a cylinder and a 3D shape of a rectangle, and the user is centered in the zone." 362

g. Claim 8: "The method of claim 1 further comprising: playing, with the speakers in the WED worn on the head of the user, an audio warning in response to the WED determining that the PED is moving outside the zone." 366

3. Independent Claim 9 369

a. 9[pre]: "A method comprising:" 369

Meta Platforms, Inc.
Exhibit 1003
Page 012

b. 9[a]: "dividing, with a portable electronic device (PED) held in a hand of a user, an area around the user into a three-dimensional (3D) zone that extends around the user and that includes sound localization points (SLPs) from where binaural sound originates to the user;" 369

c. 9[b]: "determining, with a wearable electronic device (WED) worn on a head of the user, when the user is leaving the zone; and" 370

d. 9[c]: "warning the user that the user is leaving the zone by displaying, with the WED worn on the head of the user, a 3D virtual reality (VR) image of the zone in response to the WED determining that the user is leaving the zone." 371

4. Dependent Claims 10-16.....372

a. Claim 10.....372

b. Claim 11: "The method of claim 9 further comprising: highlighting, while the user is located in the zone and with a display of the WED, color of a VR image at one of the SLPs in the zone when the PED held in the hand of the user points at the one of the SLPs in the zone." 374

c. Claim 12.....375

d. Claim 13.....375

e. Claim 14: "The method of claim 9 further comprising: playing, with the WED worn on the head of the user an audio warning indicating the user should move back into the zone in response to the WED determining that the user is leaving the zone." 377

f. Claim 15: "The method of claim 9, wherein the 3D VR image of the zone is shaped as a cylinder that extends around the user."....378

Meta Platforms, Inc.
Exhibit 1003
Page 013

g. Claim 16.....378

5. Independent Claim 17.....379

a. 17[pre]: "An electronic system comprising:".....379

b. 17[a]: "a portable electronic device (PED) held in a hand of a user that divides an area around the user into a three-dimensional (3D) zone that extends around the user and includes sound localization points (SLPs) in empty space from where binaural sound originates to the user while the user is located inside the zone; and".....379

c. 17[b]: "a wearable electronic device (WED) that is worn on a head of the user,".....380

d. 17[c]: "wirelessly communicates with the PED,".....380

e. 17[d]: "includes speakers that play to the user the binaural and that emanates from the SLPs in empty space in the zone,".....380

f. 17[e]: "includes one or more sensors that sense when the PED is leaving the zone,".....381

g. 17[f]: "and includes a display that displays a virtual reality (VR) image of the zone in response to sensing that the PED is leaving the zone,".....381

h. 17[g]: "wherein the display displays the VR image of the zone to warn the user that the user is leaving the zone.".....381

6. Dependent Claims 18-20.....381

a. Claim 18: "The electronic system of claim 17, wherein the display of the WED highlights a color of a VR image at one of the SLPs in response to the WED determining that the PED is pointing to the VR image at the one of the SLPs.".....382

Meta Platforms, Inc.
Exhibit 1003
Page 014

b. Claim 19: "The electronic system of claim 17, wherein the WED tracks a location of the user with respect to the SLPs, and automatically displays a VR image at a location of one of the SLPs in response to determining that the user is proximate to the location of the one of the SLPs."....382

c. Claim 20....384

B. Ground 2: Claims 1-20 Are Unpatentable Over McCulloch In View Of Pedrotti, And Further In View Of Flaks....385

1. Independent Claim 1....385

a. 1[pre]: "A method comprising:"....385

b. 1[a]: "dividing, with a portable electronic device (PED) held in a hand of a user, an area around the user into a zone that extends around the user and that includes a sound localization point (SLP) from where binaural sound in empty space originates to the user;"....386

c. 1[b]: "playing, with speakers in a wearable electronic device (WED) worn on a head of the user, the binaural sound that originates from the SLP in empty space;"....402

d. 1[c]: "tracking, with one or more sensors in the WED worn on the head of the user, the PED to determine when the PED held in the hand of the user is moving outside the zone that extends around the user; and"....403

e. 1[d]: "displaying, with the WED worn on the head of the user a virtual reality (VR) image that shows the zone in response to the WED determining that the PED is moving outside the zone."....408

2. Dependent Claims 2-8....412

a. Claim 2....412

Meta Platforms, Inc.
Exhibit 1003
Page 015

b. Claim 3: "The method of claim 1 further comprising: displaying, with the WED worn on the head of the user, the VR image that shows a size and a shape of the zone in response to the WED determining that the PED is moving outside the zone." 421

c. Claim 4.....422

d. Claim 5.....426

e. Claim 6.....435

f. Claim 7: "The method of claim 1, wherein the zone has one of a three-dimensional (3D) shape of a cylinder and a 3D shape of a rectangle, and the user is centered in the zone." 438

g. Claim 8: "The method of claim 1 further comprising: playing, with the speakers in the WED worn on the head of the user, an audio warning in response to the WED determining that the PED is moving outside the zone." 438

3. Independent Claim 9 439

a. 9[pre]: "A method comprising:".....439

b. 9[a]: "dividing, with a portable electronic device (PED) held in a hand of a user, an area around the user into a three-dimensional (3D) zone that extends around the user and that includes sound localization points (SLPs) from where binaural sound originates to the user;" 440

c. 9[b]: "determining, with a wearable electronic device (WED) worn on a head of the user, when the user is leaving the zone; and" 440

Meta Platforms, Inc.
Exhibit 1003
Page 016

d. 9[c]: "warning the user that the user is leaving the zone by displaying, with the WED worn on the head of the user, a 3D virtual reality (VR) image of the zone in response to the WED determining that the user is leaving the zone." 443

4. Dependent Claims 10-16.....443

a. Claim 10.....443

b. Claim 11: "The method of claim 9 further comprising: highlighting, while the user is located in the zone and with a display of the WED, color of a VR image at one of the SLPs in the zone when the PED held in the hand of the user points at the one of the SLPs in the zone." 445

c. Claim 12.....446

d. Claim 13.....447

e. Claim 14: "The method of claim 9 further comprising: playing, with the WED worn on the head of the user an audio warning indicating the user should move back into the zone in response to the WED determining that the user is leaving the zone." 449

f. Claim 15: "The method of claim 9, wherein the 3D VR image of the zone is shaped as a cylinder that extends around the user."....450

g. Claim 16.....450

5. Independent Claim 17 451

a. 17[pre]: "An electronic system comprising:".....451

Meta Platforms, Inc.
Exhibit 1003
Page 017

b. 17[a]: "a portable electronic device (PED) held in a hand of a user that divides an area around the user into a three-dimensional (3D) zone that extends around the user and includes sound localization points (SLPs) in empty space from where binaural sound originates to the user while the user is located inside the zone; and".....451

c. 17[b]: "a wearable electronic device (WED) that is worn on a head of the user,".....451

d. 17[c]: "wirelessly communicates with the PED,".....452

e. 17[d]: "includes speakers that play to the user the binaural and that emanates from the SLPs in empty space in the zone,".....452

f. 17[e]: "includes one or more sensors that sense when the PED is leaving the zone,".....452

g. 17[f]: "and includes a display that displays a virtual reality (VR) image of the zone in response to sensing that the PED is leaving the zone,".....453

h. 17[g]: "wherein the display displays the VR image of the zone to warn the user that the user is leaving the zone.".....453

6. Dependent Claim 18-20.....454

a. Claim 18: "The electronic system of claim 17, wherein the display of the WED highlights a color of a VR image at one of the SLPs in response to the WED determining that the PED is pointing to the VR image at the one of the SLPs.".....454

b. Claim 19: "The electronic system of claim 17, wherein the WED tracks a location of the user with respect to the SLPs, and automatically displays a VR image at a location of one of the SLPs in response to determining that the user is proximate to the location of the one of the SLPs.".....454

Meta Platforms, Inc.
Exhibit 1003
Page 018

c. Claim 20 456

XII. Conclusion 457

Meta Platforms, Inc.
Exhibit 1003
Page 019

I. Introduction And Qualifications

1. I, Gregory F. Welch, submit this declaration on behalf of Meta Platforms, Inc. and Meta Platforms Technologies, LLC (collectively, "Meta" or "Petitioners") to provide my opinion concerning the validity of the claims 1-14 and 17-20 of U.S. Patent No. 10,798,509 ("the '509 patent," Ex.1001-509), in support of the Petition for *Inter Partes* Review of the '509 patent and the validity of claims 1-20 of U.S. Patent No. 11,172,316 ("the '316 patent," Ex.1001-316), in support of the Petition for *Inter Partes* Review of the '316 patent.

2. I am more than eighteen years of age, and I am a citizen of the United States, currently residing in the state of Florida.

3. In formulating my opinions, I have relied upon my knowledge, training, and experience in the relevant art. My qualifications, along with a more detailed summary of my background and publications, are stated more fully in my *curriculum vitae*, which has been provided as Exhibit 1004. Here, I provide a brief summary of my qualifications.

4. I earned a Bachelor of Science degree, with *Highest Distinction*, in electrical engineering technology from Purdue University in 1986. I earned a Master of Science degree in computer science from the University of North Carolina at Chapel Hill in 1995. I earned a Ph.D. in computer science from the University of North Carolina at Chapel Hill in 1997. My doctoral dissertation is titled "SCAAT:

Incremental Tracking with Incomplete Information," which discusses the single-constraint-at-a-time tracking as implemented in tracking or navigation systems.

5. I have extensive research and industry experience with, among other things, all fundamental areas of extended reality (XR), including both Virtual Reality (VR) and Augmented Reality (AR), and in applications of XR such as for training, education, and entertainment.

6. From 1987 to 1990, I was employed by NASA at the Jet Propulsion Laboratory (California Institute of Technology). I worked on the Voyager Spacecraft Project on the Sequence Team under the Flight Command and Data Management Section. I was responsible for programming and maintaining simulators and other software associated with the Voyager spacecraft (Voyager 1 and Voyager 2), assembling "sequences" of instructions to carry out scientific experiments on the spacecraft, overseeing the upload of instructions, and analyzing spacecraft telemetry to ensure successful execution of the experiments. I worked on this before, during, and after the Voyager 2 encounter with the planet Neptune.

7. From 1990 to 1992, I was employed by Northrop Defense Systems Division. My position was Senior Engineer for Airborne Electronic Countermeasures of the Digital Systems Group. During my time there, I was responsible for developing, integrating, and maintain software for electronic radar countermeasures systems. In particular, I worked on the Receiver-Transmitter

Compatibility Feature, which was responsible for ensuring the independence of radar sensing and "jamming."

8. From 1996 to 2011, I was a Research Professor in the Department of Computer Science at the University of North Carolina at Chapel Hill. Within that time period I also held a position in Applied & Materials Sciences. From 1996 to 1998 I served as the UNC Site Coordinator for the National Science Foundation (NSF) Graphics and Visualization Center, a center comprised of the University of North Carolina at Chapel Hill, Brown University, the California Institute of Technology, Cornell University, and the University of Utah. I also served on the board of directors of HiBall Tracker Inc. (Chapel Hill, NC) from approximately 1999-2009.

9. Since 2011 through the present, I have been employed by the University of Central Florida. In various years, I have served as faculty for the Interactive Computing Experiences Research Cluster; the Modeling & Simulation Graduate Program; and the Graduate Certificate in Mixed Reality Engineering. I am currently a Professor and the AdventHealth Endowed Chair in Healthcare Simulation with appointments in the College of Nursing, the Department of Computer Science (College of Engineering and Computer Science), and the Institute for Simulation & Training (School of Modeling, Simulation, and Training).

10. I have taught courses on software engineering and programming, virtual worlds and 3D computer modeling and animation, and computer animation. Other tutorials and short courses I have presented include courses on an introduction to virtual reality, tracking, and the Kalman filter. I have also advised both undergraduate and graduate students in various areas relating to augmented and virtual reality, including displays of such environments and tracking within such environments.

11. Virtual reality (VR) and Augmented Reality (AR) have been my primary areas of research in general since the early 1990s, with human motion tracking being a particular focus, including as the subject of my PhD research. I have co-developed many systems and methods for tracking and motion capture. For example, the HiBall Tracking System that I co-developed in the 1990s was the fastest (with lowest latency), most accurate, and widest area tracking system ever developed. *See, e.g.*, G. Welch, G. Bishop, L. Vicci, S. Brumback, K. Keller, and D. Colucci. The HiBall Tracker: High-Performance Wide-Area Tracking for Virtual and Augmented Environments. In Proceedings of the ACM Symposium on Virtual Reality Software and Technology (VRST), pages 1-11. Association of Computing Machinery, ACM Press, Addison-Wesley Publishing Company, December 1999. *See also, e.g.*, G. Welch, G. Bishop, L. Vicci, S. Brumback, K. Keller, and D. Colucci. High-Performance Wide-Area Optical Tracking: The HiBall

Tracking System. Presence: Teleoperators and Virtual Environments, 10(1):1-21, 2001. I have also developed novel methods for tracking heads, hands, and devices relative to each other. G. Welch, T. Wang, G. Bishop, and G. Bruder. A Novel Approach for Cooperative Motion Capture (COMOCAP). In G. Bruder, S. Cobb, and S. Yoshimoto, editors, ICAT-EGVE 2018 - International Conference on Artificial Reality and Telexistence and Eurographics Symposium on Virtual Environments, Limassol, Cyprus, November 7-9 2018. The Eurographics Association. I am also the first named inventor on a related patent, U.S. Patent No. 11,042,028, and a first named or co-inventor 21 other patents. I have written surveys and book chapters on tracking. *See*, *e.g.*, G. Welch and E. Foxlin. Motion Tracking: No Silver Bullet, But a Respectable Arsenal. IEEE Computer Graphics and Applications, 22(6):24-38, 2002 ("Welch, *No Silver Bullet*") (Ex.1035); G. Welch and L. Davis. Tracking for Training in Virtual Environments: Estimating the Pose of People and Devices for Simulation and Assessment. In J. Cohn, D. Nicholson, and D. Schmorrow, editors, The PSI Handbook of Virtual Environments for Training and Education: Developments for the Military and Beyond, Chapter 30. Praeger Security International, November 30, 2008.

12. I have been an independent consultant on human-computer interaction, virtual and augmented reality, position and motion estimation, sensor fusion, handheld devices, and related technology.

13. As an inventor, I have been awarded 22 domestic patents, with several others in prosecution. The subject matter of these patents primarily include virtual telepresence, virtual and augmented reality displays, pose data and tracking.

14. I also have authored or contributed to over 200 publications, posters, and presentations. Over the course of my academic and professional career, I have received a number of awards and research grants. I am a Fellow of the Institute of Electrical and Electronics Engineers (IEEE), a Fellow of the National Academy of Inventors (NAI), and have been designated an Association for Computing Machinery (ACM) SIGGRAPH Pioneer. Among other honors I have received, at the 15th IEEE International Symposium on Mixed and Augmented Reality (ISMAR 2016), I received the Long Lasting Impact Paper Award for a pair of 1998 papers on "Spatial Augmented Reality" (SAR), with co-authors Professor Ramesh Raskar, Professor Henry Fuchs, and Deepak Bandyopadhyay. At the 25th IEEE Conference on Virtual Reality and 3D User Interfaces (VR 2018), I received the VR Technical Achievement Award for "contributions to human motion tracking and to mixed reality applications in medicine and training." During the 28th IEEE Virtual Reality Conference (VR 2022), I was inducted into the inaugural class of the IEEE Visualization and Graphics Technical Committee's (VGTC) Virtual Reality Academy.

II. Summary Of Materials Reviewed And Considered

15. All of the opinions contained in this Declaration are based on the documents I reviewed and my knowledge and professional judgment. In forming the opinions expressed in this Declaration, while drawing on my experience, I reviewed the following documents:

Exhibit	Description
1001-509	U.S. Patent No. 10,798,509 ("'509 patent")
1001-316	U.S. Patent No. 11,172,316 ("'316 patent")
1004	Curriculum Vitae of Dr. Gregory Welch
1005	U.S. Patent No. 9,851,786 ("Pedrotti")
1006	U.S. Patent No. 8,520,872 ("Jang")
1007	Durand R. Begault, *3-D Sound for Virtual Reality and Multimedia*, NASA/TM-2000-209606 (Aug. 2000) ("Begault")
1008	U.S. Patent No. 9,041,622 ("McCulloch")
1009	U.S. Patent No. 8,767,968 ("Flaks")
1012	International Patent Publication No. WO 2016/064435 ("Fei")
1013	U.S. Patent No. 8,884,984 ("Flaks 984")
1014	U.S. Patent No. 5,900,849 ("Gallery")
1015	U.S. Patent Application Publication No. 2007/0173265 ("Gum")
1016	U.S. Patent No. 2,955,156 ("Heilig")
1017	U.S. Patent No. 9,544,706 ("Hirst")
1018	U.S. Patent No. 10,095,031 ("Katz")
1019	U.S. Patent No. 7,330,197 ("Kobayashi")
1020	U.S. Patent No. 9,884,248 ("Koseki")
1021	U.S. Patent Application Publication No. 2015/0119130 ("Lovitt")
1022	U.S. Provisional Patent Application No. 62/289085 ("Mangiat")

Exhibit	Description
1026	U.S. Patent No. 10,509,466 ("Miller 466")
1027	U.S. Patent Application No. 13/288350 ("Mount 350")
1029	U.S. Patent No. 9,703,369 ("Mullen")
1030	U.S. Patent No. 9,767,618 ("Najaf-Zadeh")
1031	U.S. Patent No. 9,037,468 ("Osman")
1032	U.S. Patent No. 10,162,177 ("Pedrotti 177")
1033	U.S. Patent No. 9,674,507 ("Pirchheim")
1034	U.S. Patent No. 9,367,811 ("Ramachandran")
1035	U.S. Patent No. 10,070,239 ("Romigh")
1036	U.S. Patent Application Publication No. 2016/0124502 ("Sawyer")
1037	U.S. Patent No. 9,301,069 ("Seligmann")
1038	U.S. Patent No. 9,787,846 ("Srinivasan")
1040	U.S. Patent No. 10,114,465 ("Wan")
1041	U.S. Patent No. 8,419,545 ("Yen")
1042	U.S. Patent Application Publication No. 2012/0183161 ("Agevik")
1043	U.S. Patent Application Publication No. 2017/0115488 ("Ambrus")
1044	U.S. Patent No. 7,710,654 ("Ashkenazi")
1046	V.R. Algazi et al., *The CIPIC HRTF Database*, IEEE Workshop on Applications of Signal Processing to Audio and Acoustics 99-102 (2001) ("Algazi")
1047	ASME International, *The Link Flight Trainer, A Historic Mechanical Engineering Landmark*, (June 2000)
1048	Mark Billinghurst et al., *A Wearable Spatial Conferencing Space*, IEEE (1998) ("Billinghurst 1998")
1049	Mark Billinghurst et al., *A Survey of Augmented Reality*, 8 Foundations and Trends in Human-Computer Interactions 73-272 (2015) ("Billinghurst 2015")

Exhibit	Description
1050	Douglas S. Brungart, *Near-Field Virtual Audio Displays*, IMAGE 2000 Conf., Scottsdale, Ariz., July 10-14, 2000 ("Brungart")
1051	Anil Çamci et al., *Interactive Virtual Soundscapes: A Research Report*, ICMC 2015, Sept. 25-Oct. 1, 2015 ("Çamci")
1052	Michael Cohen, *Integrating Graphic and Audio Windows*, 1 Presence 468-81 (Fall 1992) ("Cohen 1992")
1053	Michael Cohen, *Throwing, Pitching and Catching Sound: Audio Windowing Models and Modes*, 39 Int. J. Man – Machine Studies 269-304 (1993) ("Cohen 1993")
1054	John David N. Dionisio et al., *3D Virtual Worlds and the Metaverse: Current Status and Future Possibilities*, 45 ACM Computing Surveys, 34 (June 2013)
1055	Steve DiPaola & David Collins, *A 3D Virtual Environment for Social Telepresence*, W. Comput. Graphics Symp., Mar. 24-27, 2002 ("DiPaola")
1056	Kai-Uwe Doerr et al., *Evaluation of a Low-Cost 3D Sound System for Immersive Virtual Reality Training Systems*, 13 IEEE Transactions on Visualization & Computer Graphics 204-12 (2007)
1057	Thomas Erickson et al., *Synchronous Interaction Among Hundreds: An Evaluation of a Conference in an Avatar-based Virtual Environment*, CHI 2001 Session: Meetings & Interaction Spaces, May 7-12, 2011 ("Erickson")
1058	Oli Welsch, *Oculus Touch Is the Gold Standard in VR Control*, (June 24, 2015) https://www.eurogamer.net/oculus-touch-is-the-gold-standard-in-vr-control
1059	Foster, Cornell Univ. (SP2012), Lecture 25 *Memory and Locality*, https://www.cs.cornell.edu/courses/cs3110/2012sp/lectures/lec25-locality/lec25.html ("Foster")

Exhibit	Description
1060	Nathan Martz, *Spatial Audio Comes to the Cardboard SDK*, Google Developers Blog (Jan. 13, 2016), https://developers.googleblog.com/2016/01/spatial-audio-comes-to-cardboard-sdk.html
1061	John L. Hennessy & David A. Patterson, *Computer Architecture, A Quantitative Approach* (5th ed. 2012) ("Hennessy") (excerpts)
1062	M.P. Hollier et al., *Spatial Audio Technology for Telepresence*, 15 BT Tech. J. 33-41 (Oct. 1997)
1063	Jason Jerald, *The VR Book: Perception and Interaction Design for Virtual Reality* (2015) ("The VR Book")
1064	Jiménez, TAMU Lecture 7: Caches, https://people.engr.tamu.edu/djimenez/taco/utsa-www/cs5513-fall07/lecture7.html (last visited Apr. 18, 2023)
1066	Dean F. Kocian, *A Visually-Coupled Airborne Systems Simulator (VCASS) – An Approach to Visual Simulation*, Report No. AMRL-TR-77-31 (1977)
1067	Julian Löhr, *OpenAL-MOB With OpenFrameworks on Android* (Dec.18, 2014), https://www.julianloehr.de/tag/ndk
1068	Bruce D. Lucas & Takeo Kanade, *An Iterative Image Registration Technique with an Application to Stereo Vision*, Proc 7th Intl Joint Conf on Artificial Intelligence (IJCAI) 674-79 (Aug. 24-28, 1981)
1069	David McGrath, *Huron – A Digital Audio Convolution Workstation*, 5th Australian Regional Convention 1-7 (Apr. 26-28, 1995) ("McGrath")
1070	Timoni West, *UX Pointers for VR Design* (Nov. 10, 2015), https://medium.com/@timoni/ux-pointers-for-vr-design-dd52b718e19
1071	Todd Holmdahl, *BUILD 2015: A Closer Look at the Microsoft HoloLens Hardware*, Microsoft Blog (Apr. 30, 2015) https://blogs.windows.com/devices/2015/04/30/build-2015-a-closer-look-at-the-microsoft-hololens-hardware/ ("Microsoft, *BUILD 2015*")

Exhibit	Description
1072	Microsoft, Overview, Spatial Audio (Dec. 1, 2015)
1073	NSA, *Virtual Reality*, DOCID: 3929132 (1992) ("NSA, *Virtual Reality*")
1074	Xueni Pan et al., *Virtual Character Personality Influences Participant Attitudes and Behavior – An Interview with a Virtual Human Character about Her Social Anxiety*, 2 Frontiers in Robots & AI Article 1 (Feb. 2015) ("Pan 2015")
1075	Tony Parisi, *Learning Virtual Reality: Developing Immersive Experiences and Applications for Desktop, Web and Mobile*, (2016) ("Parisi")
1076	Randy Pausch et al., *Disney's Aladdin: First Steps Toward Storytelling in Virtual Reality*, ACM 193-205 (1996) ("Pausch")
1077	Tabitha C. Peck et al., *An Evaluation of Navigational Ability Comparing Redirected Free Exploration with Distractors to Walking-in-Place and Joystick Locomotion Interfaces*, Proc IEEE Virtual Real Conf. 55-62 (Mar. 19, 2011) ("Peck")
1078	Glenn Chapman, *Google Glass Available in US as of April 15*, Phys.Org (Apr. 10, 2014) https://phys.org/news/2014-04-google-glass-april.html
1080	Spanner Spencer, *Sixense Picks Up CES Awards for Virtual Reality Controller* (Jan. 13, 2015), http://www.pocketgamer.biz/news/60642/sixense-picks-up-ces-awards-for-virtual-reality-controller
1081	Qualcomm, *What's So Special About the Digital Signal Processor?*, Qualcomm OnQ Blog (Dec. 5, 2013)
1082	Francisco Cheng, *Mobile Processors 101: Why Smartphones are Smarter with an All-In-One Processor*, Qualcomm OnQ Blog (June 12, 2013)
1083	RAF Museum, *Flight Simulation and Synthetic Trainers*, https://www.rafmuseum.org.uk/research/online-exhibitions/taking-flight/historical-periods/flight-simulation-and-synthetic-trainers/ (last visited Apr. 4, 2023)

Exhibit	Description
1084	VisiSonics Corp., *Manual for VisiSonics' RealSpace3D Audio Unity Plugin* (Nov. 17, 2015)
1085	Paul James, *Watch Halo Played on Microsoft HoloLens in Augmented Reality*, RoadtoVR (Dec. 7, 2015), https://www.roadtovr.com/watch-halo-played-on-microsoft-hololens-in-augmented-reality/
1086	Paul James, *Samsung Gear VR Gets Positional Tracking Via Sixense STEM, Announced at SFVR (Video)*, RoadtoVR (Nov. 8, 2014), https://www.roadtovr.com/samsunng-gear-vr-gets-positional-tracking-via-stem-demod-sfvr-video/
1087	Warren Robinett & Richard Holloway, *The Visual Display Transformation for Virtual Reality*, 4 Presence 1-23 (1995)
1088	Eric E. Sabelman & Roger Lam, *The Real-Life Dangers of Augmented Reality*, North American, Spectrum.ieee.org (July 2015) ("Sabelman")
1089	*Using the Oculus Rift with Second Life*, Linden Labs Blog (May 21, 2014), http://community.secondlife.com/blogs/entry/1275-using-the-oculus-rift-with-second-life/
1090	Jianbo Shi and Carlo Tomasi, *Good Features to Track*, IEEE Conf. on Comput. Vision & Pattern Recognition (CVPR94) (June 1994) ("Shi")
1091	M. Slater et al., *Acting in Virtual Reality*, ACM 103-10 (2000) ("Slater")
1092	*Characteristics of Flight Simulator Visual Systems*, NASA Technical Memorandum 81278 (Irving C. Statler ed., Apr. 1981)
1093	Ivan E. Sutherland, *A Head-Mounted Three Dimensional Display*, Fall Joint Comput. Conf. 757-64 (1968) ("Sutherland 1968")
1094	Frederic Lardinois, *HoloLens Hands-On: How We Built An App For Microsoft's Augmented Reality Headset*, TechCrunch (May 2015)

Exhibit	Description
1095	Stuart Dredge, *Virtual World Second Life to Be Reincarnated, with Oculus Rift*, The Guardian (June 24, 2014), https://www.theguardian.com/technology/2014/jun/24/second-life-oculus-rift-virtual-world
1096	Unity Manual: Audio Spatializer SDK (2020), https://docs.unity.cn/530/Documentation/Manual/AudioSpatializerSDK.html
1097	Ian Hamilton, *In a Cartoon World, Holojam Shows Participants a Slice of Space-Time*, Upload VR (Aug. t 4, 2015) https://www.uploadvr.com/holojam-shows-participants-slice-space-time/
1098	Joe Durbin, *Google Cardboard Now Offers Spatial Audio*, UploadVR (Jan. 15, 2016)
1099	Dean Takahashi, *Second Life Creator Linden Lab Starts Testing Its Virtual-Reality World: Project Sansar*, Venture Beat (Aug. 18, 2015), https://venturebeat.com/games/linden-lab-starts-testing-its-virtual-reality-world-projet-sansar/
1100	Dean Takahashi, *Unreal Engine's Latest Innovation Is About Building Games While Inside Virtual Reality*, Venture Beat (Feb. 4, 2016), https://venturebeat.com/games/epic-games-lets-you-design-your-game-inside-vr-with-new-edition-of-unreal-engine-editor
1101	Dean Takahashi, *Final Approach Is an HTC Vive VR Game that Turns You into a Kid Playing with Toy Airplanes*, Venture Beat (Jan. 29, 2016), https://venturebeat.com/games/final-approach-is-an-htc-vive-vr-game-that-turns-you-into-a-kid-playing-with-toys
1102	Dean Takahashi, *Valve's Virtual Reality Apps with the HTC Vive Headset Won't Make You Seasick*, Venture Beat (May 2, 2015), https://venturebeat.com/games/valves-virtual-reality-apps-with-the-htc-vive-headset-wont-make-you-seasick/
1103	Greg Welch et al., *High Performance Wide-Area Optical Tracking: The HiBall Tracking System*, 10 Presence: Teleoperators and Virtual Environments 1-22 (Feb. 2001) ("Welch 2001")

Exhibit	Description
1104	Elizabeth M. Wenzel et al., *A Virtual Display System for Conveying Three-Dimensional Acoustic Information*, Proc. Hum. Factors Soc'y – 32nd Annual Meeting (1988) ("Wenzel 1988a")
1105	Elizabeth M. Wenzel et al., *Development of a Three-Dimensional Auditory Display System*, 20 SIGCHI Bull. 52-57 (Oct. 1988) ("Wenzel 1988b")
1106	Elizabeth M. Wenzel et al., *Localization with Non-Individualized Virtual Acoustic Display Cues*, ACM (1991) ("Wenzel 1991")
1107	Zhiying Zhou, *An Experimental Study on the Role of Software Synthesized 3D Sound in Augmented Reality Environments*, 16 Interacting with Computers 989-1016 (2004) ("Zhou")
1109	Cardboard Unity (2015), https://github.com/jkammerl/cardboard-unity/blob/master/Cardboard/Editor/CardboardAudioSourceEditor.cs
1110	Aurale R. DeRuyck & Jack Kuipers, *An Electromagnetic Position Sensor*, Report No. AFAL-TR-73-281 (Nov. 30, 1973)
1111	Dmitry N. Zotkin et al., *Rendering Localized Spatial Audio in a Virtual Auditory Space*, 6 IEEE Transactions on Multimedia 553-64 (Aug. 2004) ("Zotkin")
1112	Ronald T. Azuma, *A Survey of Augmented Reality*, 6 Presence 355-85 (1997) ("Azuma")
1113	Gary Bishop & Henry Fuchs, *The Self-Tracker: A Smart Optical Sensor on Silicon*, 1984 Conf. on Advanced Rsch. in VLSI 65-73 (Jan. 23, 1984) ("Bishop")
1114	Mark R. Mine, *Working in a Virtual World: Interaction Techniques Used in the Chapel Hill Immersive Modeling Program*, TR96-029, Univ. N.C. (August 1, 1996) ("Mine 1996")
1115	Mark R. Mine, *ISAAC: A Meta-CAD System for Virtual Environments*, 29 Computer-Aided Design 547-53 (1997) ("Mine ISAAC 1997")

Exhibit	Description
1116	Mark Raymond Mine, *Exploiting Proprioception in Virtual-Environment Interaction* (1997) (Ph.D. dissertation, Univ. N.C.) ("Mine Exploiting Proprioception 1997")
1117	Adrienne Vincent-Phoenix, *Step into the DISH – A Visit to Imagineering's Digital Immersive Showroom*, MousePlanet (June 5, 2012), https://mouseplanet.com/9994/Step_into_the_DISH_a_visit_to_Imaginerrings_Digital_Immersive_Showroom
1118	Ian Hamilton, *How They Did It: Cars Land's Virtual Reality*, Orange Cnty. Reg., June 25, 2012, https://www.ocregister.com/2012/06/25/how-they-did-it-cars-lands-virtual-reality/
1119	Gregory F. Welch, *Hybrid Self-Tracker: An Inertial/Optical Hybrid Three-Dimensional Tracking System* (1995) (dissertation proposal, Univ. N.C.) ("Welch 1995")
1120	Steven M. Kaplan, *Wiley Electrical and Electronics Engineering Dictionary* 71, 335 (2004)
1121	Plaintiff's Infringement Contentions, Exhibit 16, *Eight Khz, LLC v. Meta Platforms, Inc*., No. 6:22-cv-00575 (W.D. Tex. Mar. 3, 2023)
1122	Amended Complaint for Patent Infringement and Demand for Jury *Trial*, *Eight Khz, LLC v. Meta Platforms, Inc*., No. 6:22-cv-00575 (W.D. Tex. Oct. 10, 2022)
1123	Mark Billinghurst et al., *The MagicBook – Moving Seamlessly Between Reality and Virtuality*, IEEE Computer Graphics and Applications, 6-8 (2001) ("Billinghurst 2001")
1124	Jaka Sodnik & Sašo Tomažič, *Spatial Auditory Human-Computer Interfaces*, Springer Briefs Comput. Sci. (2015) ("Sodnik")
1125	U.S. Patent No. 9,392,212 ("Ross")
1129	Plaintiff's Infringement Contentions, Exhibit 15, *Eight Khz, LLC v. Meta Platforms, Inc*., No. 6:22-cv-00575 (W.D. Tex. Mar. 3, 2023)

Exhibit	Description
1130	Plaintiff's Infringement Contentions, Exhibit 17, *Eight Khz, LLC v. Meta Platforms, Inc*., No. 6:22-cv-00575 (W.D. Tex. Mar. 3, 2023)
1131	U.S. Patent No. 5,173,944 ("Begault 944")
1132	U.S. Patent No. 5,438, 623 ("Begault 623")
1134	Mark Mine, *Towards Virtual Reality for the Masses: 10 Years of Research at Disney's VR Studio*, Eurographics Ass'n (2003) ("Mine 2003")
1135	Greg Welch & Eric Foxlin, *Motion Tracking: No Silver Bullet, but a Respectable Arsenal*, IEEE Computer Graphics and Applications 24-28 (2002) ("Welch, "*No Silver Bullet*")
1137	Dave Smith, *Three-Dimensional Audio Makes Virtual Reality So Much Better It's Crazy*, BUSINESS INSIDER (Apr. 3, 2015, 1:06PM), https://www.businessinsider.com/virtual-reality-the-importance-of-3d-positional-audio-2015-4
1138	Mona Lalwani, *Surrounded by Sound: How 3D Audio Hacks Your Brain*, THE VERGE (Feb. 12, 2015, 10:30AM), https://www.theverge.com/2015/2/12/8021733/3d-audio-3dio-binaural-immersive-vr-sound-times-square-new-york
1139	Ben Kuchera, *Google Cardboard Adds 'Inexpensive' Spatial Audio to Its SDK*, POLYGON (Jan. 13 2016, 12:00PM EST)
1140	Ivan Edward Sutherland, *Sketchpad, A Man-Machine Graphical Communication System* (Jan. 7, 1963) (Ph.D. dissertation, Mass. Inst. Tech) ("Sutherland 1963")

16. My opinions are additionally guided by my appreciation of how a person of ordinary skill in the art would have understood the claims of the '509 and '316 patents at the time of the alleged invention, which I have been asked to assume is February 20, 2016.

III. Legal Understandings

17. I am not an attorney. However, I have been informed by counsel of certain legal standards and have applied those standards, described below, in formulating my opinions.

18. I understand that the claims of a patent define the limits of the patentee's exclusive rights. I understand that to determine the scope of the claimed invention, courts may construe claim terms, the meaning of which the parties may dispute. I understand that claim terms should generally be given their ordinary and customary meaning as understood by a person of ordinary skill in the art at the time of filing of the patent application.

19. I understand that claims must be construed in light of and consistent with the intrinsic evidence. In this context, I understand that intrinsic evidence includes the claims themselves, the written disclosure in the specification, and the patent's prosecution history, including prior art that was considered by the United States Patent and Trademark Office. I understand that the specification is always highly relevant to the claim construction analysis and often is the single best guide to the meaning of a disputed term. I understand that extrinsic evidence may also be considered when construing claims and may include, for example, technical dictionaries, technical publications and books, treatises, and expert testimony,

though the intrinsic record will be more persuasive as to the meaning of a particular term.

20. I understand that a prior art reference can render a patent claim obvious to a person of ordinary skill in the art if the differences between the subject matter set forth in the patent claim and the prior art are such that the subject matter of the claim would have been obvious at the time the claimed invention was made. In analyzing obviousness, I understand that it is important to consider the scope of the claims, the level of skill of a person of ordinary skill in the relevant art, the scope and content of the prior art, the differences between the prior art and the claims, and so-called 'secondary considerations' of non-obviousness.

21. I understand that the claimed subject matter is obvious when a person of ordinary skill in the art would have been motivated to combine pre-existing elements and that combination yields no more than what a person of ordinary skill in the art would have expected. I also understand that in assessing whether a claim is obvious, one must consider whether the claimed improvement is more than the predictable use of prior art elements according to their established functions. I understand that there need not be a precise teaching in the prior art directed to the specific subject matter of a claim because one can take account of the inferences and creative steps that a person of ordinary skill in the art would employ.

22. I understand that obviousness cannot be based on the hindsight combination of components selectively culled from the prior art. I understand that in an obviousness analysis, neither the motivation nor the avowed purpose of inventors controls the inquiry. Any need or problem known in the field at the time of the invention and addressed by the patent can provide a reason for combining elements. For example, I understand that it is important to consider whether there existed at the time of the invention a known problem for which there was an obvious solution encompassed by the patent's claims. I understand that known techniques can have obvious uses beyond their primary purposes, and that in many cases a person of ordinary skill in the art can fit the teachings of multiple pieces of prior art together.

23. I understand that certain issues relating to validity must be judged from the perspective of a person of ordinary skill in the art. I further understand that factors that may be considered in determining the level of skill of a person of ordinary skill in the art include, but are not limited to, (1) the type of problems encountered in the art; (2) prior art solutions to those problems; (3) rapidity with which innovations are made; (4) sophistication of the technology; and (5) the educational level of active workers in the field.

24. I have been informed and understand that a person of ordinary skill in the art is a hypothetical person who is presumed to be aware of all pertinent prior art,

thinks along conventional wisdom in the art, and is a person of ordinary creativity. Importantly, this hypothetical person is of ordinary skill in the art to which the claimed subject matter pertains.

25. I understand that, when there is a reason to solve a problem and there are a finite number of identified, predictable solutions, a person of ordinary skill in the art has good reason to pursue the known options within his or her technical grasp. I further understand that, if this leads to the anticipated success, it is likely the product not of innovation but of ordinary skill and common sense, which bears on whether the claim would have been obvious.

26. I understand that secondary considerations of nonobviousness can include, for example, evidence of commercial success of the invention, evidence of a long-felt need that was solved by an invention, evidence that others copied an invention, or evidence that an invention achieved an unexpected result. I further understand that such evidence must have a nexus, or causal relationship to the elements of a claim, in order to be relevant.

IV. Overview of the ’509 Patent and ’316 Patent

27. The ’509 patent is entitled “Wearable Electronic Device Displays a 3D Zone From Where Binaural Sound Emanates.” ’509 patent (Ex.1001-509) at Title. I understand that the ’509 patent is assigned to Eight kHz LLC (“8K”).[1]

28. The ’509 patent purports to solve problems with obtaining accurate head-related transfer functions (“HRTFs”). ’509 Patent (Ex.1001-509) at 1:7-14, 2:59-65. The patent aims to avoid using “approximated HRTFs” through use of “individualized or unique” HRTFs. ’509 Patent (Ex.1001-509) at 1:15-23, 2:59-3:8, 3:44-46.

29. Figures 9A to 10D depict a person holding an HPED (in hand or on a pole), capturing impulse responses for generating individualized “HRTFs”:

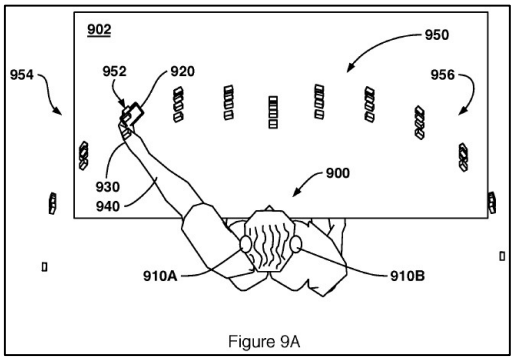


Figure 9A

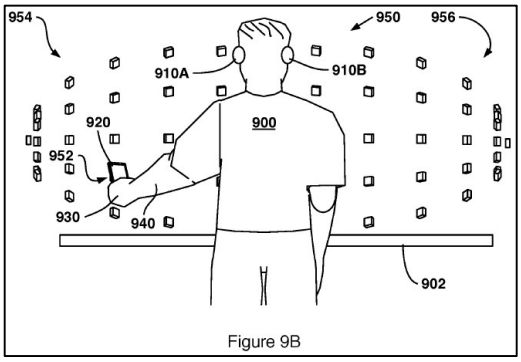


Figure 9B

[1] The ’316 patent, also entitled “Wearable Electronic Device Displays a 3D Zone From Where Binaural Sound Emanates,” contains a nearly identical disclosure. I understand that the ’316 patent is also assigned to 8K.

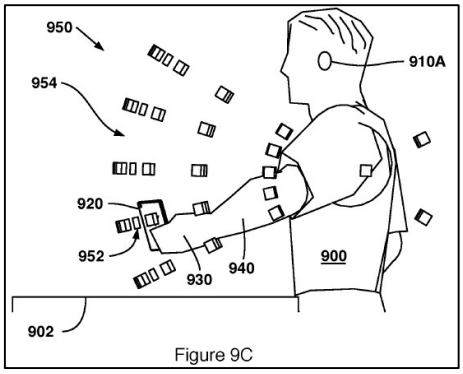


Figure 9C

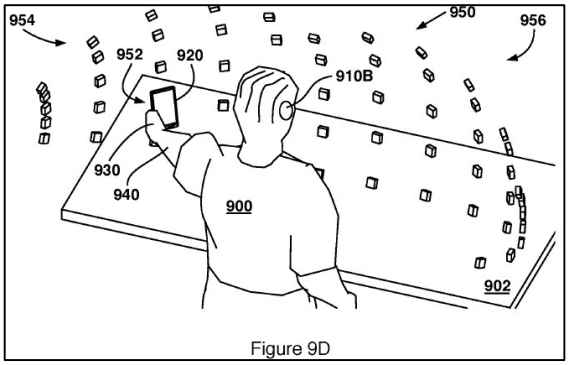


Figure 9D

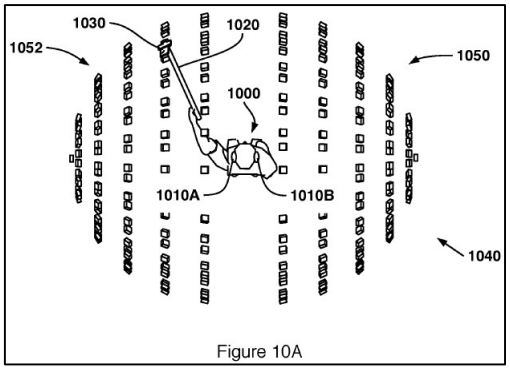


Figure 10A

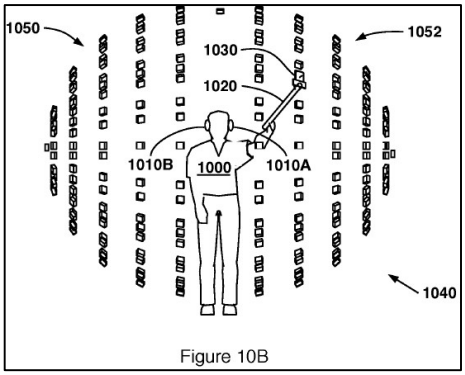


Figure 10B

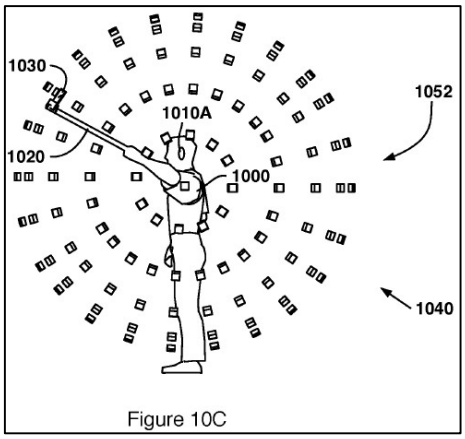


Figure 10C

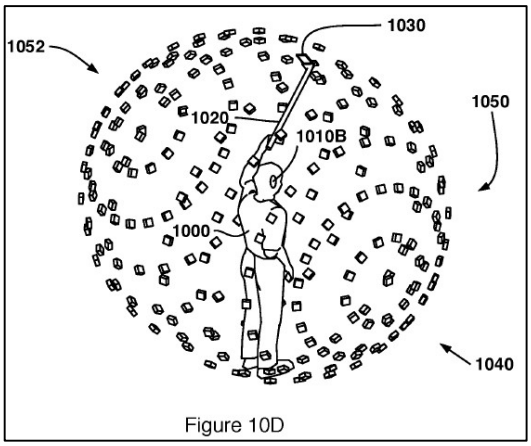


Figure 10D

'509 Patent (Ex.1001-509) at Figs. 9A-10D, 25:64-66 ("FIGS. 9A-9D show a person 900 standing next to a table 902 and capturing audio impulse responses with microphones 910A and 910B in his left and right ears."), 26:7-10 ("The HPED 920 or another electronic device processes the impulse response to generate HRIRs, BRIRs, RIRs, and/or HRTFs that are used to convolve sound to the person."). SLPs

are "formed around the person" after "the person places the HPED" at different locations, "generates [a] tone" from those locations, and "capture[s] [] impulse responses with the microphones" in his ears for each position (SLPs). '509 Patent (Ex.1001-509) at 26:36-63 (explaining how "FIGS. 9A-9D show the SLPs formed around the person in a structured pattern"), 27:8-11 (explaining that the pole in Figs 10A-D "thus ensures that the person generates and captures far-field audio impulse responses and provides more flexibility to generate SLPs in a number of locations.").

30. The user can then manage SLPs by "select[ing an] SLP for sound localization for a source he designates":

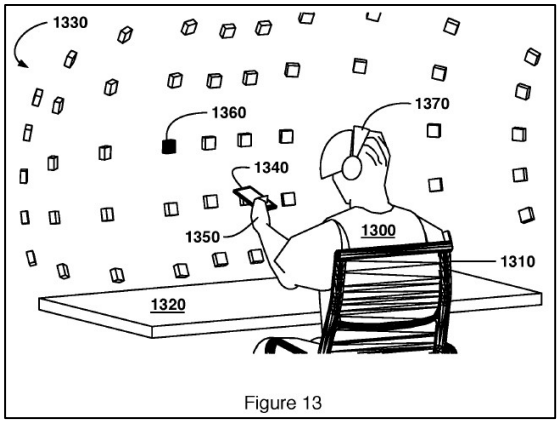


Figure 13

'509 Patent (Ex.1001-509) at Fig. 13 (showing selected SLP 1360), 28:19-32 ("Pointing the HPED at the SLP in effect selects this SLP for sound localization for a source he designates. Thereafter, sounds will localize to this selected SLP, such as sounds heard through a wearable electronic device 1370.").

31. A person can divide surrounding areas containing SLPs into "a plurality of zones" and receive "visual indication[s]" of zones and SLPs. '509 Patent

(Ex.1001-509) at 18:27-38, 18:46-57, 20:37-57, 21:64-22:7. Certain actions can occur when an HPED leaves a zone, e.g., a sound or visual warning. '509 Patent (Ex.1001-509) at 19:64-20:27 ("An action occurs when the HPED is not within a zone… Example actions include, but are not limited to, providing the user or other person with a sound warning (e.g., playing a sound warning from the HPED), providing the user or other person with a visual warning (e.g., displaying a visual indication on the HPED, such as a text or light or an image), displaying a visual indication of the zone or zones so the user can move to or navigate to the zone and correct location, providing verbal instructions that indicate where the user should physically move so the user and/or HPED is within a particular zone").

V. Level Of Skill In The Art And Perspective Applied In This Declaration

32. I understand that certain issues relating to validity must be judged from the perspective of a person of ordinary skill in the relevant art.

33. With respect to both the '509 and '316 patents, a person of ordinary skill in the art at the time of the earliest claimed priority date, February 20, 2016, would have been familiar with the development and implementation of virtual and/or augmented reality systems, and underlying technology used therein.

34. A person of ordinary skill in the art would have had a bachelor's degree in computer science/engineering, or a related field, and at least two years of industry experience or academic research experience in virtual/augmented reality, including

visual and audio rendering. In my view, more education can supplement relevant experience and vice versa.

35. At the time of the earliest claimed priority date for the ’509 and ’316 patents (February 20, 2016), I met the qualifications to be a person of ordinary skill in the art, and I believe that I also have a sufficient level of knowledge, experience, and education to provide expert opinions in the field of the ’509 and ’316 patents.

36. While my own level of skill exceeded that of the ordinary level of skill as of February 2016, I am well-acquainted with the actual performance and capabilities of a person of ordinary skill in the art as defined above. For example, during the relevant timeframe, I was supervising and evaluating the performance of such individuals, such as my graduate students who were performing research in this area. Furthermore, my participation in professional organizations and in workshops and events exposes me to the state of the industry and the level of experience of individuals who, like I did, had at least the ordinary level of skill.

37. I have applied the perspective of a person of ordinary skill in the art, as of February 2016, in forming and expressing my opinions. Unless otherwise stated, my testimony below refers to the knowledge of one of ordinary skill in the art at the relevant time.

VI. Claim Construction

38. In my analysis, I have applied the plain and ordinary meanings of the claim terms in the ’509 and ’316 patents, as a person of ordinary skill in the art would have understood them in the context of that patent in approximately February 2016. However, my analysis does not depend on any particular or precise construction of a term, because I did not find that to be necessary to provide my opinions regarding the relationship between the prior art and the claims of the ’509 and ’316 patents. The opinions that I provide in this declaration would remain true under any reasonable construction of the claim terms in the ’509 and ’316 patents.

VII. State of the Art

39. In this section, I provide overviews of technologies and prior art pertinent to the ’509 and ’316 patents and to the state of the art as of the ’509 and ’316 patents’ earliest possible priority date of February 20, 2016. In later sections, I address in detail how the prior art discloses and renders obvious the recitations of the challenged claims.

40. The prior art references described below and discussions of what was known to a person of ordinary skill in the art provide a general description of the state of the art at the time of the invention, provide additional motivation to modify the primary references evaluated in the grounds of invalidity with the knowledge of a person of ordinary skill in the art or other references cited herein, and provide

support for why a person of ordinary skill in the art would have had a reasonable expectation of success in combining the teachings of the references. The additional prior art references identified in this section are exemplary in nature and are included to provide factual support for my opinions.

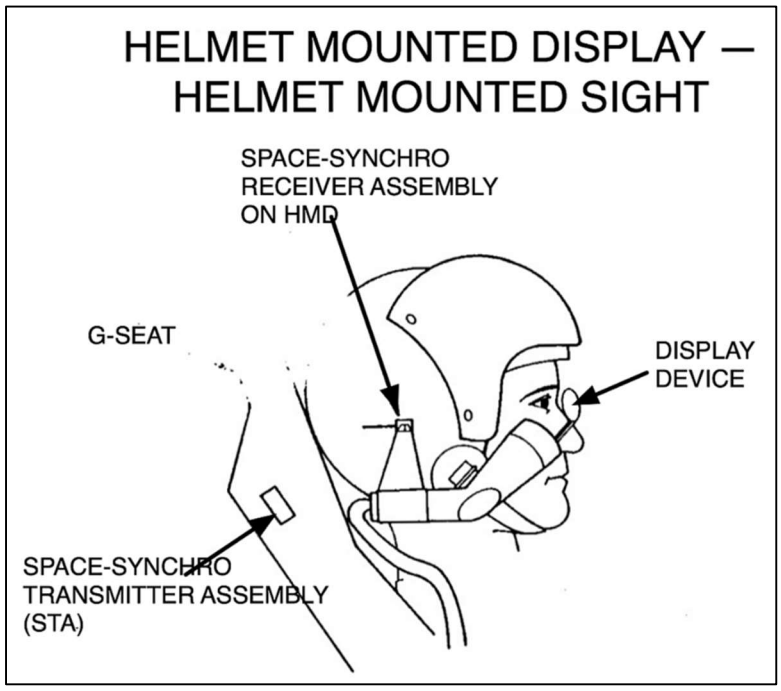
A. Brief History

41. Virtual environments generated by a computer have been around for many decades, long before February 2016. What began as targeted, virtual simulations have grown into more comprehensive virtual "experiences," with the common goal of complete immersivity driving these developments through the 2000s. A brief chronology of these developments is described in this section.

42. Some of the earliest examples of regularly used systems for 3D human-computer interaction for visual simulation were flight simulators.

43. The earliest example of a flight simulator is an electromechanical pilot trainer developed by Edwin Link in 1929. ASME, *The Link Flight Trainer* (June 10, 2000) (Ex.1047) at 2-3. Real-time simulators with digital displays became available in the 1950s to 1960s, when realistic imagery of scenery could be coupled with the motion systems of those simulators. Royal Air Force Museum, *Flight Simulation and Synthetic Trainers* (Ex.1083) at 1-2; Statler (Ex.1092) at 64-65 (describing flight simulators that upgraded their CRT displays to digital displays).

44. Looking more narrowly at systems with interactive graphics, around 1966 the Air Force Aerospace Medical Research Laboratory (AFAMRL) began work on the Visually Coupled Airborne System Simulator (VCASS), shown below, one of at least two visually coupled systems being pursued by AFAMRL:



Kocian, *A Visually-Coupled Airborne System Simulator* (1977) (Ex.1066) at Fig. 2.

45. This work gave rise to the development of the Space Synchro (SPASYN) magnetic head-tracking technique by Polhemus Navigation Services, and the Isotrak tracking system, introduced by Polhemus in 1979, which would become the primary means for head tracking in VR for years, which I further discuss in Section VII.D. DeRuyck (Ex.1110) at 9-11, 17-20, Fig. 3.

46. Systems for what we would today call mixed reality (MR), Augmented Reality (AR), and Virtual Reality (VR) also existed for decades before February 2016.

47. A seminal example of such work is that of Ivan Sutherland and his students at the University of Utah in the 1960s, including Sutherland's "head-mounted three dimensional display" paper, which is among the most well-known in the field:

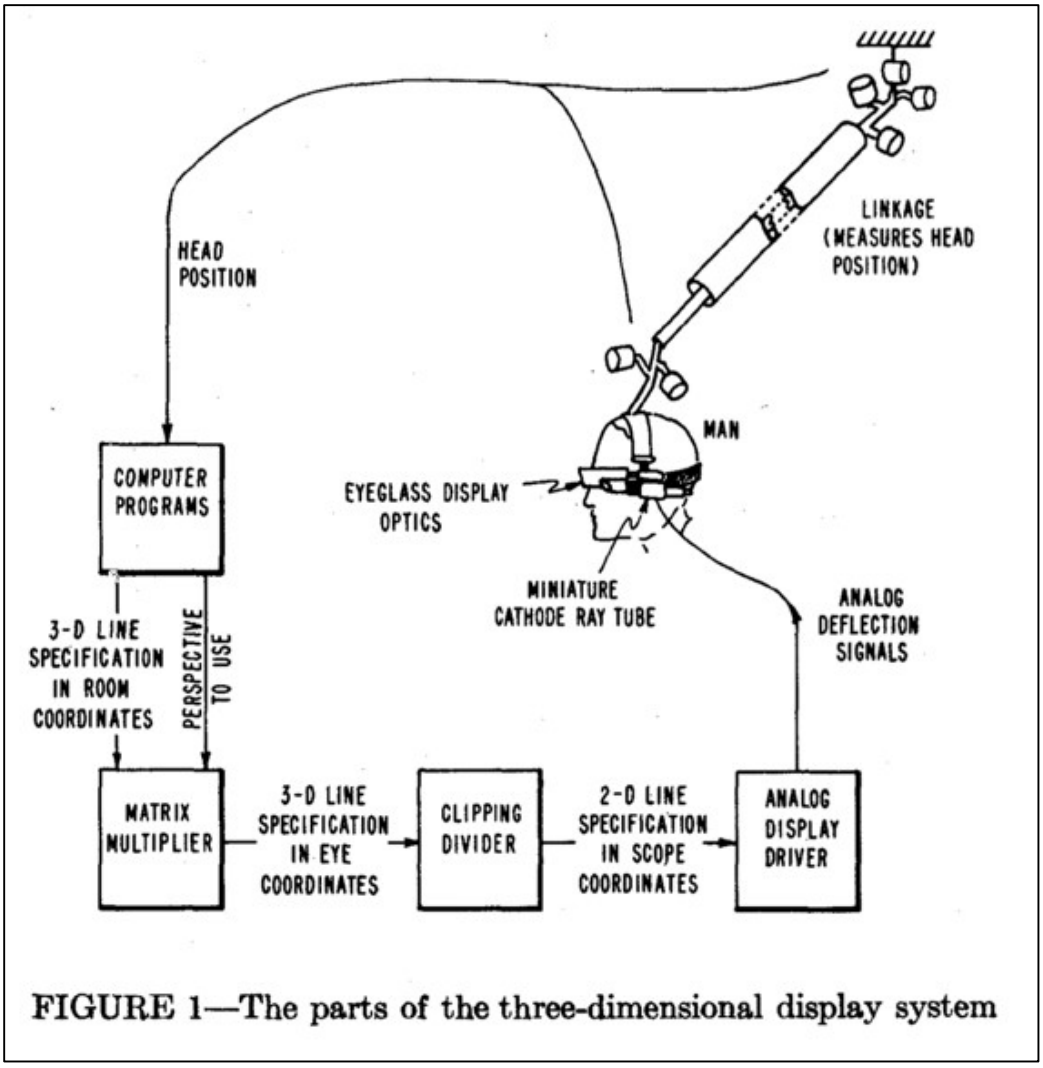


FIGURE 1—The parts of the three-dimensional display system

Sutherland, *A Head-Mounted Three Dimensional Display* (1968) ("Sutherland 1968") (Ex.1093) at Fig. 1 (Sutherland's three-dimensional display system); *see also id.* at Figs. 2-4 (photographs of Sutherland's prototype system, showing for example a custom graphics computer, a head tracking system, and a head-mounted display):

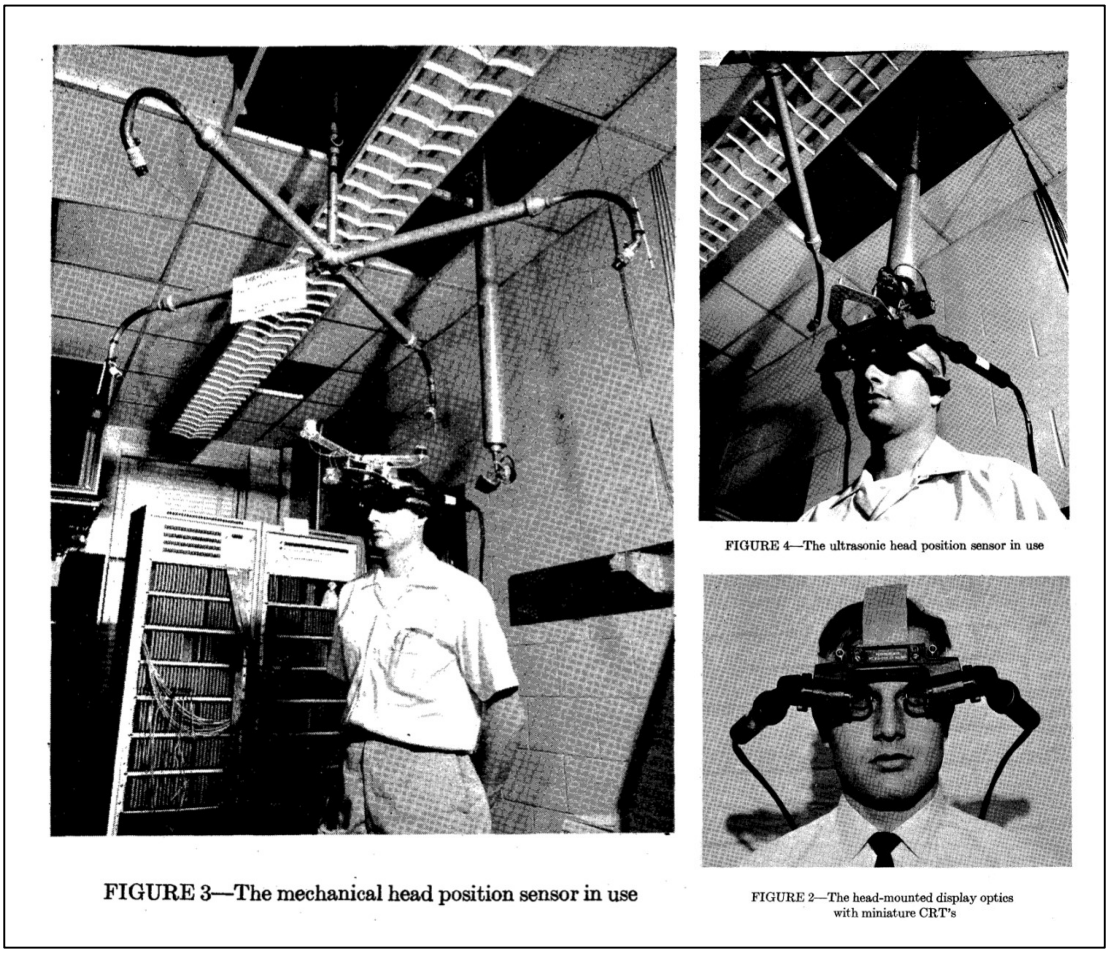


FIGURE 3—The mechanical head position sensor in use

FIGURE 4—The ultrasonic head position sensor in use

FIGURE 2—The head-mounted display optics with miniature CRT's

48. Sutherland's work above offers one of the earliest examples of AR and VR wearable electronic devices for displaying AR and VR environments to users, for tracking users' positions and orientations (the "pose") in a coordinate system corresponding to real, physical space, mathematically transforming pose estimates into a coordinate system corresponding to virtual space, rendering the virtual

environment, and displaying it in a head-worn device—i.e., a head-mounted display (or "HMD").

49. Over the years, the systems and methods associated with each of those component areas have steadily evolved into more sophisticated, higher performance, and more robust versions. *See* Jerald, THE VR BOOK (2015) ("Jerald, THE VR BOOK") (Ex.1063) at ch. 2 (providing a general history of VR). In parallel, researchers around the world have been developing sophisticated user interfaces (UI) for navigating virtual environments and interacting with virtual objects and entities.

50. For example, "tracking systems" have evolved from versions requiring relatively significant infrastructure on and around the user, to systems that can estimate a user's pose using only devices worn on the user, and trackable devices with several degrees of freedom. *See* Jerald, THE VR BOOK (Ex.1063) at 307-08 (explaining that six degrees of freedom, or "6DoF" or "6 DoF," systems, for example, "measure full 3D translation (up/down, left/right, forward/backward) and rotation (roll, pitch, and yaw)"), 308 ("VR hand tracking should have a minimum of 6 DoF"). As one example, by the early 1980s, the "Self-Tracker," prototyped at the University of North Carolina, Chapel Hill, provided "[t]racking with an outward view," which "offers the possibility of operating in many different environments, ordinary rooms with ordinary room lights, with little or no overhead of setup." *See* Bishop, *The Self-Tracker: A Smart Optical Sensor on Silicon* (1984) ("Bishop") (Ex.1113) at 67.

51. Similarly, computer graphics systems have evolved from room-sized racks of computers and specialized graphics computers to personal computers with specialized graphics processors, to battery-operated systems that reside entirely on the user.

52. Driven primarily by the advent of the smartphone—in particular the Apple iPhone in 2007—AR and VR systems became self-contained within single head-worn units that included computers, wireless networking, motion tracking, graphics rendering, and high-resolution displays. Several such examples are discussed below, and in Section VII.B.

53. The gaming industry also fueled significant advances in such features, as well as other technologies that enabled truly immersive and interactive AR and VR experiences.

54. For example, in 2015, Microsoft unveiled its HoloLens HMD and invited developers to create AR applications for it. TechCrunch, *HoloLens Hands-On: How We Built An App For Microsoft's Augmented Reality Headset* (May 1, 2015) (Ex.1094) at 1 ("Microsoft gave developers … a chance to spend some quality time with HoloLens by building our own 'holographic application' using the Unity engine and Visual Studio."). HoloLens was a "self-contained, untethered headset" that rendered "virtual objects into the users view of the real world":



RoadtoVR, Watch Halo Played on Microsoft HoloLens in Augmented Reality (Dec. 7, 2015) (Ex.1085) at 1-2.

55. The HoloLens processed head-related transfer functions (or "HRTFs"), which I discuss more below in Section VII.E, to generate "spatial sound so you can hear holograms even when they're behind you." Microsoft, *BUILD 2015: A Closer Look at the Microsoft HoloLens Hardware* (Apr. 30, 2015) ("Microsoft, *BUILD 2015*") (Ex.1071) at 4 ("Using a scientific model that characterizes how the human ear receives sound from a specific physical location, HoloLens can synthesize a binaural sound so that you perceive it to come from a specific location in the physical space around you."); Microsoft, *Spatial Audio* (Dec. 1, 2015) (Ex.1072) at 1-2 (discussing Microsoft's work on spatial sound, HRTFs, and specifically "convert[ing] spatial audio research projects to shippable code in various Microsoft products" including "the audio engine in HoloLens"). An inertial measurement unit (IMU) "coupled with head tracking cameras … enable[d] HoloLens to understand where your head is and how it's moving." Microsoft, *BUILD* 2015 (Ex.1071) at 4. Localized audio was also present in other commercially available systems, such as

HTC Vive. VentureBeat, *Valve's Virtual Reality Apps with the HTC Vive Headset Won't Make You Seasick* (May 2, 2015) ("VentureBeat Valve") (Ex.1102) at 4 (HTC Vive is configured to play "3D positional audio, so you can tell what direction the sounds are coming from.").

56. Other popular systems available before February 2016 included Samsung's Gear VR (below on left) and Google Cardboard (below on right), both of which ran on a smartphone:





Parisi, LEARNING VIRTUAL REALITY (Nov. 2015) ("Parisi") (Ex.1075) at 19 ("Through a partnership with Samsung, Oculus technology has been incorporated into the Gear VR, a revolutionary headset … with new head-tracking technology, placed in a custom headset that houses a mobile phone with a high-resolution display."), 20 ("In 2014 Google introduced Cardboard VR, which allows users to experience virtual reality using pretty much any mobile phone.").

57. Around late 2014, Samsung Gear VR also enlisted Sixense to advance the positional tracking for its controllers. *See* RoadtoVR, *Samsung Gear VR Gets Positional Tracking Via Sixense STEM* (Nov. 8, 2014) (Ex.1086) at 1; Pocket Gamer,

Sixense picks up CES awards for virtual reality controller (Jan. 13, 2015) (Ex.1080) at 3 ("very positive responses to [Sixense] demos on Samsung Gear VR").

58. All of these AR and VR systems would have been well-known to persons of ordinary skill in the art. *See* Parisi (Ex.1075) at 141-47 (compiling list of headsets, input devices, software development kits ("SDKs"), other related AR and VR technology, and "noteworthy companies" in its appendix); *see also* Parisi (Ex.1075) at 1 (identifying Unity3D and Unreal as game engines that "have become tools of choice for native VR development").

59. Companies were also pursuing the development of AR and VR software and game engines before February 2016, including the development of tools people could use to create AR and VR games and other applications.

60. For example, Unity and Unreal were freely available, full-featured VR game engines that were well known before February 2016. *See* Parisi (Ex.1075) at 1 (recognizing "Unity3D and Unreal game engines" as "tools of choice for native VR development").

61. The core components of the Unity and Unreal game engines included a modeling system to create and position virtual objects (including visual components and sound sources) throughout a three-dimensional virtual scene, a rendering engine for generating 3D graphics, an audio engine for processing sounds, a physics engine that simulated real-world physics, and a user interface (UI) system that allowed users

to navigate and interact with virtual environments. And with these pre-built tools, developers could design immersive virtual environments and intuitive ways to interact with them. *See* Parisi (Ex.1075) at 1.

62. Moreover, even before consumer-level AR and VR devices were released, the technologies underlying those devices were extensively described in industry publications, patent applications and publications, and patents, as the following subsections show.

B. Wearable Electronic Devices (WEDs) and Head-Mounted Displays (HMDs)

63. Many variants of head-mounted displays (HMDs), which are wearable electronic devices (WEDs), were well known before February 2016.

64. "Head-mounted displays (HMDs) are the most common visual interface to virtual environments." NSA, *Virtual Reality* (Dec. 1, 2011) ("NSA, *Virtual Reality*") (Ex.1073) at 25. HMDs are also sometimes referred to with other names, such as a head-worn display or a heads-up display, and sometimes provide specificity as to the type of HMD, such as "glasses" or "goggles."

65. The image below depicts some of the many different types of HMDs that were known to persons of ordinary skill in the art before February 2016:

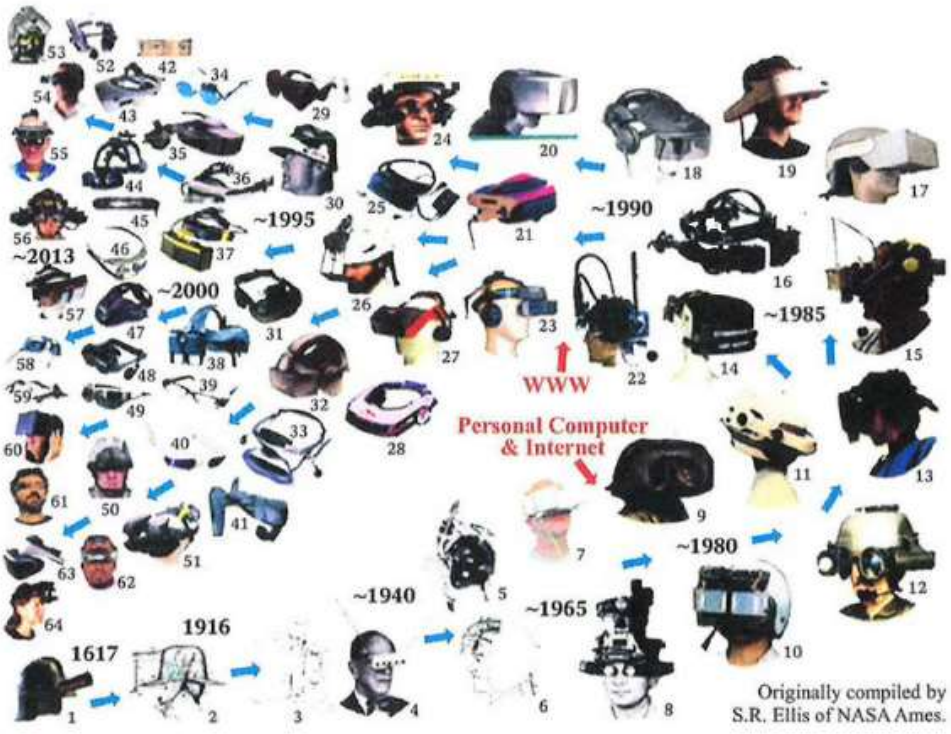
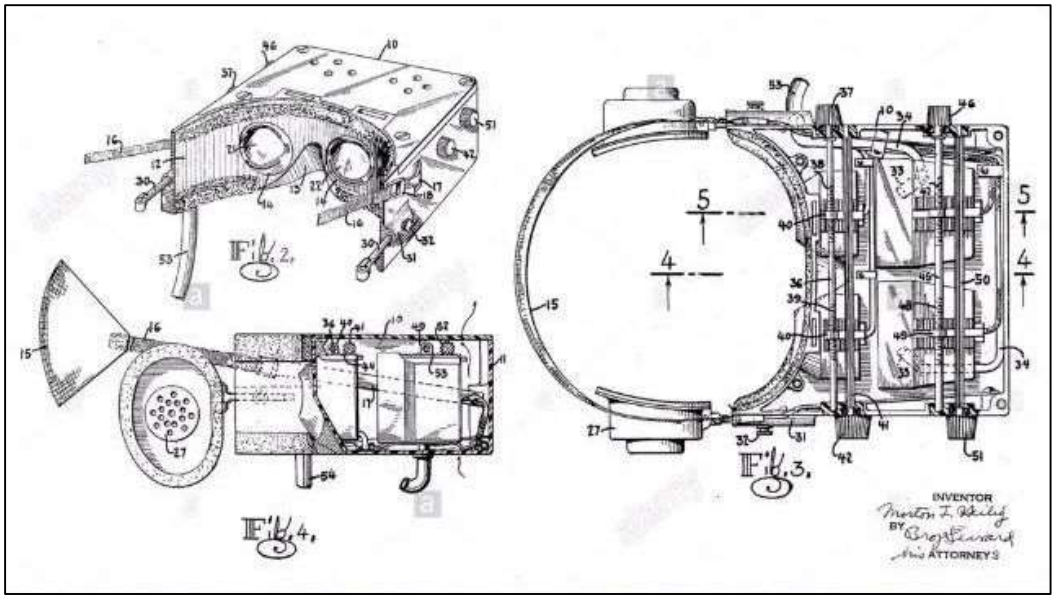


Figure 2.1 **Some head-mounted displays and viewers over time.** (Originally compiled from Ellis (2014))

Jerald, THE VR BOOK (Ex.1063) at Fig. 2.1 (discussing various types of HMDs).

66. HMDs have existed since at least the 1960s, as shown by, for example, the VCASS flight simulator system shown in Figure 2 of Kocian, or the HMD of the Sutherland system shown in Figure 2 of Sutherland, both reproduced in Section VII.A above.

67. Another example of an early HMD comes from a 1960 patent, which taught use of stereo displays to create 3D peripheral images, and stereo and binaural sound played through adjustable earphones:



U.S. Patent No. 2,955,156 ("Heilig") (Ex.1016) at 3:18-21 ("By the independent feeding of right and left eyes with images taken by separate film or TV cameras equipped with wide angle lenses, a truly three dimensional peripheral image is created."), 1:37-40 ("Another object is to provide ear phones which are so designed that the outer ear is completely free and untouched, thus allowing the ear phones to operate fully as sound focusing organs."), 3:14-17, ("the spectator is given a complete sensation of reality, i.e., moving three dimensional images, which may be in color, with 100% peripheral vision, binaural sound, scents and air breezes"), 3:22-25 ("By providing independent ear phones, which are fed separately from sounds recorded by independent microphone systems, excellent stereophonic or binaural sound 1."), Figs. 2-4. I discuss sound localization and binaural sound in further detail in Section VII.E.

68. As I explain further in Sections VII.C, VII.D and VII.E, many AR and VR systems as of February 2016 comprised head-worn systems that included far more than just displays. They typically included substantial processing units capable of head and hand (controller) tracking and the rendering of view-dependent stereo images and spatialized sound. *See, e.g.*, Jerald, THE VR BOOK (Ex.1063) at 32 ("Position and orientation tracking of HMDs is essential for VR because the display and earphones move with the head.").

C. Handheld Controllers

69. Handheld controllers were commonly known and used as input devices in AR and VR systems before February 2016, and when tracked, were used to allow the user to point at, select, and manipulate virtual objects in virtual environments.

70. "Virtual reality is an attempt to provide an interactive, immersive interface to a synthetic, computer-generated world," and it "provides direct manipulation and control of synthetic objects as well as providing the user with the illusion of immersion." NSA, *Virtual Reality* (Ex.1073) at 46.

71. To enhance user interaction, AR and VR systems commonly used handheld controllers with motion tracking to allow users to interact with virtual objects.

72. "Tracked hand-held controllers [we]re typically 6DoF devices," "known as 'wands' in the VR research community where they ha[d] been used for

decades." Jerald, THE VR BOOK (Ex.1063) at 314, 308 ("VR hand tracking should have a minimum of 6 DoF"); Billinghurst, *A Survey of Augmented Reality* (Mar. 2015) ("Billinghurst 2015") (Ex.1049) at 167-69 (describing 6DoF "wand type pointing devices" and "joysticks" that allow users to "point at or manipulate virtual objects"). Such tracked handheld controllers were "easy to use for many 3D tasks due to their natural, direct mapping to hand motion." Jerald, THE VR BOOK (Ex.1063) at 314-15.

73. Tracked handheld controllers, like those shown below, "enhance[] presence through physical touch," "facilitate communication with the virtual world," and "make spatial relationships seem more concrete to the user":



Figure 27.3 **The Sixense STEM (left) and Oculus Touch (right) tracked hand-held controllers.** (Image courtesy of Sixense)

Jerald, THE VR BOOK (Ex.1063) at 315 (describing, in 2015, "integrated analog sticks (as on the Sixense STEM and Oculus Touch controllers as shown in Figure 27.3)"), Fig. 27.3.

74. It was well known that handheld controllers were used to allow a user to select and manipulate virtual objects, and to interact with a virtual environment

and virtual characters. Typical controller gestures included pointing or moving the controller to the virtual object, then pressing a button on the controller to select or grab the object, and moving the controller to manipulate (e.g., move, throw, or aim) the object. U.S. Patent No. 8,419,545 ("Yen") (Ex.1041) at 19:67-11:5 (user waves motion controller to cause avatar to wave virtual object); U.S. Patent No. 9,703,369 ("Mullen") (Ex.1029) at 11:18-26 (handheld controller acts as a pointer using a "virtual laser [that] emanates out of [the] controller."), 9:16-24 (user points motion controller to aim virtual gun at virtual objects), 14:26-15:6 (user presses button on motion controller to grab virtual objects and moves motion controller to move them); U.S. Patent No. 10,162,177 ("Pedrotti") (Ex.1032) at 9:26-40 (user grabs virtual weapon by reaching for it with motion controller and "pressing a button on the controller," and then moves the virtual weapon by moving the controller); Mine, *Exploiting Proprioception in Virtual-Environment Interaction* (1997) ("Mine Exploiting Proprioception 1997") (Ex.1116) at 70-71 (describing "[o]bject selection/manipulation where "[u]sers select and manipulate objects with their dominant hand" and "[t]he default form of manipulation is unconstrained 6DoF manipulation"). These are forms of "direct manipulation," which include "pushing an object, and selection via hand pointing." Jerald, THE VR BOOK (Ex.1063) at 299. As "different tasks may require different interaction techniques," some techniques may require a sequence of operations, e.g., "a specific manipulation technique only

occurs after a specific selection technique"—that is, the user first selects an object with the controller and then moves that object using the controller. Jerald, THE VR BOOK (Ex.1063) at 300; Mine, *ISAAC: A Meta-CAD System For Virtual Environments* (1997) ("Mine ISAAC 1997") (Ex.1115) at 548 ("To select an object, the user points the laser beam at a desired object and clicks on a button on the input device").

75. With handheld controllers, pointing "is one of the most fundamental and often-used patterns for selection." Jerald, THE VR BOOK (Ex.1063) at 327, 328 ("When hand tracking is available, hand pointing with a ray extending from the hand or finger is the most common method of selection."); U.S. Patent No. 9,392,212 ("Ross") (Ex.1125) at 22:17-29 ("user may use a pointer (a physical pointer such as a mouse and/or other pointer and/or a virtual pointer displayed in the virtual space)," and "a controller (e.g., a pointer)" to control "fields of view, [and] view boundaries"), 14:44-52 ("the user may use a pointer"), 7:51-62 (describing authoring capabilities that use pointing). Pointing offers advantages, such as not requiring the user to travel to be close to the object to be selected, as would be required for hand selection. Jerald, THE VR BOOK (Ex.1063) at 325-27 ("The Pointing Pattern is typically better than the Hand Selection Pattern unless realistic interaction is required."), 347 (referencing paper that "found pointing to take less time and to be more preferred by users"). Pointing can be used to select objects by having the user point to an object

to select, and then applying a direct hand manipulation (e.g., selection via a user-controller trigger). Jerald, THE VR BOOK (Ex.1063) at 327.

76. Tracked handheld controllers enabled dynamic gestures, which "consist of one or more tracked points," e.g., "making a gesture with a controller." Jerald, THE VR BOOK (Ex.1063) at 296. Tracked handheld controllers also allowed conveying spatial information related to the gesture. For example, "gestures can manipulate (e.g., push/pull), indicate (e.g., point or draw a path), describe form (e.g., convey size), describe functionality (e.g., twisting motion to describe twisting a screw), or use objects." Jerald, THE VR BOOK (Ex.1063) at 296.

77. Tracked handheld controllers were known to be intuitive and easy to use "due to their natural, direct mapping to hand motion." Jerald, THE VR BOOK (Ex.1063) at 314; *see also* Jerald, THE VR BOOK (Ex.1063) at 314-15 ("[b]ecause the controllers are tracked, they can be visually co-located with the real hands").

78. It was also known that an HMD could display a "visual representation of a tracked hand-held controller" with labels to provide "immediate instruction of what [] buttons do":

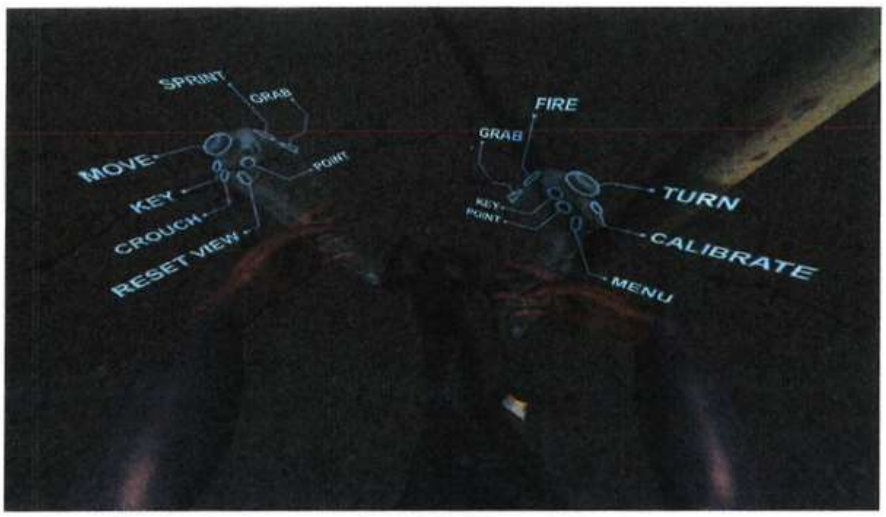


Figure 26.3 **A simple transparent texture in the hand can convey the physical interface.** (Image courtesy of NextGen Interactions)

Jerald, THE VR BOOK (Ex.1063) at 315, Fig. 26.3.

79. In AR and VR games and applications, tracked handheld controllers were used as proxies for physical objects that users would use during game play. *See, e.g.*, Medium, *UX Pointers for VR Design* (Nov. 19, 2015) (Ex.1070) at 14 ("In VR, the same physical controllers can be rejiggered to be guns, lightsabers, laser pointers, slingshots, grapplehooks, spray cans, or anything else you might dream up."); U.S. Patent No. 9,884,248 ("Koseki") (Ex.1020) at 27:38-51 ("[A] pointing device may be used depending on the game. A known gun-type controller, a known stick motion controller, or the like may be used as the pointing device …. In such a case, the pointing device may be used as the game controller 1200."); Eurogamer, *Oculus Touch is the Gold Standard in VR Control* (June 24, 2015) (Ex.1058) at 2 ("Move and Valve's solution[s] are also very good, and based on the same basic

principle - you grip one controller in each hand and both are subject to three-dimensional motion tracking, giving you two virtual hands with which to manipulate objects around you in virtual space.").

80. Pointing and selecting were also commonly used to interact with game elements, which include sound-producing game elements such as a flying plane. *See, e.g.*, VentureBeat, *Final Approach Is An HTC Vive VR Game That Turns You Into A Kid Playing With Toy Airplanes* (Jan. 29, 2016) (Ex.1101) at 4 ("Using the touch control system of the HTC Vive, you can point at aircraft and trace a path. [Y]ou can get them to fly through a series of circles and land."); VentureBeat, *Unreal Engine's Latest Innovation Is About Building Games While Inside Virtual Reality* (Feb. 4, 2016) (Ex.1100) at 3 ("You can [use motion controller to] grab objects and place them in the world or aim at them with a virtual laser pointer and then move them around.").

81. In other games and applications, tracked handheld controllers were used as tools to draw, create, and author. *See, e.g.*, UploadVR, *In a Cartoon World, Holojam Shows Participants a Slice of Space-Time* (Aug. 4, 2015) (Ex.1097) at 2 (participants "will be armed with magic wands allowing them to paint or sculpt an evolving work of art"); Mine, *Working in a Virtual World: Interaction Techniques Used in the Chapel Hill Immersive Modeling Program* (1996) ("Mine 1996") (Ex.1114) at 3 (in the 3-Draw system, "[b]y using a stylus held in the other hand,

one could draw two-dimensional curves on the palette which resulted in curves in three-dimensional space"); Mine 1996 (Ex.1114) at 3 (the THRED system "is a two-handed (6DOF each) computer-aided design system for sketching free-form polygonal surfaces"); Mine 1996 (Ex.1114) at 3 (Holosketch system is a "VR based sketching system that extends the 2D sketch-draw paradigm to 3D" using "a 6DOF wand").

82. The use of a handheld device to draw free-form polygonal objects and geometric "primitives" such as lines, circles, and rectangles in VR traces its roots back to early two-dimensional drawing and computer aided design (CAD) systems. A well-known seminal example is that of Sketchpad, a stylus-based (light pen) system developed by Ivan Sutherland at the MIT Lincoln Labs in the early 1960s:



FIGURE 1.2. TX-2 OPERATING AREA - SKETCHPAD IN USE.
On the display can be seen part of a bridge similar to that of Figure 9.6. The Author is holding the Light pen. The push buttons used to control specific drawing functions are on the box in front of the Author. Part of the bank of toggle switches can be seen behind the Author. The size and position of the part of the total picture seen on the display is obtained through the four black knobs just above the table.

Sutherland, Sketchpad: A Man-Machine Graphical Communication System, Thesis, Massachusetts Institute of Technology (1963) ("Sutherland 1963") (Ex.1140) at Fig. 1.2; *see also* Sutherland 1963 (Ex.1140) at 13-15, Fig. 1.4 (depicting steps for drawing straight lines and circle arcs and showing examples of how free-form drawing is turned into a line and a circle), and Fig. 1.5 (depicting examples showing the creation of shapes from equal-length line segments).

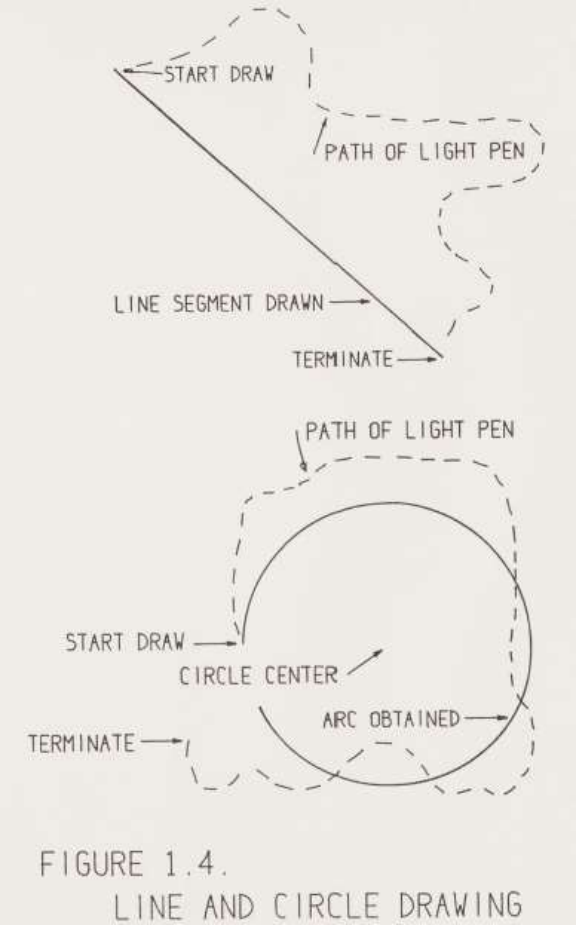


FIGURE 1.4.
LINE AND CIRCLE DRAWING

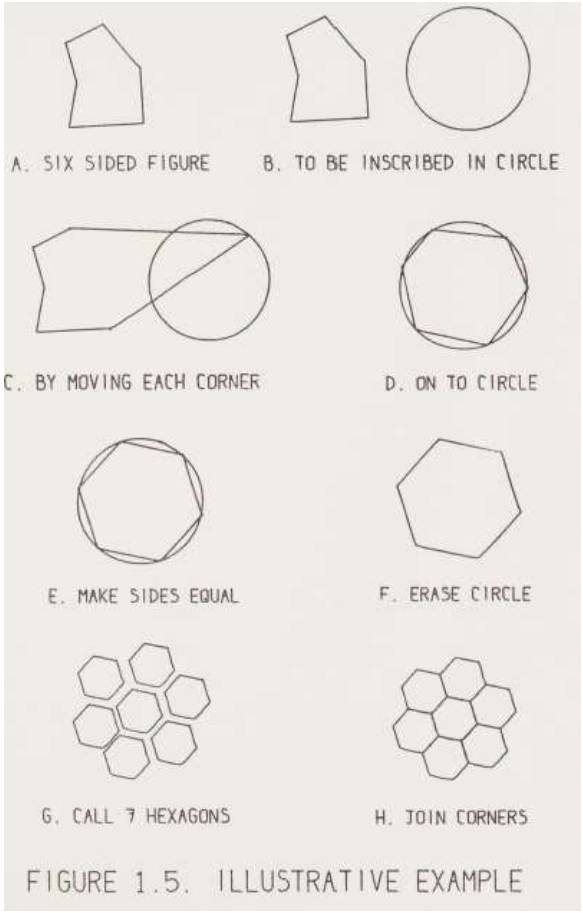


FIGURE 1.5. ILLUSTRATIVE EXAMPLE

83. It was also known before February 2016 that, in association with virtual object selection in three-dimensional virtual environments, feedback could be provided to a user, e.g., haptic, visual, or audio feedback:

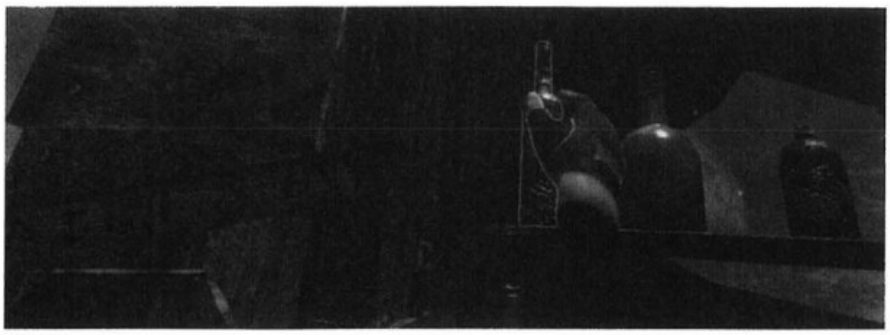


Figure 26.5 **In the game "The Gallery: Six Elements," the bottle is highlighted to show the object can be grabbed.** (Image courtesy of Cloudhead Games)

Jerald, THE VR BOOK (Ex.1063) at 356 (disclosing use of these forms of feedback "to signify touching of objects"), 305 ("Highlighting is visually outlining or changing the color of an object … Highlighting is also used to convey that an object is able to be selected or grabbed when the hand is close even though a collision has not yet occurred,"), Fig. 26.5.

D. Tracking WEDs/HMDs and Controllers

84. As I discuss in several examples in this section, both head tracking (e.g., tracking WEDs and HMDs) and hand tracking (e.g., tracking a peripheral associated with the user's hands) in AR and VR systems were known to persons of ordinary skill in the art before February 2016. Furthermore, by February 2016, HMDs included processors with sufficient processing capacity to perform such tracking.

85. "Concepts such as head tracking [and], hand tracking … are core elements for VR experiences." Jerald, THE VR BOOK (Ex.1063) at 263; *see also* Welch, *No Silver Bullet* (Ex.1135).

86. To render appropriate imagery of a virtual environment for a user's HMD and play spatialized audio as they move around, the system must estimate head pose. Jerald, THE VR BOOK (Ex.1063) at 99 ("Auditory perception is quite complex and is affected by head pose"), 156 ("[u]se binaural cues with head pose to give a sense of sound location"), 189 ("rendering needs to be tightly coupled to head pose with minimal delay"), 318 ("head tracking must be accurate, precise, fast, and

well calibrated for the virtual world to appear stable"); Begault, *3-D Sound for Virtual Reality and Multimedia*, 133 (2000) ("Begault") (Ex.1007) ("If one of the perceptual requirements is to have virtual sound images remain fixed in virtual space independent of where one's head moves, a six degree-of-freedom tracker system is necessary, consisting of a source, sensor, and a hardware unit housing power supply, electronics, and RS-232 interface to send positional data to a host computer.") (emphasis in original omitted).

87. As a general principle, to track the pose of a user's head with sensors (e.g., cameras or microphones) and sources (e.g., LEDs or speakers), one can either put the sources on the user's moving head and then mount sensors at fixed points in the environment, or the reverse—put the sensors on the user's moving head and mount sources at fixed points in the environment. The former is sometimes referred to as "outside-looking-in" tracking and the latter as "inside-looking-out" tracking:

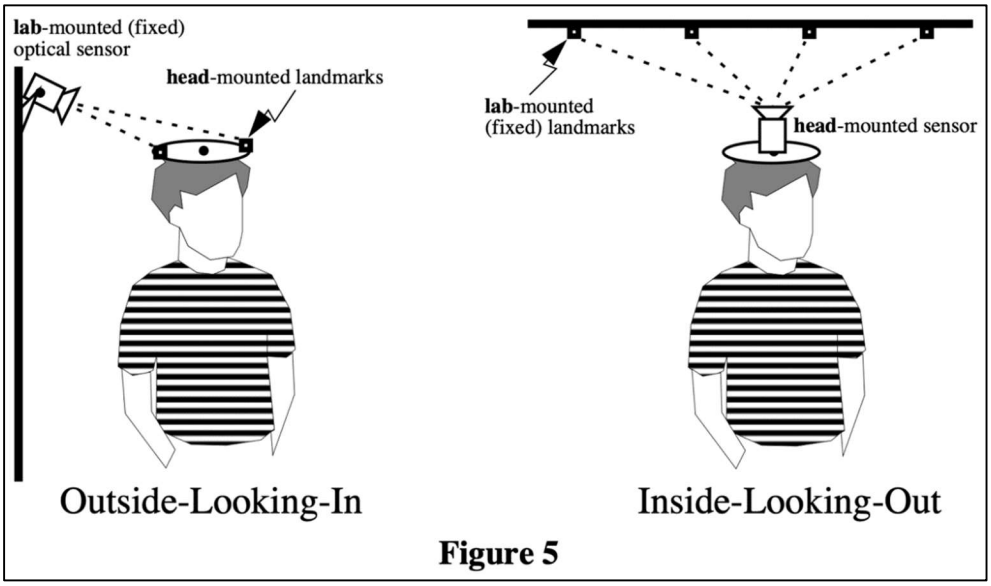


Figure 5

Welch, *High-Performance Wide-Area Optical Tracking: The HiBall Tracking System* (2001) ("Welch 2001") (Ex.1103) at Fig. 5 (describing benefits and design considerations for both configurations). Persons of ordinary skill would be very familiar with these principles and understand that the same principles apply to tracking other parts of a user's body (e.g., hands and feet) and other objects.

88. Research and development aimed at all-in-one systems that eliminate the need for intentionally added infrastructure (sensors or sources) has been going on for decades, and began at least in the 1980s. *See, e.g.*, Lucas, *An Iterative Image Registration Technique with an Application to Stereo Vision* (1981) (Ex.1068); Shi, *Good Features to Track* (1994) (Ex.1090); Bishop. Since then, tracking has been implemented in a variety of ways, including through the use of magnetic sensors (e.g., electromagnetic compasses), MEMS-based strap-down inertial sensors (e.g., gyros and accelerometers), Global Positioning Systems (GPS), small high-resolution cameras, analog optical sensors (e.g., lateral-effect photo diodes), and a variety electromagnetic sources including optical, magnetic, and acoustic sources such as infrared LEDs, small magnetic coils, and small speakers. *See, e.g.*, U.S. Patent Application Publication No. 2017/0115488 ("Ambrus") (Ex.1043) at [0075] ("pose and/or movement data may be determined based on sensor information from any combination of sensors mounted on the wearer and/or external to the wearer including … gyroscopes, accelerometers, inertial measurement units (IMUs), GPS

devices, barometers, magnetometers, cameras (e.g., visible light cameras, infrared light cameras, time-of-flight depth cameras, structured light depth cameras, etc.)"), U.S. Patent No. 9,041,622 ("McCulloch") (Ex.1008) at 8:17-22 ("Inside, or mounted to temple 102, are … an inertial sensing unit … a location sensing unit … some examples of which are a GPS transceiver, an infrared (IR) transceiver, or a radio frequency transceiver for processing RFID data."); Begault (Ex.1007) at 133 (describing "electromagnetic sensors," or "optical, mechanical, and acoustic tracking systems"); Jerald, THE VR BOOK (Ex.1063) at 315 ("Hand-held tracked devices typically use inertial, electromagnetic, ultrasonic, or optical (camera) technologies."); Mine Exploiting Proprioception 1997 (Ex.1116) at 68 ("hardware configuration includes an immersive head-mounted display, a magnetic tracking system with three 6 degree-of-freedom (DoF) sensors (one for the head and one for each hand), two separate input devices (one for each hand) and a high speed graphics computer"); Ross (Ex.1125) at 11:4-28 (describing using "one or more of a GPS sensor, a gyroscope, an accelerometer, an altimeter, a compass, a camera based sensor, a magnetic sensor, an optical sensor, an infrared sensor, a motion tracking sensor, an inertial sensor, a CCB sensor, an eye tracking sensor, a facial tracking sensor, a body tracking sensor, and/or other sensors" to "generate output signals conveying information related to any number of different view directions, (e.g., orientation of one or more parts of the user's body," "position of a user within the

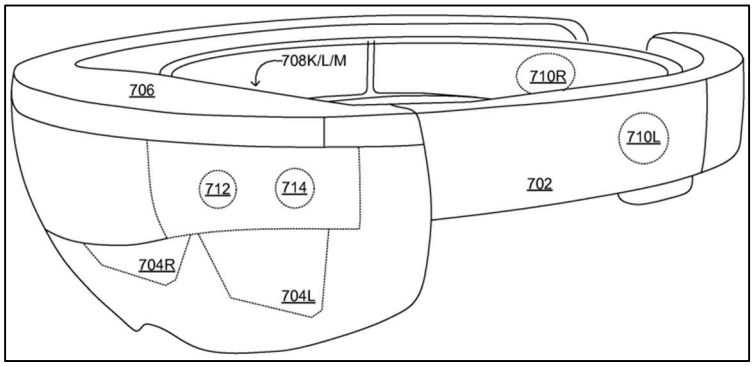
virtual space, and/or other directional information)"). Furthermore, it was common to use a "hybrid method of integrating multiple technologies together (sensor fusion) to provide both high precision and accuracy." Jerald, THE VR BOOK (Ex.1063) at 315; Billinghurst 2015 (Ex.1049) at 124-25 (describing early examples of hybrid tracking systems, and explaining that "[h]ybrid tracking systems fuse data from multiple sensors to add additional degrees of freedom, enhance the accuracy of the individual sensors, or overcome weaknesses of certain tracking methods"); Welch, *Hybrid Self-Tracker: An Inertial/Optical Hybrid Three-Dimensional Tracking System* (1995) ("Welch 1995") (Ex.1119) at 1, 11 (proposing, for example, a hybrid system including an inertial navigation subsystem and computer vision subsystem). In fact, as Sutherland shows, VR systems used both electro-mechanical linkages and sound waves as early as the 1960s. Sutherland 1968 (Ex.1093) at 760-61.

89. While vision-based (using a camera) pose tracking has been possible for at least 30 years, it was the advent of mobile phones with cameras that began to transform the fields of AR and VR, and even more so the advent of "smart" phones with inertial sensors, electromagnetic compasses, cameras, and powerful processors. Certainly by the early 2000s, mobile devices included sensors that provided pose estimation and tracking for users using these technologies. Billinghurst 2015 (Ex.1049) at 124 ("Many mobile devices include cameras, accelerometers and

gyroscopes … which can be combined to provide highly accurate pose estimation") (internal citations omitted).

90. By 2015, the AR and VR industry knew numerous ways of tracking movement of HMDs and peripherals in six degrees of freedom (again, "6DoF"), i.e., tracking movement of the HMD and controllers in three-dimensional space, and having processing take place in the HMD.

91. For example, a 2015 patent publication describes an all-in-one AR HMD that uses data from IMU sensors 708, color camera 712, and depth camera 714 that projects structured or pulsed infrared light and captures the reflections, to perform 6DoF "position tracking, direction and orientation sensing, and/or motion detection of the user's head":



Ambrus (Ex.1043) at [0016] (describing "a combined six degrees of freedom"), [0074]-[0078], Fig. 7.

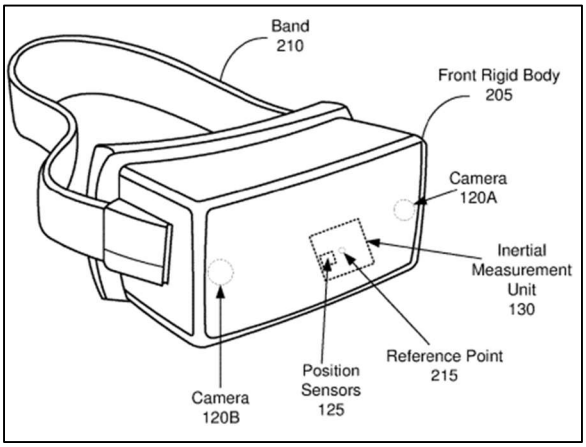
92. In another 2015 patent, a disclosed HMD was described as capable of at least 6DoF tracking, and did not rely on an external base station for tracking.

McCulloch (Ex.1008) at 7:24-67, 8:17-39, 15:31-38; *see also* Section IX.D (overview of McCulloch).

93. As another example, a 2013 patent application disclosed a device (e.g., a wearable device such as an HMD or virtual reality glasses) that "use[d] one or more sensors or application data to gather environmental information" as part of a "context aware localization, mapping, and tracking (CALMT)" module. U.S. Patent No. 9,367,811 ("Ramachandran") (Ex.1034) at 12:18-23 (CALMT "can perform visual mapping, localization, and tracking with the most effective coordinate system for use in indoor scenes."), 2:47-3:2 (describing the device and various sensors in the device), 4:36-44 (similar), Fig. 1.

94. A different 2014 patent application similarly disclosed "systems [that] can process the input of a single camera and continuously build up a three dimensional (3D) model (e.g., a SLAM map) of an environment as the camera moves in Six Degrees of Freedom (6DOF)." U.S. Patent No. 9,674,507 ("Pirchheim") (Ex.1033) at 1:18-29, 3:36-52 (describing the device, which can be a wearable device or augmented reality device, with modules for at least for image processing and 6DOF simultaneous localization and mapping that "may be combined and/or implemented in the processor"), 4:49-64 (discussing 6DOF simultaneous localization and mapping), Fig. 1.

95. As another example, a continuation patent application that references a priority application filed on January 1, 2016 discloses an HMD with tracking technology including "at least two cameras," "one or more sensors," and "an inertial measurement unit":

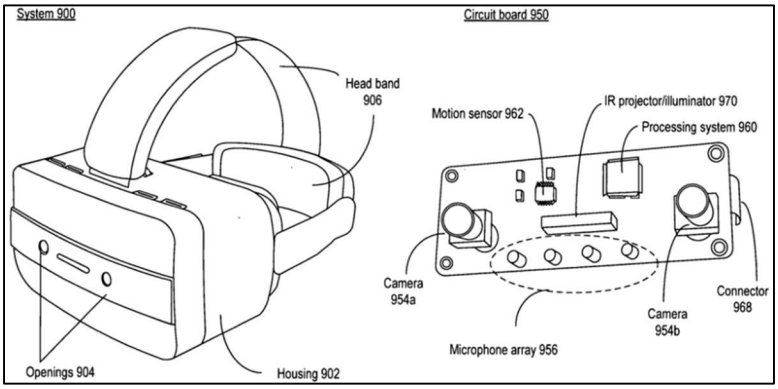


U.S. Patent No. 10,095,031 ("Katz") (Ex.1018) at Fig. 2, 3:41-4:43 (describing the VR headset and how cameras capture image data and combine this information with other sensor data).

96. As another example, a patent application filed on January 15, 2016 disclosed an HMD that also used tracking technology involving a combination of cameras and sensors. *See* U.S. Patent No. 10,114,465 ("Wan") (Ex.1040) at 2:41-45 ("Example VR functions include, but are not limited to, 6 degree-of-freedom (6DoF) head tracking, finger/hand tracking, environmental (or depth) sensing, pass-through of images for display via or in the V-HMD, tracking a VR controller or other device held by a user, etc."), 6:65-7:9 ("The 6DoF processor 316 provides

determined 6DoF tracking data 332 the VR function portion 330 for further processing"), Fig. 6A.

97. As another example, a 2014 patent application disclosed an HMD with an IR projector that "project[ed] certain patterns … onto one or more surfaces of the physical environment" for "efficient and robust tracking" of the HMD's location and orientation:



International Patent Publication No. WO 2016/064435 ("Fei") (Ex.1012) at [044]-[045], [088], Figs. 9A-9B.

98. Additionally, as I discussed in Section VII.C and further showed through a number of the examples identified above, it was well known to pair tracked handheld controllers as input devices to WEDs or HMDs or to track finger or hand movements directly using WEDs or HMDs. *See, e.g.*, McCulloch (Ex.1008) at 4:25-31 ("real controller device may be "a handheld inertial motion unit (IMU)"), 7:4-23 (describing that the real controller device communicates with the display device system); Pedrotti (Ex.1005) at 7:52-54 ("the physical controllers may also have

magnetic trackers located within them, similar to the tracker in the headset"); U.S. Patent Application Publication No. 2016/0124502 ("Sawyer") (Ex.1036) at [0025] ("The HMD and the optional sensors provide sensory input to a controller, which in turn provides sensory feedback to the HMD or another output device."); Wan (Ex.1040) at 7:19-20 ("data [from the image processing portion] can be provided to a finger/hand tracker 334 in the VR tracking portion").

99. Systems capable of tracking WEDs/HMDs and controllers also necessarily used coordinate systems (also called "coordinate spaces" or "coordinate frames") to track and display virtual objects, which were updated with respect to their HMDs (e.g., with respect to the HMDs' locations/positions). *See, e.g.*, McCulloch (Ex.1008) at 15:1-63 (describing a "scene mapping engine" for "3D space positions or position volumes for objects," which "can be aided with sensor data … from an orientation sensing unit" of the HMD); Robinett, *The Visual Display Transformation for Virtual Reality* (1995) (Ex.1087) at Abstract (describing general principle of "map[ping] points from object coordinates to screen coordinates" for display); Pirchheim (Ex.1033) at 4:37-64 (describing "tracking and mapping" in 6DOF and integrating keyframes from an image or videostream).

100. After all, in both AR and VR systems, there is a constant cycle of tracking the user's input, providing that information to an AR or VR application, and then rendering and displaying output to the user. This cycle of feedback between

the user—e.g., that the user has moved locations or is interacting with a virtual object using a controller—and the AR or VR application is what generates and changes the virtual environment experienced by the user.

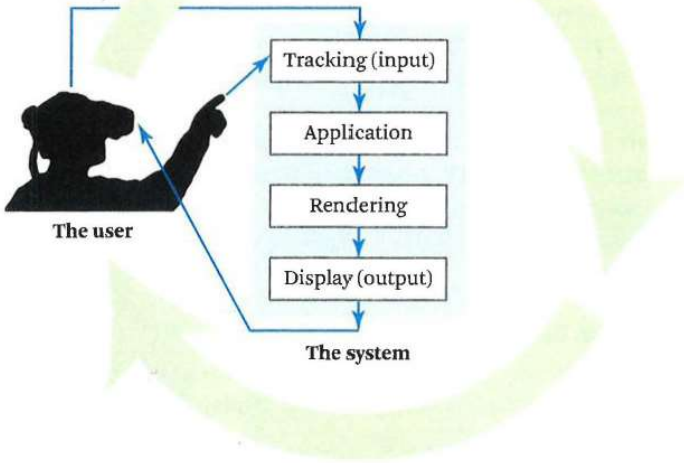


Figure 3.2 A VR system consists of input from the user, the application, rendering, and output to the user. (Adapted from Jerald (2009))

Jerald, THE VR BOOK (Ex.1063) at 31-32, Fig. 3.2. Accordingly, tracking has long been understood to be, and remains, one of the essential functions in any AR or VR system.

E. Sound Localization and Binaural Sound

101. Since well before February 2016, it was understood that sound localization is an important aspect of creating an immersive AR or VR experience. NSA, *Virtual Reality* (Ex.1043) at 35-36 ("Spatially localized sound has a dramatic effect on the sense of immersion in virtual environment … Sound is considered a very important aspect of VR since users often get 'lost' while moving in the virtual

world."); Jerald, THE VR BOOK (Ex.1063) at 239 ("Auditory cues play a crucial role in everyday life as well as VR, including adding awareness of surroundings, adding emotional impact, cuing visual attention, conveying a variety of complex information without taxing the visual system, and providing unique cues that cannot be perceived through other sensory systems."), 240 ("Spatialized audio can be useful to serve as a wayfinding aid … to provide cues of where other characters are located, and to give feedback of where the element of a user interface is located."); Unity Manual 5.3, *Audio Spatializer SDK* (2015) ("Unity Manual 5.3") (Ex.1096) at 1 ("With the advent of virtual and augmented reality systems[,] the spatialization method more and more becomes a key component of the player's immersion.").

102. Furthermore, using HRTFs to generate localized sound, and in particular binaural sound, was a well-known technique. An HRTF "describes how a given sound wave input (parameterized as frequency and source location) is filtered before the sound reaches the eardrum and inner ear." U.S. Patent No. 8,767,968 ("Flaks") (Ex.1009) at 1:31-34; *see also* Begault (Ex.1007) at 41 (defining "HRTF" as "[t]he spectral filtering of a sound source before it reaches the ear drum that is caused primarily by the outer ear," and "binaural HRTF" as "referring to both left- and right-ear HRTFs"); U.S. Patent No. 7,710,654 ("Ashkenazi") (Ex.1044) at 11:66-12:2 ("The delay and frequency response which associate a spatial audio

source location with each ear are described by a Head Related Transfer Function (HRTF) model.").[2]

103. It was known that a pair of HRTFs, one for each ear, can be used to synthesize binaural sound that appears to come from a particular point in space. Begault (Ex.1007) at 41; Ashkenazi (Ex.1044) at 11:63-66 ("By artificially introducing such delays and frequency response, a monaural signal, is transformed into a binaural signal, having spatial location characteristics."); Cohen, *Integrating Graphic and Audio Windows* (1992) ("Cohen 1992") (Ex.1052) at 470 ("Binaural localization cues may be captured by head-related transfer/functions (HRTFs),

[2] *See also* WILEY ELECTRICAL AND ELECTRONICS ENGINEERING DICTIONARY (2004) (Ex.1120) at 335, defining "head-related transfer function" as follows:

> Its abbreviation is HRTF. A transfer function that takes into account factors involved in sound reaching the ears of a listener, for sound localization and the determination of the arriving spectrum of sound. Variables such as the dimensions of the ear canal, the exterior part of the ear, head, and torso, and how these modify the spectrum of the sound heard are combined with the azimuth, elevation, range, and frequency of the sound source, the slightly different time at which a sound arrives at each ear, and so on. Each listener has a unique HRTF.

impulse responses measured for the head and pinna (outer ear) of human or dummy heads. For each spherical direction, a left-right pair of these transfer functions is measured and stored as FIR filter coefficients. Sound can then be spatialized by driving digitized input signals through these HRTFs in a convolution engine, creating psychoacoustic localization effects by introducing binaural spatial cues into an originally monaural channel, 'placing' the channel within the perceptual space of the user …."); Zhou, *An Experimental Study on the Role of Software Synthesized 3D Sound in Augmented Reality Environments* (2004) ("Zhou") (Ex.1107) at 991 ("Exact spatial 3D sound in virtual and augmented environments requires perceptual externalization of the sound source, which can only be brought about by using head related transfer functions (HRTFs)").

104. Furthermore, a common technique used in generating localized sound was to store multiple HRTFs within a library of HRTFs so that a suitable HRTF for the listener could be applied to other components of a 3D audio signal to generate a spatialized audio cue to the user. Flaks (Ex.1009) at 3:35-43 ("In some embodiments, sensor data may be analyzed to determine physical characteristics of the listener such that a suitable HRTF may be determined from a library of HRTFs. The HRTF for the listener may be applied to the different components of the 3D audio signal.").

105. HRTFs have been used to enhance immersion and intensify the 3D experience in virtual environments for decades. In the 1980s and 1990s, scientists

at NASA did significant research on HRTFs and spatialized sound. *See, e.g.*, Wenzel 1988a (Ex.1104); Wenzel 1988b (Ex.1105); Wenzel 1991 (Ex.1106). In the early 1990s, NASA developed the Convolvotron™, a real-time digital signal processing system that processed HRTFs to rendered 3D localized audio for VR displays. Begault (Ex.1007) at 12. By the late 1990s the technology was integrated into PC sound cards. Free HRTF libraries made standard HRTFs available to developers over the internet, including the MIT KEMAR library (1994) and the CIPIC library (2001). Algazi (Ex.1046) at 99 (disclosing in 2001 "a public-domain database of high-spatial-resolution head-related transfer functions measured at the U.C. Davis CIPIC," i.e., Center for Imaging Processing and Integrated Computing, "Interface Laboratory"); *see also* Sodnik, Spatial Auditory Human-Computer Interfaces (2015) ("Sodnik") (Ex.1124) at 23; Begault (Ex.1007) at 140 ("Anechoic HRTFs are taken from a library of measurements, and are used to position the virtual sound source's azimuth and elevation position."), 169-70 ("The AL-204 (see Figure 5.9), was an early four-channel DSP-based convolution device that used HRTFs based on measurements of the KEMAR mannequin head (Figure 4.25) made at Northwestern University (cf. Kendall, Martens, and Wilde, 1990)"); *see also* U.S. Patent No. 9,544,706 ("Hirst") (Ex.1017) at 8:13-23 (describing storing and retrieving a user's customized HRTF); U.S. Patent No. 10,070,239 ("Romigh") (Ex.1035) at cl. 1 (claiming "[a] system for generating a personalized Head-Related Transfer

Function"), 6:52-56 (describing using cache memories for storing and retrieving HRTFs).

106. Indeed, it was well known to persons of ordinary skill in the art before February 2016 that processing speed and efficiency can be improved by leveraging cache locality and keeping data needed for pertinent computations (e.g., HRTFs for processing binaural sound) readily available. *See, e.g.*, Foster, Cornell University, *Data Structures and Functional Programming, Lecture 25: Memory and Locality* (2012) ("Foster") (Ex.1059) at 2 ("The primary (L1) cache is the fastest cache, usually right on the processor chip and able to serve memory requests in one-three cycles"; "caches improve performance when memory accesses exhibit locality."); Jiménez, Texas A&M University, *Computer Architecture Lecture 7: Caches* (2007) (Ex.1064) at 1 ("The basic idea is to have a small, expensive cache memory hold frequently used values from the larger, cheap main memory. This way, access to data and instructions is significantly faster than it would be with just the main memory."); Hennessy & Patterson, COMPUTER ARCHITECTURE: A QUANTITATIVE APPROACH ("Hennessy") (Ex.1061) at 130 ("the extension of caches to multiple levels" "have helped keep the memory wall at bay").

107. In the mid-2000s, there were already open source software development kits (SDKs) incorporating publicly available HRTFs "[f]or easy implementation of 3D sound generation." Zhou (Ex.1107) at 992-93; *see also* Doerr,

Evaluation of a Low-Cost 3D Sound System for Immersive Virtual Reality Training Systems (2007) (Ex.1056) at 205 (describing the open-source OpenAL library, an HRTF software-based 3D sound system for "consumer-level 3D audio hardware interfaces" for immersive VR systems); Löhr, *OpenAL-MOB with openFrameworks on Android Introduction* (Dec. 18, 2014) (Ex.1067) at 1 (using "openFrameworks v0.8.4 in combination with OpenAL for Audio output" because "we need the HRTF for binaural sounds").

108. One exemplary system shows that researchers had already developed by 2004 a robust and efficient HRTF audio rendering process for AR and VR HMDs with head tracking that were "capable of making people think that the sound was coming from the external source, even though it was being rendered at the headphones." Zotkin, *Rendering Localized Spatial Audio in a Virtual Auditory Space* (2004) ("Zotkin") (Ex.1111) at 21. That system ran "in real-time on a typical office PC" and processed "multiple virtual sound sources at different positions" with HRTFs in parallel and "no noticeable latency." Zotkin (Ex.1111) at 3. "The level of detail … (interpolation quality and number of room reflections traced) [was] automatically adjusted to match the processing power available." Zotkin (Ex.1111) at 7.

109. It is therefore unsurprising that, by 2016, numerous patent publications described AR/VR HMDs that generated HRTF spatial audio. *See, e.g.*, U.S. Patent

No. 9,787,846 ("Srinivasan") (Ex.1038) at 2:3-23, 5:34-35, 11:48-12:1, Figs. 3, 7 ("audio position processor 605 may then receive the audio input signals and apply suitable head related transfer function processing" so that the resulting audio signal "appears to come from the approximate position of the object"); U.S. Patent No. 9,767,618 ("Najaf-Zadeh") (Ex.1030) at 4:41-54, Fig. 4 (HMD with "circuitry [] and applications for providing 3D audio for a HMD"); U.S. Patent No. 10,509,466 ("Miller 466") (Ex.1026) at 23:53-59 (HMD "spatially render[s]" audio to "make the user perceive various virtual audio sources as located in various x, y, z locations in world space" using "head-tracking inputs and a head-related transfer function (HRTF) to simulate acoustics"); U.S. Patent Publication No. 2012/0183161 ("Agevik") (Ex.1042) at [0044]-[0045] (HMD applies "selected HRTF to an audio signal … to generate an output signal."). By that time, AR and VR game engines offered spatial audio SDKs and the ability to use spatial audio plugins. *See, e.g.*, Parisi (Ex.1075) at 1 (as of November 2015, "[t]he Unity3D and Unreal game engines, popular for making desktop and mobile games, have become tools of choice for native VR development"); Unity Manual 5.3 (Ex.1096) at 2 ("Adding HRTF filtering already immensely improves the sensation of direction over a conventional panning solution (a typical and famous example of this is the binaural recording of the virtual barber shop)."); RealSpace3d, *Manual of VisiSonics' RealSpace 3D Audio Unity Plugin* (Nov. 17, 2015) (Ex.1084) at 13 (default HRTF set "work[s]

well for majority of users" but HRTFs could be customized by the user); Google Developers, *Spatial audio comes to the Cardboard SDK* (Jan. 13, 2016) (Ex.1060) at 1 ("The SDK combines the physiology of a listener's head with the positions of virtual sound sources to determine what users hear."); Google VR Cardboard Unity SDK, CardboardAudioSourceEditor.cs (2015) (Ex.1109) at lns. 71-73 ("Enable HRTF … [s]ets HRTF binaural rendering for the source."); UploadVR, *Google Cardboard Now Offers Spatial Audio* (Jan. 13, 2016) (Ex.1098) at 2 ("The SDK is optimized for mobile CPUs (e.g. SIMD instructions) and actually computes the audio in real-time on a separate thread, so most of the processing takes place outside of the primary CPU.").

110. It was also well known that integrated circuit chips, specifically DSP chips, available prior to 2016 were capable of processing sound with HRTFs to generate binaural sound. *See, e.g.*, U.S. Patent No. 5,173,944 ("Begault 944") (Ex.1131) at 1:21-27 (explaining that the described effects of the present invention, "pseudo-stereophony" that "allow[s] the derivation of two channels of sound from a monoaurally-recorded, one channel source"), 6:51-54 (how pseudo-stereophony "can be implemented into hardware using off-the-shelf integrated circuit chips, such as a Motorola 56001 DSP chip"), 6:54-56 ("All of the processing described with respect to FIG. 2 can be accomplished with these or equivalent DSP chips."), and 6:57-63 (explaining that "[i]n the aforementioned embodiment of pseudo-

stereophony, only four HRTF filter networks were used. However, a larger number of delay-gain-HRTF filter networks could be added in an alternative embodiment. Fewer or greater number of coefficients used to represent the HRTFs used in FIR filters 78 and 80 could also be part of an alternative embodiment."); U.S. Patent No. 5,438,623 ("Begault 623") (Ex.1132) at 8:6-15 ("Accordingly, thus what has been shown and described is a system of digital filters implemented using selectively interchangeable PROM-DSP chip combinations which generate synthetic head related transfer functions that impose natural cues to spatial hearing on the incoming signals, with a different set of cues being generated for each incoming signal such that each incoming stream is heard at a different location around the head of a user and more particularly one wearing headphones."). These DSPs provided advantages such as relatively smaller hardware size, greater predictability of noise, ease of reconfiguration, and less power consumption. Qualcomm, *Mobile Processors 101: Why Smartphones are Smarter with an All-In-One Processor* (Jun. 12, 2013) (Ex.1082) at 1-3 (describing the DSP in Qualcomm's Snapdragon processor as being small enough to be incorporated into a smartphone); Qualcomm, *What's So Special About The Digital Signal Processor* (Dec. 5, 2013) (Ex.1081) at 1-3 ("Many of these experiences—such as sound and image enhancements as well as advanced camera and sensor capabilities—include signal-processing tasks that the DSP excels in executing at low power. And saving power not only extends the battery life of the

mobile device, it also keeps your phone cooler and provides a better user experience.").

F. Designating Sound Sources

111. With the advent of sound localization techniques developed in the 1980s and 1990s, it became common to use zones or regions or areas containing sound sources to manage sound, whether by an end user of a virtual environment or a designer of that environment. *See, e.g.*, Çamci, *Interactive Virtual Soundscapes: A Research Report* (2015) ("Çamci") (Ex.1051) at 119 ("the designer can also interact with the virtual soundscape in real-time, and alter the aural reality experienced by the user … therefore allow[ing] for the mutual participation of a designer and a user in creating a real-time, non-linear sound composition presented in the form of a[] spatial structure").

112. Indeed, it was a known technique to divide sensory elements into different zones in a virtual environment. In the example shown below, which is called a "Center of Action" setup, the "world around the user" is "split … into different zones such as primary and secondary viewing directions," where "[t]he most important action occurs in the primary direction." Jerald, THE VR BOOK (Ex.1063) at 254-55. And "[a]s a user starts looking toward another zone, cues are provided to inform the user that she is starting to look at a different part of the scene

and the action and/or content is about to change if they keep looking in that direction":

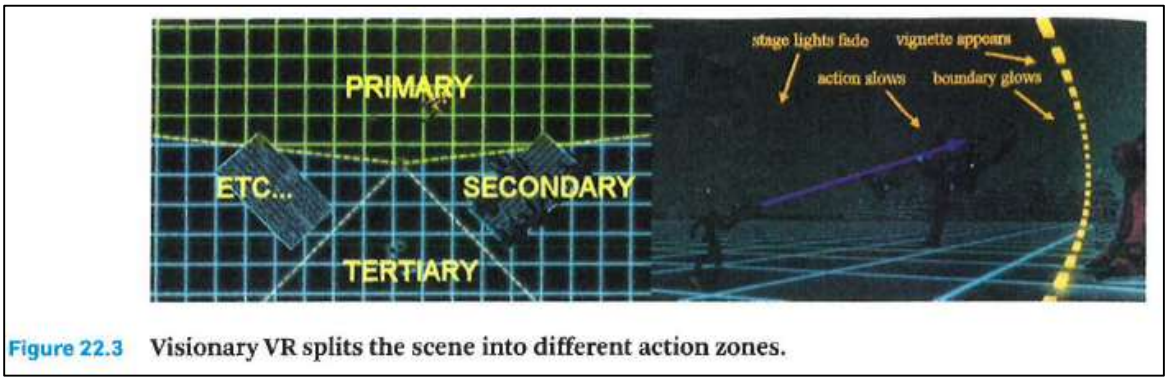


Figure 22.3 Visionary VR splits the scene into different action zones.

Jerald, THE VR BOOK (Ex.1063) at 254, Fig. 22.3.

113. Such zones could be rendered in both 2D and 3D interfaces, and as a general principle, these interfaces were implemented because they were "intuitive" and could be "quickly understood, accurately predicted, and easily used." Jerald, THE VR BOOK (Ex.1063) at 277.

114. For example, a 2015 paper—Çamci—describes the representation of a 2D environment for positioning sound sources referred to as an "Interactive Virtual Soundscape." *See* Çamci (Ex.1051) at 119.

115. Çamci describes "directional sound objects," which "act as a localized source," and also "zonal sound objects" that "demarcate regions in the virtual space" to provide "background or textural sounds that are independent of user position and orientation":

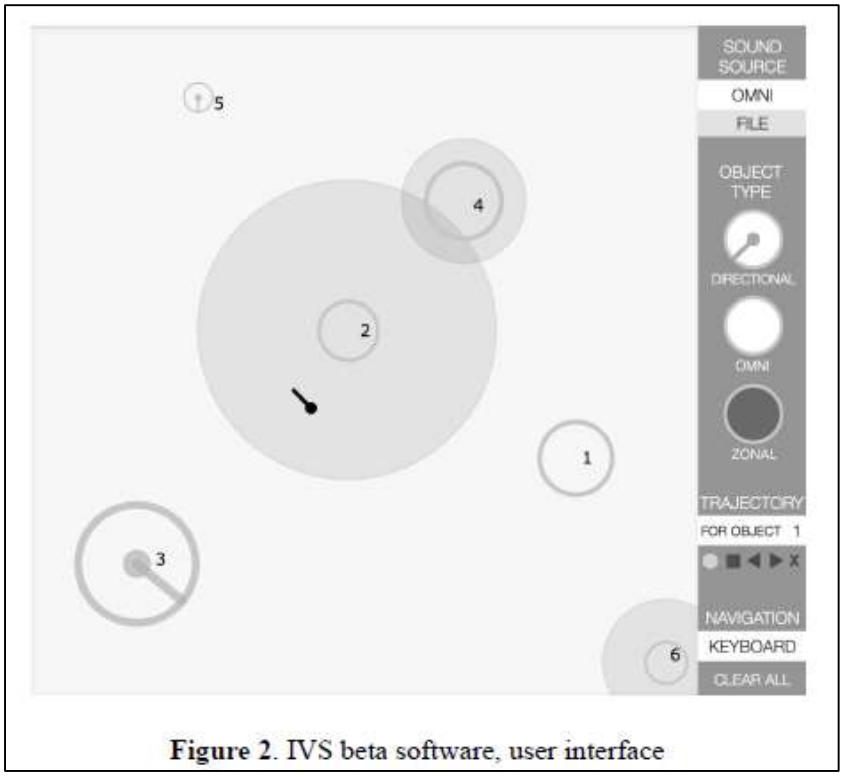


Figure 2. IVS beta software, user interface

Çamci (Ex.1051) at 119-20, Fig. 2. "The interface on the right-hand side allows the designer to choose from a variety of sound sources (i.e., audio file, external input …), assign this source to an object type (i.e. directional omnidirectional, zonal), and place the object within the virtual space," and "[t]he combination of a sound source and an object type specify an object's membership." Çamci (Ex.1051) at 120. Çamci further disclosed that "[t]he designer can [] change the amplitude (i.e., the acoustic space) or each object, as well as the coverage of zonal object," and use "the handle on the directional objects" to set "an orientation for the sound output." Çamci (Ex.1051) at 120 ("Sound objects can be added, deleted and repositioned in real-time.").

116. Çamci further expanded this to, and disclosed, a 3D implementation:

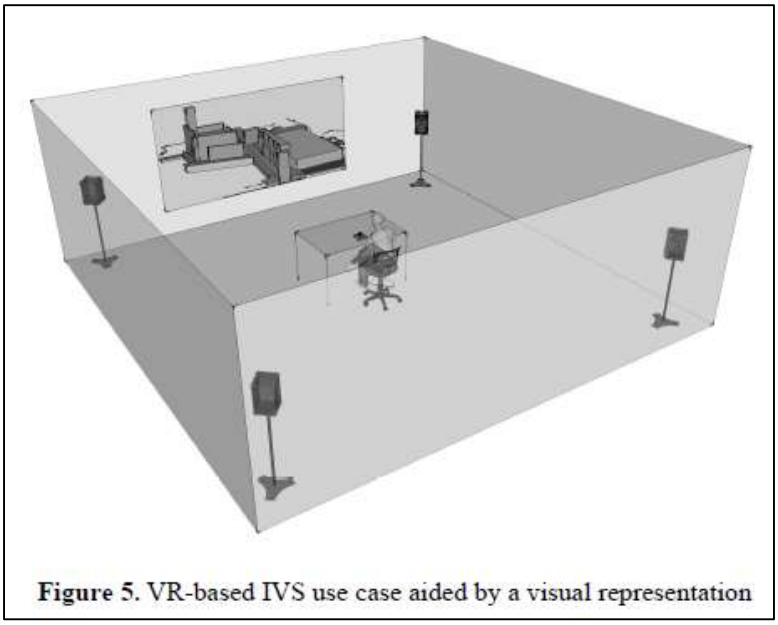


Figure 5. VR-based IVS use case aided by a visual representation

Çamci (Ex.1051) at Fig. 5. Çamci explained: "Since locomotion in the VR is not limited by physical boundaries," "we found it necessary to incorporate a two or three-dimensional landscape model of the IVS"—the Interactive Virtual Soundscape—"to give the user a sense of context and orientation." Çamci (Ex.1051) at 122.

117. In another example, as described in a series of papers from the early 1990s, MAW, which stands for Multidimensional Audio Windows, is a GUI that "integrat[es] a graphic editor with a multidimensional spatial sound engine" and thereby "permit[s] multiple simultaneous audio sources, such as in a teleconference, to coexist in a modifiable display." Cohen 1992 (Ex.1052) at Abstract, 470-71 ("MAW is an interactive audio windowing and 2D spatial sound system suitable as a teleconferencing system as well as for asynchronous applications like voicemail").

MAW, and audio windows more generally, "are a way of organizing and controlling sound." Cohen 1992 (Ex.1052) at 470 (analogizing to "standard pointing device in a window/icon/menu/pointing device (WIMP) system"), 471 (describing "a mouse-based system [that] realizes indicating, highlighting, and relocating as pointing, clicking, and dragging" icons representing sound sources), 479 (further describing MAW as "intended to interpolate between conventional telephony and VR"). With this interface, "[i]cons for [] nonomnidirectional sources and sinks indicate both their mutual positions in virtual space and their orientation," and can be manipulated, rotated, translated, and repositioned (singly or in groups) by a cursor:

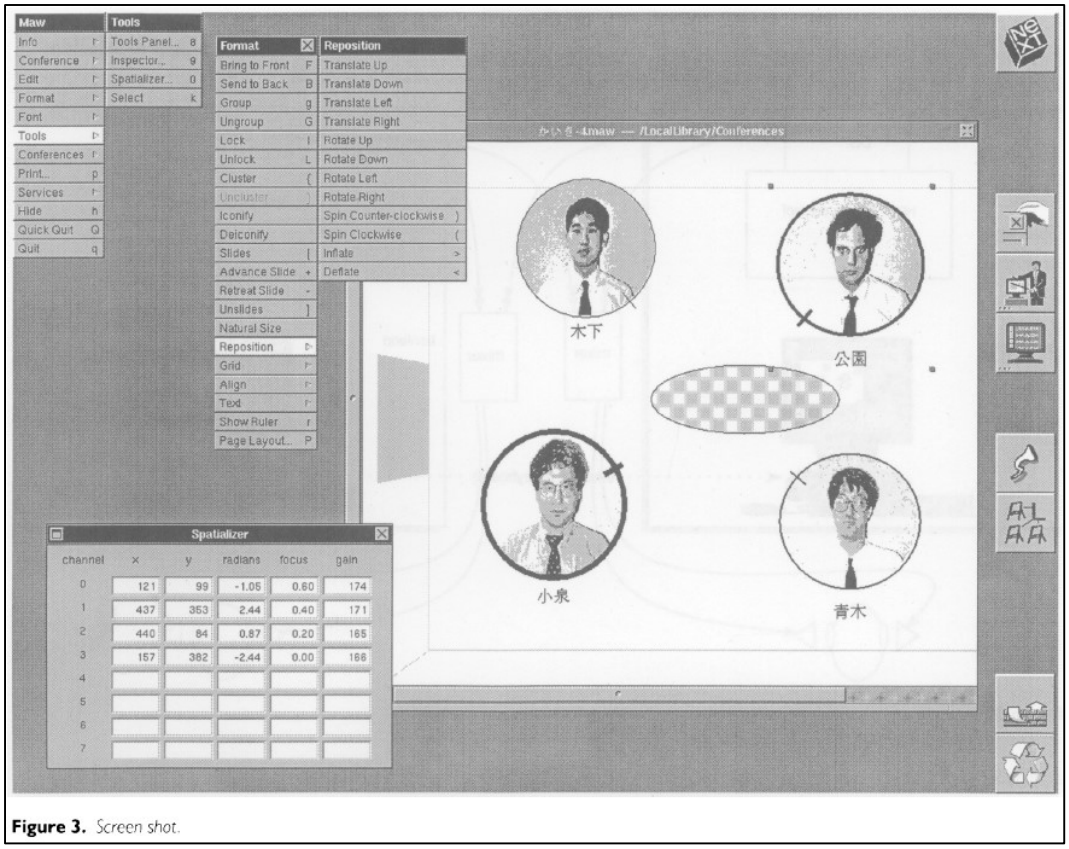


Figure 3. *Screen shot.*

Cohen 1992 (Ex.1052) at Fig. 3, 473.

Meta Platforms, Inc.
Exhibit 1003
Page 092

118. These icons are additionally able to be clustered and unclustered with zooming effects (e.g., a cluster appearing as a single point from a distance, or disassociating and distributing spatially as it gets closer). Cohen 1992 (Ex.1052) at 473-74 ("This focus allows navigation in arbitrarily large spaces, assuming a limited density of point sources."); *see also* Sodnik (Ex.1124) at 55 (further discussing MAW); Begault (Ex.1007) at 173-74 (further discussing Cohen's interfaces, including Cohen's "audio windows"). Additionally, "[t]he user can resize a selected atomic spatial sound icon by dragging one of the resize handles (knobs) on its bounding rectangle." Cohen 1992 (Ex.1052) at 473. As Cohen 1992 discloses, "[a]s long as visual tokens for the spatial sound objects are accessible through the workstation, they can be manipulated … via a suite of direct and indirect manipulation techniques." Cohen 1992 (Ex.1052) at 471.

119. Relatedly, the importance of "exploit[ing] sound as a vital communication channel for computer-human interfaces" was recognized in the 1990s. Cohen 1992 (Ex.1052) at 468; *see also* Cohen, *Throwing, Pitching, and Catching Sound* (1993) ("Cohen 1993") (Ex.1053) at 274 ("Augmenting a sound system with spatial attributes opens new dimensions for audio, making spatial sound a potentially-rich analogue of 3D graphics."); McGrath, *Huron – A Digital Audio Convolution Workstation* (1995) (Ex.1069) at 4-5 ("In the emerging field of virtual reality, where the goal is to create a believable synthesis of sensory inputs for the

human operator, the complexities of the auditory inputs are popularly overshadowed by the exciting animated graphics. However the acoustic simulation of the virtual world is just as complicated and requires similar levels of computational power.").

120. Begault, like Çamci's and Cohen's papers, shows that persons of ordinary skill in the art knew how to implement easy-to-use interfaces for controlling and positioning 3D audio long before February 2016. Begault disclosed an example interface in the form of a pie menu:

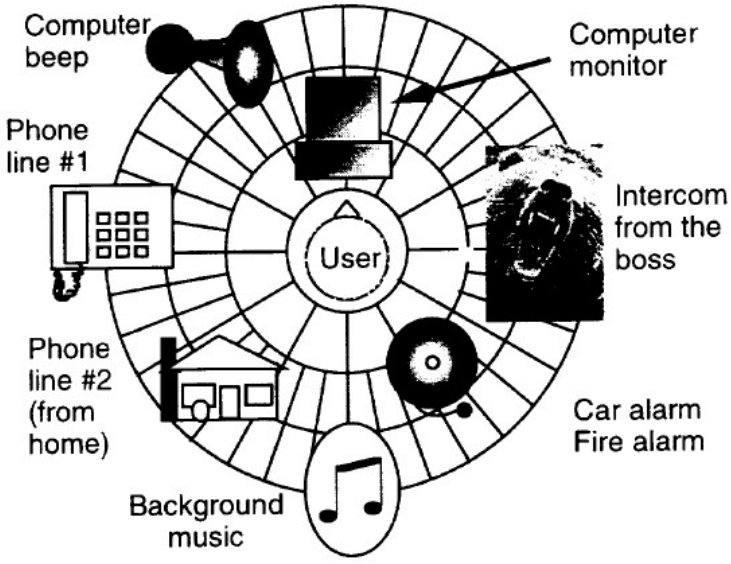


Figure 5.12. Layout for a hypothetical GUI for arranging a set of incoming sounds. By resizing the icons, volume could be adjusted independently of perceived distance. *Graphic assistance by Denise Begault.*

Begault (Ex.1007) at Fig. 5.12.[3]

[3] *See also* Jerald, THE VR BOOK (Ex.1063) at 346-47 (explaining "pie menus," which "are circular menus" where "selection is based on direction," and provides the

121. As Begault states, the "basic concept" with such an interface "is to represent each form of auditory input iconically on the screen and then allow manipulation of the distance and relative azimuth of each source." Begault (Ex.1007) at 172. Then, back-end computing devices "interpret[] the relative location of the icons on the screen as commands to a multiinput, 3-D sound spatialization subsystem," for positioning 3D audio in a virtual environment. Begault (Ex.1007) at 172.

122. Thus, with such interfaces, designers and users could control and/or navigate different sound zones, e.g., to position and/or listen to different sound sources in different locations, before February 2016. *See, e.g.*, U.S. Patent No. 8,520,872 ("Jang") (Ex.1006) at 11:64-12:5 ("For example, if a user's character moves from a basketball court to a conference room, visual, audio, or tactile

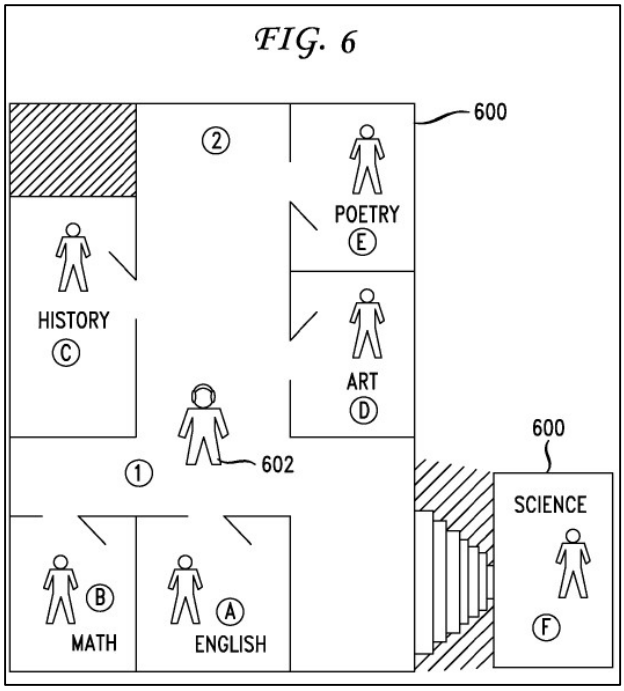
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advantage that "commonly used options are embedded into muscle memory as usage increases"), 345-49 (describing multiple "widgets and panels" patterns for UIs used to control and manipulate VR settings, including "ring" and "pie" menus and "virtual hand-held panels," among others), 346 (describing interfaces based on "2D desktop integration," borrowing "metaphors such as double-clicking on a selected window header to minimize the window," and "WIMP (Windows Icon Mouse Pointer) applications").

elements of the basketball court may decrease in magnitude, and visual, audio, or tactile elements of the conference room may begin to be transferred to a virtual reality device or a portion of the virtual reality device."); U.S. Provisional Application No. 62/289,085 ("Mangiat") (Ex.1022) at [0050] ("the HMD can advantageously spatialize the mix of the stem tracks of the audio file"), [0053] ("the HMD can identify a position of the wearer's hands, and as the hands move, the HMD can generate a different mix of the stem tracks for presentation (audibly or visually) to the wearer").

123. A patent filed in December 27, 2012 and published on July 3, 2014—Seligmann—provides a useful example that describes a system that "generates a three-dimensional sound space having a plurality of sound sources playing at a same time, wherein each of the plurality of sound sources is assigned a respective location in the three-dimensional sound space relative to one another, and wherein a user is assigned a current location in the three-dimensional sound space relative to each respective location." U.S. Patent No. 9,301,069 ("Seligmann") (Ex.1037) at Abstract.

124. Seligmann's Figure 6 illustrates a user (602) experiencing a "three-dimensional sound space with multiple sound sources," specifically lectures from classrooms A-F:

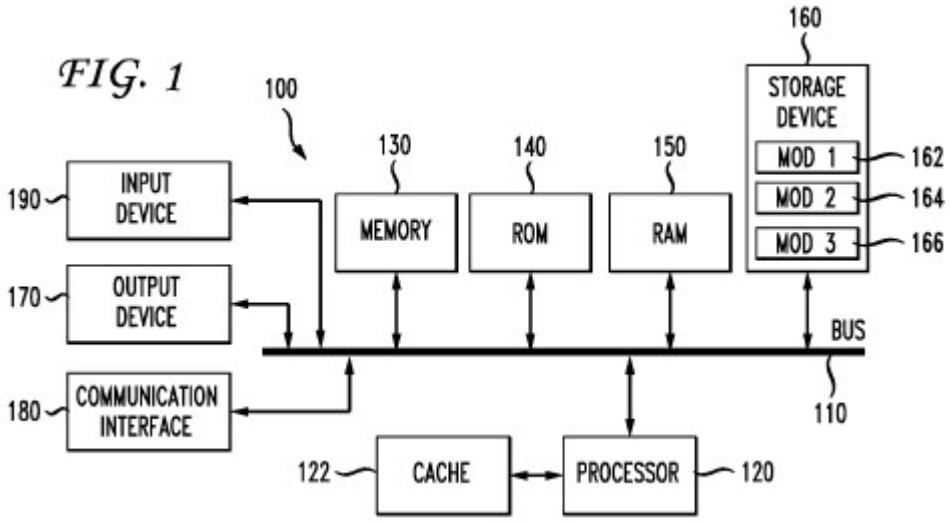


Seligmann (Ex.1037) at 10:31-50, Fig. 6.

125. As the user navigates the virtual space, "the sound perceived by the user 602 from the different classrooms will differ based on the proximity and/or location of the user 602 relative to the different classrooms," for example, sounds from classrooms A-D will be more prominent when the user is at position 1. Seligmann (Ex.1037) at 10:31-50. And this system is able to "arrange, order and/or organize the sound spaces" according to "a setting, a preference, a rule, a similarity, a relevance, a criteria, a ranking, a rating, an age, a user input, a history, a context, a topic, a level of detail and/or granularity, etc." Seligmann (Ex.1037) at 12:53-58.

126. The concept of a computer memory hierarchy and corresponding access times goes back decades and would certainly have been well known to a person of ordering skill in June of 2016. For example, relatively slow access long-term storage

(e.g., magnetic tape or hard disk drives), to random access memory (RAM), to very fast cache memory and processor registers. It was well-known that cache memory could be used automatically (e.g., via the operating system and the processor hardware), or manually/explicitly (e.g., using compiler directives). For example, Seligmann discloses the use of cache memory to store and play audio:



Seligmann (Ex.1037) at Fig. 1 (at 122); *see also* Seligmann (Ex.1037) at 4:55-57 ("The processor 120 may essentially be a completely self-contained computing system, containing multiple cores or processors, a bus, memory controller, cache, etc.") and Seligmann (Ex.1037) at 4:36-40 ("The computing device 100 copies data from the memory 130 and/or the storage device 160 to the cache 122 for quick access by the processor 120. In this way, the cache provides a performance boost that 40 avoids processor 120 delays while waiting for data.").

127. In virtual conference settings, which, by February 2016, were well-known settings for virtual interactions, it was common to create specialized spaces for specific purposes such that a user could move from one conference space to another, and also to populate virtual conference settings with parameters including different sound sources (e.g., participants) and presentations of those sources (e.g., attendees around a table) so that a user could tell who was speaking based on the direction of that sound within the virtual conference setting. *See, e.g.*, Sodnik (Ex.1124) at 52 ("A different virtual room can be used for each call with a different seating plan, a different maximum number of participants and also a different virtual conference table. A user with headphones can identify individual participants by locating them and listening to just one of them, despite multiple talks speaking simultaneously. The proposed system can also be used in other virtual environments such as gaming and VR simulations."); Erickson, *Synchronous Interaction Among Hundreds: An Evaluation of a Conference in an Avatar-based Virtual Environment* (2011) ("Erickson") (Ex.1057) at Figs. 1-3 (showing different virtual conference locations (e.g., keynote, social event, and poster session) in IBM's Academy General Meeting's Virtual Conference Center hosted entirely in a version of Second Life); Billinghurst, *A Wearable Spatial Conferencing Space* (1998) ("Billinghurst 1998") (Ex.1048) at 6 ("When users connect to the conferencing space their audio is

broadcast to all the other users in the space. This is spatialized according to the distance and direction between speaker and listener.").

128. The principle of creating and designating sound sources applies more generally to virtual objects where the virtual content is divided into different fields of view. For example, a patent filed in September 2014—Ross—describes "a system configured to present primary and secondary, tertiary, etc., virtual reality content to a user." Ross (Ex.1125) at Abstract. For a user wearing a virtual reality headset, Ross describes "boundaries to divide a virtual space into areas where primary content, secondary content, tertiary content, etc. may be presented to the user," and that the "boundaries may be indicated to a user in the virtual space via sensory cues," such as with a "darkening of the primary virtual reality content" and "brightening of related … secondary, tertiary, etc., virtual reality content." Ross (Ex.1125) at 2:32-55, 6:55-67, 9:43-51; *see also* Ross (Ex.1125) at 3:38-56 (describing headset), 4:15-29 (explaining displaying virtual reality content based on the user's field of view), 5:45-52 (explaining boundaries), 6:5-12 (similar), 7:11-33 (describing visual sensory cues), 16:17-61 (describing other examples of sensory cues). Depending on the user's view direction, including directional and positional information of the user, the processor of the HMD of Ross's system determines that the user has moved "across a view boundary into an adjacent field of view," which triggers "different virtual reality [to be] displayed to the user," including different virtual objects. Ross

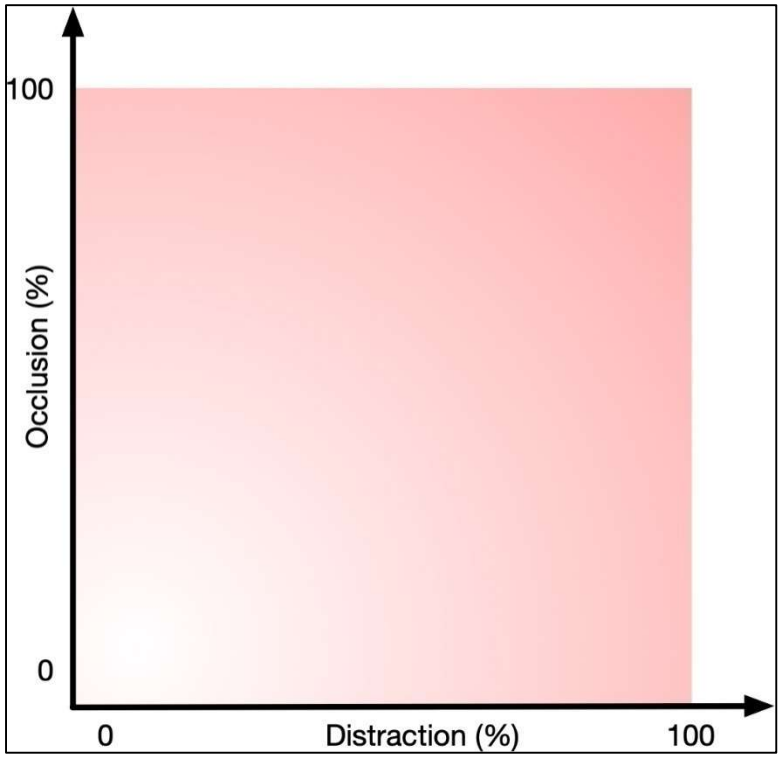
(Ex.1125) at 20:22-40, 14:53-59 (describing the virtual reality content), 15:29-55 (same).

129. In Ross's system, a boundary can be created by tracking a user's movement, and can also be manipulated using controllers or other input, such as hand gestures. Ross (Ex.1125) at 23:22-45. And, through either a two-dimensional or three-dimensional interface, a user is able to create, customize, and adjust fields of view, the view boundaries, and also the virtual reality content within those respective boundaries. Ross (Ex.1125) at 7:51-62, 20:22-21:51, Fig. 5 (providing an example of a graphical user interface). Just as with the boundary, a user can manipulate objects in the fields using standard conventions. Ross (Ex.1125) at 22:17-29.

G. Safety and Chaperone Systems

130. Safety and chaperone systems that allowed the user to define safety boundaries or an area of gameplay were well known and frequently used with AR and VR systems before February 2016.

131. There are both occlusion concerns (e.g., 0-100% of the display) and distraction concerns (e.g., 0-100% of the user's attention), which exist on independent dimensions.



132. Because VR systems occlude the user's visual perception of physical space, the utility of safety boundaries or chaperone system with a wearable VR device is clear. Pedrotti (Ex.1005) at 1:30-33 ("Typically a HMD covers the user's eyes, so that the user sees only the virtual world while wearing the HMD and is thus unable to see the actual physical world around the user while in the virtual world."), 4:32-36 ("a boundary of a selected area is determined, for example, a 'safe area' which the user or another person has determined is clear of physical obstacles in the physical world so that the user may move freely without coming into contact with such physical obstacles"). AR systems also are subject to occlusion concerns, as virtual objects may occlude real objects, even when virtual objects are "stand-ins" for real objects.

133. Further, even though a user may be able to perceive some of the physical surroundings through an AR device, the user can be susceptible to optical limitations and distractions. For example, a wearable AR device can impede a user's ability to shift focus from near-distance and far-distance objects. Sabelman, *The Real-Life Dangers of Augmented Reality* (2015) ("Sabelman") (Ex.1088) at 50. The user's ability to detect peripheral objects also often is diminished. Sabelman (Ex.1088) at 51. And the user's engagement with graphics presented in an AR environment can detract focus from surrounding physical objects. Sabelman (Ex.1088) at 52; *see also* Pedrotti (Ex.1005) at 16:16-19 ("Even some uses of a device such as Google Glass, which obscures only a small portion of the user's field of vision of the physical world, may benefit from some embodiments described herein."); Ross (Ex.1125) at 1:20-24 (identifying the problem of "maintain[ing] the attention of an audience member so he can be told a story if he can look wherever he wants and go wherever he wants in the virtual space").

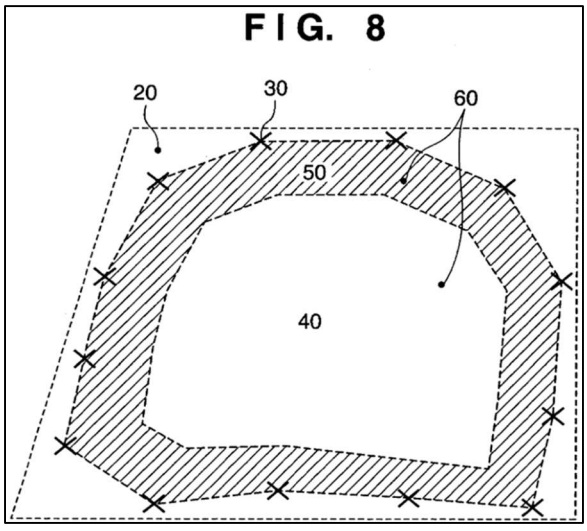
134. As I discuss in the examples below, chaperone/safe area systems typically include an initial setup step where a user defines safety boundaries that surround an area for gameplay, and a method of continuously tracking a user's location to check whether the user is approaching or has exited the established safety boundaries.

135. A 1999 patent directed toward collision warnings for HMDs explained: "[T]he user can become immersed in the virtual environment, causing them to forget about, or become disoriented with respect to, the physical environment," and this risks the user, "in a VR game playing scenario," "tripping over a connecting cable … or possibly running into a wall." U.S. Patent No. 5,900,849 ("Gallery") (Ex.1014) at 1:43-59, 1:66-2:5.

136. Persons of ordinary skill in the art would have known before February 2016 that safety and chaperone systems permitted users to define the safety/chaperone zones, including by having a user walk around with a controller or handheld device to trace the perimeter of a play area. *See, e.g.*, Gallery (Ex.1014) at 4:14-21 ("provid[ing] for a set-up mode in which the user carries the HMD to boundary positions beyond which movement is hazardous," and "[t]hese positions are monitored by the motion detect stage 30 and stored as limits in the memory 40 (as shown by dashed line 46"); Sawyer at [0034]-[0036] ("definition of Soft Bounds can be made … [b]y moving a tracked object (HMD or other worn sensors such as a game controller) to the n corners of the operating space"); U.S. Patent Publication No. 2007/0173265 ("Gum") (Ex.1015) at Abstract ("[a] wireless communications device with positioning capabilities is used to mark a boundary of a virtual operations area"), [0028] (device "may be carried to different points along a non-symmetric playing area boundary … to define the playing area boundary"); Pedrotti

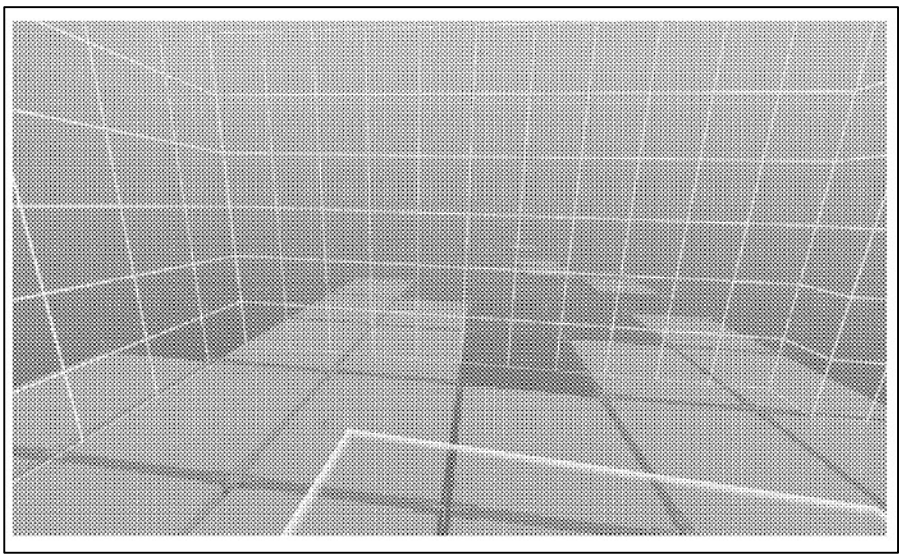
(Ex.1005) at 14:57-62 ("[a] boundary … can be defined, for example, by having the user walk around a perimeter chosen by the user with one of the trackers to define the outer boundary of a selected area"); Ross (Ex.1125) at 3:21-23 (sensor "generate[s] output signals conveying information related to a view direction of the user and/or other information"), 8:20-28 (describing hardware "to facilitate tracking physical user movements and/or position for use"), 13:28-37 (explaining that "view direction" may be based on the user's orientation or position), 20:29-34 (similar), 23:36-42 ("System 10 may be configured such that a controller" or "a body tracking system" "and/or other devices may be used to create and/or manipulate a boundary"), 23:42-45 ("System 10 may be configured to track a user's movement (e.g., walking around, leaning in, etc.) and create a boundary based on the user's movement."), Figs. 1-2 (showing the HMD with a processor).

137. In such systems, boundary points designated by the user are recorded and then connected to form a boundary:



U.S. Patent No. 7,330,197 ("Kobayashi") (Ex.1019) at Fig. 8, 5:15-20 (explaining that "by sequentially connecting the collected boundary-measured points 30 with a line, one closed area can be generated").

138. Then, in the virtual environment, it was common to display a grid, fence, or other 3D image, such as horizontal bars, to visually indicate to a user that he or she was approaching, moving toward, or crossing safety/chaperone zone's boundaries:



Sawyer (Ex.1036) at Fig. 5, [0044] ("visual warning signs displayed in the HMD"), [0054] (describing a "perimeter mesh"); *see also* Gallery (Ex.1014) at 4:22-30 (when the system "determines that one or more of the limits has been exceeded," "a visual warning to the user via display screens" is "called up from memory [] and flashed on the screen"); Kobayashi (Ex.1019) at 5:38-43 ("the positions of the boundary-measured points are presented to the user of the mixed reality apparatus when the

user enters the warning area [] and a warning is used"), 13:47-52 ("where it is determined that the viewpoint position exists inside the warning area [], the plane or the boundary line of the warning area may be rendered by CG"); Pedrotti (Ex.1005) at 12:63-66 ("this visual warning is in the form of a grid of lines or a 'virtual fence' located at the boundary"), Fig. 11; Peck, *An Evaluation of Navigational Ability Comparing Redirected Free Exploration with Distractors to Walking—Place and Joystick Locomotion Interfaces* (2001) (Ex.1077) at Fig. 2 (annotated):

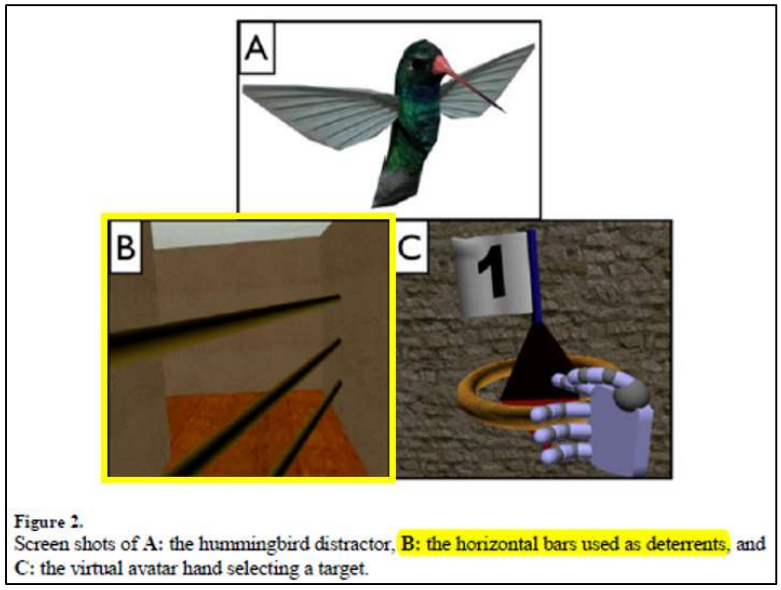


Figure 2.
Screen shots of A: the hummingbird distractor, B: the horizontal bars used as deterrents, and C: the virtual avatar hand selecting a target.

Jerald, THE VR BOOK (Ex.1063) at Fig. 18.3:

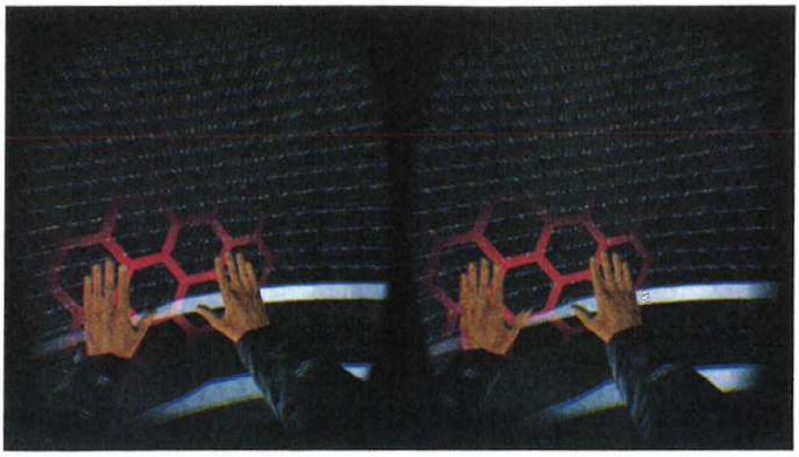


Figure 18.3 **A warning grid can be used to inform the user he is nearing the edge of tracked space.** (Image courtesy of Sixense)

Jerald, THE VR BOOK (Ex.1063) at 213 ("For a user approaching the edge of tracking, a real-world physical object not visually represented in the virtual world (e.g., a wall), or the edge of a safe zone, a warning grid (Figure 18.3), or the real world can fade in to provide a cue to the user that he should back off."). Other changes in visual presentation were also used to indicate crossing a boundary. *See, e.g.*, Ross (Ex.1125) at 16:17-39 ("a visually perceptible darkening of the primary virtual reality content, a brightening of the secondary, tertiary, etc., virtual reality content").

139. These visual warnings could change in appearance according to the user's actions. *See, e.g.*, Sawyer (Ex.1036) at [0048] (describing "an analog warning that increases in intensity (e.g., overlay of room bounds fades in [] brightness …)"); Pedrotti (Ex.1005) at 12:66-67 ("[t]he grid can be glowing or colored if desired to be more visible to the user").

140. Indeed, even in instances where a user's vision is not occluded, systems designed to create an immersive environment around the user benefit from such safety and chaperone systems. For example, in Walt Disney Imagineering's Digital Immersive Showroom (DISH) where the user is immersed in a virtual environment based on wall projections of the virtual scene, displaying a virtual image of a fence or grid indicating the boundary is useful to warn the user. *See* MousePlanet, *Step into the DISH – A Visit to Imagineering's Digital Immersive Showroom* (June 5, 2012) (Ex.1118) at 2 ("Approach a physical wall and a grid – vaguely reminiscent of Star Trek's holodeck – is generated, letting me know that I'm about to hit something real."); Orange County Register, *How They Did It: Cars Land's Virtual Reality* (June 25, 2012) (Ex.1117) (providing a detailed description of DISH). The DISH was developed by Mark Mine, formerly the Director of Technology Concept Design at WDI, and a close friend. I have personally experienced the chaperone system of the DISH on multiple occasions over many years. (I was there when they interviewed Mark and captured the video included with *Step into the DISH* above.)

141. It was also common to use audio cues to warn that the user is approaching, moving toward, or crossing safety boundaries. *See, e.g.*, Gallery (Ex.1014) at 4:22-30 ("an audio alarm may be triggered … to the headphone speakers"); Sawyer (Ex.1036) at [0042] ("a warning sound"), [0047] ("a custom warning specific to the virtual environment is made (e.g., an in-game character tells

the user to stop walking when the user approaches the boundaries of the operating space)"); Kobayashi (Ex.1019) at 13:20-28 ("the CPU 101 reads out of the RAM 102 the warning sound data warning that the user is inside the warning area 50 or outside the moveable area 60, and outputs the warning sound data to the audio output device 103 … to clearly notify the user of this apparatus that the user is currently near the boundary of the moveable area 60"); Begault (Ex.1007) at 171 (stating that "aural cues in virtual reality" often are "a means of replacing tactile sensation (haptic feedback) that would normally occur in a real environment," such as "activating auditory information in the form of a bumping or crashing sound, [so that] the user receives feedback that a particular physical boundary has been violated").

142. As discussed above, the warning can be provided via one or a combination of many ways, and even can be through the user "sensing" "when they are going to cross a boundary, which gives the user an opportunity to choose whether or not they want to cross a particular boundary." Ross (Ex.1125) at 6:8-12; *see also* Ross (Ex.1125) at 16:39-61 (listing a variety of visual, auditory, somatosensory, olfactory, haptic, and environment cues that serve as "sensory cues"). Regardless of the form of warning or cue, these indicators need to, and typically do, get the user's attention, e.g., via an abrupt appearance of visuals and/or audio, and distinct from other content presented to the user (i.e., not blending in with other content). *See* Ross (Ex.1125) at 1:33-39 (explaining the general principle of "re-direct[ing] the

attention" of the user, such as through "loud noises and/or characters telling and/or showing the [user] where to look").

VIII. Petition Grounds and Prior Art Combinations

143. Below is a summary of the grounds and related prior art that I will explain in the following sections:

'509 Patent		
Ground	**Relevant Prior Art**	**Claims**
Ground 1 (Section X.A)	Pedrotti in view of Jang, and further in view of Begault	Claims 1-14, 17-20 (claims 1, 8, 14 are independent)
Ground 2 (Section X.B)	McCulloch, in view of Pedrotti, and further in view of Flaks	Claims 1-14, 17-20 (claims 1, 8, 14 are independent)

'316 Patent		
Ground	**Relevant Prior Art**	**Claims**
Ground 1 (Section XI.A)	Pedrotti in view of Jang, and further in view of Begault	Claims 1-20 (claims 1, 9, 17 are independent)
Ground 2 (Section XI.B)	McCulloch, in view of Pedrotti, and further in view of Flaks	Claims 1-20 (claims 1, 9, 17 are independent)

144. In analyses provided below, I discuss each limitation in the challenged claims, explaining how the prior art discloses and renders obvious each limitation, and each claim as a whole.

IX. The Prior Art Relied On In The Petitions

145. In this section, I provide brief overviews of the prior art references relied upon in the obviousness combinations detailed in the Petitions and discussed in this declaration, some of which were mentioned above in discussion of the State of the Art. Each of these references is discussed further below, in my specific evaluations of the challenged claims.

A. Overview Of Pedrotti (Ex.1005)

146. I have been informed that U.S. Patent No. 9,851,786 ("Pedrotti"), which issued in December 2017, is prior art because it was filed in July 2015.

147. Pedrotti is titled "System and Method For Assisting A User In Remaining In A Selected Area While The User Is In A Virtual Reality Environment." Pedrotti (Ex.1005) at Cover.

148. Pedrotti discloses a system that "allows an area in the physical world to be defined within which the user should remain, for example to avoid physical obstacles." Pedrotti (Ex.1005) at Abstract, 2:7-12 (describing the invention as "a solution that will allow a user … to remain in a selected area, for example to avoid collisions with surrounding physical objections"), 4:32-44, 11:43-12:15.

149. Pedrotti discloses that "it is difficult for the user to maintain awareness of his or her location in the physical world while the user sees only the virtual world," such that "[i]t may be desirable that the user remain within a selected area, for example, if there are physical objects in the vicinity of the user." Pedrotti (Ex.1005) at 1:57-66. Pedrotti discloses that this applies to "taking a step or moving an arm," or "any such movement [that] results in the user moving in the physical world." Pedrotti (Ex.1005) at 1:63-66.

150. Pedrotti discloses as parts of its system "a head mounted display (HMD) that … has a tracker allow[ing] a processor to track the position and orientation of the HMD" and "physical controllers that a user may use to control certain actions or events in the virtual world." Pedrotti (Ex.1005) at 4:4-11. Pedrotti discloses that the "user is holding a handheld controller having a tracker which can be used to track the position and orientation of the handheld controller." Pedrotti (Ex.1005) at 15:7-12.

151. Additionally, Pedrotti discloses that "the user is seeing the virtual world as presented on [the] HMD" and "us[ing] the controller to interact with the virtual world to 'pick up'" virtual objections, such as "a bat, tennis racket, golf club or other sporting implement (or the handle of such an object), a gun, sword or other weapon (or again the handle thereof), or some other toy or device which will appear in the virtual world":

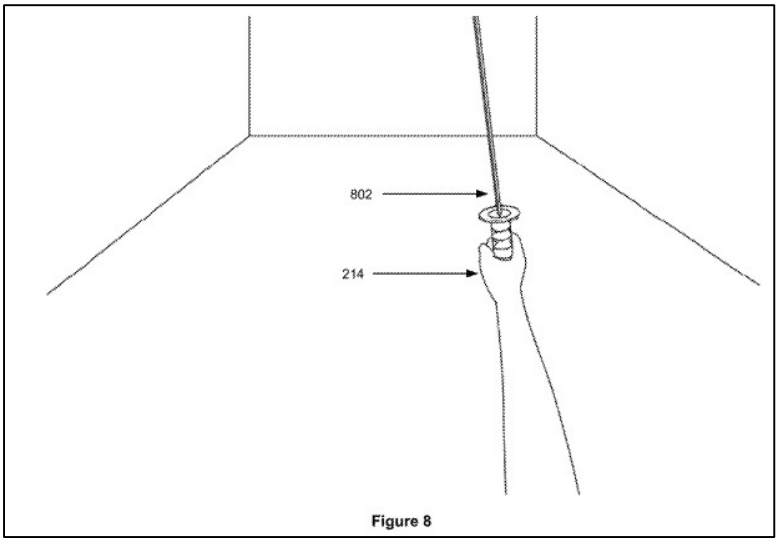


Figure 8

Pedrotti (Ex.1005) at Fig. 8 (depicting virtual sword 802), 5:47-53, 16:33-42.

152. Pedrotti provides a "flowchart of a method implemented by a processor" for the "display of a visual warning such as a virtual fence":

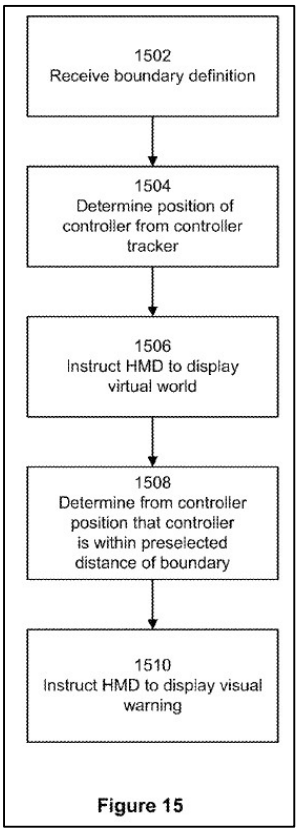


Figure 15

Pedrotti (Ex.1005) at 15:4-39, Fig. 15. This warning is displayed "to alert the user if the user approaches to within a preselected distance of the boundary." Pedrotti (Ex.1005) at Abstract.

153. Pedrotti discloses that the boundary for Pedrotti's "safe area" may be "determined in several ways." Pedrotti (Ex.1005) at 14:6-7. For example, the boundary may be defined as a circle. Pedrotti (Ex.1005) at 15:13-24 ("radius and location of the center of a circle"), Figs. 12-13. Or a boundary "around an irregularly shaped area, which is not circular can be defined, for example, by having the user walk around a perimeter chosen by the user with one of the trackers." Pedrotti (Ex.1005) at 14:56-15:3. When a boundary is defined in this manner, "[t]he processor determines the position of the tracker at a number of sampling points as the user moves around the chosen perimeter, and from those points determines the boundary":

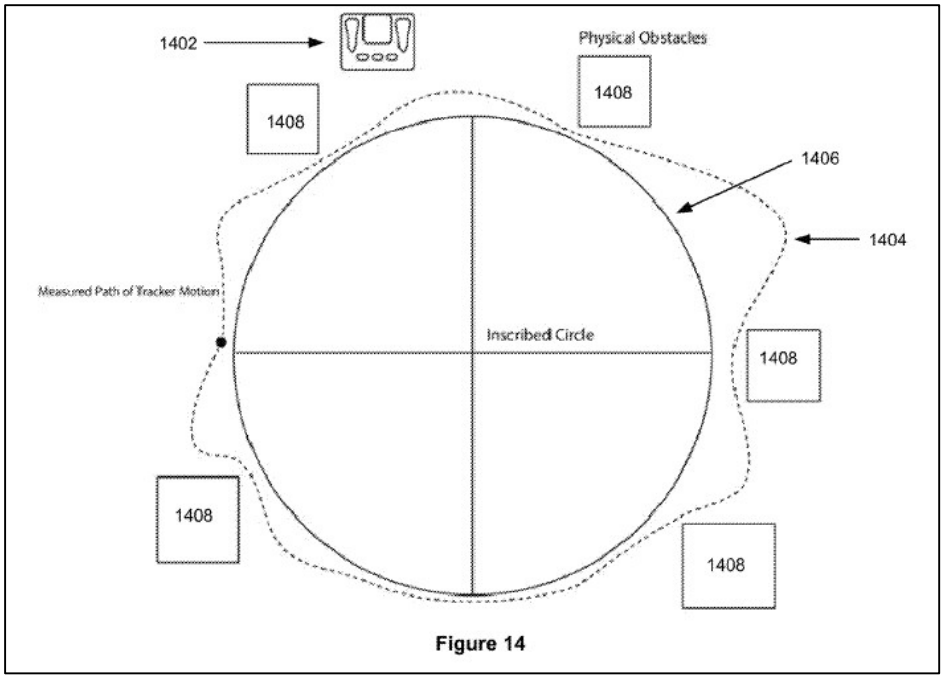


Figure 14

Pedrotti (Ex.1005) at 14:56-15:3, 15:13-22, Fig. 14.

154. Pedrotti discloses that its processor "tracks the position and orientation of the HMD tracker, and possibly the position and orientation of one or more trackers in the physical controllers," including through "various tracking techniques," such as "electromagnetic tracking." Pedrotti (Ex.1005) at 4:32-44, 4:59-5:24, 15:25-26, 16:22-26. As such, "the processor knows where the user's head and hands are located," and "if the processor has been provided with information about the boundary of the selected area then the processor can also determine when the user's head and/or hand approaches the boundary." Pedrotti (Ex.1005) at 12:31-39. For example, "when the user's head and/or hand approaches to within a preselected distance, for example, one foot (again, either preprogrammed into the processor or user selectable), of the boundary of the selected area the processor generates a

warning that the user is close to the boundary so that the user can take action to avoid the boundary and thus potential collision with the physical objects." Pedrotti (Ex.1005) at 12:40-50. Pedrotti discloses that the preselected distance "may vary by application," for example it may be "greater in an application in which larger body movements are expected from the user than in an application in which such body movements are not expected." Pedrotti (Ex.1005) at 13:46-62.

155. Pedrotti discloses that the processor "generates instructions to the HMD to generate the visual warning," e.g., "a grid of lines or a 'virtual fence' located at the boundary," which "can be glowing or colored if desired to be more visible to the user.":

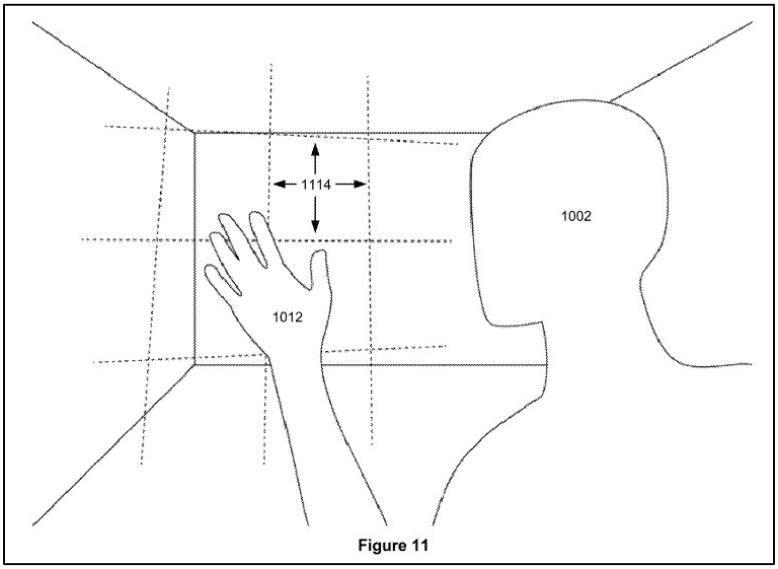


Figure 11

Pedrotti (Ex.1005) at 12:51-13:33 ("virtual fence 1114"), 15:26-29, Fig. 11.

156. Pedrotti further discloses that the type of warning may be altered, such as "with directional arrows indicating the direction of the boundary in relation to the

user's view," "text or auditory warnings," or "an additional visual warning, that persists until the user returns to the selected area within the boundary." Pedrotti (Ex.1005) at 13:34-45, 13:63-14:5.

157. Pedrotti also discloses that its system is "applicable to HMDs that block the user's view of all or only part of the physical world," including "a device such as Google Glass, which obscures only a small portion of the user's field of vision." Pedrotti (Ex.1005) at 16:14-19.

B. Overview Of Jang (Ex.1006)

158. I have been informed that U.S. Patent No. 8,520,872 ("Jang") is prior art because it issued in August 2013.

159. Jang is titled "Apparatus and Method for Sound Processing In A Virtual Reality System." Jang (Ex.1006) at Cover.

160. Jang relates to "process[ing] sound in a focus area of a virtual reality system differently from sound in an un-focus[4] area." Jang (Ex.1006) at 1:18-23.

161. Jang's "sound processing may control the sound output with a sense of realism in consideration of a space shift in a virtual reality system." Jang (Ex.1006) at 2:26-28; *see also* Jang (Ex.1006) at 2:1-11.

[4] Jang uses the terms "un-focus area" and "non-focus area" interchangeably.

162. As background, Jang explains that VR systems can "provide a high degree of realism in an electronically-manufactured environment, such as a in a virtual reality game or a 3D game." Jang (Ex.1006) at 1:28-30. Jang provides that VR systems "allow users to feel various manufactured sensory inputs (including visual sense, auditory sense, and tactile sense) … [that] replicate sensory experiences of the real world with varying degrees of realism." Jang (Ex.1006) at 1:31-33. For example, "life-like images and sounds may be generated," images "may be three-dimensionally realized by using … a Head Mounted Display (HMD)," and sound may be "generated by speakers, a headset, or any other audio device" and "use a localization technique capable of expressing the virtual location." Jang (Ex.1006) at 1:35-44.

163. Additionally, Jang discloses sound processing techniques to "model[] the path and change of sound according to relative locations of a sound-generating object, locations of surrounding things, and direction of sound propagation to give the sense of reality to the sound." Jang (Ex.1006) at 1:46-51. Jang further discloses the use of a "Head Related Transfer Function (HRTF)" to "express directionality" by modeling "the paths of the sound reaching listener's ears, which determine the direction of sound in view of the listener." Jang (Ex.1006) at 1:52-56.

164. Jang teaches that "[w]hen a user moved in a virtual environment, the real world is imitated as much as possible. However, in some situations it may be

more convenient for a user if movement in the virtual environment does not precisely mimic the real world," for example, where "a user can shift between virtual spaces without having to portray the passage of distance or time to travel from one space to another." Jang (Ex.1006) at 1:57-65. Jang discloses that "[a]n example of such a virtual reality system includes a virtual reality game, 'Second Life,' developed by Linden Lab." Jang (Ex.1006) at 1:65-67.

165. To facilitate and better manage transitions that do no mimic real-world travel, Jang discloses "process[ing] and produc[ing] sound output in sound areas," which can be divided into "focus" and "un-focus" areas. Jang (Ex.1006) at 1:18-23. "The focus area may correspond to an area in the virtual environment in the immediate foreground of a visual perspective of a character corresponding to a user, and the non-focus area may correspond to an area that is not in the immediate foreground of the visual perspective of the character." Jang (Ex.1006) at 4:20-24; *see also* Jang (Ex.1006) at 3:39-48. Jang's Figure 2 provides an illustration of this, with focus area 203 shaded in gray:

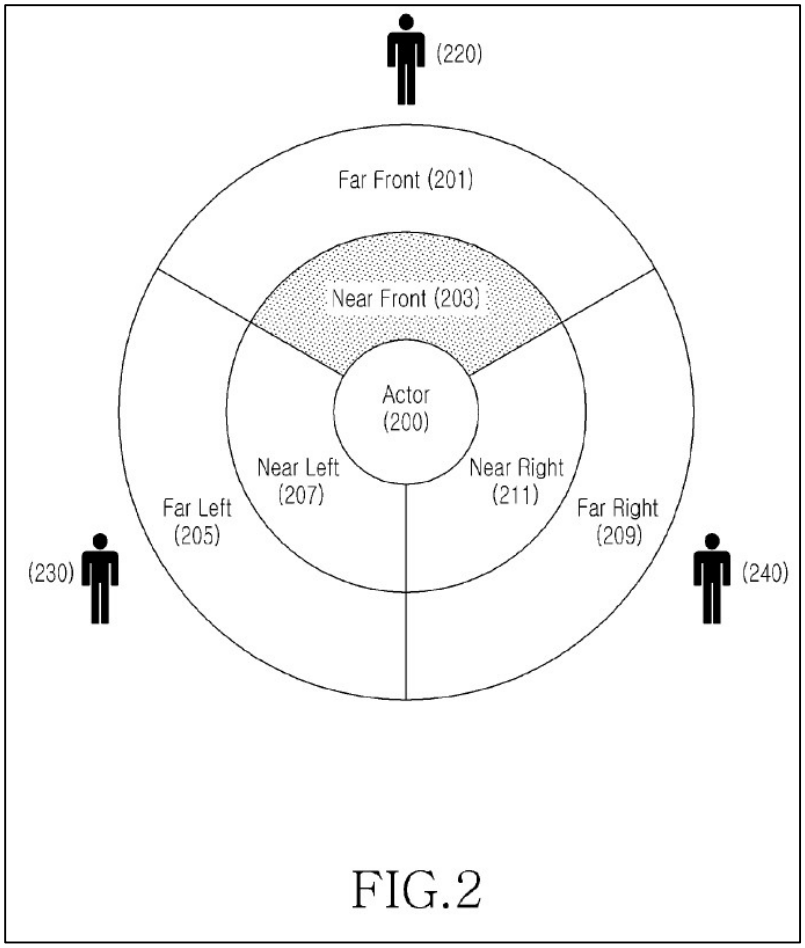


FIG.2

Jang (Ex.1006) at Fig. 2.

166. Jang discloses that "[t]he division between the focus area and the non-focus areas in FIG. 2 is only an example and may be modified in various ways according to the characteristics and/or topography of the virtual area at which [a] character is located." Jang (Ex.1006) at 8:25-40.

167. Jang taught that sound outputs for these areas is then processed differently when virtual space shifts occur. For example, "a volume of sound in a first space is gradually decreased when a space shift from the first space to the second space in the virtual reality space is detected," Jang (Ex.1006) at 2:32-48, and

"sensory output corresponding to [a] focus area" can be generated "before generating a sensory output corresponding to the non-focus area." Jang (Ex.1006) at 3:62-4:9.

168. Jang further discloses that "each divided focus or non-focus area may contain any number of virtual objects represented by sensory data that may include audio and visual data," and that "at least one of the focus area and the non-focus areas may be divided into multiple areas in the virtual reality space according to a predetermined priority in controlling the volume of the sound or the left-right balance." Jang (Ex.1006) at 8:41-49; *see also* Jang (Ex.1006) at 4:25-39 ("determining a priority of each of the plurality of sensory sources"), 9:41-65 (discussing determination of priorities of sound sources), cls. 4 and 10.

169. Jang teaches a "control unit" for dividing these areas and better managing space shifts. For example, "[w]hen the control unit detects a space shift, the control unit may direct the sensory processing unit to output a sensory output signal to reduce a sensory output corresponding to the first virtual space while increasing a sensory output corresponding to the second virtual space." Jang (Ex.1006) at 2:35-47. The shifts, as Jang discloses, "may occur in various ways," such as through "key input of [a] user for character movement" or when a "scene change" is detected "due to space shift in a video output." Jang (Ex.1006) at 9:11-17.

170. Jang discloses an example where there is a "space shift in a virtual environment from basketball court 600 to conference room (610)":

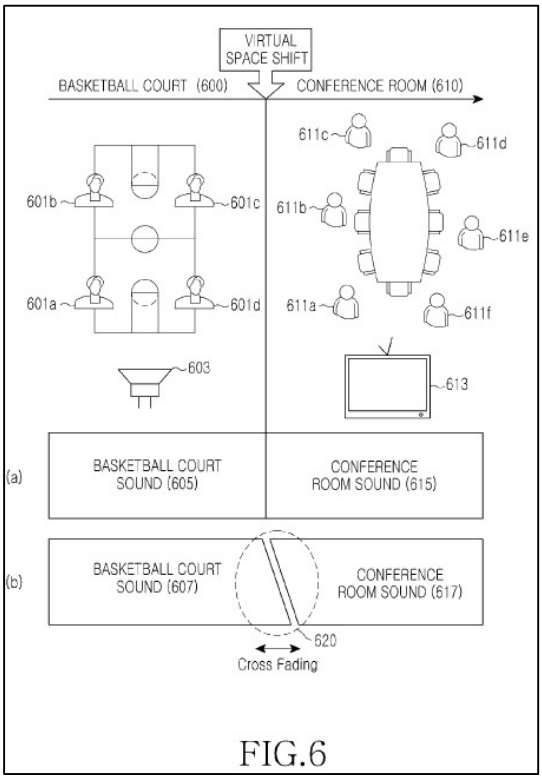


FIG.6

Jang (Ex.1006) at 10:59-60, Fig. 6.

171. When this shift in virtual spaces occurs (from the basketball court to the conference room), "priorities of the sound sources of a focus area and non-focus areas of the conference room 610 are first determined," and "the volume of the basketball court sound 607 is decreased or faded while the volume of the conference room sound 617 generated according to the priorities of the focus area or non-focus areas of the conference room 610 is increased." Jang (Ex.1006) at 11:1-16.

C. Overview Of Begault (Ex.1007)

172. I have been informed that Begault is prior art because it is a 2000 publication.

173. Begault is titled "3-D Sound for Virtual Reality and Multimedia."

174. Begault describes processes for producing "3-D sound" for VR.

175. Begault discloses that the terms "3-D sound," "binaural audio," and "spatialized sound" are "equivalent designations" in that they all "refer to techniques where the outer ears (the pinnae) are either directly implemented or modeled as digital filters." Begault (Ex.1007) at x. Begault further discloses that "[b]y filtering a digitized sound source with these filters," one can "place sounds anywhere in the virtual space about a headphone listener." Begault (Ex.1007) at x. Furthermore, "[t]he combination of 3-D sound within a human interface along with a system for managing acoustic input is termed a 3-D auditory display." Begault (Ex.1007) at x.

176. Begault explains that "[e]arly on in the development of virtual reality, it was seen that sound should have some type of interactive, spatial character imposed on it." Begault (Ex.1007) at 12. 3-D sound "improve[s] the quality and ease of interaction within a human interface, communication system, or office or home environment," and also "contribute[s] to the sense of immersivity in a 3-D environment." Begault (Ex.1007) at 13. Begault discloses that "[o]ne might be able to work more effectively within a VR environment if actions [a]re accompanied by

appropriate sounds that seemingly emit from their proper locations." Begault (Ex.1007) at 13.

177. In its Chapter 2, Begault describes in detail HRTFs and localization with HRTF cues. Begault (Ex.1007) at ch. 2.

178. Begault discloses that "[t]he spectral filtering of a sound source before it reaches the ear drum that is caused primarily by the outer ear is termed the head-related transfer function (HRTF)," and "[t]he use of HRTF spectral shaping is typically featured as the key component of a 3-D sound system." Begault (Ex.1007) at 41. Begault further explains that "binaural HRTF" is "terminology [used] for referring to both left- and right-ear HRTFs" and "can be thought of as a frequency-dependent amplitude and time-delay differences that result primarily from the complex shaping of the pinnae." Begault (Ex.1007) at 41. Begault discloses, too, that "inclusion of the binaural HRTF is fundamental for a 3-D sound system," and it discusses implementation details for HRTF processing and generating binaural sound. Begault (Ex.1007) at 99, 105-06 ("The basis of 3-D sound processing lies in imitation of the spatial cues present in natural spatial hearing, where the binaural HRTF imposes spatially dependent spectral modifications and time delays on an incoming wavefront to the hearing system. In virtual spatial hearing, it is possible to imitate these modifications using a DSP as a digital filter. One can obtain HRTF data by several methods (described later) and then use digital filters—specifically,

two different *h(n)*s, termed a binaural impulse response—to produce a desired virtual acoustic source position."), 118 ("A review of the literature shows that KEMAR's HRTFs have been used many times in both 3-D sound applications and localization studies (e.g., Kendall, Martens, and Wilde, 1990)."), 139 ("Some of these methods have been worked into 3-D sound systems, where HRTF processing is applied not only to the direct sound but to the indirect sound field as well, resulting in a synthetic spatial reverberation.").

179. Begault discloses various examples of in which "distributed 3-D audio devices" were "integrated within a dedicated virtual reality application," such as the Convolvotron 3-D audio device within NASA'S VIEW system.[5] Begault (Ex.1007) at 170.

[5] *See* Jerald, THE VR BOOK (Ex.1063) at Fig. 2.13 (photograph of NASA's VIEW system):



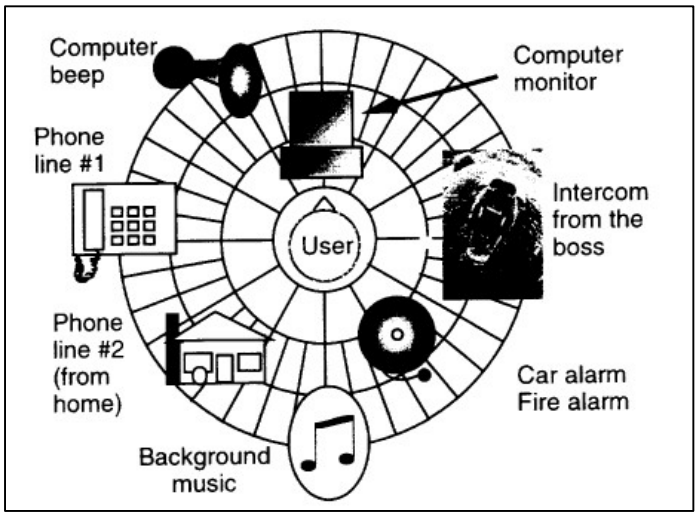
Figure 2.13 **The NASA VIEW System.** (Courtesy NASA/S.S. Fisher, W. Sisler, 1988)

180. Another example Begault discloses is "Computer Workstation 3-D Audio," where "the audio signal is brought into the computer and then spatialized," and "the communication source can be usefully arranged in virtual space." Begault (Ex.1007) at 172. As Begault explains, this feature "becomes particularly important in multiconversation teleconferencing," or "spatial audio teleconferencing," or "an audio window system." Begault (Ex.1007) at 172; *see also* Begault (Ex.1007) at 173-74 (providing further detail on "audio windows").

181. Begault also discussed a system called Multidimensional Audio Windows ("MAW"), which allowed "teleconference participants to wander around in the virtual room and to focus their voice toward particular conference participants by using a binaural HRTF to process each virtual source." Begault (Ex.1007) at 173. Begault notes that, with MAW, users could "leapfrog between teleconference sessions," or "move to a 'private conference' by moving the icons of the participants to a special region on the computer screen, symbolized as a separate room." Begault (Ex.1007) at 173.

182. Begault discloses that audio spatialization is not limited to teleconferencing environments, but "all types of sonic input," which "could be directionalized to a specific location, controlled by the user." Begault (Ex.1007) at 172.

183. Begault explains that "it is not necessary to place [] audio sources in their corresponding visual locations" because "audio spatial mapping can correspond to a prioritization scheme." Begault (Ex.1007) at 172. And Begault presents "a hypothetical GUI for arranging [] various sound inputs in virtual auditory space in a manner configurable by each individual listener":



Begault (Ex.1007) at 172-73, Fig. 5.12.

184. As Figure 5.12 depicts, "[t]he basic concept is to represent each form of auditory input iconically on the screen, and then allow manipulation" of the exact locations of the icons. Begault (Ex.1007) at 172. In turn, "[t]he computer interprets the relative location of the icons on the screen as commands to a multiinput, 3-D sound spatialization subsystem." Begault (Ex.1007) at 172. This means a sound spatialization subsystem will take the relative location of manipulated icons and generate 3D sound, or binaural sound, to users at locations around the user

corresponding to the icons' relative locations, including "the distance and relative azimuth of each source." Begault (Ex.1007) at 172.

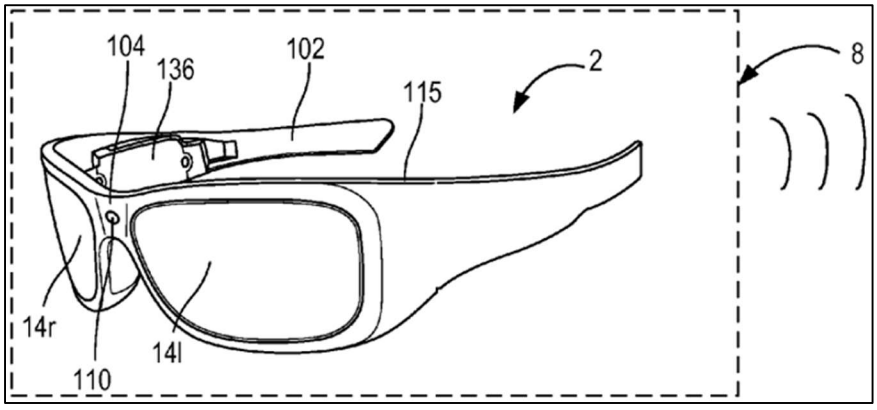
D. Overview Of McCulloch (Ex.1008)

185. I have been informed that U.S. Patent No. 9,041,622 ("McCulloch") is prior art because it issued on May 26, 2015.

186. McCulloch is titled "Controlling A Virtual Object With a Real Controller Device." McCulloch (Ex.1008) at Cover.

187. McCulloch discloses a system for "controlling a virtual object displayed by a near-eye, augmented reality display with a real controller device." McCulloch (Ex.1008) at 1:18-21, 1:46-48, Fig. 5.

188. McCulloch discloses a "display device system" (item 8) that includes a display device (e.g., an HMD) (item 2) and control circuitry (item 136) and communicates with real controller devices (e.g., a handheld inertial motion unit ("IMU")):



McCulloch (Ex.1008) at Fig. 1B, 4:25-42 (providing examples of real controller devices), 4:49-55 (describing the HMD), 6:55-7:3 (describing the real controller device), 7:4-22 (also describing the HMD).

189. As shown below, the control circuitry (item 136) for this "display device system" includes a processing unit (item 210), memory (item 244), wireless interface (item 137), and power supply (239):

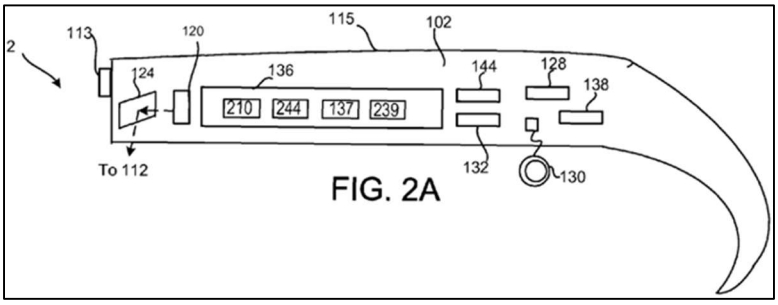


FIG. 2A

McCulloch (Ex.1008) at Fig. 2A, 8:1-39.

190. McCulloch further discloses that the software computing environment (item 54) for its "display device system" (again, item 8) includes an image and audio processing engine (item 191), device data (item 198), and real controller device interface software (item 188), among other components:

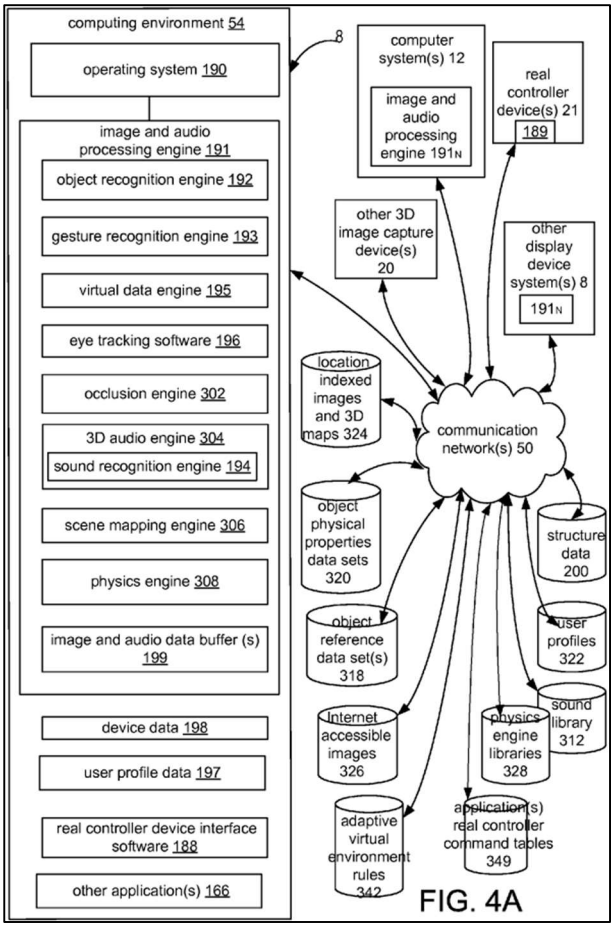


FIG. 4A

McCulloch (Ex.1008) at 13:56-14:11 (describing computing environment), Fig. 4A.

191. The "[i]mage and audio processing engine 191 includes object recognition engine 192, gesture recognition engine 193, virtual data engine 195, eye tracking software 196," "an occlusion engine 302, a 3D positional audio engine 304 with a sound recognition engine 194, a scene mapping engine 306, and a physics engine 308 which may communicate with each other." McCulloch (Ex.1008) at 14:5-11.

192. Scene mapping engine 306 maps the user's environment and "identifies the position and tracks the movement of real and virtual objects in [a] volumetric

space based on communications with the object recognition engine" and "applications [] generating virtual objects." McCulloch (Ex.1008) at 16:58-63, 19:8-27, Fig. 4C; *see also* McCulloch (Ex.1008) at 15:30-47 (describing mapping the user's environment with position and orientation data). For a virtual object, "the virtual data engine 195 has a target 3D space position of where to insert the virtual object." McCulloch (Ex.1008) at 23:39-56.

193. The 3D audio engine 304 "plays audio data for the virtual object projected from a 3D space position of the virtual object." McCulloch (Ex.1008) at 25:60-26:19, 21:21-29 (further describing 3D audio engine 304), 22:66-34:4 (describing sound library). Each virtual object is associated with "audio data… projected from a 3D space position of the virtual object" generated through HRTFs processed by the 3D audio engine. McCulloch (Ex.1008) at 26:7-19. With respect to the 3D audio engine, McCulloch incorporates by reference U.S. Patent Application No. 12/903,610, issued as U.S. Patent No. 8,767,968 ("Flaks") (Ex.1009), which I discuss in further detail below (*see* Section IX.E). Flaks provides implementation details for an audio engine that processes HRTFs to "accurately localize a sound as coming from a virtual sound source." McCulloch (Ex.1008) at 21:21-38; Flaks (Ex.1009) at 1:44-46.

194. Device data 198 on McCulloch's system includes "data from sensors or sensing units," which are associated with the HMD itself. McCulloch (Ex.1008) at

24:9-21. In this manner, McCulloch's system tracks its HMD's position and orientation with an inertial sensing unit, sensing "position, orientation, and sudden accelerations," and depth cameras that "transmit and detect infrared light from which depth data may be determined." McCulloch (Ex.1008) at 7:24-67 (describing capture devices), 8:17-39 (describing the different sensors incorporated into McCulloch's HMD), 15:31-38 (explaining that sensor data, e.g., head position data, is used to map what is around the user's environment in a depth map). Device data 198 "makes available … location data, head position data, data identifying an orientation with respect to the ground and other data from sensing units of the display device," along with gestures, sounds, and "positions of objects from the scene mapping engine." McCulloch (Ex.1008) at 14:53-67.

195. Data from McCulloch's sensors is also shared with the HMD's image generation unit that "can display virtual objects at various depths" and "a user perspective of the virtual object [] determined from a position and orientation." McCulloch (Ex.1008) at 8:40-9:16 (describing the image generation unit that is used to display virtual objects at various depths), 11:56-58 (describing that the virtual object is displayed according to the user's perspective), 12:4-17 ("virtual objects are tracked in the display field of view"), 12:41-51 ("both real and virtual objects are displayed in the display field of view as they are seen from the user perspective").

McCulloch discloses that "[i]n some examples, virtual objects are tracked in the display field of view and real objects are ignored." McCulloch (Ex.1008) at 12:3-4.

196. McCulloch's HMD tracks real controller devices, which can be used to select and control virtual objects and virtual object representations of real objects. McCulloch (Ex.1008) at 4:14-31 (describing object selection by a real controller device), 26:20-24 ("a virtual object representing the real object can be generated and controlled by the data received from the real controller device"), 28:12-20 (describing selection of an object to be controlled), 29:6-12 ("changes in position and orientation of the handheld controller causes its inertial motion unit to generate one or more signals which are converted … to be user input requesting display of an actual by the virtual object"), 29:40-43 ("speed, acceleration and direction of motion of the [real controller] device … is sent as data to the display device system"), Figs. 8B, 8D (showing examples of a user controlling a virtual basketball). McCulloch's system "receives user input data from a real controller device requesting an action to be performed by the virtual object," "appl[ies] the user input data," and "display[s] the action." McCulloch (Ex.1008) at 1:59-66, 11:42-46 (describing Figs. 3A-3F), (describing object selection by a real controller device), Figs. 3A-3F; McCulloch (Ex.1008) at 25:29-38.

197. McCulloch also discloses creating user-defined, 3D zones for gameplay: "For example, a gaming application may receive user input identifying

boundaries for a playspace in which virtual objects can be positioned." McCulloch (Ex.1008) at 20:11-13. And McCulloch discloses that its system can "execute an application" using a "current physical environment as a factor in the execution of a game," as "applications store adaptive virtual environment rules 342 for effecting the placement and display of one or more virtual objects in a 3D mapping of an environment during their execution." McCulloch (Ex.1008) at 20:4-11.

E. Overview Of Flaks (Ex.1009)

198. I have been informed that U.S. Patent No. 8,767,968 ("Flaks") is prior art because it issued on July 1, 2014.

199. Flaks is titled "System and Method for High-Precision 3-Dimensional Audio For Augmented Reality." Flaks (Ex.1009) at Cover.

200. Flaks discloses techniques "for providing 3D audio," where "the 3D audio signal may include a number of components that are determined based on collected sensor data and the listener's location." Flaks (Ex.1009) at Abstract. Flaks discloses that "sensor data may be used to collect physical characteristics of the listener such that a suitable HRTF may be determined from a library of HRTFs." Flaks (Ex.1009) at Abstract.

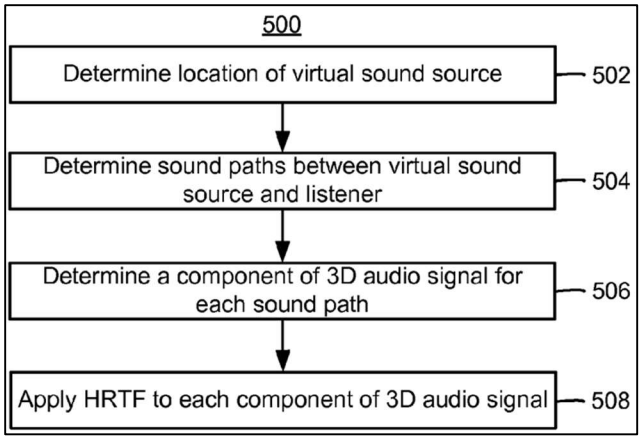
201. Flaks discloses that "[a] 3D audio signal may be generated based on sensor data collected from the actual room in which the listener is located and the actual position of the listener in the room." Flaks (Ex.1009) at 3:21-24. As Flaks

explains, "the physical characteristics of a room can be factored in," as "a sound reflecting off from a hardwood floor will be different than a sound reflecting from a carpet." Flaks (Ex.1009) at 7:6-21.

202. Flaks discloses that "[t]he audio signal may represent a 'virtual sound' that represents a sound coming from some specific location in 3D space," where the "location might represent some object being displayed on a video screen, or even a real physical object in the listener's room." Flaks (Ex.1009) at 3:23-28, 4:10-20. Flaks teaches that the room model capturing these details "may be updated at any desired interval." Flaks (Ex.1009) at 9:60-61.

203. Flaks discloses that the 3D audio signal "is provided to the listener through a set of headphones." Flaks(Ex.1009) at 3:28-29, 4:2-5.

204. Flaks also discloses a process of "determining components of a 3D audio signal" that includes identifying the virtual sound source and determining the 3D audio signal for each sound path. Flaks (Ex.1009) at 9:4-64. In this process, the listener's HRTF is applied to each component in order to "generate the 3D audio signal":



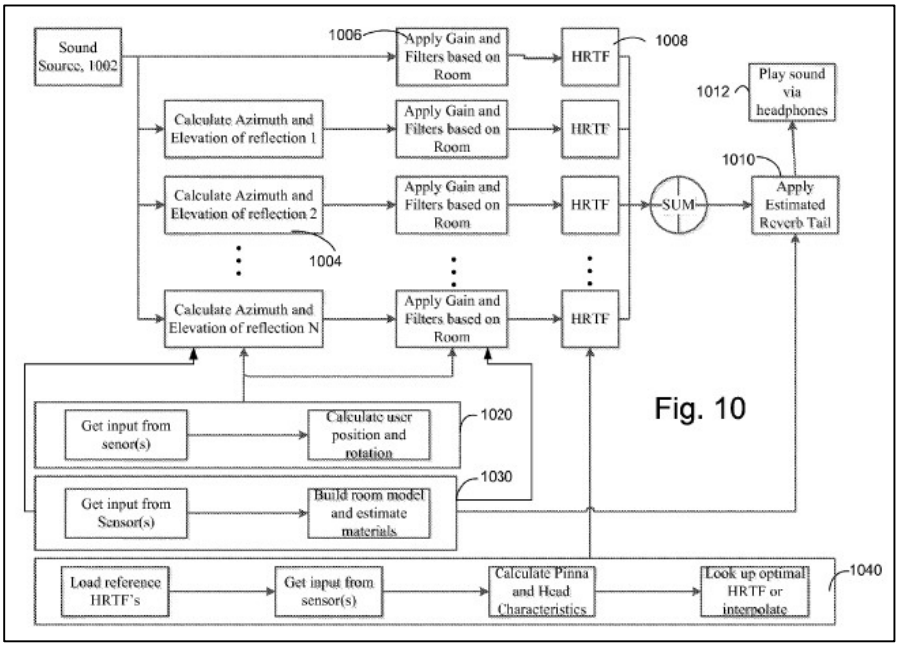


Fig. 10

Flaks (Ex.1009) at 9:65-10:4, 13:55-14:4, Figs. 5A, 10 (block diagram of one embodiment of generating a 3D audio signal).

205. Flaks further discloses a process of "determining an HRTF for a particular listener," which can be stored for the user and updated "in real time" based on "changing user position." Flaks(Ex.1009) at 11:44-12:57, 14:27-39 (describing playing a 3D audio signal for the user so the user points to the apparent source of the sound, which allows the system to determine the effectiveness of the HRTF), Fig. 7.

Because "determining detailed characteristics of the listener 8 such that an HRTF may be stored for the user might be done infrequently," Flaks also teaches selecting HRTFs from previously determined HRTFs based on "stored detailed user characteristics." Flaks(Ex.1009) at 12:58-13:16, Fig. 8.

206. Flaks discloses that its system uses cache memory (e.g., level 1 cache 102 and level 2 cache 104) to "temporarily store data and hence reduce the number of memory access cycles, thereby improving processing speed and throughput":

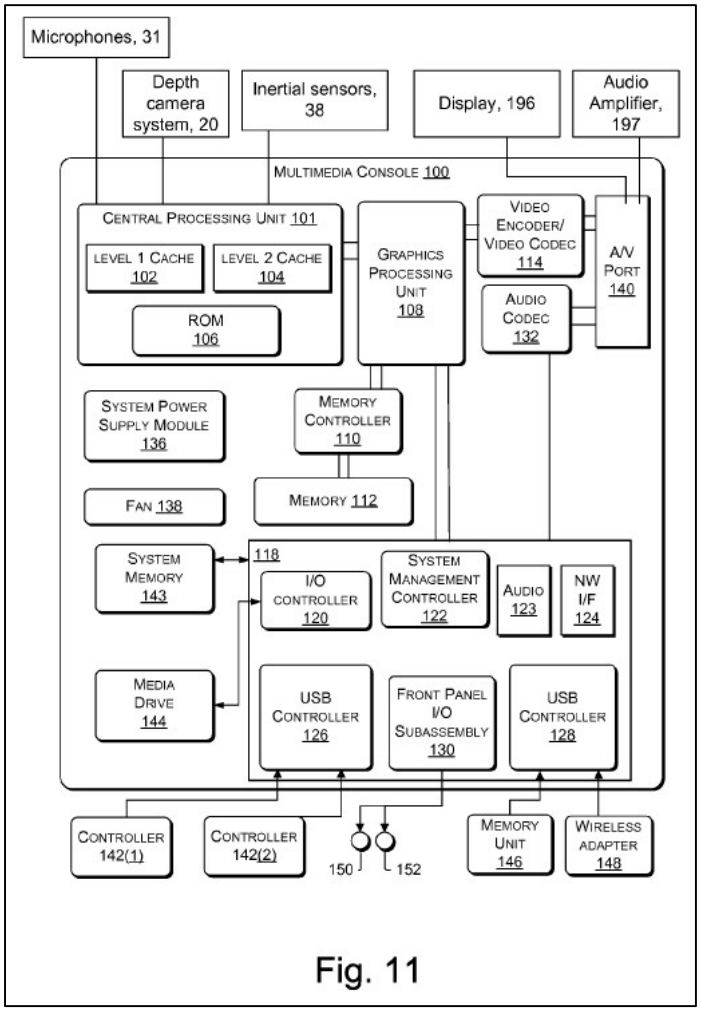


Fig. 11

Flaks (Ex.1009) at 14:60-67, Fig. 11.

X. US Patent No. 10,798,509

207. The challenged claims of the ’509 patent recite basic and straightforward systems and processes that, before February 2016, were used in virtual environments and well known to persons of ordinary skill in the art. Further, to the extent 8K argues that the challenged claims of the ’509 patent differ from the disclosures of the art relied on in the grounds of Petitioners’ petition and discussed in detail below, it is my opinion that any such differences are trivial, including in view of the many additional prior art references I discussed in this declaration, which, among other things, demonstrate the level of knowledge persons of ordinary skill in the art would have possessed before the ’509 patent’s earliest possible priority date.

A. Ground 1: Claims 1-14 and 17-20 Are Unpatentable Over Pedrotti In View Of Jang And Further In View Of Begault

208. In this section, I explain why every limitation of claims 1-14 and 17-20 of the ’509 patent, and each of claims 1-14 and 17-20 as a whole, would have been obvious to persons of ordinary skill in the art over Pedrotti in view of Jang, and further in view of Begault.

1. Reasons Persons of Ordinary Skill in the Art Would Combine Pedrotti And Jang

209. Persons of ordinary skill in the art would have understood and been motivated to combine Pedrotti's system and method for assisting a user in remaining within a selected area with Jang's sound processing methods.

210. First, Pedrotti and Jang are analogous art because both relate to improving VR applications, including VR gaming. Pedrotti (Ex.1005) at 1:8-10 ("The present invention relates generally to virtual reality devices …"); Jang (Ex.1006) at 1:18-23 ("The present general inventive concept relates to an apparatus and a method to perform sound processing in a virtual reality system …"), 1:28-30 ("Virtual reality systems may be used to provide a high degree of realism in an electronically-manufactured environment, such as in a virtual reality game or a 3D game.").

211. Second, persons of ordinary skill in the art designing a VR system and reading Pedrotti—which recognizes the importance of sound but does not specifically address sound processing—would have been motivated to look to references disclosing advantageous sound processing techniques, including references like Jang that disclose such techniques. Pedrotti itself recognizes the importance of sound in creating a sense of realism. Pedrotti (Ex.1005) at 1:18-20 ("While virtual reality can recreate a number of sensory experiences, the senses most

commonly used today to create virtual reality appear to be sight and ***sound***.") (emphasis added). And as Jang explains, its described sound processing techniques aid in "provid[ing] a virtual reality that can give a higher sense of realism." Jang (Ex.1006) at 2:7-11. Jang discloses that, in accordance with its techniques, "it is possible to make a change in the sound by modeling the path and change of sound according to relative locations of a sound-generating object, locations, or surrounding things, an direction of sound propagation, to give the sense of reality to the sound." Jang (Ex.1006) at 1:46-51, 1:52-56 (additionally disclosing use of HRTFs to express directionality for sound reaching the listener's ears).

212. Persons of ordinary skill in the art designing a VR system would have understood that Jang's disclosed sound processing techniques can be used with HMDs, such as the HMD in Pedrotti. *See* Jang (Ex.1006) at 1:38-41; Pedrotti (Ex.1005) at 15:53-58 (discussing that the HMD is able to provide audio). Also relevant to Pedrotti's disclosure directed to helping users "avoid collisions with surrounding physical objects" in the physical world (Pedrotti (Ex.1005) at 2:7-12), Pedrotti is compatible with the sound processing techniques of Jang, which are directed to help guide the user in the virtual world.

213. Because Pedrotti's teachings limit the user's physical movements to within a "safe area" (Pedrotti (Ex.1005) at 4:32-44), persons of ordinary skill in the art would have recognized that Jang teaches how to navigate a virtual reality space

(e.g., moving from a virtual basketball court to a virtual conference room) without needing to walk in the virtual world the same distance the user would have to walk in the physical world, the latter of which is constrained based on Pedrotti's teachings. *See* Jang (Ex.1006) at 2:1-11 (explaining that the "virtual reality space shifts from a first space to a second space"). Persons of ordinary skill in the art would have been motivated to incorporate the teachings of Jang into Pedrotti's system in order to enable the user to experience the full breadth of the virtual world, even with physical constraints imposed by Pedrotti's "safe area." Furthermore, persons of ordinary skill in the art would have had a reasonable expectation of success in implementing the space shifts taught by Jang with Pedrotti's system because Pedrotti's handheld controller provides a common way for the user to provide the "key input" Jang teaches, such as selection of a second space to effect the space shift. *See* Pedrotti (Ex.1005) at 1:40-45 (describing Pedrotti's handheld controllers); Jang (Ex.1006) at 9:11-17 ("The shift from the first space to the second space may occur in various ways, for example, when the control unit 114 detects a key input of the user for character movement through a key input unit (not shown) of the virtual reality apparatus 110 or when the control unit 114 detects scene change due to space shift in a video output (not shown).").

214. Third, Pedrotti and Jang are Sixense and Samsung patents, respectively. As I mentioned in Section VII.A, persons of ordinary skill in the art would have

known that both Sixense and Samsung were working on VR systems, including collaboratively. As was known in the field, Sixense had made a name in the field through its full body motion STEM system, which was a form of wireless hand and body tracking. Parisi (Ex.1075) at 24. As indicated in LEARNING VIRTUAL REALITY—which is a guide for VR development essentials for desktop, mobile, and browser-based applications and a compendium for commercially available systems including OculusVR, Samsung Gear VR, and Google Cardboard VR—persons of ordinary skill in the art were advised to "[e]xpect to see a lot of innovation in this area [relating to VR input devices] over the next few years." Parisi (Ex.1075) at 24. Thus, in view of the express urging of individuals well-versed in the field, persons of ordinary skill in the art would have been motivated to look to the technologies being developed by Samsung, such as the Samsung Gear VR, and Sixense, including but not limited to Sixense's positional tracking of controllers. *See also* Section VII.A (discussing available VR systems, including for headsets and input devices). Furthermore, persons of ordinary skill in the art would have known that companies specializing in different aspects of a VR system (e.g., headsets versus input devices) likely would have collaborated since such technologies complemented one another and could (or at a minimum could obviously) be paired in future research and development. Parisi (Ex.1075) at 24 ("At this point in time, there is no one way to interact in VR using these new input devices. Much depends on the type of

application being created, and the system to which the devices are connected … In the meantime, all this research is a big part of the fun. Expect to see a lot of innovation in this area over the next few years.").

215. Fourth, Pedrotti and Jang reference commercially available and compatible VR hardware and VR applications, respectively. Persons of ordinary skill in the art would have been motivated to look to pair VR hardware with VR applications, especially where the application has been specifically created for use on that particular device. *See, e.g.*, Parisi (Ex.1075) at 14 (referring, as an example, to a "3D third-person platform experience that was created exclusively for Oculus" by a game studio), 86 (referring to "an Oculus-enabled version" of a game).

216. In discussing HMDs, Pedrotti references "the Oculus Rift" HMD. Pedrotti (Ex.1005) at 1:28-29 ("One type of HMD presently available is the Oculus Rift from Oculus VR, now owned by Facebook."). In discussing games for which its techniques are useful, Jang references "'Second Life,' developed by Linden Lab," Jang (Ex.1006) at 1:65-67, which persons of ordinary skill in the art would have known could be "compelling" on an Oculus Rift.). As of 2014, it was known that Second Life, which is an "immersive 3D environment that represents users as avatars," was compatible with Oculus devices such as the Oculus Rift. Second Life Community, *Using the Oculus Rift with Second Life* (May 21, 2014) ("Second Life Community") (Ex.1089); YouTube, *How to Use Oculus Rift with Second Life*

(posted May 22, 2014), *available at* https://www.youtube.com/watch?v=TLL5JVwG118, at 0:06-11 ("With the Oculus Rift, Second Life is more compelling than ever."), 1:56-2:03 ("You'll soon experience Second Life in a whole new, yet natural, way."); Erickson (Ex.1057) at 504 (further describing an entire IBM conference held virtually using a "version of Second Life [that] supported spatialized audio"). Also, as of August 2015, Linden Labs, the creator of Second Life, was calling for help testing its new virtual-reality world with "3D audio" that was to include "multi-user, interactive virtual experiences" and "optimized for VR headsets like Oculus Rift." VentureBeat, *Second Life Creator: Linden Lab Starts Testing Its Virtual-Reality World: Project Sansar* (Aug. 18, 2015) (Ex.1099) at 1-2.

2. Reasons Persons Of Ordinary Skill in the Art Would Combine Pedrotti, Jang, and Begault

217. Persons of ordinary skill in the art would have understood and been motivated to further incorporate Begault's sound processing and management techniques, such as Begault's HRTF processing and hardware, e.g., Begault's digital signal processors ("DSPs"), into the combination of Pedrotti and Jang (discussed above in Section X.A.1).

218. First, Begault is analogous art to Pedrotti and Jang because it addresses the importance of "immersiveness" in "virtual reality and multimedia systems,"

which includes "both the interactivity and the quality of the rendering." Begault (Ex.1007) at 10. Furthermore, Begault explains: "3-D sound can contribute to the sense of immersivity in a 3-D environment. One might be able to work more effectively within a VR environment if actions were accompanied by appropriate sounds that seemingly emit from their proper locations." Begault (Ex.1007) at 13; *see also* Business Insider, *Three-Dimensional Audio Makes Virtual Reality So Much Better It's Crazy* (Apr. 3, 2015) (Ex.1137); The Verge, *Surrounded by Sound: How 3D Audio Hacks Your Brain* (Feb. 12, 2015) (Ex.1138).

219. Second, Begault is complementary to Pedrotti and Jang in that it emphases building a "rich auditory environment" in order to enhance the experience of a virtual environment. Begault expressly states that a "solution for improving the immersivity and perceived quality of a visual display and the virtual simulation in general is to focus on other perceptual senses—in particular, sound." Begault (Ex.1007) at 10. Begault additionally quotes a virtual reality developer who indicated that "in the video game business," it is important to focus on the quality of sound because better audio quality influences people to perceive that visual quality is better as well: "really high-quality audio will actually make people tell you that games have better pictures … but really good pictures will not make audio sound better; in fact, they make audio sound worse. So in the (virtual) world we're building, one of the features is a rich auditory environment." Begault (Ex.1007) at 10-11.

Persons of ordinary skill in the art thus would have known that use of HRTFs and implementation of binaural audio, as described in Begault (*e.g.*, Begault (Ex.1007) at chs. 2 and 4), "represents a clear signpost for increased realism (and thus immersiveness)." Dionisio (Ex.1054) at 34:12-34:13; *see also* Begault (Ex.1007) at 99 (describing in detail HRTFs and noting the "inclusion of the binaural HRTF is fundamental for a 3-D sound system"); Polygon, *Google Cardboard Adds 'Inexpensive' Spatial Audio to Its SDK* (Jan. 13, 2016) (Ex.1139).

220. Additionally, several of the teachings from Pedrotti and Jang are consistent with those of Begault, with Begault providing further technical details that persons of ordinary skill in the art would have known to use with Jang's sound processing techniques. For example, Jang discloses two dedicated sound processors (one for focused sound and another for non-focused sound) in its sound processing unit. *See, e.g.*, Jang (Ex.1006) at 3:8-15, Fig. 3. Begault, in turn, discloses the history and technical detail behind "digital signal processing (DSP) chips" that offer advantages over regular processors. *See, e.g.*, Begault (Ex.1007) at 20 (discussing that advantages of DSP "include relatively smaller hardware size, greater predictability of noise, and ease of reconfiguration—one can write different software specifications to the signal processor" and DSP chips "can be configured as filters that modify sound in the same way as in natural spatial hearing"), 100-109 ("3-D sound processing is almost always best accomplished digitally, using audio DSP

chips to manipulate signal sources" because they "are designed to perform a limited set of digital DSP instructions ***very quickly***—i.e., in real time") (emphasis in original). In this way, persons of ordinary skill in the art would have been motivated to take the teachings of Jang's sound processing techniques (e.g., using dedicated sound processors) and apply them using the detailed disclosures of Begault (e.g., based on detail regarding DSPs).

221. Relatedly, persons of ordinary skill in the art combining Pedrotti's systems and methods with Jang's sound processing methods, including with the techniques and processors (e.g., DSPs) that Begault discloses, would have had a reasonable expectation of success. These references disclose and utilize hardware that was well-known and frequently used long before February 2016, such as HMDs and handheld controllers and systems that include tracking of HMDs and handheld controllers. *See* Sections VII.B-VII.D (discussing processing ability in the HMDs, and also the ability to track such HMDs and handheld controllers, which have at least 6DoF). Additionally, persons of ordinary skill in the art would have known that by February 2016, there were several patent applications and issued patents in the industry that described HMDs with all-in-one tracking. *See* Section VII.D (discussing multiple examples).

222. Moreover, hardware appropriate for carrying out Jang's sound processing techniques, e.g., processing sound with HRTFs, was also commonly

known for years in AR and VR applications. As discussed above, the use of DSPs to handle specifically 3-D sound processing was proven and commonly used. Begault (Ex.1007) at 100 ("3-D sound processing is almost always best accomplished digitally, using audio DSP chips"), 109 ("One can obtain the HRTF of an individual or of a dummy head by playing an analytic signal at a desired position at least a meter distant, and measuring the impulse response with probe microphones placed in the vicinity of the ear canals. This measurement then can be formatted for use directly within spatial filtering DSPs."), 111-12 (section discussing "Using Digital Filters" and explaining "[s]etting up a DSP to filter a sound with an HRTF").

223. It was also well known to use HRTF cues to generate binaural sound, e.g., using DSPs:

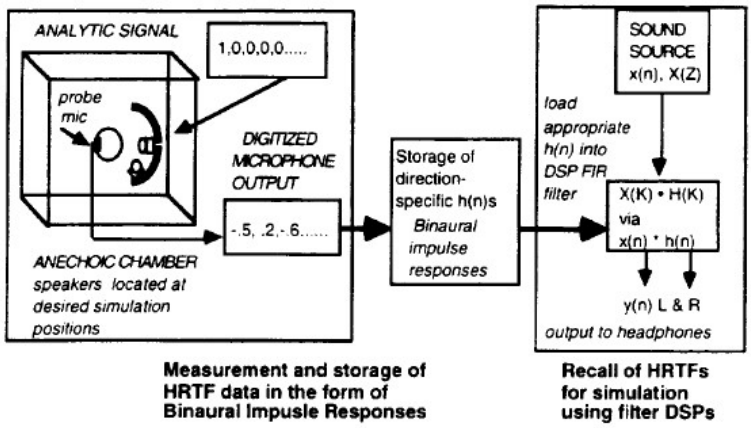


Figure 4.17. Overall plan of the HRTF measurement-storage-simulation technique. HRTFs are obtained using acoustic signals from loudspeakers that are recorded with probe microphones in the vicinity of the ear canals. The data are stored for input to DSP filters during the simulation stage. Usually, both ears are measured simultaneously. Not shown are the translation and possible compression of the measurements for use in the DSP. Note that each stage of measurement and simulation possibly can contribute significant influences to the overall character of the output signal, to the degree that each element is nonlinear (deviates from a flat frequency and phase response). In practice, some of these nonlinearities are difficult to control, although it is not certain how important they are psychoacoustically within a particular application.

Begault (Ex.1007) at 109 ("The binaural impulse response of the outer ear then is obtained from the pressure responses of the microphones and digitally recorded in stereo as a series of sampled waveform points … The sound source to be spatialized is filtered by these DSPs during simulation."), 4.17; *see also* Jerald, THE VR BOOK (Ex.1063) at 240 ("For more realistic audio and where auditory cues are especially important, ***auralization***—the rendering of sound to simulate reflections and binaural differences between the ears—can be used … Multiple HRTFs from different directions can be interpolated to create an HRTF from any direction relative to the ear.") (emphasis in original); Hollier, *Spatial Audio Technology for Telepresence* (1997) (Ex.1062) at 35 (describing a solution for "head-tracked binaural" sound

comprising "a pair of headphones with a rotational position sensor mounted on top and DSP-based hardware which encodes each of the two audio signals with the appropriate HRTF filters."), Fig. 2.

* * *

224. For the reasons I explained above, persons of ordinary skill in the art would have been motivated to combine the teachings of Pedrotti and Jang, and additionally Begault, including as described more below. And persons of ordinary skill in the art would have had a reasonable expectation of success in making these combinations since combining the teachings from Pedrotti, Jang, and Begault require only combining well-known elements through well-known methods. For example, the input for signaling a space shift as taught in Jang would have been easily managed with Pedrotti's system, which includes common elements of a VR system—an HMD and a handheld controller. As another example, it would incorporating Jang's sound processing techniques into Pedrotti's system would have been successfully accomplished using DSPs, since the use of DSPs for processing HRTFs to binaural sound was well known in the art, as explained in Begault.

3. Independent Claim 1

225. Claim 1 would have been obvious over Pedrotti and Jang, including in view of Begault, for the reasons discussed below.

a. 1[pre]: "A method comprising:"

226. Pedrotti teaches the preamble of claim 1. At a minimum, Pedrotti renders the preamble obvious.

227. Pedrotti teaches a method executed by one or more electronic devices—its "method of assisting a use in a selected area," which is executed by, among other things, an "HMD" and "handheld controller[s]." Pedrotti (Ex.1005) at 2:27-59 ("One embodiment discloses a method of assisting a user wearing a head-mounted display (HMD) in remaining within a selected area of the physical world, the user holding a handheld controller having a controller tracker which provides information regarding a position of the handheld controller …"). Both HMDs and handheld controllers are commonly known to be electronic devices in an AR and VR system. *See* Sections VII.B-VII.C (describing these common components of AR and VR systems).

228. I further note that Jang also teaches a method executed by one or more electronic devices. Jang discloses a method "to perform sound processing" that is carried out by a virtual reality apparatus comprising several electronic devices. *See* Jang (Ex.1006) at 2:15-20, 5:40-42 (describing Figure 4), 6:24-8:16 (describing Figures 1A-1B), 8:54-58 (describing Figure 3), Figs. 1A-1B, 3-4.

b. 1[a]: "dividing, with a portable electronic device (PED) held in a hand of a user, an area around the user into a zone that includes multiples sound localization points (SLPs) from where binaural sound originates to the user;"

229. Pedrotti teaches, or at a minimum renders obvious, limitation 1[a].

230. Pedrotti discloses using a handheld portable electronic device (PED) to divide an area into a zone.

231. Pedrotti's system employs an HMD and "handheld controllers," i.e. handheld portable electronic devices (PED). Pedrotti (Ex.1005) at 2:44-47 ("a handheld controller comprising: a controller tracker on the handheld controller which provides information regarding a position of the handheld controller"), 1:40-45 ("a user may wish to use a handheld controller, such as might be used to play a video game, while in a virtual world, and perhaps even two controllers, one for each hand"), Figs. 2-5, 7 (depicting Pedrotti's controllers).

232. The movement of Pedrotti's PED is tracked. Users of Pedrotti's system "wear a head-mounted display (HMD)" and "hold a handheld controller" (PED) comprising a "controller tracker," which "provides information regarding a position of the handheld controller." Pedrotti (Ex.1005) at 2:44-57, 15:7-12 ("it is assumed that a user wears a HMD having a display, a processor provides instructions that direct what appears on the display, and the user is holding a a handheld controller having a tracker which can be used to track the position and orientation of the handheld controller."), 4:49-5:24 ("trackers" "known to those of skill in the art"). A "tracker on the handheld controller [] provides information regarding [the] position of the handheld controller," for example, when a "user walk[s] around a perimeter

chosen by the user," and a processor receives and uses that information to "define a boundary surrounding a selected area." Pedrotti (Ex.1005) at 4:37-44, 12:31-41 ("the processor knows where the user's head and hands are located"), 14:56-15:3 ("processor determines the position of the tracker at a number of sampling points as the user moves around the chosen perimeter, and from those points determines the boundary"), Figs. 14-15.

233. Thus, Pedrotti teaches that movement of the PED is tracked to define a size and shape of a zone extending around a user, i.e., an area around the user is divided into a zone. This "safe area" (a zone) "can be defined, for example, by having the user walk around a perimeter chosen by the user with one of the trackers to define the outer boundary of a selected area":

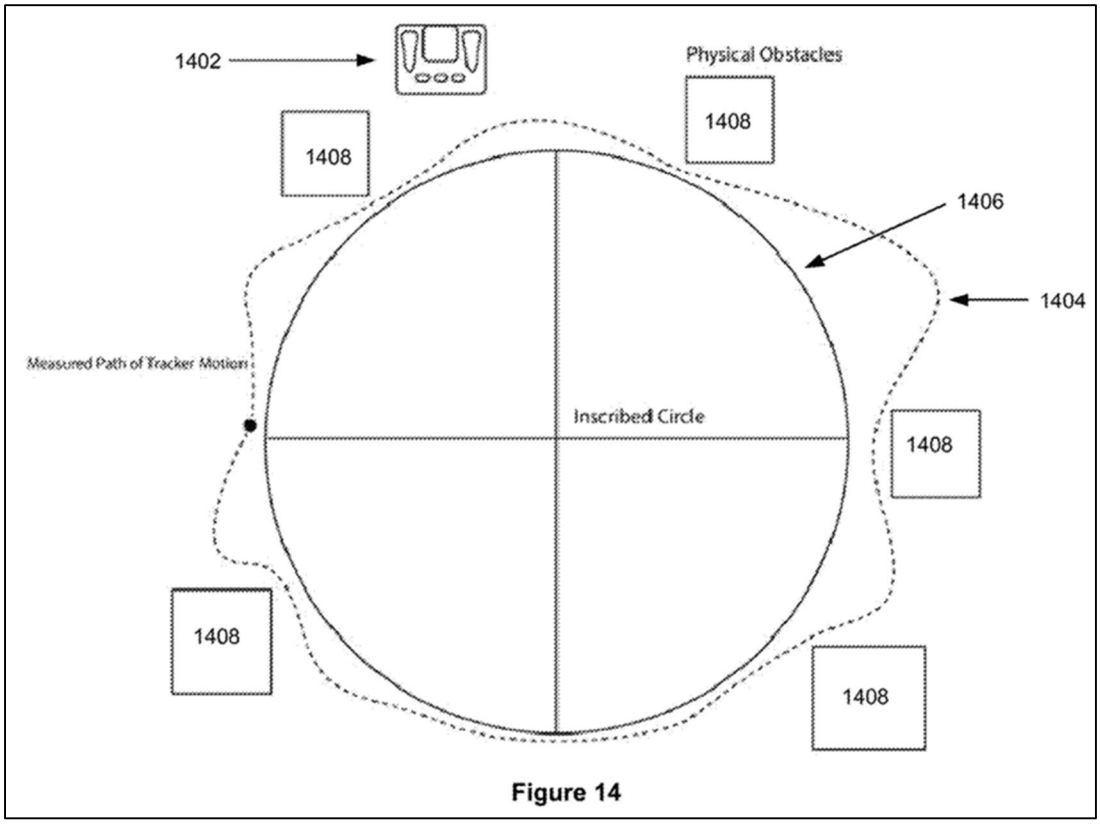


Figure 14

Pedrotti (Ex.1005) at 14:56-65, 15:13-22, Figs. 14-15 (boundary 1404 reflecting the user-defined, irregularly shaped boundary defining a 3D zone); *see also* Pedrotti (Ex.1005) at 2:44-51, 4:32-36 ("a boundary of a selected area is determined, for example, an "safe area" which the user or another person has determined is clear of physical obstacles in the physical world so that the user may move freely without coming into contact with such physical obstacles."), 12:31-41 ("the processor knows where the user's head and hands are located"), 15:7-12 ("the user is holding a handheld controller having a tracker which can be used to track the position and orientation of the handheld controller").

234. After Pedrotti's boundary is defined by, for example, the "measured path of tracker motion" (Pedrotti (Ex.1005) at Fig. 14), and a user is in "the virtual world" (e.g., by "playing a game"), the processor instructs the HMD to display "a visual warning" to the user. Pedrotti (Ex.1005) at 11:43-55. This can be "in the form of grid lines such as a virtual fence" when "the processor determines from the position of the handheld controller that the handheld controller is within a preselected distance of the boundary." Pedrotti (Ex.1005) at 15:30-37 ("the processor generates and outputs instructions to the HMD to display … a visual warning to the user" which "can be in the form of grid lines such as a virtual fence."), Figs. 11, 14-15.

235. Thus, Pedrotti's handheld controller (PED) divides an area around a user into a zone—Pedrotti's "selected" or "safe" area in VR that is bound by Pedrotti's boundary and its virtual fence.

236. Persons of ordinary skill in the art also would have understood that this perimeter or boundary divides an area around the user into a zone because it defines the user's "safe area" play space. This was a common principle applied to safety and chaperone systems. *See* Section VII.G (providing visual examples of boundaries existing in 3D space, and thereby defining a 3D zone).

237. Additionally, I have reviewed the infringement contentions 8K served on Petitioners in district court as well as the First Amended Complaint. *See* '509 8K

Infringement Contentions (Ex.1129). I note that Pedrotti's controller-divided zone is nearly identical to features that 8K contends in the parallel district court action satisfy limitation 1[a]:





'509 8K Infringement Contentions (Ex.1129) at 4; *compare* First Am. Compl. (Ex.1112) at ¶ 92 ("Accused Products have… 'safe area' functionality"), *with* Pedrotti at 4:32-36 ("boundary of a selected area" defines "a 'safe area'").

238. Further, I note that 8K contends in district court that limitation 1[a] is satisfied by the mere existence of a zone for game play that "***will include*** sound localization points for presentation of binaural sound to the user." '509 8K Infringement Contentions (Ex.1129) at 5. Thus, in 8K's view, an area defined for gameplay that will ***subsequently*** include binaural sound satisfies this limitation. Under such an interpretation, Pedrotti, alone or in view of Jang rendered obvious limitation 1[a]: the zone that Pedrotti's controller divides will., or at a minimum will obviously, include SLPs from which binaural sound will originate, when, for example, a user starts playing a VR game.

239. Pedrotti discloses that its teachings can be applied to VR games. Pedrotti (Ex.1005) at 1:42-45 ("play a video game, while in a virtual world"), 1:66-2:12 (describing a "conventional video game"), 9:26-40 (describing picking up a "virtual weapon" in a virtual game), 11:43-12:15 (describing a user in a "virtual world"), Fig. 8 (virtual sword 802). Persons of ordinary skill in the art would have known that virtual objects in games (e.g., Pedrotti's sword or another "virtual weapon," as well as VR characters) could and would have associated binaural sounds that would move with them to multiple locations (multiple SLPs). Creating and moving sounds with their associated virtual images were "extremely important" and fundamental features of VR that were known well before February 2016. *See* Sections VII.E-VII.F; Pedrotti (Ex.1005) at 1:19-20 ("the senses most commonly used today to create virtual reality appear to be sight and sound"); Ross (Ex.1125) at 17:22-18:35 (describing VR interactions, e.g., users "moving objects and/or characters"); *see also* Section X.A.3.d (further discussing examples in context of limitation 1[c]).

240. Indeed, Jang confirms as obvious the use of "multiple[] sound localization points (SLPs) from where binaural sound originates to the user" during, for example, VR game play while in a zone around a user (like Pedrotti's). Jang disclosed a sound processing system that "check[s] sound source information" on "characters and other objects" and provides localized audio (i.e., binaural sound) for

"sound sources" "according to the[ir] relative locations" (SLPs), including in "sound areas" around a user. Jang (Ex.1006) at 7:24-59; *see also* Jang (Ex.1006) at 1:28-2:11 (VR "systems may be used to provide a high degree of realism," e.g., "in a virtual reality game"), 5:35-37 (describing a "method of dividing sound areas of a virtual reality space"), 8:18-49 (same), 8:59-9:1 (describing a "control unit" which "identifies" focused sound "occurring in the focus area according to the division of the virtual reality space."), Fig. 2 (illustrating "method of dividing sound areas of a virtual reality space").

241. And as I explained above in the State of the Art section, since well before February 2016, it was understood that sound localization is an important aspect of creating an immersive AR or VR experience. NSA, *Virtual Reality* (Ex.1073) at 35-36 ("Spatially localized sound has a dramatic effect on the sense of immersion in virtual environment … Sound is considered a very important aspect of VR since users often get 'lost' while moving in the virtual world."); Jerald, THE VR BOOK (Ex.1063) at 239 ("Auditory cues play a crucial role in everyday life as well as VR, including adding awareness of surroundings, adding emotional impact, cuing visual attention, conveying a variety of complex information without taxing the visual system, and providing unique cues that cannot be perceived through other sensory systems."); Section VII.E.

242. Additionally and alternatively, if limitation 1[a] requires a zone that "includes" multiple SLPs for binaural sound when divided by a PED, limitation 1[a] would have been obvious over Pedrotti and Jang, or over Pedrotti, Jang, and Begault.

243. Jang disclosed processing and producing sound in "focus" and "un-focus" "sound areas." Jang (Ex.1006) at 2:32-47, 2:60-3:4. These sound areas contain "a plurality of sensory sources," including "audio sources." And may be sub-divided according to a "predetermined priority" or "scheme" Jang (Ex.1006) at 4:19-39 (explaining that the focus area "may correspond to an area in the virtual environment in the immediate foreground of a visual perspective" of the user), 6:51-59 (explaining that non-focus areas may have sound "be muffled or quitter than audio elements of a focus areas"), 8:46-59 (explaining that the "focus area and the non-focus areas may be divided into multiple areas in the virtual reality space according to a predetermined priority"), 9:47-10:5 (explaining how sound is controlled, including such that "when there is occurrence of sound in both the focus area and the non-focus area, the control unit 114 may determine priorities of sound sources for at least of the focus area and the non-focus area.").

244. This sub-division of sound areas allows Jang's system to "output sensory elements of the focus area differently than sensory elements of the non-focus areas" and better manage VR space shifts. Jang (Ex.1006) at 3:24-26. "For example, if a user's character moves from a basketball court to a conference room, visual,

audio, or tactile elements of the basketball court may decrease in magnitude, and visual audio, or tactile elements of the conference room may begin to be transferred to a virtual reality device," with sensory data for focus areas processed first. Jang (Ex.1006) at 11:64-12:16. Further, Jang disclosed using "a localization technique capable of expressing the virtual location" of "a sound-generating object" and HRTFs "to give the sense of reality to the sound." Jang (Ex.1006) at 1:42-56, 7:38-63 (describing a "virtual reality apparatus" that "may use a Head Related Transfer Function (HRTF) as an algorithm for identifying the sound-generating location.").

245. In view of Jang's disclosures regarding sound areas and predetermined priorities and schemes, persons of ordinary skill in the art would have been motivated to set those predetermined priorities and schemes for "sound areas" and "audio sources" by assigning locations from where different audio sources will produce sound. Using the '509 patent's terminology, those are "sound localization points" or "SLPs." For example, in the context of Jang's virtual basketball court, a virtual visiting team's bench could and would be designated into a focus area, and the nearby stands for the virtual visiting team could and would also be designated into that focus area. Between these two, the virtual visiting team's bench could and would be given priority over the stands. Similarly, the user could and would assign priorities to characters and other sound-generating objects such as an announcer, cheerleaders, a pep band, or an air horn, which also could and would be assigned

locations in the focus area. As another example, in the context of Jang's virtual conference room, one side of the conference room could and would be set as a "focus area," with priority characters and other sound-generating objects such as key attendees or a monitor. Additionally, among the key attendees, there could and would be a highest priority given to the boss, and lower priorities given to other attendees based on seniority. Persons of ordinary skill in the art also would have known and been motivated to assign specific locations for these characters and sound-generating objects (i.e., designate their SLPs). For years before Jang, it was understood that with simple user interfaces, sound sources such as conference attendees could and would be organized, clustered, and moved, e.g., into "special region[s]" or a "private conference." *See, e.g.*, Cohen 1992 (Ex.1052) at 477 (describing "[a] simple teleconferencing configuration [that] typically consists of several icons, representing the distributed users, moving around a shared conference space," and where "[e]ach of these icons represents a source, the voice of the associated user, as well as a sink, the user's ears."). To persons of ordinary skill in the art, these assignments or designation of SLPs would have facilitated obvious, advantageous organization for a user's soundscape, consistent with the disclosures of multiple publications describing interfaces for, and allowing users to make, such designations. *See* Section VII.F. Also, persons of ordinary skill in the art would

have understood based on Jang's disclosures that the same type of audio control could and would be applied to a non-focus area.

246. Indeed, this type of division of sensory elements in different zones in a VR environment and authoring of VR environments was well-known. *See, e.g.*, Jerald, THE VR BOOK (Ex.1063) at 254-55 (discussing "Center of Action" setups that "split[] the world around the user into different zones," for example, "primary and secondary viewing directions");[6] Ross (Ex.1125) at 14:53-15:28, 15:29-55, 20:22-

[6] THE VR BOOK shows an example of this type of setup:

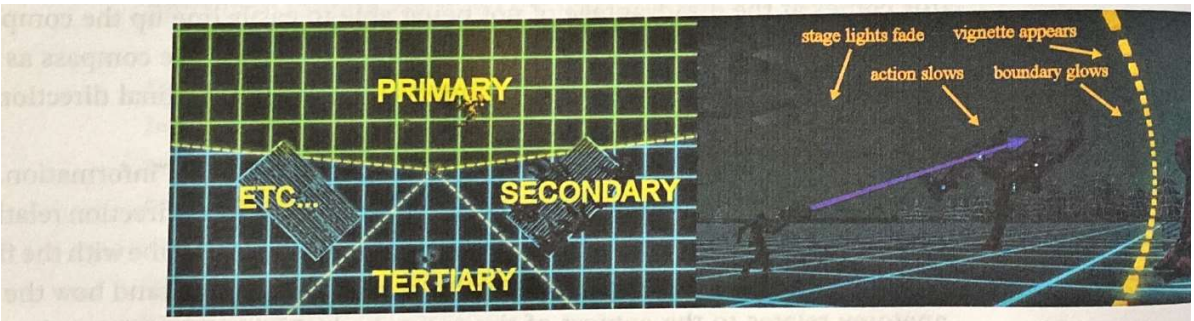


Figure 22.3 Visionary VR splits the scene into different action zones.

Jerald, THE VR BOOK (Ex.1063) at Fig. 22.3, 254 ("As a user starts looking toward another zone, cues are provided to inform the user that she is starting to look at a different part of the scene and the action and/or content is about to change …. For example, glowing boundaries between zones can be drawn, the lights might dim …, time might slow down," and "actions within th[e] [second] zone can react").

21:51 (VR content is displayed based on "determined view direction," which "may refer to… a position of the user within the virtual space," "e.g., a user may move… across a boundary"), 22:17-29 ("user may virtually reach out and grab and/or move… objects"), 22:55-56.

247. Moreover, Begault disclosed methods of setting priorities for binaural sound that persons of ordinary skill in the art would recognize as useful for authoring and managing Jang's sound areas, further demonstrating that limitation 1[a]'s zone that includes multiple SLPs would have been routine, straightforward, and obvious to persons of ordinary skill in the art before February 2016.

248. Begault taught that "[a]ll types of sonic input c[an] be directionalized to a specific location" and "controlled by a user" through "audio spatial mapping" that—as in Jang—"correspond[s] to a prioritization scheme." Begault (Ex.1007) at 174. For example, "calls from subordinates could be signaled by a phone ringing from the rear; a call from home could always ring from front right; and the intercom from the boss could be from front and center." Begault (Ex.1007) at 174.

249. Begault also disclosed a "GUI for arranging [] various sound inputs in virtual auditory space in a manner configurable by each individual listener":

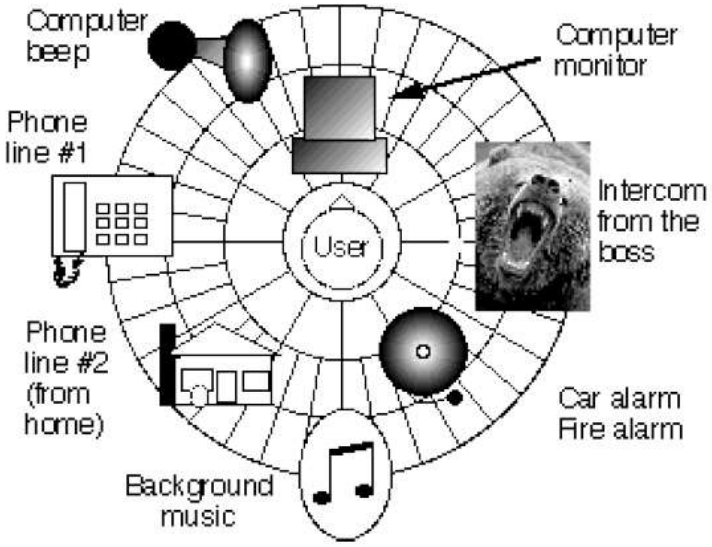


Figure 5.12. Layout for a hypothetical GUI for arranging a set of incoming sounds. By resizing the icons, volume could be adjusted independently of perceived distance. *Graphic assistance by Denise Begault.*

Begault (Ex.1007) at 174-75, Fig. 5.12. "The basic concept is to represent each form of auditory input iconically on the screen and then allow manipulation of the distance and relative azimuth of each source." Begault (Ex.1007) at 174. Then, "the relative location of the icons" are interpreted "as commands to a multiinput, 3-D sound spatialization subsystem." Begault (Ex.1007) at 174.

250. Thus, person of ordinary skill in the art would have known and recognized in view of Pedrotti, Jang, as well as Begault, that Jang and Begault's binaural sound sources at multiple locations (i.e., multiple SLPs) in a virtual environment as described above, could and would benefit from a Pedrotti "safe area" zone" because this zone could and would prevent user injury and prevent a user from accidently bumping into physical objects in the physical world. For example, if

moving between Jang's virtual basketball court and Jang's virtual conference room, a "safe area" could prevent the user from tripping over a sofa or crashing into a wall in the real, physical space of the user. Further, a Pedrotti "safe area" zone created or otherwise set in a virtual environment with 3D sound sources that are assigned to different locations as Jang and Begault teach, would, or at a minimum would obviously, include multiple SLPs for binaural sound so that the user is fully immersed in the virtual environment. *See* Ross (Ex.1125) at 6:5-27, 22:23-23:21 (users "may sense" boundaries "they can hear/see/feel" and configure boundaries, e.g., with a "[c]ontent creation preview" that allows users to "continue to make changes" to boundaries).

c. 1[b]: "determining, with a wearable electronic device (WED) worn on a head of the user, when the user is located inside the zone;"

251. Pedrotti teaches, or at a minimum renders obvious, limitation 1[b].

252. Someone using Pedrotti's system wears a HMD, i.e., a WED worn on their head, and holds handheld controllers. Pedrotti (Ex.1005) at 2:44-47. A processor in Pedrotti's system "tracks the position and orientation of [a] HMD tracker" and "the position and orientation of one or more trackers in the physical controllers." Pedrotti (Ex.1005) at 2:49-57. Pedrotti further taught that this processor may be "in the HMD." Pedrotti (Ex.1005) at 16:20-24. Thus, the WED "knows where the user's head," and thus the user him or herself, "and hands are

located." Pedrotti (Ex.1005) at 2:49-57, 4:32-44 (describing "a boundary of a selected areas"), 12:31-41 (explaining that "the processor is tracking the position and orientation of the user's head from the tracker of the HMD" and "tracking the position and orientation of the user's hand if the user is holding a controller with a tracker"), 15:7-12 (describing method that may "result in the display of a visual warning such as the virtual fence" where "the user is holding a handheld controller having a tracker which can be used to track the position and orientation of the handheld controller."). And because Pedrotti teaches that the processor tracking movement of the handheld controller may be "in the HMD," Pedrotti teaches an HMD tracking the user's location, as the user holds the handheld controller. Pedrotti (Ex.1005) at 16:22-24.[7]

253. Pedrotti discloses that the processor "determine[s] from the position of [a] handheld controller that the handheld controller is within a first preselected

[7] In addition to the disclosures and teachings of Pedrotti, in a related patent, U.S. Patent No. 10,162,177 ("Pedrotti 177") (Ex.1032) to Pedrotti, the processor is also described as being in the HMD. *See, e.g.*, Pedrotti 177 (Ex.1032) at 10:63-65 ("a processor may be located in the HMD"). Also, persons of ordinary skill in the art would have known it was common for tracking capabilities to be wholly contained in an HMD. *See* Section VII.D (describing all-in-one and inside-out tracking).

distance from [a] boundary." Pedrotti (Ex.1005) at 2:44-59, . The processor then "generate[s] and output instructions to the HMD to include in a display of a virtual world a visual warning such as a grid or virtual fence when the user comes within a preselected distance of the boundary, thus providing a warning that the user is about to move out of the selected area." Pedrotti (Ex.1005) at 2:44-59.

254. Pedrotti also discloses that the warning is provided "when the user comes within a preselected distance of the boundary, thus providing a warning that the user is about to move out of the selected area," regardless of whether the user's location is determined based on the location of the HMD or the location of the handheld controller. Pedrotti (Ex.1005) at 4:37-44 (indicating that this is done when "[t]he processor [] tracks the position and orientation of the HMD tracker, and possibly the position and orientation of one or more trackers in the physical controllers"), 12:35-13:2 ("[T]he processor knows where the user's head and hands are located; if the processor has been provided with information about the boundary of the selected area then the processor can also determine when the user's head and/or hands approaches the boundary.").

255. Pedrotti's Figure 15, which is a flowchart of this method, teaches that this method "result[s] in the display of a visual warning such as the virtual fence." Pedrotti (Ex.1005) at 15:4-39, Fig. 15.

256. Pedrotti further discloses that "the preselected distance" triggering its warning "may vary by application, so that, for example, it is greater in an application in which larger body movements are expected from the user than in an application in which such body movements are not expected." Pedrotti (Ex.1005) at 13:46-62.

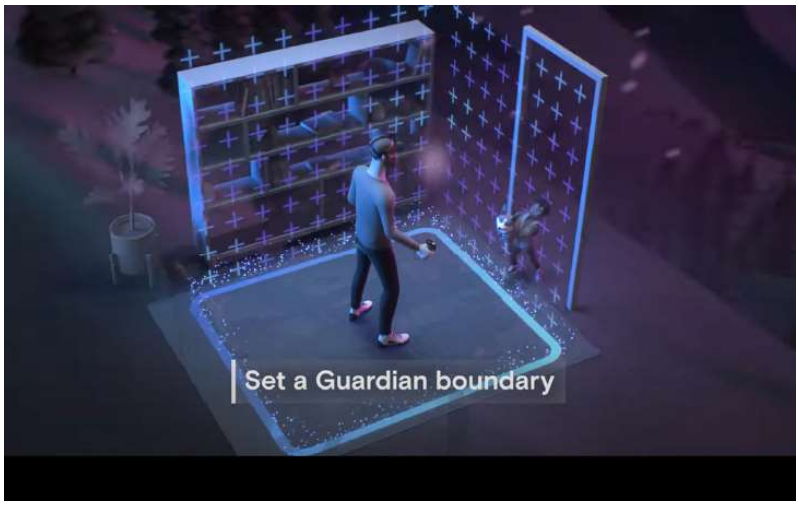
257. Pedrotti also teaches that "if the user's head goes beyond the boundary, the processor can cause the HMD to fade to black, and present, for example, only a warning message and/or a beacon or arrows directing the user to move in the direction of the boundary and the selected area," meaning that Pedrotti's system is able to identify conflicts with its boundaries. Pedrotti (Ex.1005) at 13:67-14:5.

258. Persons of ordinary skill in the art would have known and understood that this processor in the HMD, i.e., the processor in Pedrotti's WED worn a user's head, determines when a user is located inside a zone, as claimed, because Pedrotti's system is designed to determine where a user is inside a "safe area" for gameplay and to help the user stay in that area. Pedrotti (Ex.1005) at 4:32-44 (disclosing that the processor tracks the HMD and controllers and "generates instructions to the HMD to include in a display of a virtual world a visual warning such as a grid or virtual fence when the user comes within a preselected distance of the boundary, thus providing a warning that the user is about to move out of the selected area.").

259. It was also well-known that VR systems could and should determine user locations, so that, for example, when a user approaches "the edge of tracking"

or "a safe zone," "a warning grid" can "fade in to provide a cue to the user that he should back off." Jerald, THE VR BOOK (Ex.1063) at 213-14, Fig. 8.13 (showing warning grid); *see also* Section VII.G (discussing safety and chaperone systems).

260. In addition, I note that in district court, 8K contends that a limitation reciting the same elements as limitation 1[b] is satisfied by setting a virtual boundary. '509 8K Infringement Contentions (Ex.1129) at 6. The Guardian boundary shows a user in a zone of a play area and a virtual fence that marks the boundary of the zone:



'509 8K Infringement Contentions (Ex.1129) at 6. Under that interpretation, limitation 1[b] would have been obvious for the same reasons as limitation 1[a]. *See* Section X.A.3.b.

261. For these reasons, Pedrotti discloses (or at a minimum renders obvious) limitation 1[b].

d. 1[c]: "highlighting, while the user is located in the zone and with a display of the WED, one of the multiple SLPs in the zone when the PED held in the hand of the user is pointed at the one of the multiple SLPs in the zone; and"

262. Pedrotti and Jang, or Pedrotti, Jang, and Begault, render obvious limitation 1[c].

263. During use, a user of Pedrotti's system is located in a zone. *See* Section X.A.3.b (limitation 1[a]). This zone is Pedrotti's "safe area" for gameplay that includes a boundary shown by a virtual fence. *See* Section X.A.3.b.

264. And while the user is in the zone, Pedrotti's HMD displays virtual images to the user. *See* Section X.A.3.b (limitation 1[a]) (describing Pedrotti's system comprising "a head-mounted display (HMD)"); Section IX.A (Pedrotti overview); Pedrotti (Ex.1005) at Abstract (Pedrotti's wearable "head mounted display" "display[s] a virtual world"), Fig. 8 (showing image of a virtual sword 802).

265. In addition, limitation 1[c]'s requirement that an SLP is highlighted "when the PED held in the hand of the user is pointed at the one of the multiple SLPs in the zone" would have been obvious to persons of ordinary skill in the art over Pedrotti. Pedrotti discloses "one or more physical controllers that a user may use to control certain actions or events in the virtual world." Pedrotti (Ex.1005) at 4:9-10, 5:25-46 ("Various devices suitable for use as controller 110" may be "pick[ed] up with [the user's] hand" to "perform various functions in the virtual world"), 8:14-35

("once both controllers have been picked up," "instructions from the processor no longer cause the HMD to show [the controllers] so that the processor can "cause the HMD to display the user's virtual hands doing something in the virtual world, such as grasping a virtual object"). Pedrotti discloses using Pedrotti's controller to define a boundary of "an area in the physical world to be defined within which the user should remain, for example to avoid physical obstacles." Pedrotti (Ex.1005) at Abstract, 2:27-33 ("One embodiment discloses a method of assisting a user wearing a head-mounted display (HMD) in remaining within a selected area of the physical world, the user holding a handheld controller having a controller tracker which provides information regarding a position of the handheld controller, the method comprising: receiving, by a processor as an input, a definition of a boundary of the selected area;"), 2:44-51, 2:60-3:2. Persons of ordinary skill in the art would have understood that holding a handheld controller and using it to define a boundary of "an area in the physical world" would (or would obviously) include pointing the controller to trace out the intended boundary.

266. Persons of ordinary skill in the art would have known and understood that it was common to use a handheld controller, like Pedrotti's, to select, move, and control virtual objects by pointing at them. *See* Section VII.D (discussing tracking handheld controllers); *see, e.g.*, Jerald, THE VR BOOK (Ex.1063) at 314-15 ("Tracked hand-held controllers are typically 6DoF devices (known as 'wands' in the VR

research community where they have been used for decades) and can also contain functionality offered by non-tracked hand-held controllers. Tracked hand-held controllers are currently the best option for a majority of interactive VR applications. ***Tracked hand-held controllers are easy to use for many 3D tasks due to their natural, direct mapping to hand motion***.") (emphasis added); Ross (Ex.1125) at 22:17-29 ("[a] user, content creator, and/or other persons may create, customize, and/or adjust using a controller"); *see also* Jerald, THE VR BOOK (Ex.1063) at 153-54 (describing "pointing to fly" as a means to "mov[e] from one place to another" in VR and "viewpoint control via a joystick"), 251 ("[P]oint on the map where to go and then 'enter into' the map with the map becoming the surrounding world"). Indeed, "the Pointing Pattern is one of the most fundamental and often-used patterns for selection." Jerald, THE VR BOOK (Ex.1063) at 327.

267. Limitation 1[c]'s "highlighting …one of the multiple SLPs in the zone" also would have been obvious over Pedrotti because Pedrotti discloses that a virtual image of the boundary, i.e., its fence, "can be glowing or colored if desired to be more visible." Pedrotti (Ex.1005) at 12:66-13:11 ("The grid can be glowing or colored to be more visible to the user" and explaining that "brightness" or "a uniform translucent glow of a particular color, such as red, may be appropriate to serve as the visual warning").

268. Thus, persons of ordinary skill in the art would have understood that Pedrotti's system could (or at a minimum obviously could) use "glowing" or highlighting, i.e., "visually outlining or changing the color of an object."[8] Jerald, THE VR BOOK (Ex.1063) at 305. As Pedrotti explains, this type of visual change "may be appropriate to serve as the visual warning." Pedrotti (Ex.1005) at 12:66-13:11. And, the use of highlighting was frequently used to facilitate user selection. Jerald, THE VR BOOK (Ex.1063) at 305 ("Highlighting" is used "to convey that an object is able to be selected or grabbed"), 281 ("objects can… become highlighted" when "they have been selected"), 361, Fig. 26.5. Indeed, it was also known before February 2016 that, in association with virtual object selection, feedback could be provided to a user, including through the use of visual feedback. *See* Jerald, THE VR BOOK (Ex.1063) at 356 (disclosing use of various forms of feedback "to signify touching of objects"); *see also* Cohen 1992 (Ex.1052) at 471 (describing "a mouse-based system [that] realizes indicating, highlighting, and relocating as pointing,

[8] The '509 patent describes "visually distinguish[ing]" selected SLPs—i.e., images representing SLPs—in this same, well-known manner. '509 patent (Ex.1001-509) at 28:19-38 (explaining that the SLP "can be distinguished with shading, light, color, indicia, symbols, text, or other visually recognizable forms to signify its selection and to distinguish it from non-selected SLPs.")

clicking, and dragging" icons representing sound sources); McCulloch (Ex.1008) at 22:66-23:20 ("Similarly, a visual effects library may store routines for animations, highlighting, and other types of visual enhancements which may also be associated with particular actions, pre-collision events and collision effects").

269. Persons of ordinary skill in the art also would have known and understood that the above-discussed highlighting could and would happen when Pedrotti's controller is pointed at a virtual object to select or move it., i.e., "when the PED … is pointed at" an SLP as claimed because the processor in Pedrotti's HMD tracks "the position and orientation of one or more trackers in the physical controllers," and it was common for controllers (PEDs) to convey target locations to a processor. Pedrotti (Ex.1005) at 4:37-44 (describing tracking of physical controllers), 5:8-36 (describing various trackers); Section X.A.3.b (limitation 1[a]). As noted, Pedrotti discloses using Pedrotti's controller to define a boundary of "an area in the physical world to be defined within which the user should remain, for example to avoid physical obstacles." Pedrotti (Ex.1005) at 2:27-33 ("One embodiment discloses a method of assisting a user wearing a head-mounted display (HMD) in remaining within a selected area of the physical world, the user holding a handheld controller having a controller tracker which provides information regarding a position of the handheld controller, the method comprising: receiving, by a processor as an input, a definition of a boundary of the selected area;"), 2:44-

51, and 2:60-3:2. Persons of ordinary skill in the art would have understood that holding a handheld controller and using it to define a boundary of "an area in the physical world" would (or would obviously) include pointing the controller to trace out the intended boundary.

270. Moreover, persons of ordinary skill in the art would have known that the objects could and would be highlighted when pointed at as a way of facilitating selection by allowing a user to recognize either that an object can be selected or that a particular object has been selected. As I explained in the State of the Art section, these were well-known techniques. *See* Sections VII.C (discussing well-known selection methods for use with handheld controllers in AR and VR); Jerald, THE VR BOOK (Ex.1063) at 327 ("Pointing Pattern extends a ray into the distance and the first object intersected can then be selected via a user-controlled trigger."), Fig. 26.5 ("bottle is highlighted to show" it "can be grabbed"), 285 ("Shoot a ray from the hand, intersect the boulder, push the grab button, move the hand to a new location, release the grab button."); Mine ISAAC 1997 (Ex.1114) at 548 ("To select an object, the user points the laser beam at a desired object and clicks.").

271. Further, persons of ordinary skill in the art would have known that Pedrotti's HMD, which tracks the controllers, is able to detect when the user is pointing the controller at an SLP, and alter its display accordingly, such as by highlighting the SLP. As explained above, persons of ordinary skill knew that an

SLP could be highlighted in the visual display because "highlighting" is a straightforward manipulation technique realized through standard conventions, such as "pointing" and "clicking." *See, e.g.*, Cohen 1993 (Ex.1053) at 470. And it would have been obvious that these actions take place while the user is in the zone because the interactive content in the virtual environment, e.g., Pedrotti's described virtual games, are experienced while a user is in Pedrotti's zone or "safe area." Further still, if the purpose of pointing to the SLP was to perform some action on the SLP, persons of ordinary skill in the art would have understood it is essential to have some form of dynamic visual confirmation that a user is sufficiently pointing at (intersecting) the SLP at any given moment, lest the user be forced to repeatedly point and click (e.g., Pedrotti (Ex.1005) at 9:38) around an SLP until they are able to successfully carry out the action.

272. Indeed, fully immersive social VR experiences where users appeared as avatars and could move sound-producing objects, e.g., their avatars, were well-known:



Figure 22.6 An example of a fully immersive VR social experience. (Courtesy of VRChat)

Jerald, THE VR BOOK (Ex.1063) at 259, Fig. 22.6 (depicting "VRChat," which is "[a]n example of a fully immersive VR social experience"); Ross (Ex.1125) at 8:59-67 ("For example, a user may communicate with presented characters, and/or may socially interact in other ways with virtual character and/or other users in the virtual space. Socially interacting may include communicating" or "chatting."); Ross (Ex.1125) at 17:22-18:35 ("Interaction may include conversing (e.g., textual chatting, voice communication, etc.) with and/or otherwise socializing with virtual characters such as avatars, other characters, and/or other users."); Pan, *Virtual Character Personality influences Participate Attitudes and Behavior – An Interview with a Virtual Character About Her Social Anxiety* (2015) ("Pan 2015") (Ex.1074) at Introduction ("Participants in an immersive virtual reality (IVR) can interact with proximal life-sized virtual human characters, which can talk with them, look them in the eye, smile, walk around, move into their space – with the possibilities only

limited by the capabilities of the programing and system") (collecting references where studies were conducted in virtual applications involving talking virtual characters); DiPaola, *A 3D Virtual Environment For Social Telepresence* (2002) (Ex.1055) at 1 (describing the Traveler application where "users are immersed in a shared 3D world" with "other participants as fully modeled 3D characters," where "[a]s a user speaks, his or her voice emanates from the corresponding avatar on each of the other clients"), Fig. 1.

273. As THE VR BOOK states, "VR cannot exist without content," and this includes "computer- or user-controlled characters." Jerald, THE VR BOOK (Ex.1063) at 43; *see also* Ross (Ex.1125) at 8:45-59 (describing further examples of "content presented to the user," including "characters, objects, [and] settings"), 14:53-15:28 (explaining that virtual reality content may include "characters, objects," "avatars of other users (e.g., prerecorded and/or live)," "individual characters," among a number of exemplary virtual objects).

274. After all, having sounds for computer- or user-controlled virtual objects move with their objects, including in response to user manipulation of the virtual object, was a fundamental, and extremely important feature to making virtual environments immersive, long before February 2016, as Begault and other references show. *See, e.g.*, Begault (Ex.1007) at 13 ("3-D sound can contribute to the sense of immersivity in a 3-D environment. One might be able to work more

effectively within a VR environment if actions were accompanied by appropriate sounds that seemingly emit from their proper locations, in the same way that texture mapping is used to improve the quality of shaded images."), 95 ("[i]n virtual reality and multimedia applications, most sounds are somehow connected to visual events"); Brungart (Ex.1050) at 9 ("In an environment where listeners are able to grab virtual sound sources and move them around the head, realistic near-field audio cues are extremely important."); Jerald, THE VR BOOK (Ex.1063) at 240 ("Spatialized audio" "provide[s] cues of where other characters are located"), 281 ("objects can make a sound … when a hand collides with them or they have been selected" and "[f]eedback is essential for interaction"); *see also* Pausch (Ex.1076) at 194-97 (describing creating a "high-fidelity virtual reality (VR) attraction" where voices of characters were generated through "a combination of stereo ambient sound, binaural recorded sound, and eight channels of localized sound" and "localized channels provided main characters and sound effects"); Mine 2003 (Ex.1134) at 12 (describing the need for an intuitive experience).

275. Further still, persons of ordinary skill in the art would have understood that a sound source in virtual space (i.e., at an SLP) is one of many types of virtual objects that could and would be controlled and arranged, for example, by pointing at, highlighting, selecting, and moving the sound source with its associated visual element. Multiple references confirm the obviousness of manipulating sound-

producing virtual objects in AR and VR settings, such that an object's sound travels with the object. *See, e.g.*, U.S. Patent No. 9,037,468 ("Osman") (Ex.1031) at 10:3-15 (controller is used to fly a sound-producing virtual helicopter), 10:60-66 ("For example, user 406b has a game cannon, which is fired by the remote player … the firing shot is heard first, and is followed by the sound of the cannonball as the cannonball travels through the air from the location of player 406b to the location of player 406a."); McCulloch (Ex.1008) at 26:12-19 (controller used to crash a sound-producing virtual helicopter into a wall), 29:46-55 (user uses a controller to break a monitor with a virtual basketball); Slater (Ex.1091) at 105 (user-controlled talking avatars sharing a rehearsal space); Erickson (Ex.1057) at 504 (user-controlled talking avatars at a virtual conference); Zhou (Ex.1107) at 1006-07 (describing 3D audio used in an AR and VR game played by two co-players, where images of planes are displayed at the locations of the co-players' handheld controllers (their "wands"): "A constant buzz sound is applied to the co-player's airplane," and "[s]ince the plane is attached to the wand, the 3D positions can be easily obtained from the tracker in the wand," so "the user can always hear where is the location of the co-player, even when the co-player is not visually in the scene"), Figs. 9-11; U.S. Patent Application Publication No. 2015/0119130 ("Lovitt") (Ex.1021) at [0038] ("the interactive digital environment of game 208 includes virtual space sound source 238 (e.g., weapon muzzle brake of a user-controlled weapon) and virtual space sound source

242 (e.g., tank muzzle brake) … each virtual space sound source includes one or more associated sounds such that, during interaction with the virtual environment, one or more of the associated sounds are programmed to be 'output' from a particular virtual space sound source"), [0043] ("this adjusted location would take more movement of the user's on-screen avatar to see and/or engage with the approaching avatar"); Ross (Ex.1125) at 4:30-34 (describing sensory cues, including "visual" and "auditory"), 10:47-62 (describing computing device processing "visual information" and "object/position information"), 17:22-18:35 (describing "interactions" with sound-producing virtual objects, such as "physical fights, side adventures with a particular character, moving objects and/or character, and knocking things over"), 17:32-18:9 (explaining that a guiding character and/or avatar that "walks the user through a scene in the virtual space and points things out" is "like a commentary track on a DVD"), 20:65-21:16 (describing creating those virtual objects in a scene), 25:21-39 (describing displaying sensory cues, including virtual reality content.).

276. In a Pedrotti-Jang or Pedrotti-Jang-Begault system, persons of ordinary skill in the art would have known and been motivated to use Pedrotti's controller (PED) for selecting a sound source (SLP) and would have understood that highlighting could obviously be used to indicate this selection. For example, a user could use the controller to select (and highlight) an image of a pep band in Jang's virtual basketball court associated with the pep band's sound or a conference

attendee in Jang's virtual conference room. Then, the selected and highlighted sound source (e.g., the pep band or conference attended) could be moved from one location (a first SLP) to a different location in auditory space in the virtual environment (a second SLP).

277. Also, persons of ordinary skill in the art would have understood that sound sources could and would be manipulated and arranged directly in the virtual environment, for example, with immersive authoring in immersive social VR experiences as described above. *See* Ross (Ex.1125) at 7:51-62 ("user may create, customize, and/or adjust the virtual reality content, the fields of view, view boundaries"). Alternatively, sound sources could and would be manipulated and arranged through an interface like Begault's Figure 5.12. *See* Begault (Ex.1007) at 174-75 (describing a "GUI for arranging [] various sound inputs in virtual auditory space in a manner configurable by each individual listener" such that "each form of auditory input [is] iconically on the screen and then allow[ed] manipulation of the distance and relative azimuth of each source.").

278. In either case described above, it would have been obvious to persons of ordinary skill in the art to highlight a virtual image associated with an SLP when the user points a handheld controller (PED) at the SLP, to select the image. Indeed, as I indicated above, persons of ordinary skill in the art would have understood that some form of dynamic visual confirmation that a user's moving hand is sufficiently

pointing at (intersecting) the virtual image at any given moment would be essential, lest the user be forced to repeatedly point and click until they were able to successfully carry out the desired action with or on the SLP.

279. For these reasons, Pedrotti and Jang, or Pedrotti, Jang, and Begault, render obvious limitation 1[c].

e. 1[d]: "playing, with the WED worn on the head of the user, the binaural sound that emanates from the one of the multiple SLPs in response to the one of the multiple SLPs being pointed at by the PED held in the hand of the user."

280. Limitation 1[d] would have been obvious over Pedrotti, Jang, and Begault for the same reasons as limitations 1[a] and 1[c]. *See* Sections X.A.3.b and X.A.3.d.

281. Pedrotti, Jang, and Begault render obvious a WED worn on the head of a user (Pedrotti's HMD), binaural sound emanating from SLPs (taught by Jang and Begault), and pointing a PED (Pedrotti's controller) at an SLP (taught by Jang and Begault). *See* Sections X.A.3.b (limitation 1[a]), X.A.3.d (limitation 1[c]). The additional element of limitation 1[d]—"playing… binaural sound" from an SLP "in response to" the PED pointing—also would have been obvious over Pedrotti, Jang, and Begault.

282. Pedrotti's HMD plays sound. Pedrotti (Ex.1005) at 15:56-58 (discussing "an audio warning").

283. And for Jang's focus/unfocus areas, Jang taught outputting binaural sound "to the user to represent the virtual environment," and that processing binaural sound to produce that output involves mixing visual elements of a virtual environment, including "characters, objects, or features," with associated audio to provide "sound sources occurring in real time according to the[ir] relative locations." Jang (Ex.1006) at 6:17-20 (The "virtual reality device" can "output life-like sounds"), 6:36-42 ("The user may see, hear, and otherwise sense the virtual environment from the perspective of the avatar."), 7:24-32 (describing a "control unit" that "receives an input of a selected virtual reality character" and "check[s] sound source information on other characters and other objects existing in the virtual reality spaces"), 7:47-63 (describing how the "control unit 114" divides the "virtual reality space into multiple sound areas" and uses HRTFs "as an algorithm for identifying the sound generating location.").

284. Jang teaches that "the sound of the virtual reality system may use a localization technique capable of expressing the virtual location" of "a sound-generating object," and discloses a processor for identifying the "exact sound-generating location" for audio elements before sound is produced. Jang (Ex.1006) at 1:42-56 (further explaining that the sound processing method "give[s] the sense of reality to the sound"), 7:50-63 (referencing user of HRTFs in sound processing), Fig. 3 (illustrating sound processing unit 116), 8:65-9:3 (explaining how the focused

sound processor and non-focused sound processor "identify" a sound source and location). Jang further discloses that "to express directionality, the paths of sound reaching listener's ears, which determine the direction of sound in view of the listener, may be modeled by using a sound processing technique, such as a Head Related Transfer Function (HRTF), so as to determine the output sound." Jang (Ex.1006) at 1:52-56. Indeed, it was known that binaural sound often provides a more realistic representation of sound, and that binaural sound is generated using HRTFs. Jerald, THE VR BOOK (Ex.1063) at 240 ("For more realistic audio and where auditory cues are especially important, ***auralization***—the rendering of sound to simulate reflections and binaural differences between the ears—can be used … Ideally, HRTFs model a specific user's ears, but in practice a generic ear is modeled.") (emphasis in original); *see also* Section VII.E (discussing background for sound localization techniques, including use of HRTFs and generating binaural sound). And as discussed for limitations 1[a] and 1[b], the SLPs pertaining to a Pedrotti-Jang implementation exist (or at a minimum obviously exist) in a zone above from where binaural sound originates to a user. *See* Sections X.A.3.b-X.A.3.c.

285. Furthermore, the generation of binaural sound using HRTFs would have been obvious over to persons of ordinary skill based on Jang and Begault's disclosures. As explained above, Jang discloses that its binaural sound can be generated with HRTFs. Jang (Ex.1006) at 7:57-63 (referencing use of HRTFs in

sound processing). In addition, Begault, which published in 2000, discloses the use of HRTFs to localize sound, and how processors process sound with HRTFs to generate binaural sound. Begault (Ex.1007) at 12 ("The audio subsystem" for "a sound subsystem in a virtual reality system" "contains two fundamental parts: a signal source, such as a synthesizer, and a signal processor that contains components for spatializing and mixing the outputs from the signal sources."), Fig. 1.8 (depicting a "signal processor" for "spatialization and mixing of multiple monaural channels into binaural output"), 41 ("The use of HRTF spectral shaping is typically featured as the key component of a 3-D sound system … The binaural HRTF (terminology for referring to both left- and right-ear HRTFs) can be thought of as a frequency-dependent amplitude and time-delay differences that result primarily from the complex shaping of the pinnae."), 99 ("the inclusion of the binaural HRTF is fundamental for a 3-D sound system"); *see also* Section IX.C (overview of Begault).

286. Based on these disclosures and existing knowledge of how to generate binaural sound at particular locations, persons of ordinary skill in the art would have known to include binaural sound as the specific audio data associated with SLPs that are part of the virtual environment. *See* Begault (Ex.1007) at 12 ("The audio subsystem" for "a sound subsystem in a virtual reality system" "contains two fundamental parts: a signal source, such as a synthesizer, and a signal processor that contains components for spatializing and mixing the outputs from the signal

sources."), Fig. 1.8 (depicting a "signal Processor" for "spatialization and mixing of multiple monaural channels into binaural output"), 41 ("The use of HRTF spectral shaping is typically featured as the key component of a 3-D sound system, from either direct measurement or modeling."); *see also* Jang (Ex.1006) at 1:46-56 ("to express directionality, the paths of the sound … may be modeled by using a sound processing technique, such as a Head Related Transfer Function"), 7:57-63 (referencing use of HRTFs in sound processing), Fig. 3 (illustrating sound processing unit 116); Pedrotti (Ex.1005) at 15:56-58 (referencing "generat[ing] an audio warning").

287. And as discussed for limitation 1[c], persons of ordinary skill in the art would have known that Pedrotti's HMD is able to detect when the user is pointing the controller at an SLP, and then take action (e.g., playing a binaural sound). Section X.A.3.d. And playing binaural sound from an SLP in response to being pointed at would have been routine and obvious. Lovitt (Ex.1021) at [0038] ("each virtual space sound source includes one or more associated sounds such that, during interaction with the virtual environment, one or more of the associated sounds are programmed to be 'output' from a particular virtual space sound source"); Jerald, THE VR BOOK (Ex.1063) at 240 (discussing utility of spatial audio and "rendering of sound to simulate reflections and binaural differences"); Begault (Ex.1007) at 13 ("3-D sound can contribute to the sense of immersivity in a 3-D environment "), 99

("the inclusion of the binaural HRTF is fundamental for a 3-D sound system that relates natural and synthetic spatial hearing"). Begault (and Cohen 1993 that Begault references), describe processing binaural sound, which was known at least as early as 1984, in great detail. *See* Begault (Ex.1007) at ch. 2.

288. Further, before 2016, it was well known that playing a sound (e.g., Jang's binaural sound associated with a virtual image) could, like highlighting, facilitate user selection of a virtual image. *See, e.g.*, Jerald, THE VR BOOK (Ex.1063) at 281 (explaining that "objects can make a sound" "when … they have been selected"), 356 (stating that one may "use audio and highlighting to signify touching of objects").

289. Thus, because persons of ordinary skill in the art would have known that sound could and would be played upon user selection, they also would have known that a Pedrotti-Jang or Pedrotti-Jang-Begault system could and would "play[] binaural sound" from an SLP "in response to" Pedrotti's controller (PED) pointing at the SLP. Begault (Ex.1007) at 161-62 (sounds "spatialized using 3-D audio techniques," including through "HRTF filtering," i.e., binaural sounds, used for "selecting items"). As explained above, pointing is one way to select, move, and control virtual objects, and playing sound would facilitate that user selection (or movement or control) of a virtual object. *See* Section X.A.3.d.

4. Dependent Claims 2-8

290. I understand that claims 2-8 depend on independent claim 1.

291. Thus, it is my opinion that each of dependent claims 2-8 would have been obvious to persons of ordinary skill in the art for the same reasons as independent claim 1 and additionally for the reasons I discuss in the following subsections.

a. Claim 2

(1) 2[a]: "The method of claim 1 further comprising: tracking, with one or more sensors in the WED worn on the head of the user, the PED to determine when the PED moves outside the zone; and"

292. Pedrotti teaches, or at a minimum renders obvious, limitation 2[a].

293. To begin, Pedrotti discloses, or at a minimum renders obvious, "tracking" the PED in view of the disclosures I addressed in Sections X.A.3.b-X.A.3.d (limitations 1[a]-1[c]).

294. Pedrotti also discloses, or at a minimum renders obvious, tracking "with one or more sensors in the WED." Pedrotti disclosed controllers with trackers, including, for example, "light-emitting trackers" that "provide position and orientation information" to sensors, including, for example, "a camera mounted on [a] base station or elsewhere." Pedrotti (Ex.1005) at 5:8-24 ("essentially any type

of tracker… can be used in the present approach" including using "inertial sensors (e.g., accelerometers and/or gyroscopes)").

295. Persons of ordinary skill in the art would have understood the tradeoffs between electromagnetic tracking and electro-optical approaches disclosed by Pedrotti. Such tradeoffs are discussed extensively in my 2002 *No Silver Bullet* paper. Welch, *No Silver Bullet* (Ex.1135). For example, persons of ordinary skill in the art would understand that while electromagnetic tracking has some advantages, e.g., magnetic fields are relatively stable over short distances and they generally pass through humans, it also has some significant disadvantages, e.g., ferromagnetic and conductive material in the environment (difficult to control in a consumer setting) can cause systematic errors, the useful range of operation is severely limited by the inverse cubic falloff of the magnetic fields as a function of distance from the source, and they require three–four magnetic excitation and measurement operations per estimate cycle which results in a relatively low estimate rate. Welch, *No Silver Bullet* (Ex.1135) at 29. Persons of ordinary skill in the art also would have understood that while electro-optical approaches require a clear line of sight between the source and the sensor (Welch, *No Silver Bullet* (Ex.1135) at 30), occlusions between handheld controllers and an HMD are very unlikely as the controllers will always be relatively close to the user and the HMD—within arm's length. Also, persons of ordinary skill in the art also would have understood that using the optical

approach taught by Pedrotti ("light-emitting trackers" and cameras) would have relatively high signal-noise ratio (light-emitting components on the controllers would be close to any cameras on the HMD), and relatively constant error behavior, and measurements could be obtained quite fast compared to magnetic tracking, e.g., because light is very fast in general, and light emitted from the two handheld controllers to be sampled (by the cameras) and processed at the same time. Finally, persons of ordinary skill in the art would have understood that using light emitters on the controllers and one or more cameras on the HMD is well matched to processing in the HMD (tracking, rendering, etc.), which would eliminate the need to transfer measurement data from of the controllers to the processor, allowing the handheld controllers to be wireless. As such, persons of ordinary skill in the art would be significantly motivated to use an electro-optical approach taught by Pedrotti, i.e. to track the handheld controllers using Pedrotti's light-emitting components (e.g., LEDs) on the controllers and one or more cameras on the HMD.

296. Indeed, the use of sensors on HMDs for tracking controllers—including sensors that could and would be used to track light-emitting controllers—was well-known. *See, e.g.*, Ambrus (Ex.1043) at [0075] ("pose and/or movement data may be determined based on sensor information from any combination of sensors mounted on the wearer and/or external to the wearer including … gyroscopes, accelerometers, inertial measurement units (IMUs), GPS devices, barometers,

magnetometers, cameras (e.g., visible light cameras, infrared light cameras, time-of-flight depth cameras, structured light depth cameras, etc.)"); McCulloch (Ex.1008) at 8:17-22 ("Inside, or mounted to temple 102, are … an inertial sensing unit … a location sensing unit … some examples of which are a GPS transceiver, an infrared (IR) transceiver, or a radio frequency transceiver for processing RFID data."); Begault (Ex.1007) at 133 (describing "electromagnetic sensors," or "optical, mechanical, and acoustic tracking systems"); Jerald, THE VR BOOK (Ex.1063) at 315 ("Hand-held tracked devices typically use inertial, electromagnetic, ultrasonic, or optical (camera) technologies."); Mine Exploiting Proprioception 1997 (Ex.1116) at 68 ("hardware configuration includes an immersive head-mounted display, a magnetic tracking system with three 6 degree-of-freedom (DoF) sensors (one for the head and one for each hand), two separate input devices (one for each hand) and a high speed graphics computer"); Ross (Ex.1125) at 11:4-28 (describing using "one or more of a GPS sensor, a gyroscope, an accelerometer, an altimeter, a compass, a camera based sensor, a magnetic sensor, an optical sensor, an infrared sensor, a motion tracking sensor, an inertial sensor, a CCB sensor, an eye tracking sensor, a facial tracking sensor, a body tracking sensor, and/or other sensors" to "generate output signals conveying information related to any number of different view directions, (e.g., orientation of one or more parts of the user's body," "position of a user within the virtual space, and/or other directional information)"). And, persons

of ordinary skill in the art would have understood that optical tracking systems, such as those that tracked light-emitting controllers, would have "offer[ed] sufficiently accurate measurements of both position and orientation over relatively large working volumes, without many of the problems inherent in magnetic or acoustic tracking systems." Welch 1995 (Ex.1119) at 2; *see also* Section VII.D (discussing tracking, including tracking of controllers). Persons of ordinary skill in the art would have further understood and appreciated that tracking a handheld controller using LEDs on a handheld controller and cameras on an HMD as taught by Pedrotti (Ex.1005) (at 5:8-24) would have relatively high accuracy, high resolution, and high speed (with low latency), which is particularly important for handheld controllers as humans can move their wrists relatively fast.

297. Pedrotti further discloses, or at a minimum, renders obvious, "determin[ing] when the PED moves outside the zone" in view of the disclosures addressed in Section X.A.3.c (limitation 1[b]) and as explained below. I note that 8K does not distinguish between determining (i) that a user "is leaving" a zone and (ii) that a PED "leaves," or moves outside a zone, in district court. *Compare* '509 8K Infringement Contentions (Ex.1129) at 7, *with* '509 8K Infringement Contentions (Ex.1129) at 17. These actions are, at a minimum, obvious over Pedrotti for the reasons discussed because the determination that is performed by Pedrotti's processor for all three involves obtaining positional, inertial, and/or orientation

information of the user (either via the HMD worn on the head of the user or the PED that is held by the user), and comparing that information against the boundaries of the user-defined zone. Pedrotti discloses that its HMD and controllers are tracked, and furthermore, such tracking was well known in the art. *See* Section VII.D (discussing tracking of HMDs and controllers).

298. Pedrotti discloses that a processor that may be located in Pedrotti's HMD "determine[s] from the position of [a] handheld controller that the handheld controller is within a first preselected distance from [a] boundary." Pedrotti (Ex.1005) at 2:44-59. The processor then "generate[s] and output[s] instructions to the HMD to include in a display of a virtual world a visual warning such as a grid or virtual fence when the user comes within a preselected distance of the boundary, thus providing a warning that the user is about to move out of the selected area." Pedrotti (Ex.1005) at 2:44-59.

299. This warning is provided "when the user comes within a preselected distance of the boundary, thus providing a warning that the user is about to move out of the selected area," regardless of whether the user's location is determined based on the location of the HMD or the location of the handheld controller. Pedrotti (Ex.1005) at 4:37-44 (indicating that this is done when "[t]he processor [] tracks the position and orientation of the HMD tracker, and possibly the position and orientation of one or more trackers in the physical controllers"), 12:35-13:2 ("[T]he

processor knows where the user's head and hands are located; if the processor has been provided with information about the boundary of the selected area then the processor can also determine when the user's head and/or hands approaches the boundary."). Pedrotti's Figure 15, which is a flowchart of this method, discloses that this method "result[s] in the display of a visual warning such as the virtual fence." Pedrotti (Ex.1005) at 15:4-39, Fig. 15.

300. Pedrotti further discloses that "the preselected distance" triggering its warning "may vary by application, so that, for example, it is greater in an application in which larger body movements are expected from the user than in an application in which such body movements are not expected." Pedrotti (Ex.1005) at 13:46-62. Moreover, Pedrotti teaches that "if the user's head goes beyond the boundary, the processor can cause the HMD to fade to black, and present, for example, only a warning message and/or a beacon or arrows directing the user to move in the direction of the boundary and the selected area," meaning that Pedrotti's system is able to identify conflicts with its boundaries. Pedrotti (Ex.1005) at 13:67-14:5.

301. Thus, Pedrotti disclosed or at a minimum rendered obvious to a person of ordinary skill in the art tracking a PED (a Pedrotti controller containing trackers) with one or more sensors in a WED worn on a user's head (e.g., a camera mounted on Pedrotti's HMD), where that tracking is then used to determine when the PED

moves outside the zone (i.e., when Pedrotti's controller moves beyond Pedrotti's "safe area" or zone boundary).

302. For these reasons, Pedrotti and Jang, or Pedrotti, Jang, and Begault, render obvious limitation 2[a].

(2) 2[b]: "displaying, with the WED worn on the head of the user, a three dimensional (3D) virtual image that shows a size and a shape of the zone in response to the WED determining that the PED moved outside the zone."

303. Pedrotti teaches, or at a minimum renders obvious, limitation 2[b].

304. As I discussed for limitation 1[a], Pedrotti discloses WED worn on the head (Pedrotti's HMD) that displays 3D virtual images. *See* Section X.A.3.b.

305. And as I discussed for limitation 1[b], Pedrotti discloses a WED that determines when a PED has moved outside the zone. *See* Section X.A.3.c.

306. Pedrotti further discloses or at a minimum renders obvious displaying a 3D virtual image that shows a size and shape of a zone in response to that determination. Indeed, as Pedrotti explains, "when the user comes within a preselected distance of the boundary," the processor "generates instructions to the HMD to include in a display of a virtual world a visual warning such as a grid of virtual fence," "thus providing a warning that the user is about to move out of the selected area":

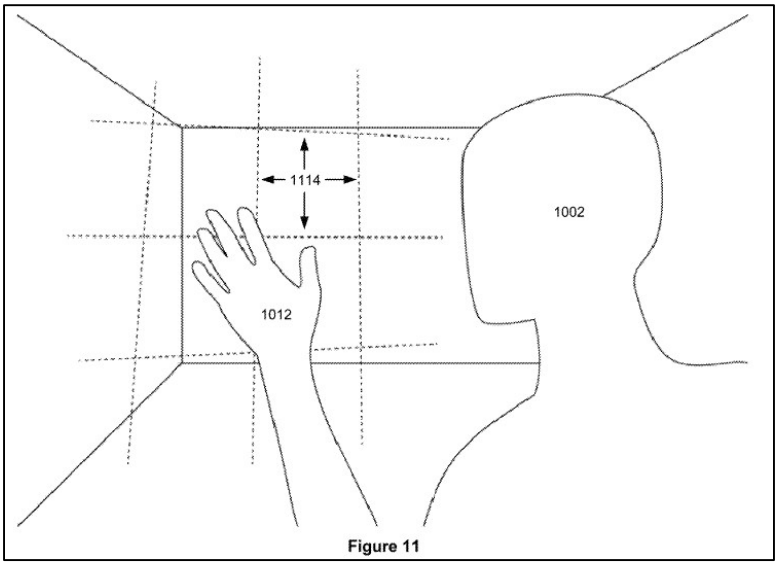
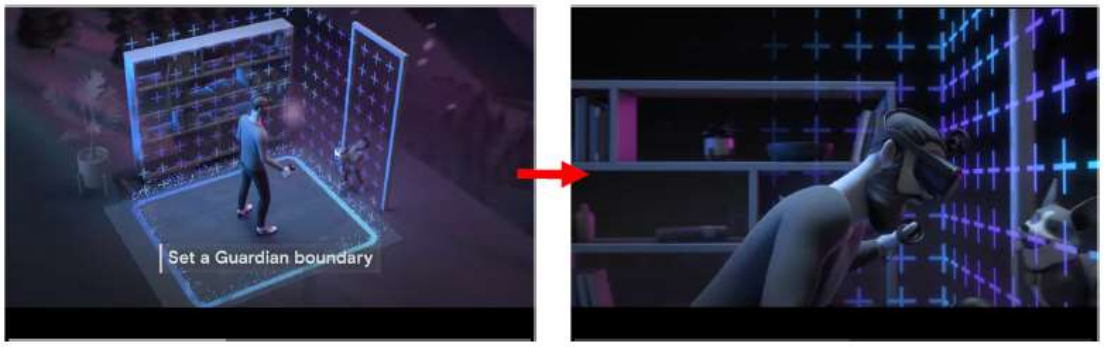


Figure 11

Pedrotti (Ex.1005) at 4:37-44, Fig. 11 (depicting a "visual warning [] in the form of a grid of lines or a 'virtual fence' located at the boundary"), 12:51-13:11 (describing its "visual warning" in the ""form of a grid or lines or a 'virtual fence' located at the boundary" that "can be glowing or colored"); *see also* Pedrotti (Ex.1005) at 12:40-50 ("the processor generates a warning that the user is close to the boundary so that the user can take action to avoid the boundary and thus potential collision with the physical objects"), 12:60-66 ("In addition, since the hand of the user 1002 is within the preselected distance of the boundary of the selected area, the processor generates instructions to the HMD to generate the visual warning As illustrated in this embodiment, this visual warning is in the form of a grid of lines or a 'virtual fence' located at the boundary, as indicated in FIG. 11 by the dashed lines 1114."), 13:63-67 ("If the user's head or hands go beyond the boundary as determined by the trackers, the processor can provide additional messaging or warning, such as text or

auditory warnings, or an additional visual warning, that persists until the user returns to the selected area within the boundary."). This "grid" or "virtual fence" is, or at a minimum obviously could and would be, a 3D virtual image appearing at Pedrotti's zone boundary that shows the size and shape of Pedrotti's zone because it is a virtual image presented in a 3D VR environment—i.e., a 3D virtual image. It also shows the size and shape because the "grid" or "virtual fence shows the boundary of the zone, thus allowing the user to view its size and shape.

307. I note that Pedrotti's 3D virtual image showing a grid or fence (reproduced above) is nearly identical to the features 8K contends in district court satisfy claim limitations requiring a "three dimensional (3D) virtual image of the zone":



'509 8K Infringement Contentions (Ex.1129) at 17 (8K's red annotation); '737 8K Infringement Contentions (Ex.1121) at 3 (similar contention for "three-dimensional (3D) virtual image that shows a size and shape of the zone").

308. In addition, Pedrotti taught that "other shapes other than a grid-shaped virtual fence can be displayed to the user" and that "the developer of a particular application may choose some other design to provide contrast with, or maintain thematic correctness with, the particular virtual world being displayed." Pedrotti (Ex.1005) at 12:60-13:11. Thus, persons of ordinary skill in the art would understand that Pedrotti contemplates other virtual images, or variations of the grid-shaped virtual fence, that shows a size and a shape of the zone, including 3D virtual images. Moreover, as I explained in Section VII.G, numerous safety and chaperone systems for virtual environments, which alerted users that their locations conflicted with boundaries, including through the use of 3D virtual images of zones to alert users, existed and were known to persons of ordinary skill in the art before February 2016.

309. For these reasons, Pedrotti discloses (or at a minimum renders obvious) limitation 2[b].

b. Claim 3

(1) 3[a]: "The method of claim 1 further comprising: tracking, with the WED worn on the head of the user, the user to determine when the user moves outside the zone; and"

310. Limitation 3[a] would have been obvious for the same reasons as limitation 2[a]. Section X.A.4.a(1).

311. As a preliminary matter, persons of ordinary skill in the art would have understood that Pedrotti's HMD (the claimed WED) is tracked, and hence the user's movement determined. Pedrotti states "[t]he present invention relates generally to virtual reality devices, and more particularly to controllers for use in a virtual reality context." Pedrotti (Ex.1005) at 1:8-10. Persons of ordinary skill in the art would have understood that discussion of an HMD in the context of virtual reality includes such tracking. Indeed, the view-dependent virtual imagery described throughout Pedrotti would not be possible without the HMD being tracked.

312. Pedrotti discloses tracking of the HMD throughout. *See, e.g.*, Pedrotti (Ex.1005) at Abstract ("A method and apparatus is disclosed for assisting a user, wearing a head mounted display (HMD) that covers a user's field of vision and has a tracker providing information regarding the position and orientation of the HMD, in locating a physical controller located on a physical base station."), 4:5-8 ("the user is wearing a head mounted display (HMD) that covers a user's field of vision and has a tracker allows a processor to track the position and orientation of the HMD"), 4:16-19 ("In one embodiment, when a user activates a display of a virtual world into which the user wishes to enter, for example, through the display of a HMD, a processor tracks the position and orientation of a tracker on the HMD.").

313. Specifically, Pedrotti's HMD includes processors capable of tracking the controller's location, which, when held in the hand of the user during game play,

also reflects the user's position. Further, the processor in Pedrotti's HMD tracks both the "trackers in the physical controllers" (PEDs) and "the positions and orientation of [a] HMD tracker," i.e., the user wearing the HMD, which in turn can trigger display of a virtual fence, including when (or obviously when) the user moves outside the zone. *See* Sections X.A.3.c (limitation 1[b]), X.A.4.a (claim 2); Pedrotti (Ex.1005) at 4:37-44 (describing a "safe area"), 16:22-24 (processor can be located "in the HMD"), 12:31-39 ("[T]he processor knows where the user's head and hands are located; if the processor has been provided with information about the boundary of the selected area then the processor can also determine when the user's head and/or hands approaches the boundary."), 13:57-14:5 (explaining the ability to vary the preselected distance based on body movements of the user and that "if the user's head goes beyond the boundary, the processor can cause the HMD to fade to black, and present, for example, only a warning message and/or a beacon or arrows directing the user to move in the direction of the boundary and the selected area").

314. Thus, Pedrotti discloses (or at a minimum renders obvious) limitation 3[a].

(2) 3[b]: "displaying, with the WED worn on the head of the user, a three dimensional (3D) virtual image that shows a size and a shape of the zone in response to the WED determining that the user moved outside the zone."

315. For the same reasons as I described for limitations 1[b], 2[a]-[b], and 3[a], limitation 3[b] would have been obvious to persons of ordinary skill in the art. *See* Sections X.A.3.c, X.A.4.a(1), X.A.4.a(2), X.A.4.b(1).

316. Specifically, Pedrotti discloses that "when the user comes within a preselected distance of the boundary," the processor "generates instructions to the HMD to include in a display of a virtual world a visual warning such as a grid of virtual fence," and "thus provid[es] a warning that the user is about to move out of the selected area." Pedrotti (Ex.1005) at 4:37-44, Fig. 11 (depicting a "visual warning [] in the form of a grid of lines or a 'virtual fence' located at the boundary"); *see also* Pedrotti (Ex.1005) at 12:40-50 ("the processor generates a warning that the user is close to the boundary so that the user can take action to avoid the boundary and thus potential collision with the physical objects"), 12:60-66 ("In addition, since the hand of the user 1002 is within the preselected distance of the boundary of the selected area, the processor generates instructions to the HMD to generate the visual warning. As illustrated in this embodiment, this visual warning is in the form of a grid of lines or a 'virtual fence' located at the boundary, as indicated in FIG. 11 by the dashed lines 1114."). Further, this virtual image that shows a size and a shape of the zone is displayed in response to the WED determining that the user moved outside the zone. Pedrotti (Ex.1005) at 13:63-67 ("If the user's head or hands go beyond the boundary as determined by the trackers, the processor can provide … an

additional visual warning, that persists until the user returns to the selected area within the boundary.").

317. And as I explained above, the displayed "grid" or "virtual fence" is, or at a minimum obviously could and would be, a 3D virtual image appearing at Pedrotti's zone boundary that shows the size and shape of Pedrotti's zone. *See* Section X.A.4.a(2).

318. Thus, Pedrotti discloses (or at a minimum renders obvious) limitation 3[b].

c. Claim 4

(1) 4[a]: "The method of claim 1 further comprising: storing, in memory of the WED, a location of the zone, a size and a shape of the zone, and locations of the multiple SLPs in the zone from where the binaural sound originates to the user; and"

319. Pedrotti taught, or at a minimum rendered obvious to persons of ordinary skill in the art, claim limitation 4[a].

320. As discussed above, Pedrotti's methods involve displaying virtual boundaries of zones. Persons of ordinary skill in the art would have known and understood that, to implement its methods, Pedrotti's system stores, or at a minimum obviously stores, the location, size, and shape of Pedrotti's zone to facilitate determining when to display a zone's virtual fence, e.g., when the user moves outside

the zone. *See* Pedrotti (Ex.1005) at 14:56-62 (creation of user-defined zone), Fig. 14, Sections X.A.3.b (limitation 1[b]), X.A.3.c (limitation 1[c]), X.A.4.a(2) (limitation 2[b]).

321. As a preliminary matter, persons of ordinary skill in the art would have known and understood that data representing "a location of the zone, a size and a shape of the zone, and locations of the multiple SLPs in the zone from where the binaural sound originates to the user" is no different from any other data used by the system in that it is stored in memory to be used, acted upon, rendered, and displayed in the user's HMD when appropriate.

322. In view of Pedrotti's disclosure that "if the processor has been provided information about the boundary of the selected area then the processor can also determine when the user's head and/or hands approaches the boundary" (Pedrotti (Ex.1005) at 12:31-50), it would have been obvious to persons of ordinary skill in the art that the Pedrotti's system stored information about the boundary such as the coordinate locations of the "sampling points" defining the boundary. Pedrotti (Ex.1005) at 14:62-65 ("The processor determines the position of the tracker at a number of sampling points as the user moves around the chosen perimeter). A person of ordinary skill in the art would have known and understood that in order to make the comparison between the user's location (either by the user's head or hands) and the boundary, those values would need to be stored and retrievable in memory.

323. Moreover, persons of ordinary skill in the art also would have known that such memory preferably would be in the HMD, since Pedrotti discloses that its processor is located in the HMD. Pedrotti (Ex.1005) at 16:22-24. Thus, the memory would be, or at a minimum would obviously be, in the HMD as well so that it is accessible to the processor. *See* Pedrotti (Ex.1005) at 2:62-65 (describing "a non-transitory computer-readable medium having embodied thereon a program, the program being executable by a processor"). This would also eliminate the need for the HMD to communicate with an external storage device, as well as eliminate hardware needed for such communications.

324. To persons of ordinary skill in the art, such storage on an HMD was well known. Indeed, Jang teaches this, disclosing a "storage unit" in its "virtual reality apparatus" that a person of ordinary skill in the art would have known could be used for the purpose of storing Pedrotti's "sampling points" defining the boundary. *See* Jang (Ex.1006) at 4:5-10 ("software code may be stored in a software-code-storing medium, ***such as a memory module***, a server in communication with a virtual reality display device, by a CD, DVD, or any other disk, ***memory storage device***, including a computer-readable medium") (emphasis added), 12:57-67 (further disclosing examples of computer-readable media that can store Jang's programs and data relied upon, including "read-only memory (ROM), random-access memory (RAM), CD-ROMs, DVDs, magnetic tapes, floppy disks, and

optical data storage devices"), Fig. 1A ("storage unit" 102 in "virtual reality apparatus" 110).

325. In fact, by February 2016, it was conventional to store information directly in the memory of HMDs. *See, e.g.*, McCulloch (Ex.1008) at 8:1-11 ("memory 244 accessible to the processing unit 210 for storing processor readable instructions and data"), Fig. 2A (depicting memory 244 as part of the HMD); Ross at Figs. 1-2 (showing "electronic storage 30" in its computing device 12), 5:26-27 (indicating that computing device 12 is a "virtual reality headset computing device"), 23:46-67 ("[e]lectronic storage may store files, software algorithms, information determined by processor(s) 20, and/or other information that enables the respective devices to function"), 24:10-19 (describing the processing devices that executes "instructions stored electronically on an electronic storage medium"), 24:59-62 ("virtual reality content … for display to the user may be obtained from electronic storage").

326. In addition, to a person of ordinary skill in the art, storing the locations of multiple SLP in the zone from where binaural sound originates to a user would have been also been straightforward and obvious over Pedrotti and Jang, or over Pedrotti, Jang, and Begault, since it would have required the same configuration of hardware between the storage and processor.

327. Further, as I explained above, Jang taught that its system, which has HMD storage, generates binaural sound from audio sources arranged at various locations in the sound areas (i.e. the "focus" and "unfocus" areas) around a user (i.e., multiple SLPs) according to "predetermined" priorities and schemes where the output of each sound source may be adjusted based on a respective priority. Sections X.A.3.b (limitation 1[a]), X.A.3.e (limitation 1[d]). Persons of ordinary skill in the art would have understood that implementing Jang's system (and the focus/un-focus priority areas and associated elements, including SLPs), involves storing the locations of focus and un-focus areas, and the locations of SLPs in those areas from which spatialized audio originates. Indeed, Jang teaches storing software code, which would include such location information needed to make determinations regarding the boundaries for game play per Pedrotti, or of focus and un-focus areas per Jang, in "a software-code-storing medium, such as a memory module." Jang (Ex.1006) at 4:5-10 (describing generating a "sensory output" for a virtual space), 6:27-28 (describing a "storage unit 102"), 12:57-67 (describing "computer-readable medium" on which the "inventive concept may be" "embodied" upon), Fig. 1A (showing "storage unit" 102), 11:64-12:16 ("sensory output data" is output after it is "[t]ransferred … from a storage unit within the virtual reality device to a control unit."), Fig. 1A ("storage unit" 102) (reproduced below).

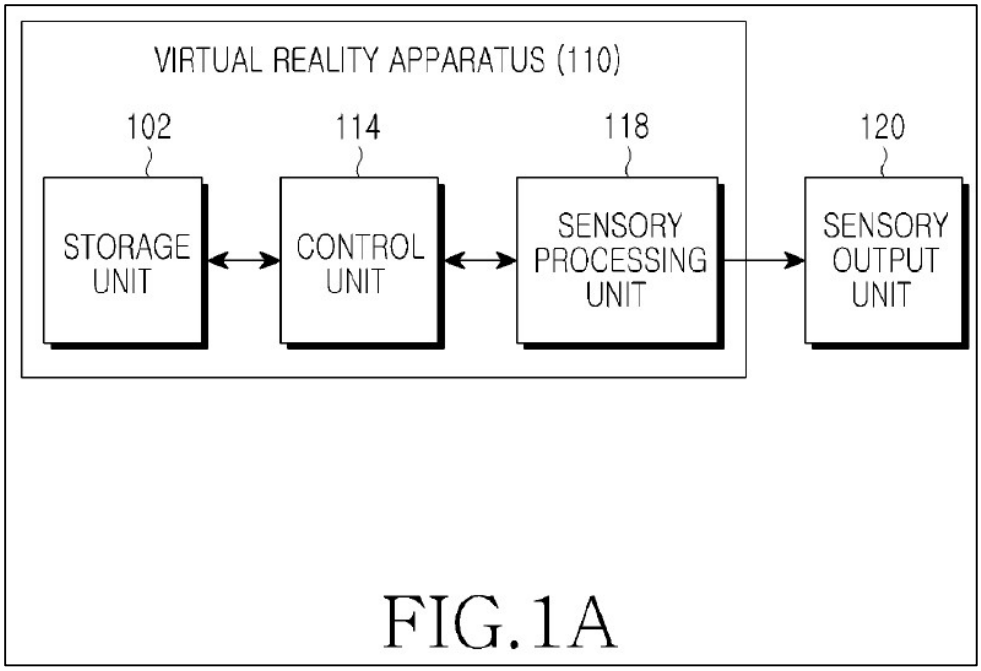


FIG.1A

328. Thus, consistent with Jang's teachings, persons of ordinary skill in the art would have known that the audio source locations from which Jang's binaural sound originates (i.e., the SLPs), including audio sources arranged in the virtual auditory space I described for limitation 1[a], are (or obviously could and would be) stored in the HMD's memory. *See* Section X.A.3.b.

(2) 4[b]: "displaying, with the WED, a virtual image having the size and the shape of the zone in response to the WED determining that the user is located in the zone."

329. For the same reasons as I described for limitations 2[b] and 33[b], limitation 4[b] would have been obvious to persons of ordinary skill in the art. *See* Sections X.A.4.a(2), X.A.4.b(2).

330. Further, limitation 4[b] would have been obvious to persons of ordinary skill in the art over Pedrotti's teachings relating to setting boundaries of the zone or safe area.

331. Pedrotti explains that as a user "moves around [a] chosen perimeter" (Pedrotti (Ex.1005) at 14:62-65), the user is located in the zone that is being tracked and stored. And it is through this process that the user draws a customized shape for the claimed zone. *See* Pedrotti (Ex.1005) at 14:62-65 ("The processor determines the position of the tracker at a number of sampling points as the user moves around the chosen perimeter, and from those points determines the boundary 1404."). Also, as I discussed above, Pedrotti discloses an HMD that displays at the boundary of a safe area a "visual warning [] in the form of a ***grid of lines*** or a 'virtual fence.'" Pedrotti (Ex.1005) at 12:10-15 ("[t]he processor provides instructions to the HMD display to include a display of a virtual fence at the boundary when the user comes within a preselected distance of the boundary of the selected area, thus providing a warning that the user is approaching the boundary of the selected area"), 12:51-13:11 (describing Figure 11), 15:4-55 (describing "flowchart of a method implemented by a processor that might result in the display of a visual warning such as the virtual fence [] of Fig. 11"), Fig. 11.

332. Persons of ordinary skill in the art also would have been motivated to display the image of the zone in response to Pedrotti's system determining that the

user is located in the zone since it would have provided guiding information to a user, for example, when the user is setting up Pedrotti's boundary, so the user receives feedback on the divided and defined area for gameplay. As I explained in the State of the Art section, it was known to use safety and chaperone systems to keep users protected while interacting in a virtual environment. *See* Section VII.G; *see also* Kobayashi (Ex.1019) at 5:15-20 (describing drawing a boundary); Sawyer (Ex.1036) at [0034]-[0036] (describing moving a tracked game controller to draw the operating space); Jerald, THE VR BOOK (Ex.1063) at 298 (a common gesture of indicating is to "point or draw a path"); Section VII.G (discussing multiple variations of how other safety systems accepted user input to create customized boundaries, e.g., Pedrotti, Gallery, Sawyer, Gum, Kobayashi, and Peck). And providing guiding information to inform the user of the zone, e.g., as the user sets up the zone, would allow the user to better use Pedrotti's safety and chaperone system, by allowing the user to visually determine the size and shape of the zone to ensure accurate boundary and zone setup.

333. Persons of ordinary skill in the art also would have understood and known that the displaying the virtual image could and would occur (or at a minimum would obviously occur) in response to determining that the user is located in the zone. Again, in view of Pedrotti's disclosure that "if the processor has been provided information about the boundary of the selected area then the processor can also

determine when the user's head and/or hands approaches the boundary" (Pedrotti (Ex.1005) at 12:31-50), it would have been obvious to persons of ordinary skill in the art that the Pedrotti's system display a virtual image showing information about the boundary such as the coordinate locations of the "sampling points" defining the boundary to allow the system to make the comparison between the user's location (either by the user's head or hands) and the boundary.

334. Thus, an obvious and straightforward way of applying Pedrotti's processing capabilities that compare the user's location and the boundary and its display functions would involve (1) determining the user's location when the boundary for a zone is created and stored, (2) comparing that location to the boundary, and (3) displaying to the user a virtual image of the created boundary to ensure accurate boundary and zone setup. *See* Ross (Ex.1125) at 22:23-23:21 (describing user configuration of boundaries and the use of a "[c]ontent creation preview" that enables users to "continue to make changes" to those boundaries).

d. Claim 5

(1) 5[a]: "The method of claim 1 further comprising: designating, with the PED held in the hand of the user, locations of the multiple SLPs in the zone from where the binaural sound originates to the user; and"

335. For the same reasons as I described for limitations 1[a] and 1[c], limitation 5[a] would have been obvious to persons of ordinary skill in the art. *See* Sections X.A.3.b, X.A.3.d.

336. Specifically, Pedrotti and Jang, or Pedrotti, Jang, and Begault, render obvious to persons of ordinary skill in the art the use of routine pointing and selecting actions using Pedrotti's handheld controller (PED) to assign or designate locations in Jang's sound areas from where binaural sound for Jang's audio sources will originate to a user (i.e., SLPs), including, for example, the locations for spatialized sounds from virtual objects in Jang's basketball court or conference room. *See* Section X.A.3.b. As discussed for limitation 1[a], persons of ordinary skill in the art would have known to associate sound with such virtual objects (and also have sound move with these objects). This type of sound management and control was known and would have been obvious to persons of ordinary skill in the art over Pedrotti and Jang, or over Pedrotti, Jang, and Begault. *See* Section X.A.3.b.

(2) 5[b]: displaying, with the WED, virtual images at the location of the multiple SLPs in the zone.

337. Limitation 5[b] would have been obvious to persons of ordinary skill in the art over Pedrotti and Jang or Pedrotti, Jang, and Begault.

338. Pedrotti and Jang both disclose HMDs that display virtual images. Pedrotti (Ex.1005) at Abstract ("processor causes the HMD to display a virtual

world"); Jang (Ex.1006) at 1:38-40 ("image of a virtual reality system" realized using "Head Mounted Display (HMD)").

339. Jang disclosed outputting "audio, sound, and/or other sensory data" "to the user to represent the virtual environment." Jang (Ex.1006) at 6:17-20. Jang's sound system can then "check sound source information on other characters and other objects existing in the virtual reality spaces" to "provide[] the virtual reality apparatus 110 with sound sources occurring in real time according to the[ir] relative locations." Jang (Ex.1006) at 7:24-32.

340. Based on these disclosures, persons of ordinary skill in the art would have known that when, as I discussed for limitations 1[a] and 5[a], Pedrotti's handheld controller is used to assign or designate SLP locations in Pedrotti's zone, a Pedrotti-Jang or Pedrotti-Jang-Begault system would (or at a minimum obviously would) display virtual images at those designated SLPs because Jang teaches that its system receives an input of a selected virtual reality character from the user" and "provides the virtual reality apparatus 110 with sound sources occurring in real time according to the relative locations or situations of the character in the virtual reality environment." Jang (Ex.1006) at 7:24-32. Thus, for instance, if a user designated a location for an announcer in Jang's virtual basketball court environment, an image of an announcer corresponding to the sound source of the announcer could and would be displayed at that location. Jang (Ex.1006) at 10:37-43, Fig. 5. Similarly,

if, for example, a user used an interface to arrange sound sources such as GUI that is used for "spatial audio mapping" where icons representing sound sources as described by Begault, persons of ordinary skill in the art would understand that the icons are "virtual images." And persons of ordinary skill in the art would have also understood that corresponding virtual images of the arranged sound sources (e.g., a computer monitor) could and would be displayed in the virtual environment at their designated locations. Begault (Ex.1007) at 172-73, Fig. 5:12 (GUI for "arranging [] various sound inputs" such that "relative location of the icons" are "commands to a multiinput, 3-D sound spatialization subsystem").

341. Thus, Limitation 5[b] would have been obvious to persons of ordinary skill in the art over Pedrotti and Jang or Pedrotti, Jang, and Begault.

e. Claim 6

(1) 6[a]: "The method of claim 1 further comprising: selecting the one of the multiple SLPs in the zone when the PED held in the hand of the user is pointed at the one of the multiple SLPs in the zone; and"

342. For the same reasons as I described for limitation 1[c], limitation 6[a] would have been obvious to persons of ordinary skill in the art. *See* Section X.A.3.d.

343. Also, as I discussed above with respect to limitation 1[c], it was well known that one could use pointing to select in VR, as well as highlighting to indicate selections. *See* Section X.A.3.d; *see also* Section VII.D (discussing tracking

handheld controllers)*;* Jerald, THE VR BOOK (Ex.1063) at 314-15 ("Tracked hand-held controllers are currently the best option for a majority of interactive VR applications. ***Tracked hand-held controllers are easy to use for many 3D tasks due to their natural, direct mapping to hand motion***.") (emphasis added). Indeed, "the Pointing Pattern is one of the most fundamental and often-used patterns for selection." Jerald, THE VR BOOK (Ex.1063) at 327.

344. Further, Pedrotti discloses the selection of objects by extending one's hands towards objects and pressing a button or issuing commands. *See, e.g.*, Pedrotti (Ex.1005) at 9:34-40 (describing the selection of a virtual weapon, "[t]hen, upon the user's extending his or her physical hand(s) in such a way as to cause the corresponding virtual hand(s) to 'reach for' the displayed virtual weapon and the user's activating a proper command (e.g., by pressing a button on the controller), the processor can cause the HMD to display the user's virtual hand(s) 214 as 'picking up' and holding that virtual weapon.") and 9:41-46 (describing selecting a virtual sword, "FIG. 8 shows one example of what a user might see in a virtual world after the user has extended the user's physical right hand to cause the virtual right hand to extend toward a virtual sword displayed in the virtual world on the HMD, and then entered the appropriate command to pick up the virtual sword 802.").

345. Thus, selecting an SLP when a PED (e.g., Pedrotti's controller) is pointed at it would have been obvious over Pedrotti and Jang, or over Pedrotti, Jang, and Begault.

(2) 6[b]: "displaying, with the WED worn on the head of the user, a virtual image at the one of the multiple SLPs in response to the one of the multiple SLPs being pointed at by the PED held in the hand of the user."

346. For the same reasons as I described for limitations 1[a], 5[a], 5[b] and 6[a], limitation 6[b] would have been obvious to persons of ordinary skill in the art for the same reasons as limitations 1[a], 5[a], 5[b] and 6[a]. *See* Sections X.A.3.b, X.A.4.d(1), X.A.4.d(2), X.A.4.e(1).

347. As I explained above with respect to claim 5, a Pedrotti-Jang or Pedrotti-Jang-Begault system could and would, with Pedrotti's HMD, display a virtual image associated with an SLP when a user points Pedrotti's controller at the SLP and its image because that would assist the user in moving the selected object from one location to another. One example of this would be the user pointing at and selecting a virtual image of the pep band virtual object in Jang's basketball court environment to aid in moving that object from one location to another.

f. Claim 7: "The method of claim 1, wherein the zone has one of a three-dimensional (3D) shape of a cylinder and a 3D shape of a rectangle, and the user is centered in the zone."

348. Pedrotti taught, or at a minimum rendered obvious to persons of ordinary skill in the art, claim 7.

349. As explained above, Pedrotti's system defines the boundary for Pedrotti's zone by having a user "walk around a perimeter chosen by the user," which thus allows a user to define "the outer boundary of a selected area" "with one of the trackers." Pedrotti (Ex.1005) at 14:56-62, Fig. 14; *see also* Section X.A.3.b (limitation 1[a]). Thus, the user can define any shape desired, including a cylinder or a rectangle, for the zone which the user will remain in while in the virtual world. Indeed, Pedrotti does not limit the shape of the zone; rather, it is customizable and could be rectangular. Pedrotti (Ex.1005) at 14:56-15:3 (allowing definition of "an irregularly shaped area" and based on "sampling points as the user moves around the chosen perimeter").

350. Persons of ordinary skill in the art would have known that a user could and would define the boundary in a shape of circle or rectangle for Pedrotti's zone because, for example, one of those two shapes would be suitable or advantageous for the user's VR gameplay area. For example, a rectangular shape would have been advantageous for users looking to maximize gameplay space and the shape of the zone could and would be set to the size of the entire room that the user is in. And a rectangular shape would have been obvious for this very reason: it mirrors physical spaces of the user (rooms typically are rectangular), or virtual spaces that similarly

mirror physical spaces. *See* Jang (Ex.1006) at Fig. 6 (depicting rectangular basketball court and conference room).

351. Pedrotti discloses that the boundary could be and would be circular. Pedrotti (Ex.1005) at 14:6-12 ("The boundary of the selected area may be determined in several ways. In some embodiments, a person, such as the user or another person, for example the parent of a child user, may input information into the processor indicating that there is a circular area in front of the base station and having a measured diameter that is clear of objects. FIG. 12 illustrates this configuration."). Further, Pedrotti discloses specifying a circular zone where the user is in the center. Pedrotti (Ex.1005) at 14:13-22 ("In one embodiment, the information input to the processor is determined by activating one of the trackers, either in the HMD or a handheld controller, at a position 1204 directly in front of a base station 1202. From the position 1204 of the tracker (and the position of a base station tracker if, for example, the electromagnetic field source or camera are not in the base station), the processor can determine how far away the tracker is from the base station 1202, and then determine a circular area 1206 having a radius of that distance centered at that point 1204."). Persons of ordinary skill in the art would have understood that the zone specified by such a circle, within which the user is centered, is a cylinder in the three-dimensional model of the world, otherwise the boundary would not function for its intended purpose. For example, Pedrotti

provides examples of actions to be taken if "the user's head or hands go beyond the boundary as determined by the trackers." Pedrotti (Ex.1005) at 13:63-67 ("If the user's head or hands go beyond the boundary as determined by the trackers, the processor can provide additional messaging or warning, such as text or auditory warnings, or an additional visual warning, that persists until the user returns to the selected area within the boundary."). Persons of ordinary skill in the art would have understood that to "go beyond" the circle disclosed by Pedrotti would mean intersecting the surface of a cylinder of infinite length extending vertically above (and below) the circle. Further, Pedrotti discloses a "cylindrical projection" of its "virtual fence," which persons of ordinary skill in the art would have known and understood to support the rendering of a cylindrical fence. Pedrotti (Ex.1005) at 13:12-33, 15:13-22 (information defining the boundary "may be the radius and location of the center of a circle of a determined diameter that is clear of obstacles"), Figs. 12-13.

352. Pedrotti's "virtual fence" showing the boundary of these zones would (or at a minimum obviously would) have the 3D shape of a cylinder or rectangle, respectively, extending up from the floor.

353. Persons of ordinary skill in the art would have known that a user could and would be centered in a cylindrical or rectangular Pedrotti zone. First, persons of ordinary skill in the art would have known that in a 3D virtual environment, it

would be advantageous for the user to be centered in the zone to both avoid leaving the zone as well as allow the user to interact with VR content in all directions. Second, persons of ordinary skill in the art would have understood that the user can walk around in the zone, including to its center. A person of ordinary skill in the art also would have known that virtual reality objects can be repositioned so that the user can remain centered in a VR zone. *See* Cohen 1993 (Ex.1053) at 473 ("Sinks and sources may be repositioned, individually or in groups. (Association is discussed later in Section 2.5.) Since the spatial sound object states include both angular and rectangular attributes, they may be rotated as well as translated. This repositioning may be by either direct or indirect manipulation, may be (rectilinearly or latticed) constrained or unconstrained, may be continuous or discrete, nonconvergent or convergent to some target, and may be absolute or relative to the starting position of the icon (Cohen 8c Koizumi, 1992a).").

354. For these reasons, Pedrotti taught or rendered obvious claim 7.

g. Claim 8: "The method of claim 1 further comprising: playing, with speakers in the WED worn on the head of the user, a verbal instruction indicating the user should move back into the zone in response to the WED determining that the user moved outside the zone."

355. Pedrotti taught, or at a minimum rendered obvious, claim 8.

356. As I previously explained, Pedrotti disclosed "generat[ing] an audio warning" which indicates that the user should move back into or remain in the zone

by "providing a warning that the user is about to move out of the selected area." Pedrotti (Ex.1005) at 2:44-59, 4:37-44, 12:31-50 (describing the processor "tracking the position and orientation" of the user's hands and head), 16:53-58; *see also* Section X.A.3.c (limitation 1[b]). Pedrotti's warnings can be presented if a user "goes beyond the boundary," to "direct[] the user to move in the direction of the boundary and the selected area." Pedrotti (Ex.1005) at 2:8-12, 3:65-67, 13:44-45 ("It is also possible to include auditory warnings instead of, or in addition to, a visual warning."), 13:67-14:5, 15:66-16:9, 16:43-45, Fig. 15 (showing a flowchart that outlines a method of assisting a user wearing an HMD in remaining in a selected area).

357. Persons of ordinary skill in the art would have known that a verbal instruction is an obvious "audio warning" that could and would be implemented in Pedrotti's HMD. Audio warnings, including verbal instructions and cues, were commonly used in chaperone systems, and more broadly to aid in navigation. Jerald, THE VR BOOK (Ex.1063) at 240 (explaining that "[v]ital information can be conveyed through spoken language (Section 8.2.3) that is either synthesized, prerecorded by a human, or live from a remote user. The spoken information might be something as simple as an interface responding with 'confirmed' or could be as complex as a spoken interface where the system both provides information and responds to the user's speech"); Gum (Ex.1015) at [0037] ("In the embodiment of

FIG. 8, the boundary setting mode includes an application that is resident on the wireless communications device, and provides an interface with a user to a graphical, audio, and/or physical interface…The wireless communications device may also provide information through an audio interface such as a speaker integrated within the device, or a headset worn by a user and linked (through a cable or wirelessly) to the wireless communications device."); Sawyer (Ex.1036) at [0042] ("a warning sound"), [0047] ("a custom warning specific to the virtual environment is made (e.g., an in-game character tells the user to stop walking when the user approaches the boundaries of the operating space)"); Kobayashi (Ex.1019) at Fig. 4, 10:49-60 ("In step S204, the CPU 101 determines whether or not the viewpoint position of the apparatus user exists in the safe area 40 described in FIG. 8, based on the viewpoint position of the apparatus user converted in step S203 and the plurality of boundary-measured values stored in the RAM 102. If the viewpoint position does not exist inside the safe area 40, warning sound is outputted. The warning sound may be changed from the case where the viewpoint position exists in the warning area 50 to the case where the viewpoint position does not exist in the safe area 40 or the warning area 50 (exists outside the movable area 60)."), 13:20-28 ("the CPU 101 reads out of the RAM 102 the warning sound data warning that the user is inside the warning area 50 or outside the moveable area 60, and outputs the warning sound data to the audio output device 103 … to clearly notify the user of this apparatus that

the user is currently near the boundary of the moveable area 60"), cl. 5 ("The method according to claim 1, wherein said notification is to output predetermined sound."); Begault (Ex.1007) at 171 (stating that "aural cues in virtual reality" often are "a means of replacing tactile sensation (haptic feedback) that would normally occur in a real environment," such as "activating auditory information in the form of a bumping or crashing sound, [so that] the user receives feedback that a particular physical boundary has been violated"); *see also* Ross (Ex.1125) at 1:33-39 (explaining the general principle of "re-direct[ing] the attention" of the user, such as through "loud noises and/or characters telling and/or showing the [user] where to look"); Gallery (Ex.1014) at 4:22-30 ("an audio alarm may be triggered … to the headphone speakers").

358. Further, persons of ordinary skill in the art would have known that Pedrotti's HMD could and would have speakers, and that those speakers could and would be used to generate "audio warnings." As indicated by Pedrotti, sound is one of the most important sensory signals for virtual reality experiences. Pedrotti (Ex.1005) at 1:18-20 ("While virtual reality can recreate a number of sensory experiences, the senses most commonly used today to create virtual reality appear to be sight and sound."). Speakers were routinely used with or included in HMDs before February 2016. *See, e.g.*, Jang (Ex.1006) at 1:44-45 ("Sound of a virtual reality system may be generated by speakers"), 7:5-6 ("sensory output unit 120 may

include speakers"); Pausch (Ex.1076) at 194-95 ("The HMD contained two speakers that rested close to, but not in physical contact with, the guest's ears"); Gallery (Ex.1014) at 4:22-30 ("an audio alarm may be triggered … to the headphone speakers"); Sawyer (Ex.1036) at [0042] ("a warning sound"), [0047] ("a custom warning specific to the virtual environment is made e.g., an in-game character tells the user to stop walking when the user approaches the boundaries of the operating space"); Kobayashi (Ex.1019) at 13:20-28 ("the CPU 101 reads out of the RAM 102 the warning sound data warning that the user is inside the warning area 50 or outside the moveable area 60, and outputs the warning sound data to the audio output device 103 … to clearly notify the user of this apparatus that the user is currently near the boundary of the moveable area 60").

359. Using a speaker in a WED to provide a warning in the form of a verbal instruction would have required no more than using known components (speakers) to provide a known function (providing a warning) using known methods (e.g., through a verbal instruction).

360. For these reasons, Pedrotti taught or rendered obvious claim 8.

5. Independent Claim 9

a. 9[pre]: "A non-transitory computer readable storage medium storing instructions that one or more electronic devices execute as a method, the method comprising:"

361. To the extent the preamble is limiting, both Pedrotti and Jang disclose it. As I explained for limitation 1[pre], both Pedrotti and Jang disclose methods. *See* Section X.A.3.a.

362. Pedrotti discloses "a non-transitory computer-readable medium having embodied thereon a program … executable by a processor to perform a method of assisting a user wearing a head-mounted display (HMD) in remaining within a selected area of the physical world." Pedrotti (Ex.1005) at 2:60-3:12 (further describing that "instructions [go] to the HMD"). Pedrotti's "Program" refers to the instructions that are executed by at least an electronic device, e.g., Pedrotti's HMD.

363. Similarly, Jang discloses that the "features and/or utilities" it describes "may be realized by a computer-readable medium having stored thereon a computer program to execute [Jang's] method." Jang (Ex.1006) at 4:45-55, 3:16-19 (also referencing "a computer readable medium to store sensory data … and to output sensory data to the control unit"), 12:57-63 (similar). According to Jang, a "virtual reality device executes the code," or computer program. Jang (Ex.1006) at 6:5-20.

b. 9[a]: "dividing, with a portable electronic device (PED) held in a hand of a user, an area around the user into a zone that includes sound localization points (SLPs) in empty space from where binaural sound originates to the user;"

364. For the same reasons as I described for limitation 1[a], limitation 9[a] would have been obvious to persons of ordinary skill in the art over Pedrotti in view of Jang. *See* Section X.A.3.b.

365. In addition, persons of ordinary skill in the art would have known and understood that the audio sources (SLPs) described for Jang's sound areas could and would be in "empty space" because they are audio sources in virtual space and not on physical objects. Jang (Ex.1006) at 4:19, 4:45-55 (disclosing "sensory sources" and "audio sources" in virtual space). Further, in the context of the '509 patent, empty space is any space not occupied by a physical object. *See* '509 patent (Ex.1001-509) at 6:1-5.

c. 9[b]: "determining, with a wearable electronic device (WED) worn on a head of the user, when the user is located inside the zone;"

366. For the same reasons as I described for limitation 1[b], limitation 9[b] would have been obvious to persons of ordinary skill in the art over Pedrotti in view of Jang. *See* Section X.A.3.c.

d. 9[c]: "determining, with the WED worn on the head of the user, when the user is leaving the zone; and"

367. For the same reasons as I described for limitations 2[a] and 3[a], limitation 9[c] would have been obvious persons of ordinary skill in the art. *See* Sections X.A.4.a(1), X.A.4.b(1).

368. Pedrotti's trackers provide the HMD-based processor information regarding position, orientation, and inertia, and the processor then determines when the user is approaching Pedrotti's boundary or when the user "is leaving" the zone. Pedrotti (Ex.1005) at 2:60-3:12 (describing that "instructions [go] to the HMD"), 5:8-24 (disclosing the use of "inertial sensors (e.g., accelerometers and/or gyroscopes)," 16:20-24 ("processor may be located … in the HMD").

369. I again note that Pedrotti's HMD display a virtual fence when a user approaches its boundary and that Pedrotti's manner of operating its "grid-shaped virtual fence" is nearly identical to what 8K contends in district court satisfies limitation 9[c]:



'509 8K Infringement Contentions (Ex.1129) at 7.

e. 9[d]: "displaying, with the WED worn on the head of the user, a three dimensional (3D) virtual image of the

zone in response to the WED determining that the user is leaving the zone."

370. For the same reasons as limitations 2[b], 3[b], and 9[c], limitation 9[d] would have been obvious to persons of ordinary skill in the art. *See* Sections X.A.4.a(2), X.A.4.b(2), X.A.5.d.

371. Additionally, I note again that the way Pedrotti's "grid-shaped virtual fence" operates is nearly identical to what 8K contends in district court satisfies limitation 9[d]. *Compare* Pedrotti (Ex.1005) at Fig. 11, *with* '509 8K Infringement Contentions (Ex.1129) at 8.

372. Pedrotti's HMD display's a virtual fence when a user approaches its boundary and zone, and it could (or at a minimum obviously could) display its fence when a user "is leaving" that zone. *See* Sections X.A.4.a(2), X.A.4.b(2), X.A.5.d.

6. Dependent Claims 10-14

373. I understand that claims 10-14 depend on independent claim 9.

374. Thus, it is my opinion that each of dependent claims 10-14 would have been obvious to persons of ordinary skill in the art for the same reasons as independent claim 9 and additionally for the reasons I discuss in the following subsections.

a. Claim 10

(1) 10[a]: "The non-transitory computer readable storage medium of claim 9 in which the method further comprises: determining, with the WED,

when the PED is pointed at one of the SLPs while the user is located in the zone; and"

375. For the same reasons as I described for limitations 1[c], 2[a], 4[a], and 5[a], limitation 10[a] would have been obvious to persons of ordinary skill in the art. *See* Sections X.A.3.d, X.A.4.a(1), X.A.4.c(1), X.A.4.d(1).

376. First, Pedrotti's HMD tracks a PED's (or controller's) position and orientation. *See* Section X.A.3.d (limitation 1[c]). And as I explained above for limitation 4[a], it would have been obvious to store SLP locations in Pedrotti's HMD's memory. Section X.A.4.c(1).

377. Further, because pointing involves placing the PED in a particular direction (i.e. the controller's orientation) from a particular location (i.e. the controller's position), it would have been obvious to a person of ordinary skill in the art to determine when the PED is pointed at an SLP by, for example, tracing this vector to determine whether the vector it intersects an SLP's location. *See* Jerald, THE VR BOOK (Ex.1063) at 327 ("Pointing Pattern extends a ray into the distance and the first object intersected can then be selected"). Indeed, pointing to interact in the virtual environment, including to select, was well known, as I explained above for limitation 1[c]. *See* Sections X.A.3.d

378. Further, it would have been obvious to persons of ordinary skill in the art for this determination to be made while the user is located in the zone. Pedrotti's

zone defines the user's "safe area" for gameplay, and thus, pointing while in the virtual world (as well as any other action) could and would be done by the user while in the zone since the user must be in the zone to play a game in the virtual environment.

(2) 10[b]: "playing the binaural sound that originates from the one of the SLPs in the zone in response to the WED determining that the PED is pointed at the one of the SLPs."

379. For the same reasons as I described for limitations 1[c], 1[d], and 10[a], limitation 10[b] would have been obvious to persons of ordinary skill in the art. *See* Sections X.A.3.d, X.A.3.e, X.A.6.a(1).

380. As explained above, playing binaural sound in response to pointing to a SLP is a common cause-and-effect in a VR environment. For example, a user partaking in a virtual sword fight may "point" or direct the controller (e.g., the sword shown in Pedrotti) to strike a virtual enemy, which emits a sound of defeat. As another example, a user in a virtual conference room who chooses to interact with another user (displayed via an avatar and an SLP) may point to the other user's avatar to begin a conversation.

b. Claim 11: "The non-transitory computer readable storage medium of claim 9 in which the method further comprises: highlighting, while the user is located in the zone and with a display of the WED, a virtual image at one of the SLPs in the zone when the PED held in the

hand of the user is pointed at the one of the multiple SLPs in the zone."

381. For the same reasons as I described for limitations 1[c], 5[a]-5[b], and 6[b], claim 11 would have been obvious to persons of ordinary skill in the art. *See* Sections X.A.3.d, X.A.4.d(1), X.A.4.d(2), X.A.4.e(2).

c. Claim 12: "The non-transitory computer readable storage medium of claim 9, wherein the 3D virtual image of the zone is shaped as a cylinder with the user being centered in the cylinder, and the WED is one of a head mounted display and electronic glasses."

382. For the same reasons as I described for claim 7, claim 12 would have been obvious to persons of ordinary skill in the art. *See* Section X.A.4.f. Indeed, if the zone itself has the shape of a cylinder, its image too has the shape of a cylinder. Further, as noted above, Pedrotti's system uses a head mounted display (WED). *See* Pedrotti (Ex.1005) at 2:44-47.

d. Claim 13: "The non-transitory computer readable storage medium of claim 9, wherein the 3D virtual image of the zone is shaped as a rectangle with the user being centered in the rectangle, and the WED is one of a head mounted display and electronic glasses."

383. For the same reasons as I described for claim 7, claim 13 would have been obvious to persons of ordinary skill in the art. *See* Section X.A.4.f. As I discussed for claim 7, Pedrotti discloses specifying a circular zone where the user is in the center. Pedrotti (Ex.1005) at 14:13-22. Pedrotti also discloses that the zone can be any desired shape or configuration. Pedrotti (Ex.1005) at 15:53-55 ("Also as

above, in various embodiments, the processor can generate the visual warning in the form of grid lines or a virtual fence, or in any other desired shape or configuration."). If the zone itself has the shape of a rectangle, its 3D virtual image too has the shape of a rectangle. Pedrotti discloses, and persons of ordinary skill in the art would have known, that "[t]o minimize rendering cost, the fence may be rendered as a projected texture on small pieces of 3D geometry that cover only the areas where the fence is to be visible."). Pedrotti (Ex.1005) at 13:17-20. Persons of ordinary skill in the art would have understood that zones with planar surfaces, such as rectangles (cubes), have the lowest rendering cost, and the lowest distance and intersection computational cost, compared to circles and irregular shapes. Thus, persons of ordinary skill in the art would have found it obvious to use rectangles (cubes) when and where possible. Further, a rectangular shape would have been obvious because it mirrors physical spaces (e.g., rooms). *See* Jang (Ex.1006) at Fig. 6 (rectangular virtual basketball court and conference room). Persons of ordinary skill in the art would have understood that the zone could be rectangular in shape, which is a common and obvious shape to use in defining zones so that they mirror physical spaces—as rooms typically follow rectangular floorplans.

e. Claim 14: "The non-transitory computer readable storage medium of claim 9 in which the method further comprises: playing, with the WED worn on the head of the user, a verbal instruction indicating the user should

move back into the zone in response to the WED determining that the user moved outside the zone."

384. For the same reasons as I described for claim 8, Claim 14 would have been obvious to persons of ordinary skill in the art. *See* Section X.A.4.g.

7. Independent Claim 17

a. 17[pre]: "The electronic system comprising:"

385. To the extent the preamble is limiting, both Pedrotti and Jang disclose this. Pedrotti discloses an electronic "system" (that includes an HMD and handheld controller) to "assist a user in remaining in a selected area of the physical world," which is an electronic system. Pedrotti (Ex.1005) at 2:44-59. Similarly, Jang discloses an "apparatus" (e.g., an HMD) that includes "a sound processing unit" and "control unit" used "to perform sound processing in a virtual reality system." Jang (Ex.1006) at 2:26-47; *see also* Sections X.A.3.a (1[pre]), X.A.5.a (9[pre]).

b. 17[a]: "a portable electronic device (PED) held in a hand of a user that divides an area around the user into a three-dimensional (3D) zone that includes sound localization points (SLPs) in empty space from where binaural sound originates to the user; and"

386. For the same reasons as limitations 1[a], 2[b], and 9[a]., limitation 17[a] would have been obvious to persons of ordinary skill in the art. *See* Sections X.A.3.b, X.A.4.a(2), X.A.5.b. In addition, Pedrotti's described "safe" area is the claimed three-dimensional zone because it is the zone in a 3D virtual environment in which the user plays a game that is bound by Pedrotti's boundary and virtual fence. This

zone extends (or at a minimum obviously extends) around the user. Pedrotti (Ex.1005) at Figs. 11 ("virtual fence 1114"), 14 ("boundary 1404")), and SLPs (and their associated images) are included in empty space in this zone for the reasons I described in claim limitation 2[b].

c. 17[b]: "a wearable electronic device (WED) that is worn on a head of the user,"

387. Pedrotti's system comprises an HMD, which is a WED worn on the head of a user. *E.g.*, Pedrotti (Ex.1005) at 2:44-47; *see also* Section X.A.3.c.

d. 17[c]: "wirelessly communicates with the PED,"

388. Pedrotti taught, or at a minimum rendered obvious, a WED that communicates wirelessly with the PED.

389. Pedrotti discloses that the HMD is able to communicate wirelessly specifically with the handheld controllers. Pedrotti (Ex.1005) at 4:49-5:24 (disclosing multiple methods of wireless tracking the controller, e.g., tracking through "sensed magnetic field[s]," "electromagnetic coupling," "light-emitting trackers," "radar," and "ultrasonic" sensing devices), 5:28-34. Persons of ordinary skill in the art would have understood that these tracking methods could and wood be implemented wirelessly and would be motivated to do so to minimize wires which could pose hazards to users wearing the HMD while interacting in a virtual world.

e. 17[d]: "includes speakers that play the binaural sound to the user that emanates from the SLPs in empty space,"

390. For the same reasons as I described for limitations 1[d] (binaural sound) and 9[a] (empty space) and claim 8 (speakers), limitation 17[d] would have been obvious to persons of ordinary skill in the art. *See* Sections X.A.3.e, X.A.5.b, X.A.4.g.

391. Additionally, Jang discloses speakers that play this binaural sound, which is an obvious way to deliver audio. Jang (Ex.1006) at 1:38-45 ("[a]n image of a virtual reality system may be three-dimensionally realized by using a monitor, a Head Mounted Display (HMD), a television, a projector, or any other visual display device … the sound of the virtual reality system may use a localization technique capable of expressing the virtual location" and "may be generated by speakers, a headset, or any other audio device").

f. 17[e]: "includes one or more sensors that sense when the PED leaves the zone,"

392. For the same reasons as limitation 2[a], limitation 17[e] would have been obvious to persons of ordinary skill in the art. *See* Section X.A.4.a(1). In addition, persons of ordinary skill in the art would have also known and found obvious that sensing when a PED "moves outside the zone" (as in limitation 2[a]) and sensing when a PED "leaves the zone" (as in limitation 17[e]) involves the same

type of sensing and processing by the same components, i.e. the sensors and WED, respectively.

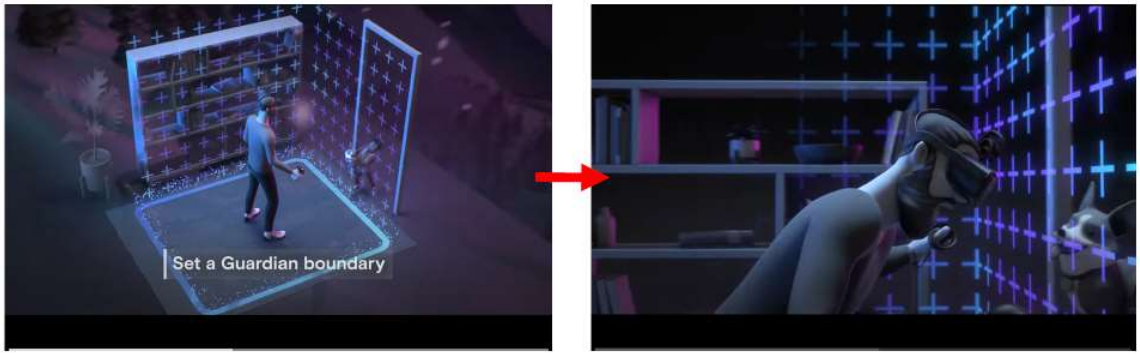
g. 17[f]: "and includes a display that displays a 3D virtual image of the zone in response to sensing that the PED leaves the zone,"

393. For the same reasons as I describe for limitations 2[b] and 17[e], limitation 17[f] would have been obvious to persons of ordinary skill in the Art. *See* Sections X.A.4.a(2), X.A.7.f.

h. 17[g]: "wherein the display displays the 3D virtual image of the zone to warn the user that the user is leaving the zone."

394. For the same reasons as I describe for limitation 3[b], limitation 17[g] would have been obvious to persons of ordinary skill in the art. *See* Section X.A.4.b(2); *see also* Section X.A.3.d (discussing the warnings Pedrotti's system delivers); Pedrotti (Ex.1005) at 12:40-50 (system "generates a warning" when the user is leaving the zone).

395. Again, I note that Pedrotti's HMD displays a virtual fence when a user approaches its boundary and is nearly identical to how 8K contends in district court that the accused products satisfy limitation 17[g]:



'509 8K Infringement Contentions (Ex.1129) at 17 (8K's red annotation, and stating that "displaying of the zone … serves as a warning to the user that the user is leaving the zone").

8. Dependent Claims 18-20

396. I understand that claims 18-20 depend on independent claim 17.

397. Thus, it is my opinion that each of dependent claims 18-20 would have been obvious to persons of ordinary skill in the art for the same reasons as independent claim 17 and additionally for the reasons I discuss in the following subsections.

a. Claim 18: "The electronic system of claim 17, wherein the display of the WED highlights a virtual image at one of the SLPs in response to the WED determining that the PED is pointing to the one of the SLPs."

398. For the same reasons as I describe for limitations 1[c] and 6[b], claim 18 would have been obvious to persons of ordinary skill in the art. *See* Sections X.A.3.d, X.A.4.e(2).

b. Claim 19: "The electronic system of claim 17, wherein the WED tracks a location of the user with respect to the SLPs, and automatically display a virtual image at a location of one of the SLPs in response to determining that the user is proximate to the location of the one of the SLPs."

399. For the same reasons as I describe for limitations 2[a] and 3[a], 4[a], and 6[b], claim 19 would have been obvious to persons of ordinary skill in the art. Sections X.A.4.a(1), X.A.4.b(1), X.A.4.c(1), X.A.4.e(2).

400. Pedrotti discloses automatically displaying virtual imagery when the user is close to real or virtual objects. For example, Pedrotti discloses automatically displaying a pair of virtual hands when the user is proximate to the physical base station. Pedrotti (Ex.1005) at 7:1-10 ("Thus, as the user approaches the virtual base station 210 presented on the display, the processor receiving information from tracker 108 (and from the base station tracker where appropriate) can determine that the user is also approaching the physical base station. FIG. 3 shows what a user might see in the virtual world in one embodiment as the user has approached the virtual base station 210 in the virtual world and is looking down towards it, and is also approaching the physical base station in the real world."), 7:16-19 ("In addition, the instructions from the processor now also cause the display to generate two virtual hands 214 (with a portion of the forearms) reaching toward the virtual base station 210.").

401. Additionally, as Pedrotti discloses automatically displaying the virtual fence when the user nears the user-defined boundaries, it would have been equally obvious to persons of ordinary skill in the art to have this logic apply to virtual objects associated with SLPs within Pedrotti's virtual games. *See* Pedrotti (Ex.1005) at 4:37-44 ("The processor … generates instructions to the HMD to include in a display of a virtual world a visual warning such as a grid or virtual fence when the user comes within a preselected distance of the boundary"). That would require no more than using the same action (displaying an image) after determining the same information (that a user is proximate to a location) using the same devices (Pedrotti's PEDs and HMD).

402. Further, displaying virtual images at the locations of their sound sources (SLPs), and doing so automatically when users approach was a well-known VR effect. In a VR game, an example of this is when a user is exploring an area and travels within distance of another character so that the other character appears on the screen for additional interactions. Another example, described in Cohen 1993 that is referenced by Begault, is in zooming effects that allow a user to navigate large spaces or dense point sources where distance sources are not displayed by default but only when the user approaches. Cohen 1993 (Ex.1053) at 475 (describing "a cluster feature": "Distant sources would not be displayed; but as it approaches, a cluster would appear as a single point; only to disassociate and distribute spatially

as it gets closer. This focus allows navigation in arbitrarily large spaces, assuming a limited density of point sources."). Doing so allows the presentation of certain content of interest to the user while pausing (or otherwise not presenting content) on which the user is not focused. *See* Ross (Ex.1125) at 2:32-67 ("primary virtual reality content may resume (e.g., automatically) when the user returns his view (e.g., and/or moves within the virtual space) to the primary field of view"), 4:21-39, 6:41-66 (describing primary, secondary, and tertiary virtual reality content presented to a user), 15:29-36 (explaining that "Content component 24 may be configured such that primary virtual reality content is presented to the user response to the user's view direction being within a first field of view….and secondary virtual reality content may be presented to the user when the user's view direction is within a second field of view").

c. Claim 20: "The electronic system of claim 17, wherein the speakers in the WED play the binaural sound that emanates from one of the SLPs in empty space in response to the WED determining that the PED is pointed to the one of the SLPs in empty space."

403. For the same reasons as I describe for limitation 1[d] and claim 10, claim 20 would have been obvious to persons of ordinary skill in the art. *See* Sections X.A.3.e, X.A.6.a.

* * *

404. For the reasons discussed above, every limitation in claims 1-14 and 17-20 of the '509 patent, and each of claims 1-14 and 17-20 as a whole, would have been obvious over Pedrotti in view of Jang, and further in view of Begault.

B. Ground 2: Claims 1-14 and 17-20 Are Unpatentable Over McCulloch In View Of Pedrotti, And Further In View Of Flaks

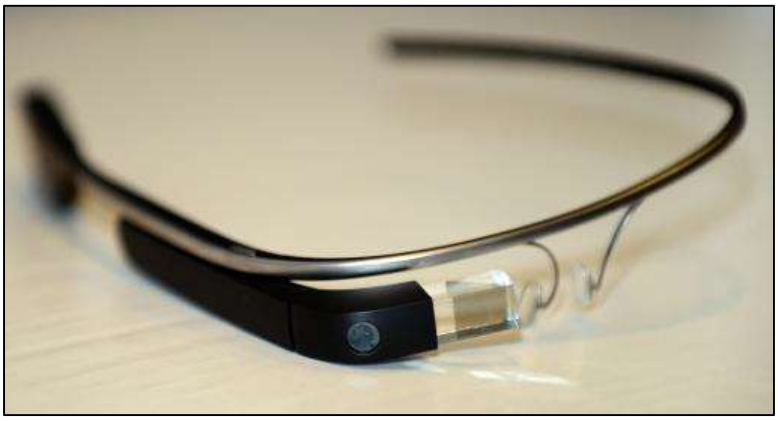
405. In this section, I explain why every limitation of claims 1-14 and 17-20 of the '509 patent, and each of claims 1-14 and 17-20 as a whole, would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, and further in view of Flaks.

1. Reasons Persons Of Ordinary Skill In The Art Would Combine McCulloch and Pedrotti

406. Persons of ordinary skill in the art would have been motivated to combine McCulloch's system Pedrotti's systems and methods for implementing safety boundaries that define a user's playspace.

407. First, McCulloch and Pedrotti are analogous art. McCulloch is a system for "controlling a virtual object displayed by a near-eye, augmented reality display with a real controller device." McCulloch (Ex.1008) at 1:18-21, 1:46-48, Fig. 5. Persons of ordinary skill in the art would have known that Pedrotti's systems and methods—which are aimed at preventing "collisions with surrounding physical objects" and "remain[ing] in a safe area"—apply to AR systems because Pedrotti expressly encourages persons of ordinary skill in the art to use boundaries with AR

and VR display devices alike (e.g., WEDs or HMDs), including see-through HMDs, such as Google Glass, and systems where a portion of the user's perception of real objects is occluded:



Phys.org, *Google Glass Available in US as of April 15* (Apr. 10, 2014) (Ex.1078) at 1; Pedrotti (Ex.1005) at 2:4-12 ("when using a HMD the user is unable to see those nearby objects while in the virtual world"), 16:10-19 ("[V]arious embodiments may be applicable to HMDs that block the user's view of all or only part of the physical world. Even some uses of a device such as Google Glass, which obscures only a small portion of the user's field of vision of the physical world, may benefit from some embodiments described herein."); Jerald, THE VR BOOK (Ex.1063) at 32-33 (describing non-see-through HMDs, video see-through HMDs, and optical-see-through HMDs as existing on a spectrum), Fig. 3.1 (similarly describing AR and VR on a continuum); *see also* Section VII.G (discussing how AR systems also benefit from safety or chaperone systems).

408. McCulloch also expressly discloses that "a gaming application may receive user input identifying boundaries for a playspace in which virtual objects can be positioned." McCulloch (Ex.1008) at 20:11-13. And persons of ordinary skill in the art would have recognized that Pedrotti's "safe area" serves the same function of McCulloch's boundaries, which are part of McCulloch's "virtual environment rules" that "provide fallback rules or alternative rules based on the real objects and real features mapped in the user environment" and are "a factor in the execution of a game." McCulloch (Ex.1008) at 20:22-25, 20:4-11 ("applications store adaptive virtual environment rules [] for effecting the placement and display of one or more virtual objects in a 3D mapping of an environment"). For instance, Pedrotti's boundaries help "the user [to] remain within a selected area," or virtual environment, "if there are physical objects in the vicinity of the user." Pedrotti (Ex.1005) at 1:57-63, 11:44-52 (describing the user "physically located in the user's living room and playing a game within a virtual world").

409. Second, persons of ordinary skill in the art would have implemented Pedrotti's boundary system to prevent injury and property damage, which is a problem in both AR and VR environments. In such environments, the user risks personal injury and property damage from collisions, tripping hazards, etc. For example, if a user of McCulloch's system is flying a virtual helicopter, the user can be focused on the virtual helicopter and trip over a sofa. *See, e.g.*, McCulloch

(Ex.1008) at 12:51-54 (describing a virtual remote control helicopter as the "current object of focus in a display field of view"), 26:12-15 (explaining the user's divided attention, e.g., "[t]he user gets distracted and does not change the path [of the helicopter] via user input"); Pedrotti (Ex.1005) at 13:34-45 (visual warning appropriate "when the user is not looking in the direction" he is walking). As another example, if a user is battling virtual monsters that are occluding the user's view of a bookshelf, and the user thrusts his hand to attack a monster, the user risks injuring his hand on the bookshelf. *See, e.g.*, U.S. Patent Application No. 13/288,350 ("Mount 350") (Ex.1027) (incorporated by reference in McCulloch (Ex.1008) at 20:60-63), [0042] (describing virtual monsters). Persons of ordinary skill would have understood that Pedrotti's methods allow the user to stay within boundaries, which protect the user physically and help the user avoid these physical collisions, without disrupting immersivity of the user's experience.

410. Even as an Augmented Reality (AR) system, McCulloch's system is susceptible to safety issues stemming from the user's impeded ability to sense the real, physical environment, which necessitates Pedrotti's "safe area" or boundaries. Persons of ordinary skill in the art would have known and understood that virtual objects and effects in an AR paradigm can occlude the user's view of the real world—indeed such occlusions are intentional. For example, in his widely cited and well-known article titled "A Survey of Augmented Reality," Ron Azuma defines AR

as "allow[ing] the user to see the real world, with virtual objects superimposed upon or composited with the real world." Azuma, *A Survey of Augmented Reality* (1997) ("Azuma") (Ex.1112) at 356.

411. Persons of ordinary skill in the art would be very familiar with this fundamental concept of AR, and also understand that occlusion concerns are independent of the see-through technology (e.g., optical see-through" displays and "video see-through" ("video-see") displays), both of which are disclosed in McCulloch. McCulloch (Ex.1008) at 3:56-4:1, 9:38-45 (explaining how optical see-through systems overlay virtual imagery on the user's view of the real world). McCulloch also teaches this, as McCulloch explains the see-through nature of optical see-through displays. McCulloch (Ex.1008) at 3:56-61 ("a user wearing a see-through, augmented reality display device system actually sees with his or her natural sight a real object, which is not occluded by image data of a virtual object or virtual effects, in a display field of view of the see-through display, hence the names see-through display and optical see-through display").

412. Further, persons of ordinary skill in the art would have understood that determining real-virtual object occlusion relationships, such as carried out by McCulloch's occlusion engine 302, is an essential aspect of AR. When describing the function of the occlusion engine 302, McCulloch teaches that virtual objects shown in the HMD may occlude portions of the user's view of the physical world.

McCulloch (Ex.1008) at 20:64-21:4 (introducing the occlusion engine 302), 21:4-12 ("In the case of complete occlusion of a virtual object by a real object, the occlusion engine can notify the virtual data engine to not display the virtual object. In the case of complete occlusion of the real object by the virtual object, the virtual object or its parts can be sized to completely cover the real object and its parts. For partial occlusions, the display is updated to show part of the virtual object and part of the real object."), Fig. 4A.

413. Persons of ordinary skill in the art would therefore understand that both optical see-through and video see-through ("video-see") AR displays are susceptible to the same safety issues that VR displays are, stemming from the user's inability to see real world objects that are partially or fully occluded by virtual objects in the see-through AR display. For example, if an AR system user with a see-through display was attacking a virtual monster standing in front of (and visually occluding) a real (physical) chair in the room, and thrusting their hand holding the controller at the virtual monster, the user is unable to sense that chair's presence and could strike it with their hand (and the controller), thus hurting themselves. Persons of ordinary skill in the art would therefore be motivated to incorporate Pedrotti's "safe area" or boundaries. Pedrotti (Ex.1005) at 11:43-65 (identifying the need for warnings "[s]ince the display in the HMD blocks the user's view of the physical world, the physical objects are not visible to the user").

414. Third, McCulloch's system is directed to creating an immersive experience for the user, which causes the user to "unintentionally ignore the hazards of navigating in the real world," an effect that is compounded because AR is intended to blend real and virtual objects into one environment. McCulloch (Ex.1008) at 21:21-28 (providing localized sound for a more immersive experience), 23:39-42 (McCulloch's display "position[s] virtual objects so that they appear realistically at 3D locations determined for them in the display"), 26:7-19 (describing localized sound of a virtual helicopter crash because "[t]he user gets distracted and does not change the path via user input"); Sabelman (Ex.1088) at 49, 52 (AR wearables like Microsoft HoloLens increase the risk of injury because they use "the central visual field to display objects integrated into the real world" with "detailed, full-color, realistic objects."). As Sabelman explains, avatars and game characters are particularly distracting. Sabelman (Ex.1088) at 52 ("AR will win the struggle for attention" in these contexts). Other effects detrimental to a user's safety when using an AR device include reduced depth of focus, distance and speed perception, and reaction time. Sabelman (Ex.1088) at 51. As Azuma explains, "[a]fter the basic problems with AR are solved, the ultimate goal will be to generate virtual objects that are so realistic that they are virtually indistinguishable from the real environment." Azuma (Ex.1112) at 380.

415. Implementing a "safe area" or boundaries in McCulloch's AR environment would allow a user to more fully enjoy the immersive experience while counteracting the user's compromised ability to sense physical surroundings. In fact, in line with McCulloch's aim to deliver an immersive experience, Pedrotti's system also aims to maintain immersion by minimizing disruption of the game experience by automatically detecting the user's location in relation to the zone boundaries and displaying a virtual fence only when the user is a specified distance from the boundaries. Pedrotti (Ex.1005) at 11:66-12:3 (describing display of a virtual fence as the user gets closer to the boundary, all "without distracting the user from the immersive virtual world"); McCulloch (Ex.1008) at 26:35-48 (managing interaction between real and virtual objects "for more realism"), 20:28-29 (users "expect a certain quality of experience whenever an application is executed"), 23:39-51 (HMD should "position virtual objects so that they appear realistically at 3D locations"). Further, persons of ordinary skill in the art would have known and understood that immersion is a goal for both AR and VR systems. Jerald, THE VR BOOK (Ex.1063) at 29 (noting that, for AR, "ideally the human mind would not be able to distinguish between computer-generated stimuli and the real world"), 30 (noting that, for VR, "[t]he goal of virtual environments is to completely engage a user in an experience so that she feels as if she is present (Chapter 4) in another world").

416. Finally, because the systems of McCulloch and Pedrotti have essentially the same underlying functionality, including HMDs and full position and orientation tracking, persons of ordinary skill in the art would have had a reasonable expectation of success in applying Pedrotti's "safe area" to McCulloch's system. Both McCulloch's and Pedrotti's systems use 6DoF head and controller tracking that allows the user to physically walk around and interact with virtual objects. McCulloch (Ex.1008) at 4:25-31 (describing "a handheld inertial motion unit (IMU)" as an example of a real controller device), 8:17-39 (describing an "inertial sensing unit" and a "location sensing unit" in the HMD); Pedrotti (Ex.1005) at 1:21-29 (disclosing an HMD (WED), such as "the Oculus Rift from Oculus VR, now owned by Facebook"), 1:40-45 (disclosing a handheld controller (HPED)), 4:37-44 ("the processor similarly tracks the position and orientation of the HMD tracker, and possibly the position and orientation of one or more trackers in the physical controllers"), 16:20-24 ("processor may be located … in the HMD"); *see also* Jerald, THE VR BOOK (Ex.1063) at 484 ("the convergence of AR and VR is not new from a research perspective"; "the same hardware might be used for both"). As such, persons of ordinary skill in the art would have reasonably expected to implement Pedrotti's method of using the movement of a handheld PED to define a size and a shape of a three-dimensional (3D) zone with McCulloch's system.

417. Persons of ordinary skill in the art also would have known that McCulloch's HMD can and does capture and store playspace boundaries, and that McCulloch's system is able to store physical properties of virtual objects and display those objects. McCulloch (Ex.1008) at 20:4-27; *see also* McCulloch (Ex.1008) at 8:17-46 (describing inertial sensing unit 132 and image generation unit 120), 19:8-62 (describing storing virtual object properties), 23:25-38 (describing virtual data engine 195). Consequently, implementing Pedrotti's virtual fence for a safe area (i.e., a virtual object depicting a playspace's boundaries) with McCulloch's system and methods would have been routine, straightforward, and well within the skill of persons of ordinary skill in the art. Persons of ordinary skill in the art also would have been motivated to implement Pedrotti's virtual fence for at least the reasons I discuss in Section VII.G. I further address skilled artisans' reasonable expectation of success in additional detail below, e.g., in discussing the challenged claims.

2. Reasons Persons Of Ordinary Skill In The Art Would Combine McCulloch, Pedrotti, And Flaks

418. McCulloch expressly incorporates Flaks by reference into its specification, and does so specifically for Flaks' "positional 3D audio engine." McCulloch (Ex.1008) at 21:21-38; *see* Section IX.D (overview of McCulloch). Thus, Flaks is a constituent part of McCulloch's disclosures and, at a minimum, persons of ordinary skill in the art reading McCulloch and its description of a

computing environment 54 comprising a 3D audio engine 304 (McCulloch (Ex.1008) at 21:21-39, Fig. 4A) would have known to look to Flaks for implementation details for 3D audio, including details concerning how the positional 3D engine uses HRTFs to produce 3D localized audio, i.e., binaural sound. *See, e.g.*, Flaks (Ex.1009) at 1:9-12 ("Humans estimate the location of a source by taking cues derived from one ear, and by comparing cues received at both ears (difference cues or ***binaural*** cues).") (emphasis added), 1:40-46 ("[o]ne possible use of 3D audio is in augmented reality scenarios," "[f]or example, a user should be able to accurately localize a sound as coming from a virtual sound source"), 7:15-16 ("an HRTF for the listener is applied to form the 3D audio signal," where the HRTF may be "determined based on sensor determined characteristics" or selected from "a library of HRTFs"), 9:65-10:4 (similarly describing applying the listener's HRTF to generate the 3D audio signal), 14:32-39 ("the 3D audio signal is constantly being updated for the changing user position" and it is also possible to "update[e] the HRTF for the user in real time").[9]

[9] As was well known in the art, binaural sound reflects sound generated from audio cues accounting for sound perceived by each of a person's ears. *See* Jerald, THE VR BOOK (Ex.1063) at 100-01 ("Binaural cues (also known as stereophonic cues) are

419. Persons of ordinary skill in the art would have expected to succeed in implementing Flaks' 3D audio processing methods with McCulloch's system because McCulloch tells skilled artisans to use Flaks' teachings and because HRTFs have long been used to generate localized, binaural sound in HMDs. *See* Section VII.E; *see also*, *e.g.*, Srinivasan (Ex.1038) at 2:3-23, 11:48-12:1, Figs. 3, 7; Najaf-Zadeh (Ex.1030) at 4:55-5:26, Fig. 4; Agevik (Ex.1042) at [0034]-[0038], Figs. 1A-1B; Romigh (Ex.1035) at 1:22-48, 2:25-47.

3. Independent Claim 1

a. 1[pre]: "A method comprising:"

420. Both McCulloch and Pedrotti disclose methods.

421. McCulloch discloses a "method for controlling a virtual object" involving a HMD ("head mounted display device 2") and tracked HPEDs ("real controller device(s) 21"). McCulloch (Ex.1008) at 1:34-36, 4:49-55 (discussing HMD), 6:55-61 (discussing HPEDs), 12:41-48 ("requested actions indicated by real

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two different audio cues, one for each ear, that help to determine the position of sounds. Each ear hears a slightly different sound—different in time and different in level."); Begault (Ex.1007) at 41 ("binaural HRTF" is "terminology for referring to both left- and right-ear HRTFs").

controller device commands being applied and displayed from the user perspective" in the "display field of view"), Figs. 1A-1B.

422. Pedrotti also discloses a "method" of providing "visual assistance to a user in a virtual reality environment." Pedrotti (Ex.1005) at 2:27-59; *see* Section X.A.3.a.

b. 1[a]: "dividing, with a portable electronic device (PED) held in a hand of a user, an area around the user into a zone that includes multiples sound localization points (SLPs) from where binaural sound originates to the user;"

423. Limitation 1[a] would have been obvious to persons of ordinary skill in the art over McCulloch, either alone or with Flaks, in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section X.A.3.b (Ground 1, limitation 1[a]).

424. As I discussed above for Ground 1, 8K contends that limitation 1[a] requires only that there be an area, or zone, defined for gameplay, as 8K contends that any area defined for game play will subsequently include binaural sound. *See* '509 8K Infringement Contentions (Ex.1129) at 4. Under this interpretation, limitation 1[a] would have been obvious over McCulloch in view of Pedrotti, and over McCulloch in view of Pedrotti and further in view of Flaks, for the following reasons.

425. Persons of ordinary skill in the art would have recognized that McCulloch's system, which includes functionalities for tracking a controller held in the hand of a user (PED), could and would be used to implement Pedrotti's method of defining a zone for gameplay with a PED, or "divid[ing] … an area around the user into a zone."

426. McCulloch discloses a "display device system 8" that comprises a "head mounted display device 2":

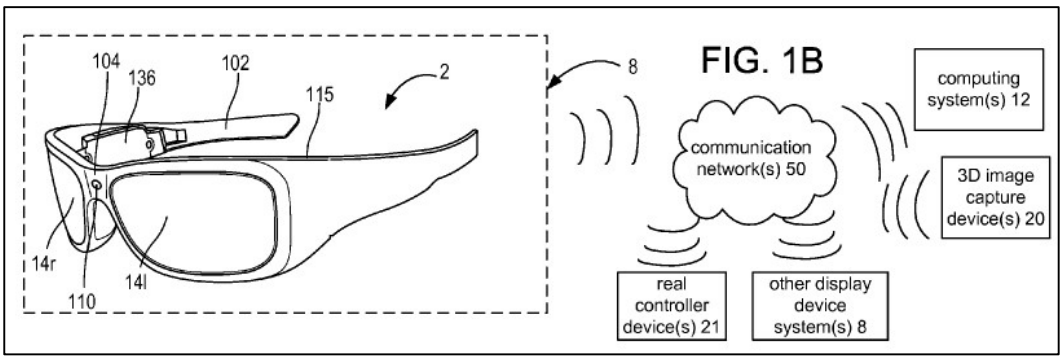


FIG. 1B

McCulloch (Ex.1008) at Fig. 1B; *see also* McCulloch (Ex.1008) at 4:49-55, 8:1-46 (describing control circuity 136 of the display device 2 and sensors, including an inertial sensing unit 132 and location or proximity sensors). McCulloch's HMD has "[c]ontrol circuitry 136" including a "processing unit 210," which "may comprise one or more processors including a central processing unit (CPU) and a graphics processing unit (GPU)" and "memory 244":

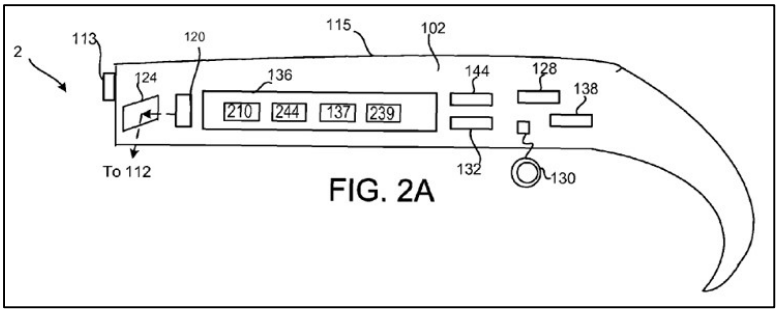


FIG. 2A

McCulloch (Ex.1008) at Fig. 2A, 8:1-16; *see also* McCulloch (Ex.1008) at 5:32-35 ("the functionality of companion processing module 4 may be integrated in software and hardware components of the display device 2 as in FIG. 1B"), Fig. 1B, 7:4-23. And the "computing environment" for McCulloch's "display device system 8," which includes the HMD, comprises an "image and audio processing engine 191" that "processes image data… and audio data." McCulloch (Ex.1008) at Fig. 4A, 13:52-18:7 (depicting and describing "computing environment 54" for McCulloch's HMD).

427. The computing environment also receives inertial and positional data from "handheld IMU controller[s]," which are PEDs held in the hands of the user. McCulloch (Ex.1008) at 4:25-31 (describing variants of controllers), 28:63-66 ("Joe is holding a handheld IMU real controller device 19 in this example"). "[C]hanges in position and orientation of [a] handheld controller cause its inertial motion unit to generate one or more signals which are converted by the handheld IMU real controller device 19 to be user input requesting display of an action by [a] virtual object," such as a virtual basketball. McCulloch (Ex.1008) at 29:4-11. And as I

explained above for Ground 1, Pedrotti also discloses a handheld PED. Pedrotti (Ex.1005) at 1:40-45, Figs. 2-5, 7; *see also* Section X.A.3.b.

428. Because McCulloch also discloses, or at a minimum renders obvious, tracking the movement of its real controller device—and specifically tracking the movement with its HMD—persons of ordinary skill would have known that McCulloch's system could and would have been used to implement Pedrotti's method to divide an area around the user into a zone for gameplay. For example, McCulloch teaches that its controllers are tracked relative to the HMD and surrounding environment using image and depth data. *See* McCulloch (Ex.1008) at 7:34-59, 8:17-30. McCulloch also discloses tracking the translation and rotation of the handheld controller, e.g., the handheld IMU real controller device 19, via its inertial sensors. McCulloch (Ex.1008) at 29:4-36 ("changes in position and orientation of the handheld controller causes its inertial motion unit to generate one or more signals which are converted by the handheld IMU real controller device 19 to be user input requesting display of an action by the virtual object 30_2"), 29:36-63 ("Inertial motion sensors ['IMU'] in the handheld real controller device 19 identify parameters like speed, acceleration and direction of motion of the device 19 which is sent as data to the display device system 8."), 29:6-12 (similar), 24:28-35 (describing real controller device interface software 188), Figs. 8B, 8D; *see also* McCulloch (Ex.1008) at 28:63-66 (explaining that the "handheld IMU real

controller device 19" "establishe[s] communication with [] display device system 8 (e.g., 2 and 4)"), 25:25-28. ("In other examples, non-NUI input like moving a displayed selection arrow with the real controller device may be used to identify a user selected object for control or force feedback as discussed below.").

429. Furthermore, persons of ordinary skill in the art would have understood that determining the handheld IMU device was being moved "in the direction of the television 16 [such] that the virtual basketball 303 collides with the display of the television" as disclosed by McCulloch ((Ex.1008) at 29:44-46) would require the dynamic determination of the position and orientation of the handheld IMU device relative to the McCulloch's HMD and the world. McCulloch teaches this relative position and orientation tracking as well because McCulloch's HMD is also tracked by the HMD itself, and the HMD provides image and depth data to track objects in front of the user, including the user's hands and controllers held in the user's hands. Persons of ordinary skill in the art would have known that determining the position and/or orientation of the handheld device, or PED held in the hand of the user, is a step in Pedrotti's method of defining a zone for gameplay.

430. Additionally, McCulloch's HMD includes front-facing cameras to develop image and depth data to track objects in front of the user, including the user's hands and controllers held in the user's hands. McCulloch at (Ex.1008) 12:18-21 ("the front facing capture devices 113 capture and provide image and depth

data from which real objects are identified as well as their positions and often orientations relative to the display portion of the device"), 7:57-59 ("capture devices 113 are also referred to as outward facing capture devices meaning facing outward from the user's head"), 7:34-37 ("the capture devices 113 may also be depth sensitive, for example, they may be depth sensitive cameras which transmit and detect infrared light from which depth data may be determined"), 22:4-8 ("gesture recognition engine 193 can identify actions performed by a user indicating a control or command to an executing application," including actions "performed by a body part of a user, e.g. a hand or finger"), 28:5-11 ("the capture devices 113 can capture data of the user's hand and finger pointing to different objects and identifying them as a control object or a force feedback object or both, and the image and depth data is processed by the gesture recognition engine 193 for identifying a pointing selection gesture").

431. And, McCulloch discloses that the HMD includes absolute position and orientation tracking of the HMD through various sensors and transceivers, which provides information that can be combined with the HMD's image and depth data for the tracking of controllers. *See, e.g.*, McCulloch (Ex.1008) at 8:17-30 ("Inside, or mounted to temple 102, are an earphone of a set of earphones 130, an inertial sensing unit 132 including one or more inertial sensors, a location sensing unit 144 including one or more location or proximity sensors, some examples of which are a GPS transceiver, an infrared (IR) transceiver, or a radio frequency transceiver for

processing RFID data. Optional electrical impulse sensing unit 128 detects commands via eye movements. In one embodiment, inertial sensing unit 132 includes as sensors a three axis magnetometer, a three axis gyro, and a three axis accelerometer. The inertial sensors are for sensing position, orientation, and sudden accelerations of head mounted display device 2. From these movements, head position, and thus orientation of the display device, may also be determined."), Fig. 2A.

432. Persons of ordinary skill in the art also would have understood that the camera-based absolute position and orientation of the handheld IMU real controller device 19 (held in the user's hand) supplements the IMU information about velocities and accelerations received from the IMU real controller device. As I discussed above, a "hybrid method of integrating multiple technologies together (sensor fusion)" can "provide both high precision and accuracy." Jerald, THE VR BOOK (Ex.1063) at 315. As such, persons of ordinary skill in the art would have known, or at minimum found it obvious, to use sensor fusion methods to combine the camera-based absolute position and orientation of the handheld IMU real controller device 19 (held in the user's hand) with the IMU-based derivative signals (e.g., velocities and accelerations) from the IMU real controller device 19.

433. McCulloch further teaches defining boundaries for a zone, or "identifying boundaries for a playspace in which virtual objects can be positioned." McCulloch (Ex.1008) at 20:11-13, 15:48-16:41, Fig. 4A.

434. Tracking the controller takes places entirely within McCulloch's HMD. The computing environment 54 is contained within the HMD, or device display system 8, which includes head mounted display device 2 and companion processing module 4. *See, e.g.*, McCulloch (Ex.1008) at 28:63-66 (referring to "display device system 8 (e.g., 2 and 4)"), 5:32-36 ("the functionality of the companion processing module 4 may be integrated in software and hardware components of the display device 2 as in FIG. 1B"), 7:14-16 ("control circuitry 136 of the display device 2 incorporates the functionality which a companion processing module provides in FIG. 1A"), 13:56-60 ("Fig. 4A illustrates a computing environment embodiment 54 from a software perspective which may be implemented by a system like display device system 8"), Fig. 4A (arrow showing item 8 pointing to computing environment 54).

435. The HMD, which contains the companion processing module, is in communication with the real controller devices in order to track the real controller devices and receive user input, as described above. *See* McCulloch (Ex.1008) at 5:19-36 ("[t]he companion processing module 4 may communicate wired or wirelessly" with "one or more real controller devices"), 24:28-30 (explaining that

real controller device interface software 188, which is part of the computing environment 54 of the HMD, "communicates over a network 50 with the device interface software 189 of a real controller device 21"). And, as noted above, the changes in position and orientation of the handheld controller, which are "user input requesting display of an action," is the input data is provided to the real controller device interface software 188, which is part of the HMD's computing environment. McCulloch (Ex.1008) at 29:6-11, 25:29-33 ("the real controller device interface software 188 receives user input data from a real controller device"), 24:47-54 ("real controller device interface software 188 identifies a virtual object for control" and "applies the user input from the controller 21 requesting an action to be performed from the user perspective by indicating display instructions to the virtual data engine 195 or the application 166").

436. In addition to receiving information provided by the real controller devices, the computing environment 54 also receives device data 198, which includes data from the HMD itself, e.g., "data from sensors or sensing units" such as "the orientation sensors in inertial sensing unit 132" and "location and proximity transceivers in location sensing unit 144." McCulloch (Ex.1008) at 24:14-21. Additionally, the computing environment 54 of McCulloch's HMD includes image and audio processing engine 191, which displays a user's actions (e.g., controlling a virtual object by real controller device 21) on the HMD. McCulloch (Ex.1008) at

13:64-14:11, 24:47-54 ("real controller device interface software 188 identifies a virtual object for control … applies the user input from the controller 21 requesting an action to be performed from the user perspective by indicating display instructions to the virtual data engine 195 or the application 166"); *see* Section IX.D (overview of McCulloch).

437. Also, persons of ordinary skill in the art would have known that McCulloch's controllers are tracked (or at a minimum could obviously be tracked) because, as I have explained, this was a common setup, particularly for gaming applications. *See* Section VII.D (discussing tracking). And, persons of ordinary skill in the art would have known that tracking these controllers include determining their position and orientation in space (e.g., where they are, or where they are pointed), and receiving information regarding a zone definition according to Pedrotti's method.

438. Accordingly, persons of ordinary skill in the art would have known and been motivated to use Pedrotti's method of defining a boundary for a safe area (a zone) with McCulloch's system. *See also* Section X.B.1 (reasons to combine McCulloch and Pedrotti).

439. In addition, McCulloch discloses that "a gaming application may receive user input identifying boundaries for a playspace," but offered one example of user input—gaze tracking with voice command. McCulloch (Ex.1008) at 20:11-

18. Persons of ordinary skill in the art would have known and understood that Pedrotti's method, which uses HMD-tracked handheld controllers to draw a boundary, is advantageous, efficient, and accurate, and thus would have been motivated to use it.

440. With a handheld controller, as taught in Pedrotti, the user can readily and accurately ensure that hazardous conditions are sufficiently outside the boundaries by a simple action of pointing or moving the controller along the desired boundaries. Jerald, THE VR BOOK (Ex.1063) at 282 ("hand-tracked devices work well … for pointing"), 327 ("[p]ointing is faster when speed of remote selection is important, but is also often used for precisely selecting close objects") (internal citations omitted). In comparison, skilled artisans would have understood that gaze tracking is resource-intensive and imprecise when used alone. Jerald, THE VR BOOK (Ex.1063) at 318-19 ("Interacting via eye tracking alone is usually not a good idea—eye tracking works better with multimodal input."), 319 ("Gaze data is noisy."), 328 ("eye gaze selection is typically not a good selection technique"). Additionally, even if gaze tracking were supplemented with voice commands for demarcating boundary points for better precision, persons of ordinary skill in the art would have been motivated to pursue a simpler approach, especially when McCulloch's HMD already tracks the controller using the real controller device or IMU, with comparable hardware as disclosed in Pedrotti and consistent with how boundaries were defined

in many safety and chaperone systems before February 2016. *See* Section X.B.1 (discussing McCulloch's and Pedrotti's HMDs and controllers among reasons to combine McCulloch and Pedrotti); Section VII.G (summary of safety and chaperone systems).

441. Further, because McCulloch's zone is "for a playspace in which virtual objects can be positioned" (McCulloch (Ex.1008) at 20:11-23), persons of ordinary skill in the art would have known to use McCulloch's system to implement Pedrotti's method, which renders obvious "dividing, with a portable electronic device (PED) held in a hand of a user, an area around the user into a zone." *See* Section X.A.3.b (Ground 1, limitation 1[a]).

442. Persons of ordinary skill in the art would have understood that Pedrotti's method that divides an area around the user into a zone creates a zone that would subsequently "include[s] multiples sound localization points (SLPs) from where binaural sound originates to the user." Indeed, McCulloch discloses that the virtual "playspace" is an area "in which virtual objects can be positioned," which confirms that it would have been obvious for the area to subsequently contain multiple SLPs, reflecting the location of binaural sound-producing virtual objects. McCulloch (Ex.1008) at 20:11-23. In fact, McCulloch provides several examples of sound-producing virtual objects. McCulloch (Ex.1008) at 26:7-19 (flying helicopter that crashes into wall), 29:3-30:3 (bouncing basketball that crashes into

television), 25:6-26:34, Fig. 5 (describing "play[ing] audio for the virtual object projected from a 3D space position of the virtual object"), Figs. 8A-8D, 24:67-25:3.

443. McCulloch further teaches that localized sound, such as binaural sound, originates from these virtual objects because McCulloch's 3D audio engine produces audio "projected from a 3D space position of the virtual object." McCulloch (Ex.1008) at 26:7-9. McCulloch also incorporates Flaks for implementation details for its 3D audio engine, including that the 3D audio engine's sound is generated using HRTFs, which POSAs would have understood are used to produce binaural sound. McCulloch (Ex.1008) at 14:53-67 (sounds can be "identified to the 3D audio engine 304 with data identifying from which direction or position to make the sound seem to come from"), 16:58-63 (similar), 21:21-54 (describing the 3D audio engine as a "positional 3D audio engine" where "[a]udio data for virtual objects generated by an application can be output to the earphones to sound as if coming from the direction of the virtual object"), 29:43-57 (describing a basketball colliding with a television screen). Flaks discloses that its 3D audio engine "applies a head related transfer function (HRTF) for the listener to each of the components of the 3D audio signal, and provides the 3D audio signal." Flaks at (Ex.1009) 2:6-20; *see also* Flaks (Ex.1009) at 4:10-15 (describing generating sound that originates from a virtual sound source). Such components can reflect a right and left HRTF to provide

binaural sound to the user, which was a common technique well known in the art. *See* Section VII.E (summary of binaural sound).

444. And, Flaks explains that binaural sound is generated "by comparing cues received at both ears (difference cues or binaural cues)" and that sound "appear[ing] to come from a particular location in 3-dimensional space" can be achieved through a technique where "one audio-speaker is placed over or near each ear" and "creating an audio signal using a 'head-related transfer function' (HRTF) to create the illusion that sound is originating from a location in 3D space." Flaks (Ex.1009) at 1:9-12, 1:17-28.

445. As further evidence that Flaks' audio engine generates binaural sound, Flaks discloses that, as part of its "process 600 of determining a listener's location and rotation in the room," the model of the human target "include[s] information that describes the rotation of the user's head such that the orientation of the user's ears is known." Flaks (Ex.1009) at 10:5-9, 11:22-24. As part of Flaks' process of determining HRTFs for a particular listener, Flaks explains "if the system was expecting data for a right ear, then the system determines whether the data matches what is expected for a right ear." Flaks (Ex.1009) at 11:61-65. Because binaural sound accounts for both ears, persons of ordinary skill in the art would have understood these express statements to show that Flaks' 3D audio engine generates binaural sound. *See also* Section VII.E (discussing background for binaural sound).

446. For these reasons, limitation 1[a] would have been obvious over McCulloch, either alone or with Flaks, in view of Pedrotti under 8K's apparent interpretation of this limitation.

447. Additionally, if limitation 1[a] is interpreted to require a zone that "includes" multiple SLPs for binaural sound when divided by a PED, limitation 1[a] also would have been obvious over McCulloch, either alone or with Flaks, in view of Pedrotti.

448. As I discussed above, McCulloch discloses that the virtual "playspace" is an area "in which virtual objects can be positioned." McCulloch (Ex.1008) at 20:11-13. Additionally, McCulloch taught that its system uses a 3D audio engine that "plays audio data for [a] virtual object projected from a 3D space position," i.e., an SLP. McCulloch (Ex.1008) at 26:7-9. McCulloch explains that "[a]udio data for virtual objects … can be output to the earphones to sound as if coming from the direction of [a] virtual object projected into the display field of view." McCulloch (Ex.1008) at 21:25-29. Thus, McCulloch teaches that its virtual environment, or virtual playspace, includes multiple virtual objects—including when that space is divided into a zone according to Pedrotti's method, which persons of ordinary skill in the art would have been motivated to use with McCulloch's virtual environment. *See* Section X.B.1 (motivations to combine McCulloch and Pedrotti). These virtual objects in the McCulloch environment and also in the Pedrotti zone are "positioned"

at "3D space positions" for "3D audio," or at multiple locations where sound localizes—i.e., multiple SLPs. And, in accordance with the teachings in Flaks providing details of the audio generated by the 3D audio engine, persons of ordinary skill in the art would have understood that the sound produced from those virtual objects, or at the multiple SLPs, is binaural sound.

449. For these reasons limitation 1[a] would have been obvious over McCulloch, either alone or with Flaks, in view of Pedrotti if limitation 1[a] requires a zone that "includes" multiple SLPs for binaural sound when divided by a PED.

c. 1[b]: "determining, with a wearable electronic device (WED) worn on a head of the user, when the user is located inside the zone;"

450. Limitation 1[b] would have been obvious to persons of ordinary skill in the art over McCulloch, either alone or with Flaks, in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section X.A.3.c (Ground 1, limitation 1[b]).

451. As I discussed for limitation 1[a], McCulloch's HMD, which is a WED worn on the head of the user, includes absolute position and orientation tracking of the HMD through various sensors and transceivers. *See, e.g.*, McCulloch (Ex.1008) at 8:17-30 ("Inside, or mounted to temple 102, are an earphone of a set of earphones 130, an inertial sensing unit 132 including one or more inertial sensors, a location sensing unit 144 including one or more location or proximity sensors, some

examples of which are a GPS transceiver, an infrared (IR) transceiver, or a radio frequency transceiver for processing RFID data. Optional electrical impulse sensing unit 128 detects commands via eye movements. In one embodiment, inertial sensing unit 132 includes as sensors a three axis magnetometer, a three axis gyro, and a three axis accelerometer. The inertial sensors are for sensing position, orientation, and sudden accelerations of head mounted display device 2. From these movements, head position, and thus orientation of the display device, may also be determined."), Fig. 2A; *see* Section X.A.3.b (limitation 1[a]).

452. Furthermore, the computing environment 54 receives device data 198, which includes data from the HMD itself, e.g., "data from sensors or sensing units" such as "the orientation sensors in inertial sensing unit 132" and "location and proximity transceivers in location sensing unit 144." McCulloch (Ex.1008) at 24:14-21; *see* Section IX.D (overview of McCulloch). In addition to determining the position of the user through McCulloch's HMD, just as with Pedrotti's HMD according to Pedrotti's disclosure, persons of ordinary skill in the art would have used McCulloch's HMD to determine when the user is located in the zone defined by Pedrotti's method, or the zone for gameplay. This is because McCulloch's HMD not only provides information about the user's absolute location, but the "inertial sensing unit 132 may ***identify position changes*** of the head mounted display device

2," such as whether the user's location is within the zone. *See* McCulloch (Ex.1008) at 12:4-7 (emphasis added).

453. Both McCulloch and Pedrotti disclose that the WED determines the user's location, either based on the WED on the head of the user or by tracking the controller that is held by the user. McCulloch (Ex.1008) at 8:17-28 (HMD includes "an inertial sensing unit 132 … a location sensing unit 144"), 12:4-7, 29:4-43; *see* Section X.A.3.c (Ground 1, limitation 1[b] discussing Pedrotti). And as Pedrotti discloses, the tracked location of the user could and would be used to determine "when the user comes within a preselected distance of the boundary," which indicates when the user is within the zone. Pedrotti (Ex.1005) at 4:37-44. Pedrotti lso discloses that the tracked location of the user can be used to take action if the user enters or exits a zone. Pedrotti (Ex.1005) at 13:63-67 ("If the user's head or hands go beyond the boundary as determined by the trackers, the processor can provide additional messaging or warning, such as text or auditory warnings, or an additional visual warning, that persists until the user returns to the selected area within the boundary.").

454. Further, as described above for limitation 1[a], McCulloch discloses defining boundaries for a zone, or "playspace." McCulloch (Ex.1008) at 20:11-13 ("a gaming application may receive user input identifying boundaries for a playspace in which virtual objects can be positioned"), 15:48-16:41 (using a scene mapping

engine to compare the location of tracked objects against stored data of a zone based on a common coordinate system), Fig. 4A; *see also* Section X.B.3.b. Persons of ordinary skill in the art would have known that these boundaries described in McCulloch apply to the bounds of the user's playspace as well, and not just the placement of virtual objects. This is because, given either a VR or AR environment, there are safety concerns for the user who is focused on the game. *See, e.g.*, Sabelman (Ex.1088) (discussing dangers of AR because of the user's focus, even if the user is able to visually perceive the surrounding physical environment); Jerald, THE VR BOOK (Ex.1063) at 220 (with respect to safety, "[c]onsider forcing users to stay within safe areas"). Accordingly, persons of ordinary skill in the art would have been motivated by McCulloch's teachings, e.g., its disclosure of boundaries for a playspace, to implement the rules and methods Pedrotti discloses for determining when a user's location conflicts with the boundary of a safe area for gameplay.

455. Further, Flaks discloses that the user's location is tracked and updated in order to generate the appropriate localized sound (i.e., binaural sound) using the 3D audio engine. *See, e.g.*, Flaks (Ex.1009) at 7:33-34 ("Since the listener's location might change quite frequently, it might be carefully tracked."), 9:18-20 ("the system may track the physical location of the user"), 11:25-43 ("at least one inertial sensor is located on the user's head to allow tracking of the user's head" and "updating the person's location several times per second"), 14:30-37 ("For example, the user might

be moving such that the sensor data that captures user location changes quite frequently. These changes may be fed into, for example, the azimuth and elevation calculations 1004 such that the 3D audio signal is constantly being updated for the changing user position. Similarly, the change in user position may be fed, in real time, to the gain and filters 1006.").

456. As discussed in the context of Ground 1, it was well known for chaperone systems to determine user locations in order to assist the user in remaining within the zone for gameplay or within a "safe area." *See also* Sections X.A.3.c (Ground 1, limitation 1[b]), VII.G (discussing safety and chaperone systems).

457. Thus, persons of ordinary skill in the art would have found it obvious for McCulloch, alone or with Flaks, in view of Pedrotti, to determine, with a wearable electronic device (WED) worn on a head of the user, when the user is located inside the zone.

d. 1[c]: "highlighting, while the user is located in the zone and with a display of the WED, one of the multiple SLPs in the zone when the PED held in the hand of the user is pointed at the one of the multiple SLPs in the zone; and"

458. Limitation 1[c] would have been obvious to persons of ordinary skill in the art over McCulloch, either alone or with Flaks, in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section X.A.3.d (Ground 1, limitation 1[c]).

459. Limitation 1[c]'s recitation of "while the user is located in the zone and with a display of the WED" would have been obvious because a user using McCulloch's system and Pedrotti's method would have used McCulloch's HMD (WED) while in the Pedrotti-type zone, which defines the user's area for gameplay or "safe area" zone. McCulloch discloses examples of the user wearing McCulloch's HMD while engaged in a virtual environment or game. *See, e.g.*, McCulloch (Ex.1008) at Figs. 8A-8D. McCulloch's HMD has a display that displays virtual images to the user in McCulloch's playspace including virtual objects, which could and would be inside Pedrotti's zone defining the area for gameplay. *See* McCulloch (Ex.1008) at 8:40-49 ("Mounted to or inside temple 102 is an image source of image generation unit 120 which produces visible light representing images."), 9:17-35 ("FIG. 3B is a top view of an embodiment of one side of an optical see-through, near-eye, augmented reality display device including a display optical system 14," which "is an integrated eye tracking and display system."), Figs. 2B, 4A.

460. As discussed in the context of limitation 1[a], McCulloch discloses, or at a minimum renders obvious limitation 1[c]'s recitation of "the PED held in the hand of the user is pointed at the one of the multiple SLPs in the zone." *See* Section X.B.3.b (limitation 1[a]). Moreover, McCulloch discloses, or at a minimum renders obvious, tracking the movement of the handheld, real controller device with its HMD

such that the HMD is able to determine where the controller device is pointed. McCulloch (Ex.1008) at 24:28-35, 29:4-63, Figs. 8B, 8D; *see* Section X.B.3.b (limitation 1[a]). Persons of ordinary skill in the art would have found this obvious as well, as this setup—where the controller is used to point at a virtual object—was common especially for gaming. *See* Yen (Ex.1041) at 19:67-11:5 (user waves motion controller to cause avatar to wave virtual object); Mullen (Ex.1029) at 11:18-26 (handheld controller acts as a pointer using a "virtual laser [that] emanates out of [the] controller."), 9:16-24 (user points motion controller to aim virtual gun at virtual objects), 14:26-15:6 (user presses button on motion controller to grab virtual objects and moves motion controller to move them); Pedrotti (Ex.1005) at 9:26-40 (user grabs virtual weapon by reaching for it with motion controller and "pressing a button on the controller," and then moves the virtual weapon by moving the controller); Mine Exploiting Proprioception 1997 (Ex.1116) at 70-71 (describing "[o]bject selection/manipulation where "[u]sers select and manipulate objects with their dominant hand" and "[t]he default form of manipulation is unconstrained 6DoF manipulation"); *see also* Section VII.C (describing tracking of handheld PEDs for use in gaming). In addition, Pedrotti also teaches such tracking, and the processor responsible for tracking movement of Pedrotti's controller may be "in the HMD." Pedrotti (Ex.1005) at 16:22-24; Section X.A.3.d (Ground 1, limitation 1[c]).

461. Additionally, limitation 1[c]'s "pointed" PED would have been obvious over McCulloch because McCulloch discloses multiple examples in which movement of a handheld controller selects and moves a virtual object, such as by pointing at it. McCulloch (Ex.1008) at 12:49-13:51 ("FIGS. 3A and 3B illustrate a contextual example of a virtual object being controlled with a real controller device from a user perspective."), 25:6-26:34 (describing the process by which a user is able to control a virtual object using the real controller device), 25:25-27 (describing other inputs for controlling objects), 29:4-17 ("FIG. 8B illustrates an example of a virtual object representation of the user selected real object being controlled with the real controller device. The changes in position and orientation of the handheld controller causes its inertial motion unit to generate one or more signals which are converted by the handheld IMU real controller device 19"). And, with respect to Figures 8B-8D, McCulloch depicts the user pointing the handheld IMU real controller device at the virtual basketball, which is a virtual object associated with an SLP.

462. Indeed, the title of McCulloch is "Controlling a Virtual Object with a Real Controller Device," and it disclosed multiple examples of controllers for controlling virtual objects, including "a joystick," "a pointing device," and the "handheld inertial motion unit (IMU)" discussed above, which obviously could be pointed. McCulloch (Ex.1008) at Title, 4:25-33, cl. 12, 6:55-66 (example "real

controller device[s]" for providing "user input data" "for controlling an object"), 25:25-28 ("moving a displayed selection arrow with [a] real controller device may be used to identify a user selected object for control").

463. As discussed in the context of Ground 1, pointing is an obvious convention used to select and is rendered obvious by Pedrotti as well. *See* Sections Section VII.C (describing actions carried out by handheld controllers), X.A.3.d (Ground 1, limitation 1[c]); *see, e.g.*, Jerald, THE VR BOOK (Ex.1063) at 327 ("Pointing Pattern" is "fundamental" "for selection"). For example, Pedrotti discloses using Pedrotti's controller to define a boundary of "an area in the physical world to be defined within which the user should remain, for example to avoid physical obstacles." Pedrotti (Ex.1005) at Abstract, 2:27-33 ("One embodiment discloses a method of assisting a user wearing a head-mounted display (HMD) in remaining within a selected area of the physical world, the user holding a handheld controller having a controller tracker which provides information regarding a position of the handheld controller, the method comprising: receiving, by a processor as an input, a definition of a boundary of the selected area;"), 2:44-51, 2:60-3:2. Persons of ordinary skill in the art would have understood that holding a handheld controller and using it to define a boundary of "an area in the physical world" would (or would obviously) include pointing the controller to trace out the intended boundary.

464. McCulloch also renders obvious limitation 1[c]'s recitation of "highlighting … one of the multiple SLPs in the zone" when the PED is pointed at it. McCulloch's HMD uses a "visual effects library [with] routines for animations, ***highlighting***, and other types of visual enhancements which may also be ***associated with particular actions***," such as pointing. McCulloch (Ex.1008) at 23:4-7 (emphasis added); *see also* McCulloch (Ex.1008) at 8:40-46 (describing the image generation unit of McCulloch's computing environment), 9:4-52 (describing the display optical system of the HMD), 11:42-46 (explaining that "commands from the real controller device are interpreted, applied and display[ed]").

465. As discussed in the context of Ground 1, highlighting is an obvious convention used to indicate selection or that a virtual object is being pointed at, and is rendered obvious by Pedrotti as well. *See* Sections VII.C (describing actions carried out by handheld controllers), X.A.3.d (Ground 1, limitation 1[c]); *see, e.g.*, Jerald, THE VR BOOK (Ex.1063) at 281 ("objects can make a sound" or "become highlighted" "when … they have been selected"), 305 ("Highlighting" conveys "that an object is able to be selected or grabbed").

466. More generally, if the purpose of pointing to an object is to perform some action with or on it, persons of ordinary skill in the art would have understood the need to have some form of dynamic visual confirmation that a user is sufficiently pointing at (intersecting) the object at any given moment, e.g., the "highlighting"

effect from McCulloch's visual effects library (McCulloch (Ex.1008) at 23:4-7), lest the user be forced to repeatedly point and click around the object until they can successfully carry out the action.

467. Thus, in view of McCulloch, persons of ordinary skill in the art would have understood that a user could and would take McCulloch's handheld controller device (PED) to point at a sound-producing virtual object, which is associated with an SLP, such as a "virtual basketball" or a "virtual remote helicopter," as described in McCulloch's examples, to select and move the virtual object and its associated SLP. A sound-producing virtual object is associated with an SLP; likewise, a sound source in virtual space (e.g., an SLP) is just one kind of virtual object that a user could and would select and arrange in a virtual environment. *See* Section X.A.3.d (Ground 1, limitation 1[c]).

468. For example, the user could select a virtual basketball and move the basketball to collide with a television display, which emits a crashing sound on collision. McCulloch (Ex.1008) at 29:36-63, Fig. 8D. Furthermore, in the process of pointing the controller device (PED) at the virtual object, and its associated SLP, persons of ordinary skill in the art would have understood that McCulloch's display consequently could and would highlight the sound-producing virtual object and its associated SLP, to indicate and facilitate user selection.

469. Further, McCulloch's HMD displays "highlighting," or alteration of the visual image "when the PED … is pointed at" the SLP, or virtual object, because McCulloch's HMD is able to track the position and orientation of the handheld controller through a variety of means (e.g., inertial motion unit, image and depth data), and also identify gestures such as pointing by the user. McCulloch (Ex.1008) at 7:34-59 (describing McCulloch's capture devices providing depth and image data), 8:17-30 (describing sensing units on McCulloch's HMD), 12:18-21 ("capture devices [] capture and provide image and depth data from which real objects [such as the user's hands or controllers] are identified as well as their positions and often orientations relative to the display portion of the device"), 22:4-8 (describing gesture recognition engine that "can identify actions performed by a user indicating a control of command" such actions "performed by a body part of a user, e.g., a hand or finger"), 28:5-11 ("capture devices [] can capture data of the user's hand and finger pointing to different objects" "and the image and depth data is processed by the gesture recognition engine [] for identifying a pointing selection gesture"); *see* Section X.B.3.b (limitation 1[a]). As noted above, it would have been obvious that these actions take place while the user is in the Pedrotti-type zone.

e. 1[d]: "playing, with the WED worn on the head of the user, the binaural sound that emanates from the one of the multiple SLPs in response to the one of the multiple SLPs being pointed at by the PED held in the hand of the user."

470. For the reasons discussed above for limitations 1[a] and 1[c], limitation 1[d] would have been obvious to persons of ordinary skill in the art over McCulloch (alone or with Flaks) in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section X.A.3.e (Ground 1, limitation 1[d]). *See* Sections X.B.3.b, X.B.3.d. I address the additional limitation in limitation 1[d] that the binaural sound is played "in response to the one of the multiple SLPs being pointed at by the PED" below.

471. As explained, McCulloch's HMD is able to determine when the user is pointing the real controller device at an SLP. *See* Section X.B.3.d (limitation 1[c]). Persons of ordinary skill in the art would have found it obvious to trigger an action based on pointing the PED at an SLP (e.g., playing a binaural sound with McCulloch's HMD that includes "a set of earphones"). McCulloch (Ex.1008) at 8:17-22, 11:42-46, 21:21-38 ("The 3D audio engine 304 is a positional 3D audio engine which receives input audio data and outputs audio data for the earphones 130"). This type of control and manipulation in game play where an action of a PED, i.e., selecting, causes something else to occur in the game, i.e., making a noise or emitting a crashing sound due to a collision between moved virtual objects, was well known well before February 2016. *See* Section X.B.3.d (limitation 1[c]); *see also* Jerald, THE VR BOOK (Ex.1063) at 281 ("objects can make a sound" or "become highlighted" "when … they have been selected"), 356 ("use audio and highlighting

to signify touching of objects"). Finally, as discussed above for limitation 1[a], McCulloch's HMD plays a binaural sound emanating from the SLP using Flaks' 3D audio engine. *See* Section X.B.3.b (limitation 1[a]).

4. Dependent Claims 2-8

472. I understand that claims 2-8 depend on independent claim 1.

473. Thus, it is my opinion that each of dependent claims 2-8 would have been obvious to persons of ordinary skill in the art for the same reasons as independent claim 1 and additionally for the reasons I discuss in the following subsections.

a. Claim 2

(1) 2[a]: "The method of claim 1 further comprising: tracking, with one or more sensors in the WED worn on the head of the user, the PED to determine when the PED moves outside the zone; and"

474. Limitation 2[a] would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti.

475. McCulloch discloses, or at a minimum renders obvious to a person of ordinary skill in the art, tracking the handheld controller device (PED) with the HMD (WED worn on the head of the user) for the reasons I discussed above for limitations 1[a]-1[c]. Sections X.B.3.b-X.B.3.d.

476. Further, McCulloch discloses that its HMD contains capture devices, including cameras and infrared transceivers (sensors) that detect and track infrared light that may be emitted by a controller (i.e., one or more sensors in the WED). McCulloch (Ex.1008) at 7:34-67 (describing capture devices), 8:7-39 (describing multiple types of "sensors" in the HMD, including transceivers), 5:19-36 (describing "companion processing module 4," which "may be integrated in" "display device 2," that communicates with the "controller devices 21" through infrared light). And McCulloch's processor stores the information needed compare the PED's or HMD's location with the zone's boundaries in view of McCulloch's shared coordinate system. McCulloch (Ex.1008) at 15:48-54, 16:18-21. Further, methods of using sensors on HMDs to track controllers such as controllers that emit infrared light that is captured by the HMD, were well known and widely used—either alone or in combination—because they were very accurate for tracking. *See* Section VII.D; Jerald, THE VR BOOK (Ex.1063) at 315 ("Hand-held tracked devices typically use inertial, electromagnetic, ultrasonic, or optical (camera) technologies."). Persons of ordinary skill in the art would have known that optical tracking systems, such as those described in McCulloch, offer advantages, such as "accurate measurements of both position and orientation over relatively large working volumes, without many of the problems inherent in magnetic or acoustic tracking systems." Welch 1995

(Ex.1119) at 1 (also discussing disadvantages of mechanical tracking systems and acoustic tracking systems).

477. Additionally, using Pedrotti's method of determining when the PED moves outside the zone through McCulloch's system with its HMD-tracked controllers would render obvious limitation 2[a]'s "determin[ing] when the PED moves outside the zone" in view of Pedrotti's disclosures discussed for this limitation in Ground 1. *See* Section X.A.4.a(1). Pedrotti discloses tracking the PED's location in relation to the boundary; therefore, Pedrotti's method can determine when the PED moves outside the zone. Pedrotti (Ex.1005) at 2:44-59 (describing "determin[ing] from the position of the handheld controller that the handheld controller is within a first preselected distance from the boundary"), 12:31-50 ("tracking the position and orientation of the user's hand if the user is holding a controller with a tracker," and explaining that "the processor knows where the user's head and hands are located" and "when the user's head and/or hand approaches the boundary"), 13:44-14:5 (describing warning "when the user's head or hands are approaching the boundary as determined by the trackers on the user's head or hands" and "if the user's head or hands go beyond the boundary as determined by the trackers"); *see also* Section X.A.4.a(1).

(2) 2[b]: "displaying, with the WED worn on the head of the user, a three dimensional (3D) virtual image that shows a size and a shape of the zone

in response to the WED determining that the PED moved outside the zone."

478. Limitation 2[b] would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section X.A.4.a(2) (Ground 1, limitation 2[b]).

479. Further, McCulloch's HMD displays virtual images, and persons of ordinary skill in the art would have known and understood that the HMD could and would display a Pedrotti-type zone as a virtual image. *See* Section X.B.3.d (limitation 1[c]). It would have been obvious to a person of ordinary skill in the art to incorporate Pedrotti's visual warnings, which are rendered as a warning fence or grid, into the McCulloch HMD's image and audio processing engine and virtual data engine since the HMD is already capable of rendering virtual surfaces such as walls using a 3D mesh similar to Pedrotti's grid-shaped virtual fence. *See* McCulloch (Ex.1008) at 17:14-31 (describing "3D mapping of an environment" including by using a "mesh" for "things like walls and floors"); *see also* McCulloch (Ex.1008) at 17:47-48 ("[a] polygon mesh may also be used to represent the object's boundary"), 23:25-56 (describing McCulloch's virtual data engine that "processes virtual objects and register the 3D position and orientation of virtual objects or imagery in relation to one or more coordinate systems" and that provides "a target 3D space position of where to insert the virtual object").

480. As a preliminary matter, persons of ordinary skill in the art would have readily understood how to carry out the very basic steps of testing whether the position (x, y, z coordinates) of McCulloch's tracked handheld controller device (PED) moves outside a zone, for example a zone defined by a set of connected vertices or a parametric equation for a geometric primitive (similar to Pedrotti's zone).

481. Further, McCulloch discloses "collision processing" to determine when virtual objects come into contact (collide) with real or virtual objects, which persons of ordinary skill in the art would have understood could be used to determine when a tracked handheld controller device (PED) moves outside a zone. McCulloch (Ex.1008) at 23:62-63 (disclosing the existence of collision processing: "The virtual images include any modifications to virtual image data based on collision processing."), 27:39-54 (disclosing examples of collision processing: "In step 508, a collision is identified between the virtual object under control of the real controller and the user selected force feedback object. Either the scene mapping engine 306 or an application 166 may identify the collision based on object 3D space position data for the virtual object and the user selected force feedback object from a 3D mapping of the user environment tracking the positions of the objects. The collision may occur inside or outside the display field of view but one or more forces associated with the collision may be modeled by the physics engine 308 based on the properties

of the virtual object and the force feedback object and collision parameters like the speed and acceleration of each object. Based on the collision modeling performed by the physics engine 308 and the collision being in the display field of view, the virtual data engine 195 displays the collision from the user perspective.") Persons of ordinary skill in the art would have understood that such collision processing includes the very basic processing to determine whether a collision between two objects have occurred, e.g., whether the vertices of one object penetrate the surface of another object, and that this processing could also be used to determine when a tracked handheld controller device (PED) moves outside a zone.

b. Claim 3

(1) 3[a]: "The method of claim 1 further comprising: tracking, with the WED worn on the head of the user, the user to determine when the user moves outside the zone; and"

482. Limitation 3[a] would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section X.A.4.b(1) (Ground 1, limitation 3[a]).

483. As a preliminary matter, persons of ordinary skill in the art would have understood that McCulloch's HMD (the claimed WED) is tracked, and hence the user's movement determined. McCulloch states "[t]he technology described herein provides for controlling an object displayed by a near-eye, augmented reality display

with a real controller device." McCulloch (Ex.1008) at 1:18-20. Persons of ordinary skill in the art would understand that discussion of an HMD in the context of augmented reality includes this. Indeed, the view-dependent virtual imagery described throughout McCulloch would not be possible without the HMD being tracked.

484. McCulloch discloses that the HMD (the claimed WED) is tracked. McCulloch (Ex.1008) at 15:30-47 ("Mapping what is around the user in the user's environment can be aided with sensor data. Data from an orientation sensing unit 132, e.g. a three axis accelerometer and a three axis magnetometer, determines position changes of the user's head and correlation of those head position changes with changes in the image and depth data from the front facing capture devices 113 can identify positions of objects relative to one another and at what subset of an environment a user is looking. As mentioned above, depth map data of another HMD device, currently or previously in the environment, along with position and head orientation data for this other HMD device can also be used to map what is in the user environment. Shared real objects in their depth maps can be used for image alignment and other techniques for image mapping. With the position and orientation data as well, what objects are coming into view can be predicted as well so physical interaction processing, occlusion and other processing can start even before the objects are in view.") McCulloch's HMD includes the "inertial sensors"

(e.g., a three axis accelerometer) for "sensing position, orientation, and sudden accelerations of head mounted display device 2." McCulloch (Ex.1008) at 8:17-28; 24:14-21 ("device data may also include data from sensors or sensing units or determined from the sensors or sensing units like the orientation sensors in inertial sensing unit 132"). In other words, the sensors provided on McCulloch's HMD are used for tracking the user's head and thus can be used to track the location of the user, e.g., through position and orientation information; the same is true with respect to McCulloch's system's ability to track the handheld controllers, which are held in the hand of the user and therefore reflects the location of the user as well. *See also* Sections X.B.3.b-X.B.3.c (limitations 1[a]-1[b]). It would have been obvious to use McCulloch's system that includes information regarding the location of the user—whether via the HMD worn on the user's head or the controller held in the user's hand—to implement Pedrotti's method of displaying a warning when the user leaves the zone.

485. In addition, persons of ordinary skill in the art would have readily understood how "to determine when the user moves outside the zone" for the same reasons I discuss for limitation 2[b], including for example their basic knowledge and McCulloch's disclosures of collision processing. *See* Section X.B.4.a(2) (limitation 2[b]).

(2) 3[b]: "displaying, with the WED worn on the head of the user, a three dimensional (3D) virtual image that shows a size and a shape of the zone in response to the WED determining that the user moved outside the zone."

486. For the same reasons as I described for limitations 2[b] and 3[a], limitation 3[b] would have been obvious to persons of ordinary skill in the art over McCulloch and Pedrotti, including based on the Pedrotti disclosures discussed in Section X.A.4.b(2) (Ground 1, limitation 3[b]). *See* Sections X.B.4.a(2) (limitation 2[b]), X.B.4.b(1) (limitation 3[a]).

c. Claim 4

(1) 4[a]: "The method of claim 1 further comprising: storing, in memory of the WED, a location of the zone, a size and a shape of the zone, and locations of the multiple SLPs in the zone from where the binaural sound originates to the user; and"

487. Limitation 4[a] would have been obvious to persons of ordinary skill in the art over Pedrotti, including based on the Pedrotti disclosures discussed in Section X.A.4.c(1) (Ground 1, limitation 4[a]).

488. As a preliminary matter, persons of ordinary skill in the art would have known and understood that data representing "a location of the zone, a size and a shape of the zone, and locations of the multiple SLPs in the zone from where the binaural sound originates to the user" is no different than any other data used by the

system in that it is stored in memory to be used, acted upon, rendered, and displayed in the user's HMD when appropriate.

489. Limitation 4[a] also would have been obvious over McCulloch in view of Pedrotti. Persons of ordinary skill in the art would have known and understood that a McCulloch system implementing Pedrotti's method would have to (or at a minimum would obviously) store the zone's location, size, and shape because that information is necessary for Pedrotti's method of determining when a user approaches a zone boundary or leaves the zone.

490. And persons of ordinary skill in the art also would have understood that such information could advantageously be stored in memory in an HMD, consistent with McCulloch's teachings (*see* McCulloch (Ex.1008) at 8:1-11 ("memory 244"), 19:8-21, 19:51-62, Fig. 2A (depicting same), 20:22-27 (McCulloch's system utilizes "adaptive virtual environment rules … based on the real objects and real features mapped in the user environment" including "size dimensions"), to allow the HMD's processor to access that information without the need to connect it to an external or remote memory.

491. Additionally, McCulloch teaches storing the location and size and shape of a zone because McCulloch teaches generating and storing 3D maps of environments, and it would have been obvious to store the Pedrotti-type zone in relation to McCulloch's mapped environments. *See* McCulloch (Ex.1008) at 15:48-

54 ("The scene mapping engine 306 can also use a view independent coordinate system for 3D mapping. ***The map can be stored in the view independent coordinate system in a storage location (e.g. 324)*** accessible as well by other display device systems 8, other computer systems 12 or both, ***be retrieved from memory and be updated over time*** as one or more users enter or ***re-enter the environment***.") (emphasis added), 15:63-67 ("When a user enters an environment, the scene mapping engine 306 may first search for a pre-generated 3D map identifying 3D space positions and identification data of objects stored locally or accessible from another display device system 8 or a network accessible computer system 12."). For example, if a user enters a new environment (e.g., moves into a different room or a different part of the room), persons of ordinary skill in the art would have understood to retrieve the stored 3D map and the associated boundary in order to apply the appropriate or updated boundary for that user's location. As McCulloch indicates, location information can be based not only on a relative coordinate system, but also an absolute location, such as based on GPS information retrieved from the HMD's sensors. McCulloch (Ex.1008) at 8:17-22.

492. Furthermore, storing multiple SLP locations would have been equally straightforward and obvious because McCulloch taught that its system stores multiple virtual objects' locations and generates binaural sound for those objects, from their locations (SLPs). McCulloch (Ex.1008) at 15:48-54 (storing maps in

memory), 19:8-27 (storage of virtual object properties), 19:51-62 (using stored properties to "update a 3D space position or position volume for an object"), 21:21-39 (McCulloch's 3D audio engine outputs "[a]udio data for virtual objects" "as if coming from the direction of [a] virtual object projected into the display field of view"). Thus, from these disclosures, persons of ordinary skill in the art would have known that multiple virtual object locations, including ones from which binaural sound originates (i.e., SLPs) are, or obviously could and would be, stored in McCulloch's HMD memory.

(2) 4[b]: "displaying, with the WED, a virtual image having the size and the shape of the zone in response to the WED determining that the user is located in the zone."

493. For the same reasons that I discussed for limitations 2[b] and 3[a]-3[b], limitation 4[b] would have been obvious over McCulloch in view of Pedrotti. *See* Sections X.B.4.a(2) (limitation 2[b]), X.B.4.b(1) (limitation 3[a]), X.B.4.b(2) (limitation 3[b]).

494. As I discussed in Ground 1, Pedrotti's HMD tracks the controllers and can determine the location of the user's body in relation to the boundary of the zone, and thus it is able to determine when the user is located in the zone. *See* Sections X.A.3.c (Ground 1, limitation 1[b]), X.A.4.c(2) (Ground 1, limitation 4[b]

495. In addition, it would have been obvious to display the zone when the HMD determines that a user has "enter[ed] or re-enter[ed] the environment" an environment (i.e., when a user is determined to be "located in the zone") based on McCulloch's disclosure of storing 3D maps for when users enter or re-enter virtual environments. McCulloch (Ex.1008) at 15:48-54 ("[t]he map can be stored" "in a storage location," "be retrieved from memory and be updated over time"), 15:63-67 ("[w]hen a user enters an environment, the scene mapping engine 306 may first search for a pre-generated 3D map identifying 3D space positions and identification data of objects stored locally"). According to these teachings in McCulloch, it would have been obvious to display the virtual image having the size and shape of the zone (retrieving from memory and then displaying it to the user) since the size and shape of the zone reflects information similar to 3D space position for the user's virtual environment. Displaying the virtual image of the size and shape of the zone (e.g., the zone itself or the contours of the zone) in these scenarios can be used to, for example, inform the user of applicable boundaries while in the virtual environment.

d. Claim 5

(1) 5[a]: "The method of claim 1 further comprising: designating, with the PED held in the hand of the user, locations of the multiple SLPs in the zone from where the binaural sound originates to the user; and"

496. Limitation 5[a] would have been obvious to persons of ordinary skill in the art over McCulloch, either alone or with Flaks, in view of Pedrotti.

497. In addition, I understand that 8K contends with respect to similar claim language that two images of a game character "taken from a video depicting the user experience with the 'Bogo' application" show the character in different locations, and this satisfies the claim language requiring "designating, with the HPED held in the hand of a user, a sound localization point (SLP) in empty space in the zone above the physical floor from where the binaural sound originates to the user":



'737 8K Infringement Contentions (Ex.1121) at 4.

498. Consequently, it appears that, in 8K's view, limitation 5[a] merely requires a game character that can be "moved by direction of the HPED" because,

as a result, an "SLP will likewise move along with the corresponding location of the game character." *See* '737 8K Infringement Contentions (Ex.1121) at 4.

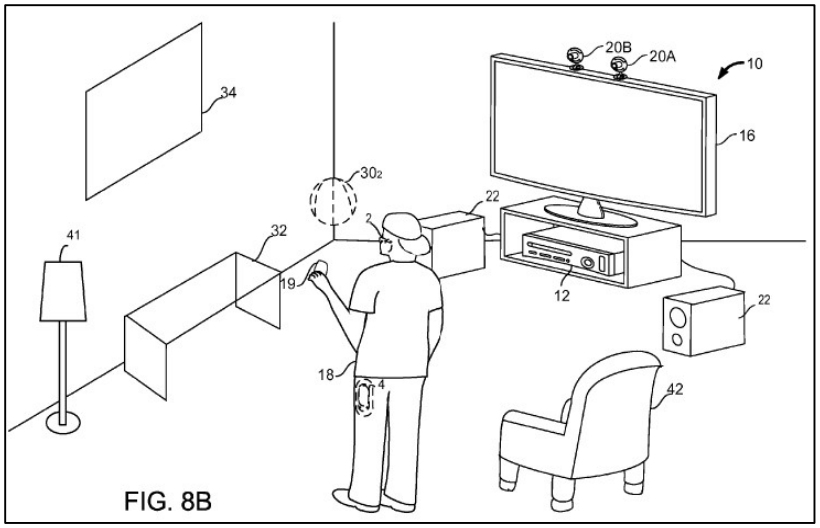
499. If 8K's interpretation applies and limitation 5[a] requires only moving sound-producing virtual objects, such as game characters, this limitation would have been basic, straightforward, and of course obvious to persons of ordinary skill in the art long before February 2016, over numerous AR and VR references. *See* X.A.4.d(1) (Ground 1, limitation 5[a]); *see also* Section VII.F.

500. As I discussed, persons of ordinary skill in the art would have understood having SLPs move with their corresponding virtual image is the essence of creating a realistic virtual environment. To summarize, having a virtual object's sound move with it, including in response to user manipulation, was a fundamental, "extremely important" feature of AR and VR, long before February 2016. *See* Brungart (Ex.1050) at 9 ("realistic near-field audio cues are extremely important" "where listeners are able to grab virtual sound sources and move them around the head"). It was also well known that sounds in these settings are associated with sound sources, which provide cues of characters' or objects' locations. Indeed, McCulloch discloses that localized sound emanates from the virtual object, indicating that the virtual object is associated with the SLP. McCulloch (Ex.1008) at 14:53-64 ("sound to be played … [is] identified to the 3D audio engine 304 with

data identifying from which direction or position to make the sound seem to come from").

501. McCulloch discloses multiple examples in which movement of a handheld controller moves a virtual object. McCulloch (Ex.1008) at 12:49-13:51 ("FIGS. 3A and 3B illustrate a contextual example of a virtual object being controlled with a real controller device from a user perspective."), 25:6-26:34 (describing the process by which a user is able to control a virtual object using the real controller device), 25:25-27 (describing other inputs for controlling objects), 29:4-17 ("FIG. 8B illustrates an example of a virtual object representation of the user selected real object being controlled with the real controller device …."), Figs. 3A-3E, 8B. And, with respect to Figure 8B, McCulloch explains controlling virtual objects with movement of the controller, including changes in its position and orientation: "[t]he changes in position and orientation of the handheld controller causes its inertial motion unit to generate one or more signals which are converted by the handheld IMU real controller device 19 to be user input." McCulloch (Ex.1008) at 29:6-9.

502. As one example, McCulloch discloses that "the movement of the real controller device 19 up by the user has translated into an up action to be applied to the basketball virtual object 30_2, which the user sees from his perspective as he is looking straight at the virtual basketball 30_2":



McCulloch (Ex.1008) at Fig. 8B, 29:12-16.

503. And persons of ordinary skill in the art would have known and understood that sound associated with a virtual object moves with the object. Thus, with respect to McCulloch's example, sound associated with the virtual basketball moves with the basketball (e.g., the ball bouncing on the floor or whooshing through the air). As McCulloch explains, "the 3D audio engine 304 plays audio data for the virtual object projected from a 3D space position of the virtual object relative to a 3D space position and orientation identified for the display device which is used to approximate the position and orientation of the user's head supporting the display device." McCulloch (Ex.1008) at 26:7-12. In another of McCulloch's example concerning a virtual helicopter, the user's input using the controller "caus[es] the display to show the tail rotors going down and the pulling effect this has on the rest of the helicopter"; and, when the user is not paying attention and the helicopter

crashes into a wall behind the user, "the 3D audio engine 304 plays the audio of the virtual crash to project from a position of the wall behind the user." McCulloch (Ex.1008) at 13:24-48, 26:12-19; *see also* Section X.A.3.d (Ground 1, limitation 1[c] providing additional examples of sound associated with a virtual object moving with the object). Persons of ordinary skill in the art would have known that such sounds could and would be implemented in any of McCulloch's examples. McCulloch (Ex.1008) at 24:58-25:5 ("The technology may be embodied in other specific forms without departing from the spirit or essential characteristics thereof … the method embodiments are not limited to operating in the system embodiments described" and "may be implemented in other system embodiments.").

504. Persons of ordinary skill in the art would know this is how McCulloch's system works because McCulloch discloses storing input audio data with respect to virtual objects, and incorporates by reference Flaks' disclosure of a positional 3D audio engine. McCulloch (Ex.1008) at 21:21-38 (incorporating Flaks), 14:21-22 ("sound effects for an application from the 3D audio engine 304 to be output to the user via earphones 130"), 14:53-67 (scene mapping engine 305 combines information regarding position and movement of virtual objects with the image and audio processing engine 191). And, as I have explained above in Ground 1, it was well known, straightforward, and basic (and, of course, obvious) that virtual characters or objects, including characters and objects that can be controlled and

moved by a handheld controller, are programmed to be associated with their sounds in AR and VR settings, such that sounds emanate from the locations for the virtual characters' and objects' images. *See* Section X.A.3.d (Ground 1, limitation 1[c]).

505. McCulloch, in fact, provides several examples of localized sound emanating from virtual objects controlled by "real controller device[s]." McCulloch (Ex.1008) at 26:7-19 (flying helicopter that crashes into wall), 29:3-30:3 (bouncing basketball that crashes into television), 25:6-26:34, Fig. 5 (describing a process for "controlling a virtual object" "with a real controller device" that includes "play[ing] audio for the virtual object projected from a 3D space position of the virtual object"), Figs. 8A-8D, 24:67-25:3.

506. Furthermore, McCulloch incorporates by reference Flaks' disclosure of a positional 3D audio engine, which demonstrates to persons of ordinary skill in the art that McCulloch discloses a virtual environment where virtual objects are associated with their localized, binaural sounds. McCulloch (Ex.1008) at 21:29-34; Flaks (Ex.1009) at 1:9-11 (explaining "[h]umans estimate the location of a source by taking cues derived from one ear, and by comparing cues received at both ears (difference cues or binaural cues)"), 1:44-46 (disclosing HRTF processing to "localize a sound as coming from a virtual sound source"), 1:62-67 (indicating that Flaks' invention is directed to binaural sound because "[a] realistic 3D audio signal may be generated based on the data collected from sensors," where the data

"describes physical characteristics of the listener (e.g., head and pinna shape and size) in order to determine a suitable HRTF for that listener"), 13:55-14:4.

507. Persons of ordinary skill in the art would have understood from McCulloch's (and Flaks') disclosures that binaural sound for McCulloch's bouncing (and crashing) basketball will (or at a minimum will obviously) track the basketball's virtual image, e.g., for "realistic 3D audio" improving a user's experience. McCulloch (Ex.1008) at 1:62-64.

(2) 5[b]: "displaying, with the WED, virtual images at the location of the multiple SLPs in the zone."

508. Limitation 5[b] would have been obvious to persons of ordinary skill in the art over McCulloch (alone or with Flaks) in view of Pedrotti, including based on Pedrotti's disclosures discussed in Section X.A.4.d(2) (Ground 1, limitation 5[b]).

509. As discussed for limitation 1[c], McCulloch discloses an HMD that displays virtual images, and so does Pedrotti. *See* Section X.B.3.d (limitation 1[c]); McCulloch (Ex.1008) at Fig. 8B, 8:40-46, Fig. 4A; Pedrotti (Ex.1005) at Abstract ("processor causes the HMD to display a virtual world"); *see* Section X.B.3.d (limitation 1[c]). For example, as noted, McCulloch's HMD displays a virtual basketball to the user. McCulloch (Ex.1008) at Fig. 8B-8D.

510. Additionally, McCulloch discloses (or at a minimum renders obvious), displaying virtual images at the locations of the respective multiple SLPs, or sound

sources of the binaural sounds. For example, McCulloch describes a virtual basketball smashing into a television or a virtual helicopter crashing into a wall where both the virtual image (i.e., the basketball or helicopter) and the associated sound (smashing and crashing sounds, respectively) are provided to the user. McCulloch (Ex.1008) at Figs. 3A-3E, 8A-8D.

511. McCulloch discloses a scene mapping engine 306 that "identifies the position and tracks the movement of real and virtual objects in [a] volumetric space," and McCulloch's HMD's image generation unit 120 "display[s] a virtual object" such that it appears "at a designated depth location in a field of view to provide a realistic, in-focus three dimensional display of a virtual object." McCulloch (Ex.1008) at 8:40-46, 16:58-63, 13:52-14:5 (describing associated software components), Fig. 4A. McCulloch also teaches linking visual and audio data, e.g., with collision-related events:

> The sound library … may also store audio data for sound effects to be played by the 3D audio engine 304 and which may be linked with different simulated actions, pre-collision events and collision events. Similarly, a visual effects library may store routines for animations, highlighting, and other types of visual enhancements which may also be associated with particular actions, pre-collision events and collision effects … An application can register virtual objects and pre-collision events and the associated visual effects, sound effects, and collision effects …

McCulloch (Ex.1008) at 22:66-23:20.

512. Additionally, Flaks discloses that "[a]s one example, the virtual sound source 29a could be an object being displayed on the display 196." Flaks (Ex.1009) at 4:10-20, 1:17-28 (similar).

513. Persons of ordinary skill in the art would have understood that the virtual image that is displayed by McCulloch's HMD is displayed "at the location of the multiple SLPs in the zone," as required by limitation 5[b]. This would have been obvious over McCulloch, including because it expressly incorporates Flaks or in view of Flaks, since both McCulloch and Flaks disclose associating the audio data from a virtual object with the display of the virtual object or sound source, i.e., SLP. *See, e.g.*, McCulloch (Ex.1008) at 21:25-28 ("Audio data for virtual objects generated by an application can be output to the earphones to sound as if coming from the direction of the virtual object projected into the display field of view."); Flaks (Ex.1009) at 4:10-20 ("the sound in the 3D audio signal may appear to be originating from some virtual sound source," which "could be an object being displayed on the display"). For example, if the basketball crashed into the monitor, persons of ordinary skill in the art would have known, including based on McCulloch's and Flaks' disclosures, that sound for that crash should be perceived to originate from the point of the collision, not from any other object in the room. McCulloch (Ex.1008) at 29:46-55 ("[t]he physics engine 308 models the collision

and the virtual data engine 195 displays a collision effect"), 21:35-38 ("Audio data from a sound library 312 may be associated with one or more collisions or actions" "so that the 3D audio engine 304 will play the audio data during display of one or more collisions or actions.").

e. Claim 6

(1) 6[a]: "The method of claim 1 further comprising: selecting the one of the multiple SLPs in the zone when the PED held in the hand of the user is pointed at the one of the multiple SLPs in the zone; and"

514. For the same reasons as I described for limitation 1[c], limitation 6[a] would have been obvious over McCulloch in view of Pedrotti. *See* Section X.B.3.d (limitation 1[c]).

515. McCulloch discloses that objects can be selected. For example, McCulloch (Ex.1008) at 1:21-23 ("The technology described herein provides for controlling an object displayed by a near-eye, augmented reality display with a real controller device. The object may be selected based on user input, often input captured via a natural user interface (NUI)."), 4:14-15 ("A user may select an object for control by a real controller device."), and 26:20-21 ("A user may select a real object to be controlled by the real controller device 21."). McCulloch discloses multiple methods of selection that involve pointing. McCulloch (Ex.1008) at 25:18-28 ("For example, a selection gesture like pointing one's finger may be identified by

the gesture recognition engine 193 and a notification sent to the operating system identifying the selection gesture and the object to which it is related.").

516. Persons of ordinary skill in the art would have known and understood that it was common to use a handheld controller to select, move, and control virtual objects by pointing at them. *See* Section VII.D (discussing tracking handheld controllers); *see, e.g.*, Jerald, THE VR BOOK (Ex.1063) at 314-15 ("Tracked hand-held controllers are typically 6DoF devices (known as 'wands' in the VR research community where they have been used for decades) and can also contain functionality offered by non-tracked hand-held controllers. Tracked hand-held controllers are currently the best option for a majority of interactive VR applications. ***Tracked hand-held controllers are easy to use for many 3D tasks due to their natural, direct mapping to hand motion***.") (emphasis added), 327 ("[T]he Pointing Pattern is one of the most fundamental and often-used patterns for selection."); Ross at 22:17-29 ("[a] user, content creator, and/or other persons may create, customize, and/or adjust using a controller").

517. Thus, because pointing as a method of selecting an object in virtual environments, as well as highlighting to indicate those selections were made, were well known before February 2016, selecting an SLP when a PED (e.g., McCulloch's controller) is pointed at the SLP would have been obvious over McCulloch (alone or with Flaks) and Pedrotti. *See* Section X.B.3.d (limitation 1[c]).

(2) 6[b]: "displaying, with the WED worn on the head of the user, a virtual image at the one of the multiple SLPs in response to the one of the multiple SLPs being pointed at by the PED held in the hand of the user."

518. For the same reasons as I described for limitations 1[a], 5[a]-5[b] and 6[a], limitation 6[b] would have been obvious over McCulloch, either alone or with Flaks, in view of Pedrotti. *See* Sections X.B.3.b (limitation 1[a]), X.B.4.d(1) (limitation 5[a]), X.B.4.d(2) (limitation 5[b]), X.B.4.e(1) (limitation 6[a]); X.A.8.b (Ground 1, claim 19).

519. Persons of ordinary skill in the art would have known and understood that a McCulloch-Pedrotti or McCulloch-Flaks-Pedrotti system could and would display, using McCulloch's HMD, a virtual image associated with an SLP, when a user points McCulloch's controller at the image (and thus the associated SLP). For example, when a user points at and selects at a virtual helicopter (a virtual object associated with an SLP), the helicopter's virtual image is displayed and also moves with that virtual helicopter. McCulloch (Ex.1008) at 26:7-19 (describing the virtual helicopter crashing into a wall based on the user's input dictating its path), Figs. 3A-3E. Both the corresponding image and sound would move together and be displayed at a different location, in response to the user's pointing and under the user's direction. The same is true for McCulloch's virtual basketball. McCulloch

(Ex.1008) at 30:36-63 (describing the virtual basketball moving as directed by the user and colliding with the display of the television); Figs. 8B-8D.

f. Claim 7: "The method of claim 1, wherein the zone has one of a three-dimensional (3D) shape of a cylinder and a 3D shape of a rectangle, and the user is centered in the zone."

520. Claim 7 would have been obvious in view of the Pedrotti disclosures discussed in Section X.A.4.f (Ground 1, claim 7).

521. Pedrotti discloses an example of a circular boundary defining a zone with a 3D shape of a cylinder where the user is centered in the cylinder. *See* Section X.A.4.f (Ground 1, claim 7). In addition, this is consistent with McCulloch, which does not restrict the zone for game play to any particular shape. *See* McCulloch (Ex.1008) at 20:11-18.

g. Claim 8: "The method of claim 1 further comprising: playing, with speakers in the WED worn on the head of the user, a verbal instruction indicating the user should move back into the zone in response to the WED determining that the user moved outside the zone."

522. Claim 8 would have been obvious in view of the Pedrotti disclosures discussed in Section X.A.4.g (Ground 1, claim 8).

523. Specifically, Pedrotti discloses "it may [] be appropriate to generate an audio warning … instead of, the visual warning" to alert the user. Pedrotti (Ex.1005) at 2:44-59, 4:37-44 (explaining that the processor tracks the position and orientation

of trackers in the HMD and controllers), 12:31-50 (same). Pedrotti's warning indicates the user should move back into the zone so as not "to move out of the selected area," and can take the form of a verbal instruction as was a common technique for chaperone systems. *See* Section X.A.4.g (Ground 1, claim 8).

524. In addition, persons of ordinary skill in the art would have known that verbal instructions could and would be played through McCulloch's HMD's earphones, which include, or at a minimum obviously include, speakers that play audio because using verbal instructions for use as an "audio warning" would have been an obvious type of warning. *See* Section X.B.3.e (limitation 1[d]) (McCulloch's HMD's earphones play binaural sound); McCulloch (Ex.1008) at 8:17-22 (describing earphones); Flaks (Ex.1009) at 1:18-23. Indeed, audio warnings, including through verbal instructions and cues, were commonly used in chaperone systems, and more broadly to aid in navigation. *See* Jerald, THE VR BOOK (Ex.1063) at 240 (explaining that "[v]ital information can be conveyed through spoken language (Section 8.2.3) that is either synthesized, prerecorded by a human, or live from a remote user. The spoken information might be something as simple as an interface responding with 'confirmed' or could be as complex as a spoken interface where the system both provides information and responds to the user's speech").

5. Independent Claim 9

a. 9[pre]: "A non-transitory computer readable storage medium storing instructions that one or more electronic devices execute as a method, the method comprising:"

525. Both McCulloch and Pedrotti disclose the preamble of claim 9. As explained for limitation 1[pre], both McCulloch and Pedrotti disclose methods. *See* Sections X.B.3.a (limitation 1[pre] for McCulloch), X.A.3.a (Ground 1, limitation 1[pre] for Pedrotti).

526. In addition, McCulloch disclosed "computer readable storage" and "processor readable storage" used in its systems and methods as well as a "processing unit" for executing "processor readable instructions and data." McCulloch (Ex.1008) at 8:1-16 (describing electronics that include "a memory" for "storing processor readable instructions and data"), 30:35-50 (describing "computer readable storage devices" and "processor readable storage device"). Pedrotti likewise discloses "a non-transitory computer-readable medium." *See* Section X.A.5.a (Ground 1, limitation 9[pre]).

b. 9[a]: "dividing, with a portable electronic device (PED) held in a hand of a user, an area around the user into a zone that includes sound localization points (SLPs) in empty space from where binaural sound originates to the user;"

527. For the same reasons as I described for limitation 1[a], limitation 9[a] would have been obvious to persons of ordinary skill in the art over McCulloch, either alone or with Flaks, in view of Pedrotti. *See* Section X.B.3.b (limitation 1[a]).

528. In addition, persons of ordinary skill in the art would have known and understood that McCulloch's virtual objects, as well as their associated SLPs, are positioned in empty space because they take up space, i.e. they have a size and shape, within the boundaries of McCulloch's playspace (or inside Pedrotti's zone) and thus could and would be in "empty space," or space not occupied by a physical object. *See* '509 patent (Ex.1001-509) at 6:1-5. McCulloch (Ex.1008) at 21:1-4 ("virtual and real objects have size and shape"), Fig. 8B.

529. For example, persons of ordinary skill in the art would have understood that McCulloch's virtual basketball, that replaces a "real" basketball in the physical world, is in "empty space." McCulloch (Ex.1008) at Fig. 8B, 29:4-17 (actions are applied to "basketball virtual object 30_2" and "real basketball 30 has been erased"). Similarly, persons of ordinary skill in the art would have known and understood that McCulloch's other virtual objects such as the virtual helicopter and its associated binaural sound could and would be in "empty space." McCulloch (Ex.1008) at 25:8-11, 26:12-19.

c. 9[b]: "determining, with a wearable electronic device (WED) worn on a head of the user, when the user is located inside the zone;"

530. For the same reasons as I described for limitation 1[b], Limitation 9[b] would have been obvious over McCulloch, either alone or with Flaks, in view of Pedrotti. *See* Section X.B.3.c (limitation 1[b]).

d. 9[c]: "determining, with the WED worn on the head of the user, when the user is leaving the zone; and"

531. For the same reasons as I described for limitations 2[a] and 3[a], limitation 9[c] would have been obvious over McCulloch, either alone or with Flaks, in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section X.A.5.d (Ground 1, limitation 9[c]). *See* Sections X.B.4.a(1) (limitation 2[a]), X.B.4.b(1) (limitation 3[a]).

e. 9[d]: "displaying, with the WED worn on the head of the user, a three dimensional (3D) virtual image of the zone in response to the WED determining that the user is leaving the zone."

532. For the same reasons as I describe for limitations 2[b], 3[b], and 9[c], limitation 9[d] would have been obvious over McCulloch, either alone or with Flaks, in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section X.A.5.e (Ground 1, limitation 9[d]). *See* Sections X.B.4.a(2) (limitation 2[b]), X.B.4.b(2) (limitation 3[b]).

6. Dependent Claims 10-14

533. I understand that claims 10-14 depend on independent claim 9.

534. Thus, it is my opinion that each of dependent claims 10-14 would have been obvious to persons of ordinary skill in the art for the same reasons as independent claim 9 and additionally for the reasons I discuss in the following subsections.

a. Claim 10

(1) 10[a]: "The non-transitory computer readable storage medium of claim 9 in which the method further comprises: determining, with the WED, when the PED is pointed at one of the SLPs while the user is located in the zone; and"

535. For the same reasons as I described for limitations 1[c] and 4[a], Limitation 10[a] would have been obvious over McCulloch, either alone or with Flaks, in view of Pedrotti. *See* Sections X.B.3.d (limitation 1[c]), X.B.4.c(1) (limitation 4[a]).

536. McCulloch's HMD receives position and orientation data from its controller, (the handheld IMU). It also would have been obvious for a person of ordinary skill in the art to store in McCulloch's HMD's memory the locations of the SLPs.

537. Additionally, as discussed in Ground 1, it would have been obvious to use this information to determine when the PED is pointed at an SLP while the user is located in the zone. Section X.A.6.a(1) (Ground 1, limitation 10[a]). Indeed, because pointing is represented by a direction (controller's orientation) from a

location (controller's position), it would have been obvious to trace this vector to determine when it intersects any SLP's location to determine when the PED is pointed at an SLP. *See* Jerald, THE VR BOOK (Ex.1063) at 327 ("Pointing Pattern extends a ray into the distance and the first object intersected can then be selected"). It also would have been obvious to make this determination while the user is located in the zone, as the zone defines the user's "safe area" for gameplay.

(2) 10[b]: "playing the binaural sound that originates from the one of the SLPs in the zone in response to the WED determining that the PED is pointed at the one of the SLPs."

538. For the same reasons as I described for limitations 1[c], 1[d], and 10[a], limitation 10[b] would have been obvious over McCulloch, either alone or with Flaks, in view of Pedrotti. *See* Sections X.B.3.d (limitation 1[c]), X.B.3.e (limitation 1[d]), X.B.6.a(1) (limitation 10[a]).

539. Specifically, for the same reasons it would have been obvious to process sound with HRTFs to generate binaural sound originating from designated SLPs and sound-generating virtual objects, which I discussed above in the context of limitation 1[d], it would have been obvious to process sound with HRTFs to generate binaural sound in response to the WED determining that the PED is pointed at an SLP using McCulloch's 3D audio engine (including as described in Flaks), such as before or when the television is shattered by a basketball, as McCulloch

describes. *See* Section X.B.3.e (limitation 1[d]). Indeed, playing the binaural sound in response to pointing to a SLP is common cause-and-effect in a VR environment. As another example, a user partaking in a virtual sword fight may "point" or direct the controller (e.g., the sword shown in Pedrotti) to strike a virtual enemy, which in turn emits a sound of defeat.

b. Claim 11: "The non-transitory computer readable storage medium of claim 9 in which the method further comprises: highlighting, while the user is located in the zone and with a display of the WED, a virtual image at one of the SLPs in the zone when the PED held in the hand of the user is pointed at the one of the multiple SLPs in the zone."

540. For the same reasons as I described for limitations 1[c] and 6[b], claim 11 would have been obvious over McCulloch, either alone or with Flaks, in view of Pedrotti. *See* Sections X.B.3.d (limitation 1[c]), X.B.4.e(2) (limitation 6[b]).

c. Claim 12: "The non-transitory computer readable storage medium of claim 9, wherein the 3D virtual image of the zone is shaped as a cylinder with the user being centered in the cylinder, and the WED is one of a head mounted display and electronic glasses."

541. For the same reasons as I described for claim 7, claim 12 would have been obvious over McCulloch in view of Pedrotti. *See* Section X.B.4.f (claim 7).

542. Additionally, McCulloch's system uses an HMD. *See* McCulloch (Ex.1008) at Fig. 2A (item 2). Indeed, if the zone itself has the shape of a cylinder, its image too has the shape of a cylinder.

d. Claim 13: "The non-transitory computer readable storage medium of claim 9, wherein the 3D virtual image of the zone is shaped as a rectangle with the user being centered in the rectangle, and the WED is one of a head mounted display and electronic glasses."

543. Claim 13 would have been obvious in view of Pedrotti's disclosures I discussed for this claim in Ground 1. *See* Section X.A.6.d (Ground 1, claim 13). If the zone itself has the shape of a rectangle, its image too has the shape of a rectangle.

544. Further, it would have been obvious for a person of ordinary skill in the art for a 3D virtual image of the zone to be shaped as a rectangle. For instance, Pedrotti does not limit the shape of the zone; rather, it is customizable and could be rectangular. Pedrotti(Ex.1005) at 14:56-15:3 (allowing definition of "an irregularly shaped area" and based on "sampling points as the user moves around the chosen perimeter"). In addition, rectangular shaped zones mirror both common physical and virtual environments (i.e., rooms).

e. Claim 14: "The non-transitory computer readable storage medium of claim 9 in which the method further comprises: playing, with the WED worn on the head of the user, a verbal instruction indicating the user should move back into the zone in response to the WED determining that the user moved outside the zone."

545. As I noted in Ground 1, claim 14 is similar to, but broader than, claim 8. Thus, to a person of ordinary skill in the art, claim 14 is obvious for the same reasons as I described for claim 8. *See* Section X.B.4.g (claim 8).

7. Independent Claim 17

a. 17[pre]: "The electronic system comprising:"

546. Both McCulloch and Pedrotti disclose an electronic system. McCulloch discloses a "display device system," which is an electronic system. McCulloch (Ex.1008) at 4:43-49, Fig. 1. Pedrotti also discloses an electronic system. S*ee* Section X.A.7.a (Ground 1, limitation 17[pre]).

b. 17[a]: "a portable electronic device (PED) held in a hand of a user that divides an area around the user into a three-dimensional (3D) zone that includes sound localization points (SLPs) in empty space from where binaural sound originates to the user; and"

547. For the same reasons as I described for limitations 1[a], 2[b], and 9[a], limitation 17[a] would have been obvious over McCulloch in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section X.A.7.b (Ground 1, limitation 17[a]). *See* Sections X.B.3.b (limitation 1[a]), X.B.4.a(2) (limitation 2[b]), X.B.5.b (limitation 9[a]).

c. 17[b]: "a wearable electronic device (WED) that is worn on a head of the user,"

548. For the same reasons as I described for limitation 1[b], limitation 17[b] would have been obvious over McCulloch in view of Pedrotti. *See* Section X.B.3.c (limitation 1[b]).

549. Further, McCulloch's system comprises an HMD (WED) that is worn on the head. McCulloch (Ex.1008) at Fig. 2A (item 2).

d. 17[c]: "wirelessly communicates with the PED,"

550. Both McCulloch and Pedrotti disclose that the HMD can communicate wirelessly with other devices, including with the PED. McCulloch (Ex.1008) at 5:19-36, 6:55-58 (real controller devices "coupled to the display device system" "via a wireless connection"); Section X.A.7.d (Ground 1, limitation 17[c] for Pedrotti's disclosures).

e. 17[d]: "includes speakers that play the binaural sound to the user that emanates from the SLPs in empty space,"

551. For the same reasons as I described for limitations 1[d] and 9[a], and claim 8 (speakers), limitation 17[d] would have been obvious over McCulloch, either alone or with Flaks, in view of Pedrotti *See* Sections X.B.3.e (limitation 1[d] regarding playing binaural sound), X.B.5.b (limitation 9[a] regarding the SLPs in empty space), X.B.4.g (claim 8 regarding playing with speakers).

f. 17[e]: "includes one or more sensors that sense when the PED leaves the zone,"

552. For the same reasons as I described for limitation 2[a], limitation 17[e] would have been obvious over McCulloch in view of Pedrotti. *See* Section X.B.4.a(1) (limitation 2[a]).

g. 17[f]: "and includes a display that displays a 3D virtual image of the zone in response to sensing that the PED leaves the zone,"

553. For the same reasons as I described for limitations 2[b] and 17[e], limitation 17[f] would have been obvious over McCulloch in view of Pedrotti. *See* Sections X.B.4.a(2) (limitation 2[b]), X.B.7.f (limitation 17[e]).

h. 17[g]: "wherein the display displays the 3D virtual image of the zone to warn the user that the user is leaving the zone."

554. For the same reasons as I described for limitation 3[b], limitation 17[g] would have been obvious over McCulloch in view of Pedrotti. *See* Section X.B.4.b(2) (limitation 3[b]).

555. Specifically, Pedrotti discloses that its system "generates a warning" "when the user's head and/or hand approaches to within a preselected distance." Pedrotti (Ex.1005) at 12:40-50. Persons of ordinary skill in the art would have understood that "approach[ing] to within a preselected distance, for example, one foot … of the boundary" indicates that the user is leaving the zone, especially when that "preselected distance" is set to be a small number or zero. Pedrotti (Ex.1005) at 12:40-50.

8. Dependent Claims 18-20

556. I understand that claims 18-20 depend on independent claim 17.

557. Thus, it is my opinion that each of dependent claims 18-20 would have been obvious to persons of ordinary skill in the art for the same reasons as

independent claim 17 and additionally for the reasons I discuss in the following subsections.

a. Claim 18: "The electronic system of claim 17, wherein the display of the WED highlights a virtual image at one of the SLPs in response to the WED determining that the PED is pointing to the one of the SLPs."

558. For the same reasons as I described for limitations 1[c] and 6[b], Claim 18 would have been obvious over McCulloch in view of Pedrotti. *See* Sections X.B.3.d (limitation 1[c]), X.B.4.e(2) (limitation 6[b]).

b. Claim 19: "The electronic system of claim 17, wherein the WED tracks a location of the user with respect to the SLPs, and automatically display a virtual image at a location of one of the SLPs in response to determining that the user is proximate to the location of the one of the SLPs."

559. For the same reasons as I described for limitations 2[a] and 3[a], 4[a], and 6[b], Claim 19 would have been obvious over McCulloch in view of Pedrotti. *See* Sections X.B.4.a(1) (limitation 2[a]), X.B.4.b(1) (limitation 3[a]), X.B.4.c(1) (limitation 4[a]), X.B.4.e(2) (limitation 6[b]).

560. In addition, McCulloch discloses storing virtual objects' locations. McCulloch (Ex.1008) at 19:8-21 (describing "data fields in an object physical properties data set" including "size," "shape," and "boundary data"), 19:51-62 ("scene mapping engine 306 can update a 3D space position or position volume for an object"). These virtual objects are associated with SLPs because McCulloch

describes sounds coming from the virtual objects such as a basketball smashing into a television or a helicopter. Thus, McCulloch also stores the SLPs' locations. McCulloch's system is then able to compare the user's location with those of SLPs to determine when the user is proximate thereto. McCulloch (Ex.1008) at 19:8-21, 19:51-62 (describing position history or motion path).

561. Persons of ordinary skill in the art would have understood that Pedrotti's system does in fact automatically displays the virtual fence when the condition that the PED is at the boundary of the 3D zone is met. *See* Pedrotti (Ex.1005) at 15:4-58 (explaining the flow chart shown in Fig. 15), Fig. 15. Furthermore, as discussed in Ground 1, it would have been obvious to persons of ordinary skill in the art to apply Pedrotti's logic for automatically displaying a fence's virtual image in response to determining that the user is in a specific location (i.e., when leaving or being outside the zone) to automatically displaying other virtual images at SLPs based on the user's location. Section X.A.8.b (Ground 1, claim 19); Pedrotti (Ex.1005) at 4:37-44 (explaining that the processor "tracks the position and orientation of the HMD track" and the "trackers in the physical controllers"). Automatically displaying images when users get close was a well-known effect in virtual environments (Section X.A.8.b (Ground 1, claim 19)), e.g., to present content of interest to the user while pausing or not presenting content on which the user is not focused. *See* Ross (Ex.1125) at 2:32-67 ("The system may be

configured such that primary virtual reality content may be displayed to a user, and, responsive to the user turning his view away from the primary virtual reality content; moving away from the primary virtual reality content; and/or taking other actions … The primary virtual reality content may resume (e.g., automatically) when the user returns his view.")

562. Furthermore, McCulloch's HMD supports this ability because its scene mapping engine "identifies the position and tracks the movement of real and virtual objects" McCulloch (Ex.1008) at 16:49-65 (describing "3D mapping" using "Depth images from multiple perspectives"), 4:4-15, 21:1-4 ("a 3D space position for each object may be defined by the scene mapping engine"), 28:23-25. Thus, McCulloch's HMD could and would compare a user's location with locations of virtual objects (as well as their SLPs).

c. Claim 20: "The electronic system of claim 17, wherein the speakers in the WED play the binaural sound that emanates from one of the SLPs in empty space in response to the WED determining that the PED is pointed to the one of the SLPs in empty space."

563. For the same reasons as I described for limitations 1[d] and 10, Claim 20 would have been obvious over McCulloch in view of Pedrotti. *See* Sections X.B.3.e, X.B.6.a.

* * *

564. For these reasons, every limitation in claims 1-14 and 17-20 of the '509 patent, and each of claims 1-14 and 17-20 as a whole, would have been obvious over McCulloch in view of Pedrotti, and further in view of Flaks.

XI. US Patent No. 11,172,316

565. The challenged claims of the '316 patent recite basic and straightforward systems and processes that, before February 2016, were used in virtual environments and well known to persons of ordinary skill in the art. Further, to the extent 8K argues that the challenged claims of the '316 patent differ from the disclosures of the art relied on in the grounds of Petitioners' petition and discussed in detail below, it is my opinion that any such differences are trivial, including in view of the many additional prior art references I discussed in this declaration, which, among other things, demonstrate the level of knowledge persons of ordinary skill in the art would have possessed before the '316 patent's earliest possible priority date.

A. Ground 1: Claims 1-20 Are Unpatentable Over Pedrotti In View Of Jang, And Further In View Of Begault

566. In this section, I explain why every limitation of claims 1-20 of the '316 patent, and each of claims 1-20 as a whole, would have been obvious to persons of ordinary skill in the art over Pedrotti in view of Jang, and further in view of Begault.

1. Independent Claim 1

a. 1[pre]: "A method comprising:"

567. Pedrotti teaches the preamble of claim 1. At a minimum, Pedrotti renders the preamble obvious.

568. Pedrotti teaches a method executed by one or more electronic devices—its "method of assisting a use in a selected area," which is executed by, among other things, an "HMD" and "handheld controller[s]." Pedrotti (Ex.1005) at 2:27-59 ("One embodiment discloses a method of assisting a user wearing a head-mounted display (HMD) in remaining within a selected area of the physical world, the user holding a handheld controller having a controller tracker which provides information regarding a position of the handheld controller"); *see also* Sections VII.B-VII.C (describing these common components of AR and VR systems).

569. I further note that Jang also teaches a method executed by one or more electronic devices. Jang discloses a method "to perform sound processing" that is carried out by a virtual reality apparatus comprising several electronic devices. *See* Jang (Ex.1006) at 2:15-20, 5:40-42 (describing Figure 4), 6:24-8:16 (describing Figures 1A-1B), 8:54-58 (describing Figure 3), Figs. 1A-1B, 3-4.

b. 1[a]: "dividing, with a portable electronic device (PED) held in a hand of a user, an area around the user into a zone that extends around the user and that includes a sound localization point (SLP) from where binaural sound in empty space originates to the user;"

570. Pedrotti teaches, or at a minimum renders obvious, limitation 1[a].

571. Pedrotti discloses using a handheld portable electronic device (PED) to divide an area into a zone.

572. Pedrotti's system employs a HMD and "handheld controllers," i.e. handheld portable electronic devices (PED). Pedrotti (Ex.1005) at 2:44-47 ("a handheld controller comprising: a controller tracker on the handheld controller which provides information regarding a position of the handheld controller"), 1:40-45 ("a user may wish to use a handheld controller, such as might be used to play a video game, while in a virtual world, and perhaps even two controllers, one for each hand"), Figs. 2-5, 7 (depicting Pedrotti's controllers).

573. The movement of Pedrotti's PED is tracked. Users of Pedrotti's system "wear a head-mounted display (HMD)" and "hold a handheld controller" (PED) comprising a "controller tracker," which "provides information regarding a position of the handheld controller." Pedrotti (Ex.1005) at 2:44-57, 15:7-12 ("it is assumed that a user wears a HMD having a display, a processor provides instructions that direct what appears on the display, and the user is holding a a handheld controller having a tracker which can be used to track the position and orientation of the handheld controller."), 4:49-5:24 ("trackers" "known to those of skill in the art"). A "tracker on the handheld controller [] provides information regarding [the] position of the handheld controller," for example, when a "user walk[s] around a perimeter chosen by the user," and a processor receives and uses that information to "define a

boundary surrounding a selected area." Pedrotti (Ex.1005) at 4:37-44, 12:31-41 ("the processor knows where the user's head and hands are located"), 14:56-15:3 ("processor determines the position of the tracker at a number of sampling points as the user moves around the chosen perimeter, and from those points determines the boundary"), Figs. 14-15.

574. Thus, Pedrotti teaches that movement of the PED is tracked to define a size and shape of a zone extending around a user, i.e., an area around the user is divided into a zone. This "safe area" (a zone) "can be defined, for example, by having the user walk around a perimeter chosen by the user with one of the trackers to define the outer boundary of a selected area":

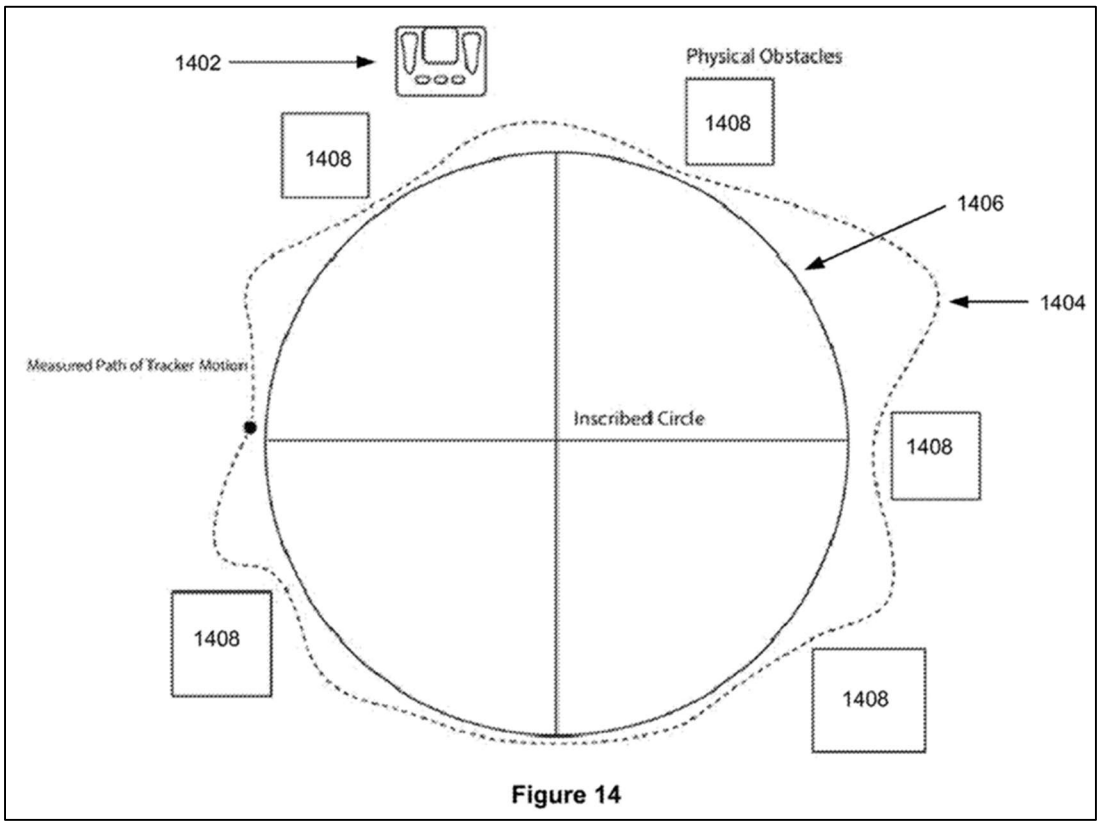


Figure 14

Pedrotti (Ex.1005) at 14:56-65, 15:13-22, Figs. 14-15 (boundary 1404 reflecting the user-defined, irregularly shaped boundary defining a 3D zone); *see also* Pedrotti (Ex.1005) at 2:44-51, 4:32-36 ("a boundary of a selected area is determined, for example, an "safe area" which the user or another person has determined is clear of physical obstacles in the physical world so that the user may move freely without coming into contact with such physical obstacles."), 12:31-41 ("the processor knows where the user's head and hands are located"), 15:7-12 ("the user is holding a handheld controller having a tracker which can be used to track the position and orientation of the handheld controller").

575. After Pedrotti's boundary is defined by, for example, the "measured path of tracker motion" (Pedrotti (Ex.1005) at Fig. 14), and a user is in "the virtual world" (e.g., by "playing a game"), the processor instructs the HMD to display "a visual warning" to the user. Pedrotti (Ex.1005) at 11:43-55. This can be "in the form of grid lines such as a virtual fence" when "the processor determines from the position of the handheld controller that the handheld controller is within a preselected distance of the boundary." Pedrotti (Ex.1005) at 15:30-37 ("the processor generates and outputs instructions to the HMD to display … a visual warning to the user" which "can be in the form of grid lines such as a virtual fence."), Figs. 11, 14-15.

576. Thus, Pedrotti's handheld controller (PED) divides an area around a user into a zone—Pedrotti's "selected" or "safe" area in VR that is bound by Pedrotti's boundary and its virtual fence.

577. Persons of ordinary skill in the art also would have understood that this perimeter or boundary divides an area around the user into a zone that extends around the user because it defines the user's "safe area" play space. This was a common principle applied to safety and chaperone systems. *See* Section VII.G (providing visual examples of boundaries existing in 3D space, and thereby defining a 3D zone).

578. Additionally, I have reviewed the infringement contentions 8K served on Petitioners in district court as well as the First Amended Complaint. *See* '316 8K Infringement Contentions (Ex.1130). I note that Pedrotti's controller-divided zone is nearly identical to features that 8K contends in the parallel district court action satisfy limitation 1[a]:





'316 8K Infringement Contentions (Ex.1130) at 4; *compare* First Am. Compl. (Ex.1122) ¶ 92 ("Accused Products have… 'safe area' functionality"), *with* Pedrotti (Ex.1005) at 4:32-36 ("boundary of a selected area" defines "a 'safe area'").

579. Further, I note that 8K contends in district court that limitation 1[a] is satisfied by the mere existence of a zone for game play that "***will include*** sound localization points for presentation of binaural sound to the user." '316 8K Infringement Contentions (Ex.1130) at 5. Thus, in 8K's view, an area defined for gameplay that will ***subsequently*** include binaural sound satisfies this limitation. Under such an interpretation, Pedrotti, alone or in view of Jang rendered obvious limitation 1[a]: the zone that Pedrotti's controller divides will, or at a minimum will obviously, include SLPs from which binaural sound will originate, when, for example, a user starts playing a VR game.

580. Pedrotti discloses that its teachings can be applied to VR games. Pedrotti (Ex.1005) at 1:42-45 ("play a video game, while in a virtual world"), 1:66-2:12 (describing a "conventional video game"), 9:26-40 (describing picking up a "virtual weapon" in a virtual game), 11:43-12:15 (describing a user in a "virtual world"), Fig. 8 (virtual sword 802). Persons of ordinary skill in the art would have known that virtual objects in games (e.g., Pedrotti's sword or another "virtual weapon," as well as VR characters) could and would have associated binaural sounds that would move with them to multiple locations (multiple SLPs). Creating

and moving sounds with their associated virtual images were "extremely important" and fundamental features of VR that were known well before February 2016. *See* Sections VII.E-VII.F; Pedrotti (Ex.1005) at 1:19-20 ("the senses most commonly used today to create virtual reality appear to be sight and sound"); Ross (Ex.1125) at 17:22-18:35 (describing VR interactions, e.g., users "moving objects and/or characters"); *see also* Section XI.A.2.a(1) (further discussing examples in context of limitation 2[a]).

581. Indeed, Jang confirms as obvious the use of "multiple[] sound localization points (SLPs) from where binaural sound originates to the user" during, for example, VR game play while in a zone around a user (like Pedrotti's). Jang disclosed a sound processing system that "check[s] sound source information" on "characters and other objects" and provides localized audio (i.e., binaural sound) for "sound sources" "according to the[ir] relative locations" (SLPs), including in "sound areas" around a user. Jang (Ex.1006) at 7:24-59; *see also* Jang (Ex.1006) at 1:28-2:11 (VR "systems may be used to provide a high degree of realism," e.g., "in a virtual reality game"), 5:35-37 (describing a "method of dividng sound areas of a virtual reality space"), 8:18-49 (same), 8:59-9:1 (describing a "control unit" which "identifies" focused sound "occurring in the focus area according to the division of the virstual reality space."), Fig. 2 (illustrating "method of dividing sound areas of a virtual reality space").

582. And as I explained above in the State of the Art section, since well before February 2016, it was understood that sound localization is an important aspect of creating an immersive AR or VR experience. NSA, *Virtual Reality* (Ex.1073) at 35-36 ("Spatially localized sound has a dramatic effect on the sense of immersion in virtual environment … Sound is considered a very important aspect of VR since users often get 'lost' while moving in the virtual world."); Jerald, THE VR BOOK (Ex.1063) at 239 ("Auditory cues play a crucial role in everyday life as well as VR, including adding awareness of surroundings, adding emotional impact, cuing visual attention, conveying a variety of complex information without taxing the visual system, and providing unique cues that cannot be perceived through other sensory systems."); Section VII.E.

583. Additionally and alternatively, if limitation 1[a] requires a zone that "includes" multiple SLPs for binaural sound when divided by a PED, limitation 1[a] would have been obvious over Pedrotti and Jang, or over Pedrotti, Jang, and Begault.

584. Jang disclosed processing and producing sound in "focus" and "un-focus" "sound areas." Jang (Ex.1006) at 2:32-47, 2:60-3:4. These sound areas contain "a plurality of sensory sources," including "audio sources," and may be sub-divided according to a "predetermined priority" or "scheme." Jang (Ex.1006) at 4:19-39 (explaining that the focus area "may correspond to an area in the virtual environment in the immediate foreground of a visual perspective" of the user), 6:51-

59 (explaining that non-focus areas may have sound "be muffled or quitter than audio elements of a focus areas"), 8:46-59 (explaining that the "focus area and the non-focus areas may be divided into multiple areas in the virtual reality space according to a predetermined priority"), 9:47-10:5 (explaining how sound is controlled, including such that "when there is occurrence of sound in both the focus area and the non-focus area, the control unit 114 may determine priorities of sound sources for at least of the focus area and the non-focus area.").

585. This sub-division of sound areas allows Jang's system to "output sensory elements of the focus area differently than sensory elements of the non-focus areas" and better manage VR space shifts. Jang (Ex.1006) at 3:24-26. "For example, if a user's character moves from a basketball court to a conference room, visual, audio, or tactile elements of the basketball court may decrease in magnitude, and visual audio, or tactile elements of the conference room may begin to be transferred to a virtual reality device," with sensory data for focus areas processed first. Jang (Ex.1006) at 11:64-12:16. Further, Jang disclosed using "a localization technique capable of expressing the virtual location" of "a sound-generating object" and HRTFs "to give the sense of reality to the sound." Jang (Ex.1006) at 1:42-56, 7:38-63 (describing a "virtual reality apparatus" that "may use a Head Related Transfer Function (HRTF) as an algorithm for identifying the sound-generating location.").

586. In view of Jang's disclosures regarding sound areas and predetermined priorities and schemes, persons of ordinary skill in the art would have been motivated to set those predetermined priorities and schemes for "sound areas" and "audio sources" by assigning locations from where different audio sources will produce sound. Using the '316 patent's terminology, those are "sound localization points" or "SLPs." For example, in the context of Jang's virtual basketball court, a virtual visiting team's bench could and would be designated into a focus area, and the nearby stands for the virtual visiting team could and would also be designated into that focus area. Between these two, the virtual visiting team's bench could and would be given priority over the stands. Similarly, the user could and would assign priorities to characters and other sound-generating objects such as an announcer, cheerleaders, a pep band, or an air horn, which also could and would be assigned locations in the focus area. As another example, in the context of Jang's virtual conference room, one side of the conference room could and would be set as a "focus area," with priority characters and other sound-generating objects such as key attendees or a monitor. Additionally, among the key attendees, there could and would be a highest priority given to the boss, and lower priorities given to other attendees based on seniority. Persons of ordinary skill in the art also would have known and been motivated to assign specific locations for these characters and sound-generating objects (i.e., designate their SLPs). For years before Jang, it was

understood that with simple user interfaces, sound sources such as conference attendees could and would be organized, clustered, and moved, e.g., into "special region[s]" or a "private conference." *See, e.g.*, Cohen 1992 (Ex.1052) at 477 (describing "[a] simple teleconferencing configuration [that] typically consists of several icons, representing the distributed users, moving around a shared conference space," and where "[e]ach of these icons represents a source, the voice of the associated user, as well as a sink, the user's ears."). To persons of ordinary skill in the art, these assignments or designation of SLPs would have facilitated obvious, advantageous organization for a user's soundscape, consistent with the disclosures of multiple publications describing interfaces for, and allowing users to make, such designations. *See* Section VII.F. Also, persons of ordinary skill in the art would have understood based on Jang's disclosures that the same type of audio control could and would be applied to a non-focus area.

587. Indeed, this type of division of sensory elements in different zones in a VR environment and authoring of VR environments was well-known. *See, e.g.*, Jerald, THE VR BOOK (Ex.1063) at 254-55 (discussing "Center of Action" setups that "split[] the world around the user into different zones," for example, "primary and secondary viewing directions");[10] Ross (Ex.1125) at 14:53-15:28, 15:29-55,

[10] The VR Book shows an example of this type of setup:

20:22-21:51 (VR content is displayed based on "determined view direction," which "may refer to… a position of the user within the virtual space," "e.g., a user may move… across a boundary"), 22:17-29 ("user may virtually reach out and grab and/or move… objects"), 22:55-56.

588. Moreover, Begault disclosed methods of setting priorities for binaural sound that persons of ordinary skill in the art would recognize as useful for authoring and managing Jang's sound areas, further demonstrating that limitation 1[a]'s zone

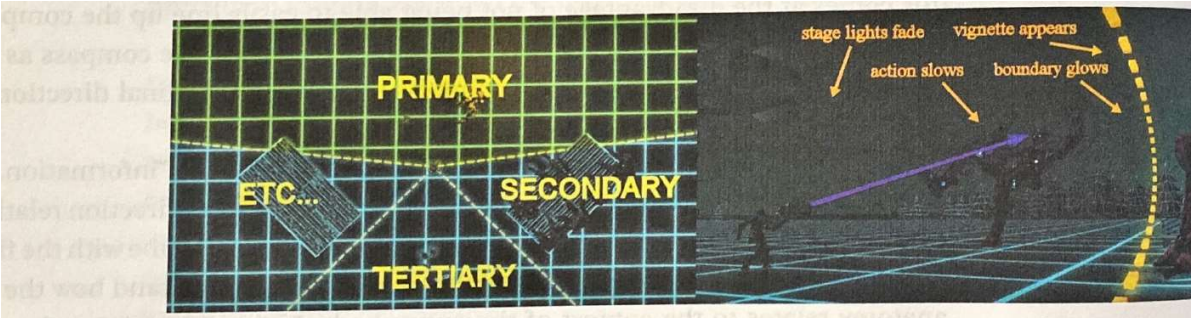


Figure 22.3 Visionary VR splits the scene into different action zones.

Jerald, THE VR BOOK (Ex.1063) at Fig. 22.3, 254 ("As a user starts looking toward another zone, cues are provided to inform the user that she is starting to look at a different part of the scene and the action and/or content is about to change … For example, glowing boundaries between zones can be drawn, the lights might dim …, time might slow down," and "actions within th[e] [second] zone can react").

that includes multiple SLPs would have been routine, straightforward, and obvious to persons of ordinary skill in the art before February 2016.

589. Begault taught that "[a]ll types of sonic input c[an] be directionalized to a specific location" and "controlled by a user" through "audio spatial mapping" that—as in Jang—"correspond[s] to a prioritization scheme." Begault (Ex.1007) at 174. For example, "calls from subordinates could be signaled by a phone ringing from the rear; a call from home could always ring from front right; and the intercom from the boss could be from front and center." Begault (Ex.1007) at 174.

590. Begault also disclosed a "GUI for arranging [] various sound inputs in virtual auditory space in a manner configurable by each individual listener":

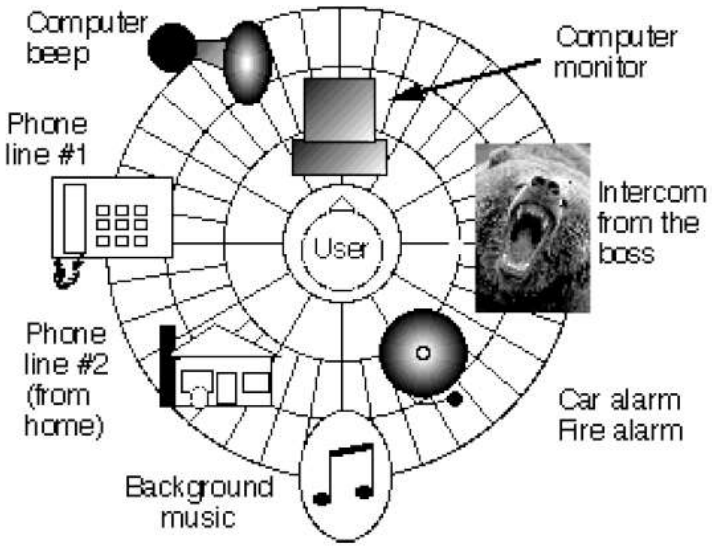


Figure 5.12. Layout for a hypothetical GUI for arranging a set of incoming sounds. By resizing the icons, volume could be adjusted independently of perceived distance. *Graphic assistance by Denise Begault.*

Begault (Ex.1007) at 174-75, Fig. 5.12. "The basic concept is to represent each form of auditory input iconically on the screen and then allow manipulation of the distance

and relative azimuth of each source." Begault (Ex.1007) at 174. Then, "the relative location of the icons" are interpreted "as commands to a multiinput, 3-D sound spatialization subsystem." Begault (Ex.1007) at 174.

591. Thus, person of ordinary skill in the art would have known and recognized in view of Pedrotti, Jang, as well as Begault, that Jang and Begault's binaural sound sources at multiple locations (i.e., multiple SLPs) in a virtual environment as described above, could and would benefit from a Pedrotti "safe area" zone" because this zone could and would prevent user injury and prevent a user from accidently bumping into physical objects in the physical world. For example, if moving between Jang's virtual basketball court and Jang's virtual conference room, a "safe area" would prevent the user from tripping over a sofa or crashing into a wall in the real, physical space of the user. Further, a Pedrotti "safe area" zone created or otherwise set in a virtual environment with 3D sound sources that are assigned to different locations as Jang and Begault teach, would, or at a minimum would obviously include multiple SLPs for binaural sound so that the user is fully immersed in the virtual environment. *See* Ross (Ex.1125) at 6:5-27, 22:23-23:21 (users "may sense" boundaries "they can hear/see/feel" and configure boundaries, e.g., with a "[c]ontent creation preview" that allows users to "continue to make changes" to boundaries). Jerald, THE VR BOOK (Ex.1063) at 239 ("Auditory cues play a crucial role in everyday life as well as VR, including adding awareness of surroundings,

adding emotional impact, cuing visual attention, conveying a variety of complex information without taxing the visual system, and providing unique cues that cannot be perceived through other sensory systems.").

592. And, persons of ordinary skill in the art would have known and understood that the audio sources (SLPs) described for Jang's sound areas could and would be in "empty space" because they are audio sources in virtual space and not on physical objects. Jang (Ex.1006) at 4:19, 4:45-55 (disclosing "sensory sources" and "audio sources" in virtual space). Further, in the context of the '316 patent, empty space is any space not occupied by a physical object. *See* '316 patent (Ex.1001-316) at 6:1-5.

c. 1[b]: "playing, with speakers in a wearable electronic device (WED) worn on a head of the user, the binaural sound that originates from the SLP in empty space;"

593. Limitation 1[b] would have been obvious over Pedrotti, Jang, and Begault for the same reasons as limitations 1[a]. *See* Section XI.A.1.b

594. Specifically, Pedrotti, Jang, and Begault render obvious a WED worn on the head of a user (Pedrotti's HMD), binaural sound emanating from SLPs (taught by Jang and Begault). *See* Section XI.A.1.b. The additional element of limitation 1[b]—"playing with speakers… binaural sound" from an SLP also would have been obvious over Pedrotti, Jang, and Begault.

595. Pedrotti's HMD plays sound. Pedrotti (Ex.1005) at 15:56-58 (discussing "an audio warning"). And Jang taught outputting binaural sound "to the user to represent the virtual environment," and that its binaural sound processing mixes visual sensory elements of a virtual environment, including "characters, objects, or features," with associated audio data before sounds are output to the user, thus providing "sound sources occurring in real time according to the[ir] relative locations." Jang (Ex.1006) at 6:17-20 (The "virtual reality device" can "output life-like sounds"), 6:36-42 ("The user may see, hear, and otherwise sense the virtual environment from the perspective of the avatar."), 7:24-32 (describing a "control unit" that "receives an input of a selected virtual reality character" and "check[s] sound source information on other characters and other objects existing in the virtual reality spaces"), 7:47-63 (describing how the "control unit 114" divides the "virtual reality space into multiple sound areas" and uses HRTFs "as an algorithm for identifying the sound generating location.").

596. Jang teaches that "the sound of the virtual reality system may use a localization technique capable of expressing the virtual location" of "a sound-generating object," and discloses a processor for identifying the "exact sound-generating location" for audio elements before sound is produced. Jang (Ex.1006) at 1:42-56 (further explaining that the sound processing method "give[s] the sense of reality to the sound"), 7:50-63 (referencing use of HRTFs in sound processing),

Fig. 3 (illustrating sound processing unit 116), 8:65-9:3 (explaining how the focused sound processor and non-focused sound processor "identify" a sound source and location). Jang further discloses that "to express directionality, the paths of sound reaching listener's ears, which determine the direction of sound in view of the listener, may be modeled by using a sound processing technique, such as a Head Related Transfer Function (HRTF), so as to determine the output sound." Jang (Ex.1006) at 1:52-56. Indeed, it was known that binaural sound often provides a more realistic representation of sound, and that binaural sound is generated using HRTFs. Jerald, THE VR BOOK (Ex.1063) at 240 ("For more realistic audio and where auditory cues are especially important, ***auralization***—the rendering of sound to simulate reflections and binaural differences between the ears—can be used … Ideally, HRTFs model a specific user's ears, but in practice a generic ear is modeled.") (emphasis in original); *see also* Section VII.E (discussing background for sound localization techniques, including use of HRTFs and generating binaural sound). And as discussed for limitations 1[a] and 1[b], the SLPs pertaining to a Pedrotti-Jang implementation exist (or at a minimum obviously exist) in a zone above from where binaural sound originates to a user. *See* Sections X.A.3.b-X.A.3.c.

597. Furthermore, the generation of binaural sound using HRTFs would have been obvious over to persons of ordinary skill based on Jang and Begault's disclosures. As explained above, Jang discloses that its binaural sound can be

generated with HRTFs. Jang (Ex.1006) at 7:57-63 (referencing use of HRTFs in sound processing). In addition, Begault, which published in 2000, discloses the use of HRTFs to localize sound, and how processors process sound with HRTFs to generate binaural sound. Begault (Ex.1007) at 12 ("The audio subsystem" for "a sound subsystem in a virtual reality system" "contains two fundamental parts: a signal source, such as a synthesizer, and a signal processor that contains components for spatializing and mixing the outputs from the signal sources."), Fig. 1.8 (depicting a "signal processor" for "spatialization and mixing of multiple monaural channels into binaural output"), 41 ("The use of HRTF spectral shaping is typically featured as the key component of a 3-D sound system … The binaural HRTF (terminology for referring to both left- and right-ear HRTFs) can be thought of as a frequency-dependent amplitude and time-delay differences that result primarily from the complex shaping of the pinnae."), 99 ("the inclusion of the binaural HRTF is fundamental for a 3-D sound system"); *see also* Section IX.C (overview of Begault).

598. Based on these disclosures and existing knowledge of how to generate binaural sound at particular locations, persons of ordinary skill in the art would have known to include binaural sound as the specific audio data associated with SLPs that are part of the virtual environment. *See* Begault (Ex.1007) at 12 ("The audio subsystem" for "a sound subsystem in a virtual reality system" "contains two fundamental parts: a signal source, such as a synthesizer, and a signal processor that

contains components for spatializing and mixing the outputs from the signal sources."), Fig. 1.8 (depicting a "signal Processor" for "spatialization and mixing of multiple monaural channels into binaural output"), 41 ("The use of HRTF spectral shaping is typically featured as the key component of a 3-D sound system, from either direct measurement or modeling."); *see also* Jang (Ex.1006) at 1:46-56 ("to express directionality, the paths of the sound … may be modeled by using a sound processing technique, such as a Head Related Transfer Function"), 7:57-63 (referencing use of HRTFs in sound processing), Fig. 3 (illustrating sound processing unit 116); Pedrotti (Ex.1005) at 15:56-58 (referencing "generat[ing] an audio warning").

599. Playing a binaural sound from a SLP have been routine and obvious. Lovitt (Ex.1021) at [0038] ("each virtual space sound source includes one or more associated sounds such that, during interaction with the virtual environment, one or more of the associated sounds are programmed to be 'output' from a particular virtual space sound source"); Jerald, THE VR BOOK (Ex.1063) at 240 (discussing utility of spatial audio and "rendering of sound to simulate reflections and binaural differences"); Begault (Ex.1007) at 13 ("3-D sound can contribute to the sense of immersivity in a 3-D environment "), 99 ("the inclusion of the binaural HRTF is fundamental for a 3-D sound system that relates natural and synthetic spatial hearing"). Begault (and Cohen 1993 that Begault references), describe processing

binaural sound, which was known for decades before February 2016, in great detail. *See* Begault (Ex.1007) at ch. 2; *see also* Section IX.C (overview of Begault). Thus, POSAs would have known that a Pedrotti-Jang or Pedrotti-Jang-Begault system could and would "play[] binaural sound" from an SLP. *See* Begault (Ex.1007) at 161-62 (sounds "spatialized using 3-D audio techniques," including through "HRTF filtering," i.e., binaural sounds, used for "selecting items"); Jang (Ex.1006) at 8:65-9:3 (explaining how the focused sound processor and non-focused sound processor "identify" a sound source and location).

d. 1[c]: "tracking, with one or more sensors in the WED worn on the head of the user, the PED to determine when the PED held in the hand of the user is moving outside the zone that extends around the user; and"

600. Pedrotti teaches, or at a minimum renders obvious, limitation 1[c].

601. A user of Pedrotti's system wears a HMD, i.e., a WED worn on the head of a user, and holds handheld controllers. Pedrotti (Ex.1005) at 2:44-47. A processor in Pedrotti's system "tracks the position and orientation of [a] HMD tracker" and "the position and orientation of one or more trackers in the physical controllers." Pedrotti (Ex.1005) at 2:49-57. Thus, the WED "knows where the user's head," and thus the user him or herself, "and hands are located." Pedrotti (Ex.1005) at 2:49-57, 4:32-44 (describing "a boundary of a selected areas"), 12:31-41 (explaining that "the processor is tracking the position and orientation

of the user's hand if the user is holding a controller with a tracker"), 15:7-12 (describing method that may "result in the display of a visual warning such as the virtual fence" where "the user is holding a handheld controller having a tracker which can be used to track the position and orientation of the handheld controller."). Pedrotti further taught that its processor may be "in the HMD." Pedrotti (Ex.1005) at 16:20-24. [11]

602. Pedrotti also discloses, or at a minimum renders obvious, tracking "with one or more sensors in the WED." Pedrotti disclosed controllers with trackers, including, for example, "light-emitting trackers" that "provide position and orientation information" to sensors, including, for example, "a camera mounted on [a] base station or elsewhere." Pedrotti (Ex.1005) at 5:8-24 ("essentially any type of tracker… can be used in the present approach" including using "inertial sensors (e.g., accelerometers and/or gyroscopes)").

[11] In addition to the disclosures and teachings of Pedrotti, in a related patent, U.S. Patent No. 10,162,177 ("Pedrotti 177") (Ex.1032) to Pedrotti, the processor is also described as being in the HMD. *See, e.g.*, Pedrotti 177 (Ex.1032) at 10:63-65 ("a processor may be located in the HMD"). Also, persons of ordinary skill in the art would have known it was common for tracking capabilities to be wholly contained in an HMD. *See* Section VII.D (describing all-in-one and inside-out tracking).

603. Persons of ordinary skill in the art would have understood the tradeoffs between electromagnetic tracking and electro-optical approaches disclosed by Pedrotti. Such tradeoffs are discussed extensively in my 2002 *No Silver Bullets* paper. Welch, *No Silver Bullet* (Ex.1135). For example, persons of ordinary skill in the art would understand that while electromagnetic tracking has some advantages, e.g., magnetic fields are relatively stable over short distances and they generally pass through humans, it also has some significant disadvantages, e.g., ferromagnetic and conductive material in the environment (difficult to control in a consumer setting) can cause systematic errors, the useful range of operation is severely limited by the inverse cubic falloff of the magnetic fields as a function of distance from the source, and they require three–four magnetic excitation and measurement operations per estimate cycle which results in a relatively low estimate rate. Welch, *No Silver Bullet* (Ex.1135) at 29. Persons of ordinary skill in the art also would have understood that while electro-optical approaches require a clear line of sight between the source and the sensor (Welch, *No Silver Bullet* (Ex.1135) at 30), occlusions between handheld controllers and an HMD are very unlikely as the controllers will always be relatively close to the user and the HMD—within arm's length. Also, persons of ordinary skill in the art also would have understood that using the optical approach taught by Pedrotti ("light-emitting trackers" and cameras) would have relatively high signal-noise ratio (light-emitting components on the controllers

would be close to any cameras on the HMD), and relatively constant error behavior, and measurements could be obtained quite fast compared to magnetic tracking, e.g., because light is very fast in general, and light emitted from the two handheld controllers to be sampled (by the cameras) and processed at the same time. Finally, persons of ordinary skill in the art would have understood that using light emitters on the controllers and one or more cameras on the HMD is well matched to processing in the HMD (tracking, rendering, etc.), which would eliminate the need to transfer measurement data from of the controllers to the processor, allowing the handheld controllers to be wireless. As such, persons of ordinary skill in the art would be significantly motivated to use an electro-optical approach taught by Pedrotti, i.e. to track the handheld controllers using Pedrotti's light-emitting components (e.g., LEDs) on the controllers and one or more cameras on the HMD.

604. Indeed, the use of sensors on HMDs for tracking controllers—including sensors that could and would be used to track light-emitting controllers—was well-known. *See, e.g.*, Ambrus (Ex.1043) at [0075] ("pose and/or movement data may be determined based on sensor information from any combination of sensors mounted on the wearer and/or external to the wearer including … gyroscopes, accelerometers, inertial measurement units (IMUs), GPS devices, barometers, magnetometers, cameras (e.g., visible light cameras, infrared light cameras, time-of-flight depth cameras, structured light depth cameras, etc.)"), McCulloch (Ex.1008)

at 8:17-22 ("Inside, or mounted to temple 102, are … an inertial sensing unit … a location sensing unit … some examples of which are a GPS transceiver, an infrared (IR) transceiver, or a radio frequency transceiver for processing RFID data."); Begault (Ex.1007) at 133 (describing "electromagnetic sensors," or "optical, mechanical, and acoustic tracking systems"); Jerald, THE VR BOOK (Ex.1063) at 315 ("Hand-held tracked devices typically use inertial, electromagnetic, ultrasonic, or optical (camera) technologies."); Mine Exploiting Proprioception 1997 (Ex.1116) at 68 ("hardware configuration includes an immersive head-mounted display, a magnetic tracking system with three 6 degree-of-freedom (DoF) sensors (one for the head and one for each hand), two separate input devices (one for each hand) and a high speed graphics computer"); Ross (Ex.1125) at 11:4-28 (describing using "one or more of a GPS sensor, a gyroscope, an accelerometer, an altimeter, a compass, a camera based sensor, a magnetic sensor, an optical sensor, an infrared sensor, a motion tracking sensor, an inertial sensor, a CCB sensor, an eye tracking sensor, a facial tracking sensor, a body tracking sensor, and/or other sensors" to "generate output signals conveying information related to any number of different view directions, (e.g., orientation of one or more parts of the user's body," "position of a user within the virtual space, and/or other directional information)"). And, persons of ordinary skill in the art would have understood that optical tracking systems, such as those that tracked light-emitting controllers, would have "offer[ed] sufficiently

accurate measurements of both position and orientation over relatively large working volumes, without many of the problems inherent in magnetic or acoustic tracking systems." Welch 1995 (Ex.1119) at 2; *see also* Section VII.D (discussing tracking, including tracking of controllers). Persons of ordinary skill in the art would have further understood and appreciated that tracking a handheld controller using LEDs on a handheld controller and cameras on an HMD as taught by Pedrotti (Ex.1005) (at 5:8-24) would have relatively high accuracy, high resolution, and high speed (with low latency), which is particularly important for handheld controllers as humans can move their wrists relatively fast.

605. Pedrotti further discloses, or at a minimum, renders obvious, "determin[ing] when the PED" "is moving outside the zone" as explained below. I note that 8K does not distinguish between determining (i) that a user "is leaving" a zone and (ii) that a PED "moves outside" or "is moving outside" a zone, in district court. *Compare* '316 8K Infringement Contentions (Ex.1130) at 6. As the contentions show, 8K contends that the "is leaving" limitation is met with an image of a PED that is depicted as in the process of moving beyond the boundaries of the zone. And, these actions are, at a minimum, obvious over Pedrotti because the determination that is performed by Pedrotti's processor for all three involves obtaining positional, inertial, and/or orientation information of the user (either via the HMD worn on the head of the user or the PED that is held by the user), and

comparing that information against the boundaries of the user-defined zone. Pedrotti discloses that its HMD and controllers are tracked, and furthermore, such tracking was well known in the art. *See* Section VII.D (discussing tracking of HMDs and controllers).

606. Pedrotti discloses that the processor uses the tracking described above to "determine from the position of [a] handheld controller that the handheld controller is within a first preselected distance from [a] boundary." Pedrotti (Ex.1005) at 2:44-59. The processor then "generate[s] and output instructions to the HMD to include in a display of a virtual world a visual warning such as a grid or virtual fence when the user comes within a preselected distance of the boundary, thus providing a warning that the user is about to move out of the selected area." Pedrotti (Ex.1005) at 2:44-59.

607. Pedrotti also discloses that the warning is provided "when the user comes within a preselected distance of the boundary, thus providing a warning that the user is about to move out of the selected area," regardless of whether the user's location is determined based on the location of the HMD or the location of the handheld controller. Pedrotti (Ex.1005) at 4:37-44 (indicating that this is done when "[t]he processor [] tracks the position and orientation of the HMD tracker, and possibly the position and orientation of one or more trackers in the physical controllers"), 12:35-13:2 ("[T]he processor knows where the user's head and hands

are located; if the processor has been provided with information about the boundary of the selected area then the processor can also determine when the user's head and/or hands approaches the boundary.").

608. Pedrotti's Figure 15, which is a flowchart of this method, discloses that this method "result[s] in the display of a visual warning such as the virtual fence." Pedrotti (Ex.1005) at 15:4-39, Fig. 15.

609. Pedrotti further discloses that "the preselected distance" triggering its warning "may vary by application, so that, for example, it is greater in an application in which larger body movements are expected from the user than in an application in which such body movements are not expected"—which would apply to when a user is holding with its hand a controller, or PED. Pedrotti (Ex.1005) at 13:46-62.

610. Pedrotti also teaches that "if the user's head goes beyond the boundary, the processor can cause the HMD to fade to black, and present, for example, only a warning message and/or a beacon or arrows directing the user to move in the direction of the boundary and the selected area," meaning that Pedrotti's system is able to identify conflicts with its boundaries. Pedrotti (Ex.1005) at 13:67-14:5.

611. Persons of ordinary skill in the art would have known and understood that this processor in the HMD, i.e., the processor in Pedrotti's WED worn a user's head, determines when the controlled held in the hand of the user is moving outside the zone, as claimed because Pedrotti's system is designed to determine where a user

is inside a "safe area" for gameplay and to help the user stay in that area. Pedrotti (Ex.1005) at 4:32-44 (disclosing that the processor tracks the HMD and controllers and "generates instructions to the HMD to include in a display of a virtual world a visual warning such as a grid or virtual fence when the user comes within a preselected distance of the boundary, thus providing a warning that the user is about to move out of the selected area."). It was also well-known that VR systems could and should determine user locations (e.g., through proxies such as the HMD worn on the head of a user or by the controllers held in the hand of the user), so that, for example, when a user approaches "the edge of tracking" or "a safe zone," "a warning grid" can "fade in to provide a cue to the user that he should back off." Jerald, THE VR BOOK (Ex.1063) at 213-14, Fig. 8.13 (showing warning grid); *see also* Section VII.G (discussing safety and chaperone systems).

612. For these reasons, Pedrotti discloses (or at a minimum renders obvious) limitation 1[c].

e. 1[d]: "displaying, with the WED worn on the head of the user a virtual reality (VR) image that shows the zone in response to the WED determining that the PED is moving outside the zone."

613. Pedrotti teaches, or at a minimum renders obvious, limitation 1[d].

614. As I discussed for limitation 1[a], Pedrotti discloses a WED worn on the head (Pedrotti's HMD) that displays 3D virtual images. *See* Section XI.A.1.b.

615. Pedrotti further discloses that "when the user comes within a preselected distance of the boundary," the processor "generates instructions to the HMD to include in a display of a virtual world a visual warning such as a grid of virtual fence," "thus providing a warning that the user is about to move out of the selected area":

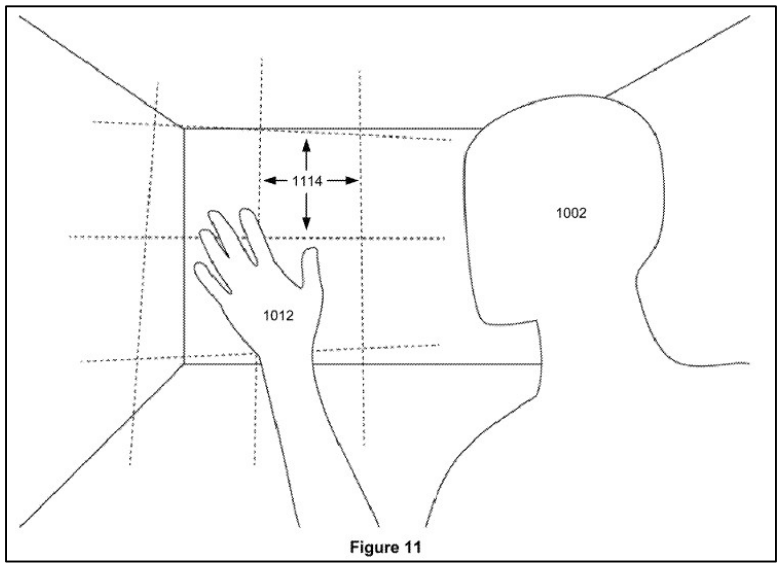


Figure 11

Pedrotti (Ex.100) at 4:37-44, Fig. 11 (depicting a "visual warning [] in the form of a grid of lines or a 'virtual fence' located at the boundary"), 12:51-13:11 (describing its "visual warning" in the ""form of a grid or lines or a 'virtual fence' located at the boundary" that "can be glowing or colored"); *see also* Pedrotti (Ex.1005) at 12:40-50 ("the processor generates a warning that the user is close to the boundary so that the user can take action to avoid the boundary and thus potential collision with the physical objects"), 12:60-66 ("In addition, since the hand of the user 1002 is within the preselected distance of the boundary of the selected area, the processor generates

instructions to the HMD to generate the visual warning As illustrated in this embodiment, this visual warning is in the form of a grid of lines or a 'virtual fence' located at the boundary, as indicated in FIG. 11 by the dashed lines 1114."), 13:63-67 ("If the user's head or hands go beyond the boundary as determined by the trackers, the processor can provide additional messaging or warning, such as text or auditory warnings, or an additional visual warning, that persists until the user returns to the selected area within the boundary."). This "grid" or "virtual fence" is, or at a minimum obviously could be, a virtual image appearing at Pedrotti's zone boundary that shows the size and shape of Pedrotti's zone. Moreover, as I explained in Section VII.G, numerous safety and chaperone systems for virtual environments, which alerted users that their locations conflicted with boundaries, including through the use of virtual images of zones to alert users, existed and were known to persons of ordinary skill in the art before February 2016.

616. I note that Pedrotti's 3D virtual image showing a grid or fence is nearly identical to features 8K contends in district court satisfy the limitation "displaying … a 3D virtual reality (VR) image of the zone":



Source: https://www.youtube.com/watch?v=zh5ldprM5Mg at 1:44

'316 8K Infringement Contentions (Ex.1130) at 6; Pedrotti (Ex.1005) at Fig. 11.

617. For these reasons, Pedrotti discloses (or at a minimum renders obvious) limitation 1[d].

2. Dependent Claims 2-8

618. I understand that claims 2-8 depend on independent claim 1.

619. Thus, it is my opinion that each of dependent claims 2-8 would have been obvious to persons of ordinary skill in the art for the same reasons as independent claim 1 and additionally for the reasons I discuss in the following subsections.

a. Claim 2

(1) 2[a]: "The method of claim 1 further comprising: highlighting, while the user is located inside the zone and with a display of the WED, a VR image at the SLP in the zone when

the PED held in the hand of the user is pointed at the SLP in the zone; and"

620. Pedrotti and Jang, or Pedrotti, Jang, and Begault, render obvious this limitation.

621. During use, a user of Pedrotti's system is located in a zone. *See* Section XI.A.1.b (limitation 1[a]). This zone is Pedrotti's "safe area" for gameplay that includes a boundary shown by a virtual fence. *See* Section XI.A.1.b (limitation 1[a]).

622. And while the user is in the zone, Pedrotti's HMD displays virtual images to the user. *See* Section XI.A.1.b (limitation 1[a]) (describing Pedrotti's system comprising "a head-mounted display (HMD)"); Section IX.AIX.A (Pedrotti overview); Pedrotti (Ex.1005) at Abstract (Pedrotti's wearable "head mounted display" "display[s] a virtual world"), Fig. 8 (showing image of a virtual sword 802).

623. In addition, limitation 2[a]'s requirement that an SLP is highlighted "when the PED held in the hand of the user is pointed at the one of the multiple SLPs in the zone" would have been obvious to persons of ordinary skill in the art over Pedrotti. Pedrotti discloses "one or more physical controllers that a user may use to control certain actions or events in the virtual world." Pedrotti (Ex.1005) at 4:9-10, 5:25-46 ("Various devices suitable for use as controller 110" may be "pick[ed] up with [the user's] hand" to "perform various functions in the virtual world"), 8:14-35 ("once both controllers have been picked up," "instructions from the processor no longer cause the HMD to show [the controllers] so that the processor can "cause the

HMD to display the user's virtual hands doing something in the virtual world, such as grasping a virtual object"). Pedrotti discloses using Pedrotti's controller to define a boundary of "an area in the physical world to be defined within which the user should remain, for example to avoid physical obstacles." Pedrotti (Ex.1005) at Abstract, 2:27-33 ("One embodiment discloses a method of assisting a user wearing a head-mounted display (HMD) in remaining within a selected area of the physical world, the user holding a handheld controller having a controller tracker which provides information regarding a position of the handheld controller, the method comprising: receiving, by a processor as an input, a definition of a boundary of the selected area;"), 2:44-51, 2:60-3:2. Persons of ordinary skill in the art would have understood that holding a handheld controller and using it to define a boundary of "an area in the physical world" would (or would obviously) include pointing the controller to trace out the intended boundary.

624. Persons of ordinary skill in the art would have known and understood that it was common to use a handheld controller, like Pedrotti's, to select, move, and control virtual objects by pointing at them. *See* Section VII.D (discussing tracking handheld controllers); *see, e.g.*, Jerald, THE VR BOOK (Ex.1063) at 314-15 ("Tracked hand-held controllers are typically 6DoF devices (known as 'wands' in the VR research community where they have been used for decades) and can also contain functionality offered by non-tracked hand-held controllers. Tracked hand-

held controllers are currently the best option for a majority of interactive VR applications. ***Tracked hand-held controllers are easy to use for many 3D tasks due to their natural, direct mapping to hand motion***.") (emphasis added); Ross (Ex.1125) at 22:17-29 ("[a] user, content creator, and/or other persons may create, customize, and/or adjust using a controller"); *see also* Jerald, THE VR BOOK (Ex.1063) at 153-54 (describing "pointing to fly" as a means to "mov[e] from one place to another" in VR and "viewpoint control via a joystick"), 251 ("[P]oint on the map where to go and then 'enter into' the map with the map becoming the surrounding world"). Indeed, "the Pointing Pattern is one of the most fundamental and often-used patterns for selection." Jerald, THE VR BOOK (Ex.1063) at 327.

625. Limitation 2[a]'s "highlighting … a VR image at the SLP in the zone" also would have been obvious over Pedrotti because Pedrotti explained that a virtual image of the boundary, i.e.. its fence, "can be glowing or colored if desired to be more visible." Pedrotti (Ex.1005) at 12:66-13:11 ("The grid can be glowing or colored to be more visible to the user" and explaining that "brightness" or "a uniform translucent glow of a particular color, such as red, may be appropriate to serve as the visual warning").

626. Thus, persons of ordinary skill in the art would have understood that Pedrotti's system could (or at a minimum obviously could) use "glowing" or highlighting, which is merely "visually outlining or changing the color of an

object."[12] Jerald, THE VR BOOK (Ex.1063) at 305. As Pedrotti explains, this type of visual change "may be appropriate to serve as the visual warning." Pedrotti (Ex.1005) at 12:66-13:11. And, the use of highlighting was frequently used to facilitate user selection. Jerald, THE VR BOOK (Ex.1063) at 305 ("Highlighting" is used "to convey that an object is able to be selected or grabbed"), 281 ("objects can… become highlighted" when "they have been selected"), 361, Fig. 26.5. Indeed, it was also known before February 2016 that, in association with virtual object selection, feedback could be provided to a user, including through the use of visual feedback. *See* Jerald, THE VR BOOK (Ex.1063) at 356 (disclosing use of various forms of feedback "to signify touching of objects"); *see also* Cohen 1992 (Ex.1052) at 471 (describing "a mouse-based system [that] realizes indicating, highlighting, and relocating as pointing, clicking, and dragging" icons representing sound sources); McCulloch (Ex.1008) at 22:66-23:20 ("Similarly, a visual effects library may store routines for animations, highlighting, and other types of visual enhancements which

[12] The '316 patent describes "visually distinguish[ing]" selected SLPs—i.e., images representing SLPs—in this same, well-known manner. '316 patent (Ex.1001-316) at 28:19-38 (explaining that the SLP "can be distinguished with shading, light, color, indicia, symbols, text, or other visually recognizable forms to signify its selection and to distinguish it from non-selected SLPs.")

may also be associated with particular actions, pre-collision events and collision effects").

627. Thus, persons of ordinary skill in the art would have known and understood that Pedrotti's controllers could and would be pointed at virtual objects to select or move them "when the PED … is pointed at" an SLP as claimed because the processor in Pedrotti's HMD tracks "the position and orientation of one or more trackers in the physical controllers," and it was common for controllers (PEDs) to convey target locations to a processor. Pedrotti (Ex.1005) at 4:37-44 (describing tracking of physical controllers), 5:8-36 (describing various trackers); Jerald, THE VR BOOK (Ex.1063) at 263 ("Concepts such as … hand tracking … are core elements for VR experiences."); Section X.A.3.b (limitation 1[a]). As noted, Pedrotti discloses using Pedrotti's controller to define a boundary of "an area in the physical world to be defined within which the user should remain, for example to avoid physical obstacles." Pedrotti (Ex.1005) at 2:27-33 ("One embodiment discloses a method of assisting a user wearing a head-mounted display (HMD) in remaining within a selected area of the physical world, the user holding a handheld controller having a controller tracker which provides information regarding a position of the handheld controller, the method comprising: receiving, by a processor as an input, a definition of a boundary of the selected area;"), 2:44-51, and 2:60-3:2. Persons of ordinary skill in the art would have understood that holding a handheld

controller and using it to define a boundary of "an area in the physical world" would (or would obviously) include pointing the controller to trace out the intended boundary.

628. Moreover, persons of ordinary skill in the art would have known that the objects could and would be highlighted when pointed at as a way of facilitating selection by allowing a user to recognize either that an object can be selected or that a particular object has been selected. As I explained in the State of the Art section, these were well-known techniques. *See* Sections VII.C (discussing well-known selection methods for use with handheld controllers in AR and VR); Jerald, THE VR BOOK (Ex.1063) at 327 ("Pointing Pattern extends a ray into the distance and the first object intersected can then be selected via a user-controlled trigger."), Fig. 26.5 ("bottle is highlighted to show" it "can be grabbed"), 285 ("Shoot a ray from the hand, intersect the boulder, push the grab button, move the hand to a new location, release the grab button."); Mine ISAAC 1997 (Ex.1115) at 548 ("To select an object, the user points the laser beam at a desired object and clicks.").

629. Further, persons of ordinary skill in the art would have known that Pedrotti's HMD, which tracks the controllers, is able to detect when the user is pointing the controller at an SLP, and alter its display accordingly, such as by highlighting the SLP. As explained above, persons of ordinary skill knew that an SLP could be highlighted in the visual display because "highlighting" is a

straightforward manipulation technique realized through standard conventions, such as "pointing" and "clicking." *See, e.g.*, Cohen 1993 (Ex.1053) at 470. And it would have been obvious that these actions take place while the user is in the zone because the interactive content in the virtual environment, e.g., Pedrotti's described virtual games, are experienced while a user is in Pedrotti's zone or "safe area." Further still, if the purpose of pointing to the SLP was to perform some action on the SLP, persons of ordinary skill in the art would have understood it is essential to have some form of dynamic visual confirmation that a user is sufficiently pointing at (intersecting) the SLP at any given moment, lest the user be forced to repeatedly point and click (e.g., Pedrotti (Ex.1005) at 9:38) around an SLP until they are able to successfully carry out the action.

630. Indeed, fully immersive social VR experiences where users appeared as avatars and could move sound-producing objects, e.g., their avatars, were well-known:



Figure 22.6 An example of a fully immersive VR social experience. (Courtesy of VRChat)

Jerald, THE VR BOOK (Ex.1063) at 259, Fig. 22.6 (depicting "VRChat," which is "[a]n example of a fully immersive VR social experience"); Ross (Ex.1125) at 8:59-67 ("For example, a user may communicate with presented characters, and/or may socially interact in other ways with virtual character and/or other users in the virtual space. Socially interacting may include communicating" or "chatting."); Ross (Ex.1125) at 17:22-18:35 ("Interaction may include conversing (e.g., textual chatting, voice communication, etc.) with and/or otherwise socializing with virtual characters such as avatars, other characters, and/or other users."); Pan (Ex.1074) at Introduction ("Participants in an immersive virtual reality (IVR) can interact with proximal life-sized virtual human characters, which can talk with them, look them in the eye, smile, walk around, move into their space – with the possibilities only limited by the capabilities of the programing and system") (collecting references where studies were conducted in virtual applications involving talking virtual

characters); DiPaola (Ex.1055) at 1 (describing the Traveler application where "users are immersed in a shared 3D world" with "other participants as fully modeled 3D characters," where "[a]s a user speaks, his or her voice emanates from the corresponding avatar on each of the other clients"), Fig. 1.

631. As THE VR BOOK states, "VR cannot exist without content," and this includes "computer- or user-controlled characters." Jerald, THE VR BOOK (Ex.1063) at 43; *see also* Ross (Ex.1125) at 8:45-59 (describing further examples of "content presented to the user," including "characters, objects, [and] settings"), 14:53-15:28 (explaining that virtual reality content may include "characters, objects," "avatars of other users (e.g., prerecorded and/or live)," "individual characters," among a number of exemplary virtual objects).

632. After all, having sounds for computer- or user-controlled virtual objects move with their objects, including in response to user manipulation of the virtual object, was a fundamental, and extremely important feature to making virtual environments immersive, long before February 2016, as Begault and other references show. *See, e.g.*, Begault (Ex.1007) at 13 ("3-D sound can contribute to the sense of immersivity in a 3-D environment. One might be able to work more effectively within a VR environment if actions were accompanied by appropriate sounds that seemingly emit from their proper locations, in the same way that texture mapping is used to improve the quality of shaded images."), 95 ("[i]n virtual reality

and multimedia applications, most sounds are somehow connected to visual events"); Brungart (Ex.1050) at 9 ("In an environment where listeners are able to grab virtual sound sources and move them around the head, realistic near-field audio cues are extremely important."); Jerald, THE VR BOOK (Ex.1063) at 240 ("Spatialized audio" "provide[s] cues of where other characters are located"), 281 ("objects can make a sound … when a hand collides with them or they have been selected" and "[f]eedback is essential for interaction"); *see also* Pausch (Ex.1076) at 194-97 (describing creating a "high-fidelity virtual reality (VR) attraction" where voices of characters were generated through "a combination of stereo ambient sound, binaural recorded sound, and eight channels of localized sound" and "localized channels provided main characters and sound effects"); Mine, *Towards virtual reality for the masses: 10 years of research at Disney's VR studio* (2003) ("Mine 2003") (Ex.1134) at 12 (describing the need for an intuitive experience).

633. Further still, persons of ordinary skill in the art would have understood that a sound source in virtual space (i.e., at an SLP) is one of many types of virtual objects that could and would be controlled and arranged in VR, for example, by pointing at, highlighting, selecting, and moving the sound source with its associated visual element. Multiple references confirm the obviousness of manipulating sound-producing virtual objects in AR and VR settings, such that an object's sound travels with the object. *See, e.g.*, Osman (Ex.1031) at 10:3-15 (controller is used to fly a

sound-producing virtual helicopter), 10:60-66 ("For example, user 406b has a game cannon, which is fired by the remote player … the firing shot is heard first, and is followed by the sound of the cannonball as the cannonball travels through the air from the location of player 406b to the location of player 406a."); McCulloch (Ex.1008) at 26:12-19 (controller used to crash a sound-producing virtual helicopter into a wall), 29:46-55 (user uses a controller to break a monitor with a virtual basketball); Slater (Ex.1091) at 105 (user-controlled talking avatars sharing a rehearsal space); Erickson (Ex.1057) at 504 (user-controlled talking avatars at a virtual conference); Zhou (Ex.1107) at 1006-07 (describing 3D audio used in an AR and VR game played by two co-players, where images of planes are displayed at the locations of the co-players' handheld controllers (their "wands"): "A constant buzz sound is applied to the co-player's airplane," and "[s]ince the plane is attached to the wand, the 3D positions can be easily obtained from the tracker in the wand," so "the user can always hear where is the location of the co-player, even when the co-player is not visually in the scene"), Figs. 9-11; Lovitt (Ex.1021) at [0038] ("the interactive digital environment of game 208 includes virtual space sound source 238 (e.g., weapon muzzle brake of a user-controlled weapon) and virtual space sound source 242 (e.g., tank muzzle brake) … each virtual space sound source includes one or more associated sounds such that, during interaction with the virtual environment, one or more of the associated sounds are programmed to be 'output' from a particular

virtual space sound source"), [0043] ("this adjusted location would take more movement of the user's on-screen avatar to see and/or engage with the approaching avatar"); Ross (Ex.1125) at 4:30-34 (describing sensory cues, including "visual" and "auditory"), 10:47-62 (describing computing device processing "visual information" and "object/position information"), 17:22-18:35 (describing "interactions" with sound-producing virtual objects, such as "physical fights, side adventures with a particular character, moving objects and/or character, and knocking things over"), 17:32-18:9 (explaining that a guiding character and/or avatar that "walks the user through a scene in the virtual space and points things out" is "like a commentary track on a DVD"), 20:65-21:16 (describing creating those virtual objects in a scene), 25:21-39 (describing displaying sensory cues, including virtual reality content.).

634. In a Pedrotti-Jang or Pedrotti-Jang-Begault system, persons of ordinary skill in the art would have known and been motivated to use Pedrotti's controller (PED) for selecting a sound source (SLP) and that highlighting could obviously be used to indicate this selection. A user could use the controller to select (and thus highlight) an image of a pep band in Jang's virtual basketball court associated with the pep band's sound or a conference attendee in Jang's virtual conference room. Then, the selected and highlighted sound source (e.g., the pep band or conference attended) could be moved from one location (a first SLP) to a different location in auditory space in the virtual environment (a second SLP).

635. Also, persons of ordinary skill in the art would have understood that sound sources could and would be manipulated and arranged directly in the virtual environment, for example, with immersive authoring in immersive social VR experiences as described above. *See* Ross (Ex.1125) at 7:51-62 ("user may create, customize, and/or adjust the virtual reality content, the fields of view, view boundaries"). Alternatively, sound sources could and would be manipulated and arranged through an interface like Begault's Figure 5.12. *See* Begault (Ex.1007) at 174-75 (describing a "GUI for arranging [] various sound inputs in virtual auditory space in a manner configurable by each individual listener" such that "each form of auditory input [is] iconically on the screen and then allow[ed] manipulation of the distance and relative azimuth of each source.").

636. In either case described above, it would have been obvious to persons of ordinary skill in the art to highlight a virtual image (that is associated with a SLP) when the user points a handheld controller (PED) at the SLP to select the image. Indeed, as I indicated above, persons of ordinary skill in the art would have understood that some form of dynamic visual confirmation that a user's moving hand is sufficiently pointing at (intersecting) the virtual image at any given moment would be essential, lest the user be forced to repeatedly point and click until they were able to successfully carry out the desired action with or on the SLP.

637. For these reasons, Pedrotti discloses (or at a minimum renders obvious) limitation 2[a].

(2) 2[b]: "playing, with the WED worn on the head of the user, the binaural sound that emanates from the SLP in response to the PED pointing at the SLP."

638. For the same reasons as I described for limitations 1[a], 1[b], and 2[a], limitation 10[b] would have been obvious to persons of ordinary skill in the art. *See* Sections XI.A.1.b, XI.A.1.c, XI.A.2.a(1).

639. Pedrotti's HMD plays binaural sound that emanates from an SLP, and Pedrotti's HMD tracks controllers and thus can determine when a controller is pointed at an SLP. *See* Sections XI.A.1.c, XI.A.2.a(1).

640. And as explained above, playing binaural sound in response to pointing to a SLP is a common cause-and-effect in a VR environment known well before February 2016. *See* Jerald, THE VR BOOK (EX.1063) at 281 ("objects can make a sound" "when … they have been selected"), 356 ("use audio and highlighting to signify touching of objects"); Begault (Ex.1007) at 159-60 (sounds "spatialized using 3-D audio techniques," i.e., binaural sounds, used for "selecting items," e.g., "click" and "latch" sounds). For example, a user partaking in a virtual sword fight may "point" or direct the controller (e.g., the sword shown in Pedrotti) to strike a virtual enemy, which emits a sound of defeat. As another example, a user in a virtual conference room who chooses to interact with another user (displayed via an avatar

and an SLP) may point to the other user's avatar to begin a conversation. *See also* Jerald, THE VR BOOK (Ex.1063) at 281 ("objects can make a sound" "when … they have been selected"), 356 ("use audio and highlighting to signify touching of objects").

b. Claim 3: "The method of claim 1 further comprising: displaying, with the WED worn on the head of the user, the VR image that shows a size and a shape of the zone in response to the WED determining that the PED is moving outside the zone."

641. For the same reasons as I described for limitations 1[a], 1[c], 1[d], and 2[a], claim would have been obvious to persons of ordinary skill in the art. *See* Sections XI.A.1.b, XI.A.1.d, XI.A.1.e, XI.A.2.a(1).

642. Specifically, Pedrotti discloses that "when the user comes within a preselected distance of the boundary," the processor "generates instructions to the HMD to include in a display of a virtual world a visual warning such as a grid of virtual fence," and "thus provid[es] a warning that the user is about to move out of the selected area." Pedrotti (Ex.1005) at 4:37-44, Fig. 11 (depicting a "visual warning [] in the form of a grid of lines or a 'virtual fence' located at the boundary"); *see also* Pedrotti (Ex.1005) at 12:40-50 ("the processor generates a warning that the user is close to the boundary so that the user can take action to avoid the boundary and thus potential collision with the physical objects"), 12:60-66 ("In addition, since the hand of the user 1002 is within the preselected distance of the boundary of the

selected area, the processor generates instructions to the HMD to generate the visual warning. As illustrated in this embodiment, this visual warning is in the form of a grid of lines or a 'virtual fence' located at the boundary, as indicated in FIG. 11 by the dashed lines 1114.").

643. Further, this virtual image that shows a size and a shape of the zone is displayed in response to the WED determining that the user is moving outside the zone. Pedrotti (Ex.1005) at 12:51-13:11 (describing its "visual warning" in the "'form of a grid or lines or a 'virtual fence' located at the boundary" that "can be glowing or colored"); *see also* Pedrotti (Ex.1005) at 12:40-50 ("the processor generates a warning that the user is close to the boundary so that the user can take action to avoid the boundary and thus potential collision with the physical objects").

644. Thus, Pedrotti discloses (or at a minimum renders obvious) limitation 3.

c. Claim 4

(1) 4[a]: "The method of claim 1 further comprising: storing, in memory of the WED, a location of the zone, a size and a shape of the zone, and a location of the SLP in the zone from where the binaural sound originates to the user; and"

645. Pedrotti taught, or at a minimum rendered obvious to persons of ordinary skill in the art, claim limitation 4[a].

646. As discussed above, Pedrotti's methods involve displaying virtual boundaries of zones. Persons of ordinary skill in the art would have known and understood that, to implement its methods, Pedrotti's system stores, or at a minimum obviously stores, the location, size, and shape of Pedrotti's zone to facilitate determining when to display a zone's virtual fence, e.g., when the user moves outside the zone. *See* Pedrotti (Ex.1005) at 14:56-62 (creation of user-defined zone), Fig. 14; Sections IX.A (Overview of Pedrotti), XI.A.1.b (claim limitation 1[a]), XI.A.2.a(1) (claim limitation 2[a]).

647. As a preliminary matter, persons of ordinary skill in the art would have known and understood that data representing "a location of the zone, a size and a shape of the zone, and locations of the multiple SLPs in the zone from where the binaural sound originates to the user" is no different from any other data used by the system in that it is stored in memory to be used, acted upon, rendered, and displayed in the user's HMD when appropriate.

648. In view of Pedrotti's disclosure that "if the processor has been provided information about the boundary of the selected area then the processor can also determine when the user's head and/or hands approaches the boundary" (Pedrotti (Ex.1005) at 12:31-50), it would have been obvious to persons of ordinary skill in the art that the Pedrotti's system stored information about the boundary such as the coordinate locations of the "sampling points" defining the boundary. Pedrotti

(Ex.1005) at 14:62-65 ("The processor determines the position of the tracker at a number of sampling points as the user moves around the chosen perimeter). A person of ordinary skill in the art would have known and understood that in order to make the comparison between the user's location (either by the user's head or hands) and the boundary in order to display a size and shape of the zone, data regarding the size, shape, and location of the zone would need to be stored and retrievable in memory.

649. Moreover, persons of ordinary skill in the art also would have known that such memory preferably would be in the HMD, since Pedrotti discloses that its processor is located in the HMD. Pedrotti (Ex.1005) at 16:22-24. Thus, the memory would be, or at a minimum would obviously be, in the HMD as well so that it is accessible to the processor. *See* Pedrotti (describing "a non-transitory computer-readable medium having embodied thereon a program, the program being executable by a processor"). This would also eliminate the need for the HMD to communicate with an external storage device, as well as eliminate hardware needed for such communications.

650. Persons of ordinary skill in the art would have known that such storage on an HMD was known. Indeed, Jang teaches this, disclosing a "storage unit" in its "virtual reality apparatus" that a person of ordinary skill in the art would have known could be used for the purpose of storing Pedrotti's "sampling points" defining the

boundary. *See* Jang (Ex.1006) at 4:5-10 ("software code may be stored in a software-code-storing medium, ***such as a memory module***, a server in communication with a virtual reality display device, by a CD, DVD, or any other disk, ***memory storage device***, including a computer-readable medium") (emphasis added), 12:57-67 (further disclosing examples of computer-readable media that can store Jang's programs and data relied upon, including "read-only memory (ROM), random-access memory (RAM), CD-ROMs, DVDs, magnetic tapes, floppy disks, and optical data storage devices"), Fig. 1A ("storage unit" 102 in "virtual reality apparatus" 110).

651. In fact, by February 2016, it was conventional to store information directly in the memory of HMDs. *See, e.g.*, McCulloch (Ex.1008) at 8:1-11 ("memory 244 accessible to the processing unit 210 for storing processor readable instructions and data"), Fig. 2A (depicting memory 244 as part of the HMD); Ross at Figs. 1-2 (showing "electronic storage 30" in its computing device 12), 5:26-27 (indicating that computing device 12 is a "virtual reality headset computing device"), 23:46-67 ("[e]lectronic storage may store files, software algorithms, information determined by processor(s) 20, and/or other information that enables the respective devices to function"), 24:10-19 (describing the processing devices that executes "instructions stored electronically on an electronic storage medium"), 24:59-62

("virtual reality content … for display to the user may be obtained from electronic storage").

652. In addition, to a person of ordinary skill in the art, storing the locations of an SLP in the zone from where binaural sound originates to a user would have been also been straightforward and obvious over Pedrotti and Jang, or over Pedrotti, Jang, and Begault since it would have required the same configuration of hardware between the storage and processor.

653. As I explained above, Jang taught that its system, which has HMD storage, generates binaural sound from audio sources arranged at various locations in the sound areas (i.e. the "focus" and "unfocus" areas) around a user (i.e., multiple SLPs) according to "predetermined" priorities and schemes where the output of each sound source may be adjusted based on a respective priority. *See* Sections XI.A.1.b (limitation 1[a]), XI.A.1.c (limitation 1[b]). Persons of ordinary skill in the art would have understood that implementing Jang's system (and the focus/un-focus priority areas and associated elements, including SLPs), involves storing the locations of focus and un-focus areas, as well as the sizes and shapes of these areas, and the locations of SLPs in those areas from which spatialized audio originates. Indeed, Jang teaches storing software code, which would include such location information needed to make determinations regarding the boundaries for game play per Pedrotti, or of focus and un-focus areas per Jang, in "a software-code-storing medium, such

as a memory module." Jang (Ex.1006) at 4:5-10 (describing a method for generating a "sensory output" for a virtual space), 6:27-28 (describing a "storage unit 102"), 12:57-67 (describing "computer-readable medium" on which the "inventive concept may be" "embodied" upon), Fig. 1A (showing "storage unit" 102), 11:64-12:16 ("sensory output data" is output after it is "[t]ransferred … from a storage unit within the virtual reality device to a control unit."), Fig. 1A ("storage unit" 102) (reproduced below).

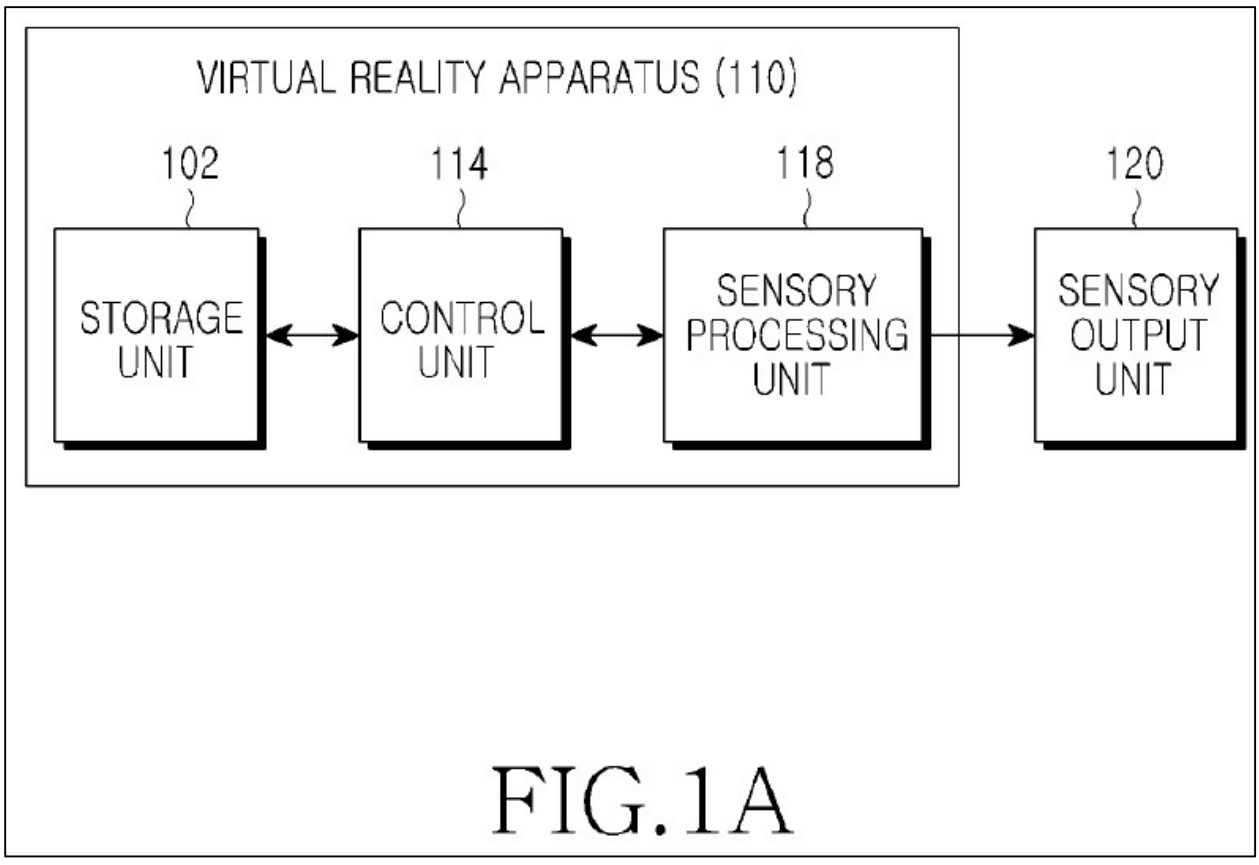


FIG.1A

654. Thus, persons of ordinary skill in the art would have known that the audio source locations from which Jang's binaural sound originates (i.e., the SLPs), including audio sources arranged in the virtual auditory space I described for

limitation 1[a], are (or obviously could and would be) stored in the HMD's memory, which is consistent with Jang's teachings. *See* Section X.B.3.b.

(2) 4[b]: "retrieving, from the memory of the WED, the size and the shape of the zone in response to the WED determining that the user is in the location of the zone."

655. Limitation 4[b] would have been obvious for the same reasons as limitation 4[a]. *See* Section XI.A.2.c(1). In order for Pedrotti's system to determine "when the user's head and/or hand approaches the boundary," the HMD's processor must be provided with information about the boundary of the selected area, and thus, Pedrotti's system could and would retrieve the size and shape of its zone from HMD memory in response to the HMD determining that the user is in the location of the zone. And as discussed above, a person of ordinary skill in the art would have understood that placing memory in the HMD would have facilitated the processor's accessing of the zone boundary information and would have eliminated the need for the HMD to be connected to an external memory.

656. Further, Jang teaches that control over sensory data presented to a user is exercised by the control unit after that unit accesses, i.e., retrieves, sensory data from memory for "audio, sound, and/or other sensory data to output to the user to represent the virtual environment." Jang (Ex.1006) at 6:39-44 ("Upon receiving the virtual reality space information, the control unit 114 may access the storage unit 102 to access audio, sound, and/or other sensory data to output to the user to

represent the virtual environment."). Thus, in a Pedrotti-Jang system, retrieving information about the zone (i.e. its size and shape) from memory in the HMD is what would (or would obviously) occur so that Pedrotti's HMD can display the VR image of its zone with a virtual fence.

d. Claim 5

(1) 5[a]: "The method of claim 1 further comprising: designating, with the PED held in the hand of the user, locations of multiple SLPs in empty space in the zone from where the binaural sound originates to the user; and"

657. Limitation 5[a] would have been obvious for the same reasons as limitations 1[a] and 2[a]. *See* Sections XI.A.1.b (discussing assigning, or designating, SLPs in empty space in the zone) and XI.A.2.a(1) (discussing highlighting).

658. Specifically, Pedrotti and Jang, or Pedrotti, Jang, and Begault, render obvious to persons of ordinary skill in the art the use of routine pointing and selecting actions using Pedrotti's handheld controller (PED), including to assign (i.e., designate) locations in Jang's sound areas from where binaural sound for Jang's audio sources will originate to a user (i.e., SLPs), for example, the locations for spatialized sounds from virtual objects in Jang's basketball court or conference room. *See* Section XI.A.1.b. Also, as discussed for limitation 1[a], persons of ordinary skill in the art would have known to associate sound with such virtual objects (and

have sound move with these objects). This type of sound management and control was known and would have been obvious to persons of ordinary skill in the art over Pedrotti and Jang, or over Pedrotti, Jang, and Begault. *See* Section XI.A.1.b.

(2) 5[b]: "displaying, with the WED, VR images at the locations of the multiple SLPs in empty space in the zone."

659. Limitation 5[b] would have been obvious to persons of ordinary skill in the art over Pedrotti and Jang or Pedrotti, Jang, and Begault.

660. Pedrotti and Jang both disclose HMDs that display virtual images. Pedrotti (Ex.1005) at Abstract ("processor causes the HMD to display a virtual world"); Jang (Ex.1006) at 1:38-40 ("image of a virtual reality system" realized using "Head Mounted Display (HMD)").

661. Jang further disclosed outputting "audio, sound, and/or other sensory data" "to the user to represent the virtual environment." Jang (Ex.1006) at 6:17-20. Jang's sound system can then "check sound source information on other characters and other objects existing in the virtual reality spaces" to "provide[] the virtual reality apparatus 110 with sound sources occurring in real time according to the[ir] relative locations." Jang (Ex.1006) at 7:24-32.

662. Based on these disclosures, persons of ordinary skill in the art would have known that, as I discussed for limitations 1[a] and 5[a], when a user uses Pedrotti's handheld controller to assign (i.e., designate) SLP locations in Pedrotti's

zone, a Pedrotti-Jang or Pedrotti-Jang-Begault system would (or at a minimum obviously would) display virtual images at those designated SLPs because Jang teaches that its system receives "an input of a selected virtual reality character from the user" and "provides the virtual reality apparatus 110 with sound sources occurring in real time according to the relative locations or situations of the character in the virtual reality environment." Jang (Ex.1006) at 7:24-32. Thus, for instance, if a user designated a location for an announcer in Jang's virtual basketball court, an image of an announcer corresponding to the sound source of the announcer would be displayed at that location. Jang (Ex.1006) at 10:37-43, Fig. 5.

663. Similarly, for example, if a user used an interface to arrange sound sources such as GUI that is used for "spatial audio mapping" where icons representing sound sources as described by Begault, persons of ordinary skill in the art would understand that the icons are "virtual images." And persons of ordinary skill in the art would have also understood that corresponding virtual images of the arranged sound sources (e.g., a computer monitor) could and would be displayed in the virtual environment at their designated locations. Begault (Ex.1007) at 172-73 (GUI for "arranging [] various sound inputs" such that "relative location of the icons" are "commands to a multiinput, 3-D sound spatialization subsystem"), Fig. 5:12.

664. Thus, limitation 5[b] would have been obvious to persons of ordinary skill in the art over Pedrotti and Jang or Pedrotti, Jang, and Begault

e. Claim 6

(1) 6[a]: "The method of claim 1 further comprising: selecting one of multiple SLPs in the zone when the PED held in the hand of the user is pointed at the one of the multiple SLPs in the zone; and"

665. For the same reasons as I described for limitation 1[a], 2[a], and 5[a], limitation 6[a] would have been obvious to persons of ordinary skill in the art. *See* Sections XI.A.1.b, XI.A.2.a(1), XI.A.2.d(1).

666. And as I discussed above with respect to limitation 2[a], pointing to select in VR, as well as highlighting to indicate selections, was well known. *See* Section XI.A.2.a(1); *see also* Section VII.D (discussing tracking handheld controllers)*;* Jerald, THE VR BOOK (Ex.1063) at 314-15 ("Tracked hand-held controllers are currently the best option for a majority of interactive VR applications. ***Tracked hand-held controllers are easy to use for many 3D tasks due to their natural, direct mapping to hand motion***.") (emphasis added). Indeed, "the Pointing Pattern is one of the most fundamental and often-used patterns for selection." Jerald, THE VR BOOK (Ex.1063) at 327.

667. Further, Pedrotti discloses the selection of objects by extending one's hands towards objects and pressing a button or issuing commands. *See, e.g.*, Pedrotti

(Ex.1005) at 9:34-40 (describing the selection of a virtual weapon, "[t]hen, upon the user's extending his or her physical hand(s) in such a way as to cause the corresponding virtual hand(s) to 'reach for' the displayed virtual weapon and the user's activating a proper command (e.g., by pressing a button on the controller), the processor can cause the HMD to display the user's virtual hand(s) 214 as 'picking up' and holding that virtual weapon.") and 9:41-46 (describing selecting a virtual sword, "FIG. 8 shows one example of what a user might see in a virtual world after the user has extended the user's physical right hand to cause the virtual right hand to extend toward a virtual sword displayed in the virtual world on the HMD, and then entered the appropriate command to pick up the virtual sword 802.").

668. Thus, selecting an SLP when a PED (e.g., Pedrotti's controller) is pointed at it would have been obvious over Pedrotti and Jang, or over Pedrotti, Jang, and Begault.

(2) 6[b]: "displaying, with the WED worn on the head of the user, a VR image at the one of the multiple SLPs in response to the one of the multiple SLPs being pointed at by the PED held in the hand of the user."

669. For the same reasons as I described for limitations 1[a], 5[a], 5[b] and 6[a], limitation 6[b] would have been obvious to persons of ordinary skill in the art. *See* Sections XI.A.1.b, XI.A.2.d(1), XI.A.2.d(2), XI.A.2.e(1).

670. As I explained above with respect to claim 5, a Pedrotti-Jang or Pedrotti-Jang-Begault system could and would, with Pedrotti's HMD, display a virtual image associated with an SLP when a user points Pedrotti's controller at the SLP and its image to assist the user in moving the selected object from one location to another.

f. Claim 7: "The method of claim 1, wherein the zone has one of a three-dimensional (3D) shape of a cylinder and a 3D shape of a rectangle, and the user is centered in the zone."

671. Pedrotti taught, or at a minimum rendered obvious to persons of ordinary skill in the art, claim 7.

672. As explained above, Pedrotti's system defines the boundary for Pedrotti's zone by having a user "walk around a perimeter chosen by the user," which thus allows a user to define "the outer boundary of a selected area" "with one of the trackers." Pedrotti (Ex.1005) at 14:56-62, Fig. 14; *see also* Section XI.A.1.b (limitation 1[a]. Thus, the user can define any shape desired, including a 3D cylinder or rectangle, for the zone which the user will remain in while in the virtual world. Indeed, Pedrotti does not limit the shape of the zone; rather, it is customizable and could be rectangular. Pedrotti (Ex.1005) at 14:56-15:3 (allowing definition of "an irregularly shaped area" and based on "sampling points as the user moves around the chosen perimeter").

673. Persons of ordinary skill in the art would have known that a user could and would define the boundary in a shape of circle or rectangle for Pedrotti's zone because, for example, one of those two shapes would be suitable or advantageous for the user's VR gameplay area. For example, a rectangular shape would have been advantageous for users looking to maximize gameplay space and the shape of the zone could and would be set to the size of the entire room that the user is in. And a rectangular shape would have been obvious for this very reason: it mirrors physical spaces of the user (rooms typically are rectangular), or virtual spaces that similarly mirror physical spaces. *See* Jang (Ex.1006) at Fig. 6 (depicting rectangular basketball court and conference room).

674. Pedrotti discloses that the boundary could be circular. Pedrotti (Ex.1005) at 14:6-12 ("The boundary of the selected area may be determined in several ways. In some embodiments, a person, such as the user or another person, for example the parent of a child user, may input information into the processor indicating that there is a circular area in front of the base station and having a measured diameter that is clear of objects. FIG. 12 illustrates this configuration."). Further, Pedrotti discloses specifying a circular zone where the user is in the center. Pedrotti (Ex.1005) at 14:13-22 ("In one embodiment, the information input to the processor is determined by activating one of the trackers, either in the HMD or a handheld controller, at a position 1204 directly in front of a base station 1202. From

the position 1204 of the tracker (and the position of a base station tracker if, for example, the electromagnetic field source or camera are not in the base station), the processor can determine how far away the tracker is from the base station 1202, and then determine a circular area 1206 having a radius of that distance centered at that point 1204."). Persons of ordinary skill in the art would have understood that the zone specified by such a circle, within which the user is centered, is a cylinder in the three-dimensional model of the world, otherwise the boundary would not function for its intended purpose. For example, Pedrotti provides examples of actions to be taken if "the user's head or hands go beyond the boundary as determined by the trackers." Pedrotti (Ex.1005) at 13:63-67 ("If the user's head or hands go beyond the boundary as determined by the trackers, the processor can provide additional messaging or warning, such as text or auditory warnings, or an additional visual warning, that persists until the user returns to the selected area within the boundary."). Persons of ordinary skill in the art would have understood that to "go beyond" the circle disclosed by Pedrotti would mean intersecting the surface of a cylinder of infinite length extending vertically above (and below) the circle. Further, Pedrotti discloses a "cylindrical projection" of its "virtual fence," which persons of ordinary skill in the art would have known and understood to support the rendering of a cylindrical fence. Pedrotti (Ex.1005) at 13:12-33, 15:13-22 (information defining

the boundary "may be the radius and location of the center of a circle of a determined diameter that is clear of obstacles"), Figs. 12-13.

675. Pedrotti's "virtual fence" showing the boundary of these zones would (or at a minimum obviously would) have the 3D shape of a cylinder or rectangle, respectively, extending up from the floor.

676. Persons of ordinary skill in the art would have known that a user could and would be centered in a cylindrical or rectangular Pedrotti zone. First, persons of ordinary skill in the art would have known that in a 3D virtual environment, it would be advantageous for the user to be centered in the zone to both avoid leaving the zone as well as allow the user to interact with VR content in all direction. Second, persons of ordinary skill in the art would have understood that the user can walk around in the zone, including to its center. A person of ordinary skill in the art also would have known that virtual reality objects can be repositioned so that the user can remain centered in a VR zone. *See* Cohen 1993 (Ex.1053) at 473 ("Sinks and sources may be repositioned, individually or in groups. (Association is discussed later in Section 2.5.) Since the spatial sound object states include both angular and rectangular attributes, they may be rotated as well as translated. This repositioning may be by either direct or indirect manipulation, may be (rectilinearly or latticed) constrained or unconstrained, may be continuous or discrete, nonconvergent or

convergent to some target, and may be absolute or relative to the starting position of the icon (Cohen 8c Koizumi, 1992a).").

677. For these reasons, Pedrotti taught or rendered obvious claim 7.

g. Claim 8: "The method of claim 1 further comprising: playing, with the speakers in the WED worn on the head of the user, an audio warning in response to the WED determining that the PED is moving outside the zone."

678. Pedrotti taught, or at a minimum rendered obvious, claim 8.

679. As I previously explained, Pedrotti disclosed "generat[ing] an audio warning" in response to the WED determining that the PED is moving outside the zone by its disclosure that it "provid[es] a warning that the user is about to move out of the selected area." Pedrotti (Ex.1005) at 2:44-59, 4:37-44, 12:31-50 (describing the processor "tracking the position and orientation" of the user's hands and head), 16:53-58, 13:44-45 ("It is also possible to include auditory warnings instead of, or in addition to, a visual warning."). Pedrotti's warnings can also be presented if a user "goes beyond the boundary," as a way of "direct[ing] the user to move in the direction of the boundary and the selected area." Pedrotti (Ex.1005) at 2:8-12, 3:65-67, 13:67-14:5, 15:66-16:9, 16:43-45, Fig. 15 (showing a flowchart that outlines a method of assisting a user wearing an HMD in remaining in a selected area).

680. Audio warnings (including through verbal instructions and cues) were commonly used in chaperone systems, and more broadly to aid in navigation. *See*

Jerald, THE VR BOOK (Ex.1063) at 239-40, 242 ("spatialized audio" is an example of a "VR wayfinding aid[]"); Gum (Ex.1015) at [0037] ("In the embodiment of FIG. 8, the boundary setting mode includes an application that is resident on the wireless communications device, and provides an interface with a user to a graphical, audio, and/or physical interface…The wireless communications device may also provide information through an audio interface such as a speaker integrated within the device, or a headset worn by a user and linked (through a cable or wirelessly) to the wireless communications device."); Sawyer (Ex.1036) at [0042] ("a warning sound"), [0047] ("a custom warning specific to the virtual environment is made (e.g., an in-game character tells the user to stop walking when the user approaches the boundaries of the operating space)"); Kobayashi (Ex.1019) at Fig. 4, 10:49-60 ("In step S204, the CPU 101 determines whether or not the viewpoint position of the apparatus user exists in the safe area 40 described in FIG. 8, based on the viewpoint position of the apparatus user converted in step S203 and the plurality of boundary-measured values stored in the RAM 102. If the viewpoint position does not exist inside the safe area 40, warning sound is outputted. The warning sound may be changed from the case where the viewpoint position exists in the warning area 50 to the case where the viewpoint position does not exist in the safe area 40 or the warning area 50 (exists outside the movable area 60)."), 13:20-28 ("the CPU 101 reads out of the RAM 102 the warning sound data warning that the user is inside the warning area 50 or outside

the moveable area 60, and outputs the warning sound data to the audio output device 103 … to clearly notify the user of this apparatus that the user is currently near the boundary of the moveable area 60"), cl. 5 ("The method according to claim 1, wherein said notification is to output predetermined sound."); Begault (Ex.1007) at 171 (stating that "aural cues in virtual reality" often are "a means of replacing tactile sensation (haptic feedback) that would normally occur in a real environment," such as "activating auditory information in the form of a bumping or crashing sound, [so that] the user receives feedback that a particular physical boundary has been violated"); *see also* Ross (Ex.1125) at 1:33-39 (explaining the general principle of "re-direct[ing] the attention" of the user, such as through "loud noises and/or characters telling and/or showing the [user] where to look"); Gallery (Ex.1014) at 4:22-30 ("an audio alarm may be triggered … to the headphone speakers").

681. Further, persons of ordinary skill in the art would have known that Pedrotti's HMD could and would have speakers and that could be used to generate "audio warnings." *See* Section XI.B.1.c (limitation 1[b]). As indicated by Pedrotti, sound is one of the most important sensory signals for virtual reality experiences. Pedrotti (Ex.1005) at 1:18-20 ("While virtual reality can recreate a number of sensory experiences, the senses most commonly used today to create virtual reality appear to be sight and sound."). Indeed, speakers were routinely used with or included in HMDs before February 2016. *See, e.g.*, Jang (Ex.1006) at 1:44-45

("Sound of a virtual reality system may be generated by speakers"), 7:5-6 ("sensory output unit 120 may include speakers"). Further, using a speaker in a WED to provide a warning would require no more than using known components (speakers) to provide a known function (providing a warning) with known methods.

682. For these reasons, Pedrotti taught or rendered obvious claim 8.

3. Independent Claim 9

a. 9[pre]: "A method comprising:"

683. The preamble, 9[pre], would have been obvious for the same reasons as 1[pre]. *See* Section XI.A.1.a.

b. 9[a]: "dividing, with a portable electronic device (PED) held in a hand of a user, an area around the user into a three-dimensional (3D) zone that extends around the user and that includes sound localization points (SLPs) from where binaural sound originates to the user;"

684. For the same reasons as limitations 1[a] and 1[b], limitation 9[a] would have been obvious to persons of ordinary skill in the art. *See* Sections XI.A.1.b, XI.A.1.c. In addition, Pedrotti's described "safe" area is the claimed three-dimensional zone because it is the zone in a 3D virtual environment in which the user plays a game that is bound by Pedrotti's boundary and virtual fence. This zone is (or at a minimum obviously is) around the user (Pedrotti (Ex.1005) at Figs. 11 ("virtual fence 1114"), 14 ("boundary 1404")), and SLPs (and their associated

images) are included in this virtual space for the reasons I described in claim limitations 1[a]-[b].

685. Furthermore, as explained above with respect to claim limitation 1[a], the zone defined by Pedrotti's fence is nearly identical to the Guardian features 8K contends in district court satisfies the claim element "three-dimensional (3D) zone that extends around a user." '316 8K Infringement Contentions (Ex.1130) at 3.

c. 9[b]: "determining, with a wearable electronic device (WED) worn on a head of the user, when the user is leaving the zone; and"

686. For the same reasons as I described for limitations 1[c]-1[d], limitation 9[b] would have been obvious to persons of ordinary skill in the art over Pedrotti in view of Jang. *See* Sections XI.A.1.d, XI.A.1.e.

687. As a preliminary matter, persons of ordinary skill in the art would have understood that Pedrotti's HMD (the claimed WED) is tracked, and hence the user's movement determined. Pedrotti states "[t]he present invention relates generally to virtual reality devices, and more particularly to controllers for use in a virtual reality context." Pedrotti (Ex.1005) at 1:8-10. Persons of ordinary skill in the art would have understood that discussion of an HMD in the context of virtual reality includes this. Indeed, the view-dependent virtual imagery described throughout Pedrotti would not be possible without the HMD being tracked.

688. Pedrotti discloses tracking of the HMD throughout. *See, e.g.*, Pedrotti (Ex.1005) at Abstract ("A method and apparatus is disclosed for assisting a user, wearing a head mounted display (HMD) that covers a user's field of vision and has a tracker providing information regarding the position and orientation of the HMD, in locating a physical controller located on a physical base station."), 4:5-8 ("the user is wearing a head mounted display (HMD) that covers a user's field of vision and has a tracker allows a processor to track the position and orientation of the HMD"), 4:16-19 ("In one embodiment, when a user activates a display of a virtual world into which the user wishes to enter, for example, through the display of a HMD, a processor tracks the position and orientation of a tracker on the HMD.").

689. Pedrotti's trackers provide the HMD-based processor information regarding position, orientation, and inertia, and the processor then determines when the user is approaching as well as going beyond Pedrotti's boundary, or when the user "is leaving" the zone. Pedrotti (Ex.1005) at 2:60-3:12 (describing that "instructions [go] to the HMD"), 5:8-24 (disclosing the use of "inertial sensors (e.g., accelerometers and/or gyroscopes)," 16:20-24 ("processor may be located … in the HMD"), 12:31-41 ("processor knows where the user's head and hands are located" and "determine[s] when the user's head and/or hands approaches the boundary"), 13:57-62 ("auditory warning" provided if user goes "beyond the boundary").

d. 9[c]: "warning the user that the user is leaving the zone by displaying, with the WED worn on the head of the

user, a 3D virtual reality (VR) image of the zone in response to the WED determining that the user is leaving the zone."

690. For the same reasons as limitations 1[c] and 1[d], and 9[b] and claim 3, limitation 9[d] would have been obvious to persons of ordinary skill in the art. *See* XI.A.1.d, XI.A.1.e, XI.A.3.c, XI.A.2.b.

691. Further, Pedrotti's "grid or virtual fence" is (or at a minimum is obviously) a "3D" VR image of the zone because it is a virtual image presented in a 3D VR environment that shows the zone boundary. Pedrotti (Ex.1005) at 12:51-13:11. And as I explained in the State of the Art section, safety and chaperone systems that alert users of boundaries by displaying 3D VR images of the zones were known. *See* Section VII.G.

4. Dependent Claims 10-16

692. I understand that claims 10-16 depend on independent claim 9.

693. Thus, it is my opinion that each of dependent claims 10-16 would have been obvious to persons of ordinary skill in the art for the same reasons as independent claim 9 and additionally for the reasons I discuss in the following subsections.

a. Claim 10

(1) 10[a]: "The method of claim 9 further comprising: determining, with the WED, when the PED is pointed at one of the SLPs while the user is located in the zone; and"

694. For the same reasons as I described for limitations 1[c], 2[a], and 5[a], limitation 10[a] would have been obvious to persons of ordinary skill in the art. *See* Sections XI.A.1.d, XI.A.2.a(1), XI.A.2.d(1).

695. First, Pedrotti's HMD tracks the PED's (or controller's) position and orientation. *See* Section XI.A.1.d (limitation 1[c]).

696. Further, because pointing involves placing the PED in a particular direction (i.e. the controller's orientation) from a particular location (i.e. the controller's position), it would have been obvious to a person of ordinary skill in the art to determine when the PED is pointed at an SLP by, for example, tracing this vector to determine whether the vector it intersects an SLP's location. *See* Jerald, THE VR BOOK (Ex.1063) at 327("Pointing Pattern extends a ray into the distance and the first object intersected can then be selected"). Indeed, pointing to interact in the virtual environment, including to select, was well known, as I explained above for limitation 1[c]. *See* Section XI.A.1.d.

697. Further, it also would have been obvious to persons of ordinary skill in the art for this determination to be made while the user is located in the zone. Pedrotti's the zone defines the user's "safe area" for gameplay, and thus, any pointing while in the virtual world (as well as any other action) would be done by the user while in the zone.

(2) 10[b]: "playing the binaural sound that originates from the one of the SLPs in the zone

in response to the WED determining that the PED is pointed at the one of the SLPs."

698. For the same reasons as I described for limitation 2[b], limitation 10[b] would have been obvious to persons of ordinary skill in the art. *See* Section XI.A.2.a(2).

699. Specifically and as explained above, playing binaural sound in response to pointing to a SLP is a common cause-and-effect in a VR environment. For example, a user partaking in a virtual sword fight may "point" or direct the controller (e.g., the sword shown in Pedrotti) to strike a virtual enemy, which emits a sound of defeat. As another example, a user in a virtual conference room who chooses to interact with another user (displayed via an avatar and an SLP) may point to the other user's avatar to begin a conversation.

b. Claim 11: "The method of claim 9 further comprising: highlighting, while the user is located in the zone and with a display of the WED, color of a VR image at one of the SLPs in the zone when the PED held in the hand of the user points at the one of the SLPs in the zone."

700. For the same reasons as I described for limitation 2[a], claim 11 would have been obvious to persons of ordinary skill in the art. *See* XI.A.2.a(1). Persons of ordinary skill in the art knew that "[h]ighlighting is visually outlining or changing the color of an object." Jerald, THE VR BOOK (Ex.1063) at 305; *see also* Pedrotti (Ex.1005) at 12:66-13:11 ("The grid can be glowing or colored to be more visible to the user").

c. Claim 12

(1) 12[a]: "A method of claim 9, wherein the 3D VR image of the zone is shaped as a cylinder with the user being centered in the cylinder, and"

701. For the same reasons as I described for claim 7 and limitation 9[b], limitation 12[a] would have been obvious to persons of ordinary skill in the *art. See* Sections XI.A.2.f, XI.A.3.c; *see also* Section XI.B.1.a (describing disclosures of a "method"). Indeed, if the zone itself has the shape of a cylinder, its 3D VR image too has the shape of a cylinder.

(2) 12[b]: "the WED is a head mounted display that display VR images and"

702. For the same reasons as I described for limitations 1[a] and 1[d], 12 would have been obvious to persons of ordinary skill in the art. *See* Sections XI.A.1.b, XI.A.1.e. Pedrotti's system uses a head mounted display (WED) that displays VR image. *See* Pedrotti (Ex.1005) at 2:44-47.

(3) 12[c]: "plays the binaural sound while the user plays a game."

703. Limitation 12[b] would have been obvious for the same reasons as limitations 1[b]. *See* Section XI.A.1.c.

704. In addition, Pedrotti and Jang both disclose application of their systems to VR game play. Pedrotti (Ex.1005) at 1:40-44, 9:24-40; Jang (Ex.1006) at 1:28-38, 7:14-19.

d. Claim 13

(1) 13[a]: "A method of claim 9, wherein the 3D VR image of the zone is shaped as a rectangle with the user being centered in the rectangle, and"

705. For the same reasons as I described for claim 7 and limitation 9[b], limitation 13[a] would have been obvious to persons of ordinary skill in the art. *See* Sections XI.A.3.c, XI.A.2.f. As I discussed for claim 7, Pedrotti discloses specifying a circular zone where the user is in the center. Pedrotti (Ex.1005) at 14:13-22. Pedrotti also discloses that the zone can be any desired shape or configuration. Pedrotti (Ex.1005) at 15:53-55 ("Also as above, in various embodiments, the processor can generate the visual warning in the form of grid lines or a virtual fence, or in any other desired shape or configuration."). If the zone itself has the shape of a rectangle, its 3D virtual image too has the shape of a rectangle. Pedrotti discloses, and persons of ordinary skill in the art would have known, that "[t]o minimize rendering cost, the fence may be rendered as a projected texture on small pieces of 3D geometry that cover only the areas where the fence is to be visible."). Pedrotti (Ex.1005) at 13:17-20. Persons of ordinary skill in the art would have understood that zones with planar surfaces, such as rectangles (cubes), have the lowest rendering cost, and the lowest distance and intersection computational cost, compared to circles and irregular shapes. Thus, persons of ordinary skill in the art would have found it obvious to use rectangles (cubes) when and where possible. Further, a rectangular shape would have been obvious because it mirrors physical spaces (e.g.,

rooms). *See* Jang (Ex.1006) at Fig. 6 (rectangular virtual basketball court and conference room). Persons of ordinary skill in the art would have understood that the zone could be rectangular in shape, which is a common and obvious shape to use in defining zones so that they mirror physical spaces—as rooms typically follow rectangular floorplans.

(2) 13[b]: "the WED is a head mounted display that displays VR images and"

706. For the same reasons as I describe for limitations 1[a], 1[d], and 12[b], Limitation 12[b] would have been obvious to persons of ordinary skill in the art. *See* Sections XI.A.1.c, XI.A.1.e, XI.A.4.c(2).

(3) 13[c]: "plays the binaural sound while the user plays a game."

707. For the same reasons as limitations 1[b] and 12[c], limitation 13[c] would have been obvious to persons of ordinary skill in the art. *See* Sections XI.A.1.c, XI.A.4.c(3).

e. Claim 14: "The method of claim 9 further comprising: playing, with the WED worn on the head of the user an audio warning indicating the user should move back into the zone in response to the WED determining that the user is leaving the zone."

708. For the same reasons as I describe for claim 8, Claim 14 would have been obvious to a person of ordinary skill in the art. *See* Section XI.A.2.g. As discussed, Pedrotti's warning indicates the user should move back into the zone so

that the user does not, for example, crash into a wall or trip over a sofa. Pedrotti (Ex.1005) at 4:37-44, 11:48-54.

f. Claim 15: "The method of claim 9, wherein the 3D VR image of the zone is shaped as a cylinder that extends around the user."

709. For the same reasons as I describe for claim 7 and limitation 12[a], claim 15 would have been obvious to a person of ordinary skill in the art. *See* Sections XI.A.2.f, XI.A.4.c(1). Also, Pedrotti's zone extends around the user while the user is in the zone, so the 3D VR image of Pedrotti's zone also would (or at a minimum obviously would) be shaped to extend around the user.

g. Claim 16

(1) 16[a]: "The method of claim 9 further comprising: determining, with the WED worn on the head of the user when the PED is leaving the zone; and"

710. For the same reasons as I describe for limitation 1[c]-1[d], limitation 16[a] would have been obvious to persons of ordinary skill in the art. *See* Sections XI.A.1.d-XI.A.1.e. Indeed, persons of ordinary skill in the art would have considered limitation 16[a]'s "leaving the zone" to be just as obvious over Pedrotti as limitation 1[c]'s "moving outside the zone" because both involve the same action by the user and the same processing and determinations made by Pedrotti's system.

(2) 16[b]: "warning the user that the PED is leaving the zone by displaying, with the WED worn on the head of the user, the 3D VR image of the zone

in response to the WED determining that the PED is leaving the zone."

711. For the same reasons as limitations 1[d], 9[c], and 16[a], limitation 16[b] would have been obvious to a person of ordinary skill in the art. *See* Sections XI.A.1.e, XI.A.3.d, XI.A.4.g(1).

5. Independent Claim 17

a. 17[pre]: "An electronic system comprising:"

712. To the extent the preamble is limiting, both Pedrotti and Jang disclose this. Pedrotti discloses an electronic "system" (that includes an HMD and handheld controller) to "assist a user in remaining in a selected area of the physical world," which is an electronic system. Pedrotti (Ex.1005) at 2:44-59. Similarly, Jang discloses an "apparatus" (e.g., an HMD) that includes "a sound processing unit" and "control unit" used "to perform sound processing in a virtual reality system." Jang (Ex.1006) at 2:26-47; *see also* Sections XI.A.1.a(1[pre]), XI.A.3.a (9[pre]).

b. 17[a]: "a portable electronic device (PED) held in a hand of a user that divides an area around the user into a three-dimensional (3D) zone that extends around the user and includes sound localization points (SLPs) in empty space from where binaural sound originates to the user while the user is located inside the zone; and"

713. For the same reasons as I describe for limitation 1[a] and 9[a], limitation 17[a] would have been obvious to a person of ordinary skill in the art. *See* Sections XI.A.1.b, XI.A.3.b.

c. 17[b]: "a wearable electronic device (WED) that is worn on a head of the user,"

714. For the same reasons as I describe for limitation 1[b], limitation 17[b] would have been obvious to a person of ordinary skill in the art. *See* Section XI.A.1.c.

d. 17[c]: "wirelessly communicates with the PED,"

715. Pedrotti taught, or at a minimum rendered obvious, a WED that communicates wirelessly with the PED.

716. Pedrotti discloses that the HMD is able to communicate wirelessly specifically with the handheld controllers. Pedrotti (Ex.1005) at 4:49-5:24 (disclosing multiple methods of wireless tracking the controller, e.g., tracking through "sensed magnetic field[s]," "electromagnetic coupling," "light-emitting trackers," "radar," and "ultrasonic" sensing devices.), 5:28-34. Persons of ordinary skill in the art would have understood that these tracking methods could and wood be implemented wirelessly and would be motivated to do so to eliminate wires which could pose hazards to users wearing the HMD while interacting in a virtual world.

e. 17[d]: "includes speakers that play to the user the binaural and that emanates from the SLPs in empty space in the zone,"

717. For the same reasons as I describe for limitation 1[b], limitation 17[d] would have been obvious to a person of ordinary skill in the art. *See* Section XI.A.1.c.

f. 17[e]: "includes one or more sensors that sense when the PED is leaving the zone,"

718. For the same reasons as I describe for limitations 1[c] and 16[a], limitation 17[e] would have been obvious to a person of ordinary skill in the art. *See* Sections XI.A.1.d, XI.A.4.g(1).

g. 17[f]: "and includes a display that displays a virtual reality (VR) image of the zone in response to sensing that the PED is leaving the zone,"

719. For the same reasons as I describe for limitation 1[d] and 17[e], limitation 17[f] would have been obvious to a person of ordinary skill in the art. *See* Sections XI.A.1.e, XI.A.5.f.

h. 17[g]: "wherein the display displays the VR image of the zone to warn the user that the user is leaving the zone."

720. For the same reasons as I describe for limitation 1[d] and 9[c], limitation 17[g] would have been obvious to a person of ordinary skill in the art. *See* Sections XI.A.1.e, XI.A.3.d.

6. Dependent Claims 18-20

721. I understand that claims 18-20 depend on independent claim 17.

722. Thus, it is my opinion that each of dependent claims 18-20 would have been obvious to persons of ordinary skill in the art for the same reasons as independent claim 1 and additionally for the reasons I discuss in the following subsections.

a. Claim 18: "The electronic system of claim 17, wherein the display of the WED highlights a color of a VR image at one of the SLPs in response to the WED determining that the PED is pointing to the VR image at the one of the SLPs."

723. For the same reasons as I describe for limitations 2[a] and claim 11, claim 18 would have been obvious to a person of ordinary skill in the art. *See* Sections XI.A.2.a(1), XI.A.4.b.

b. Claim 19: "The electronic system of claim 17, wherein the WED tracks a location of the user with respect to the SLPs, and automatically displays a VR image at a location of one of the SLPs in response to determining that the user is proximate to the location of the one of the SLPs."

724. For the same reasons as I describe for l limitations 1[c], 1[d], 4[a], 5[b], 6[b], and claim 3, claim 19 would have been obvious to persons of ordinary skill in the art. Sections XI.A.1.d, XI.A.1.e, XI.A.2.d(2), XI.A.2.d(2).

725. Pedrotti discloses automatically displaying virtual imagery when the user is close to real or virtual objects. For example, Pedrotti discloses automatically displaying a pair of virtual hands when the user is proximate to the physical base station. Pedrotti (Ex.1005) at 7:1-10 ("Thus, as the user approaches the virtual base station 210 presented on the display, the processor receiving information from tracker 108 (and from the base station tracker where appropriate) can determine that the user is also approaching the physical base station. FIG. 3 shows what a user might see in the virtual world in one embodiment as the user has approached the

virtual base station 210 in the virtual world and is looking down towards it, and is also approaching the physical base station in the real world."), 7:16-19 ("In addition, the instructions from the processor now also cause the display to generate two virtual hands 214 (with a portion of the forearms) reaching toward the virtual base station 210.").

726. In addition, just as with displaying the virtual fence when the user is nears the user-defined boundaries as Pedrotti describes, it would have been equally obvious to persons of ordinary skill in the art to have the same logic apply to other virtual objects associated with SLPs. *See* Pedrotti (Ex.1005) at 4:37-44 ("The processor … generates instructions to the HMD to include in a display of a virtual world a visual warning such as a grid or virtual fence when the user comes within a preselected distance of the boundary …."). That would require no more than using the same action (displaying an image) after determining the same information (that a user is proximate to a location) using the same devices (Pedrotti's PEDs and HMD).

727. Further, displaying virtual images at the locations of their sound sources (SLPs), and doing so automatically when users are proximate to one of them was a well-known VR effect. In a VR game, an example of this is when a user is exploring an area and travels within distance of another character so that the other character appears on the screen for additional interactions. Another example, described in Cohen 1993 that is referenced by Begault, is in zooming effects that allow a user to

navigate large spaces or dense point sources where distance sources are not displayed by default but only when the user approaches. Cohen 1993 (Ex.1053) at 475 (describing "a cluster feature": "Distant sources would not be displayed; but as it approaches, a cluster would appear as a single point; only to disassociate and distribute spatially as it gets closer. This focus allows navigation in arbitrarily large spaces, assuming a limited density of point sources."). Doing so allows the presentation of certain content of interest to the user while pausing (or otherwise not presenting content) on which the user is not focused. *See* Ross (Ex.1125) at 2:32-67 ("primary virtual reality content may resume (e.g., automatically) when the user returns his view (e.g., and/or moves within the virtual space) to the primary field of view"), 4:21-39, 6:41-66 (describing primary, secondary, and tertiary virtual reality content presented to a user), 15:29-36 (explaining that "Content component 24 may be configured such that primary virtual reality content is presented to the user response to the user's view direction being within a first field of view….and secondary virtual reality content may be presented to the user when the user's view direction is within a second field of view").

c. Claim 20

(1) 20[a]: "The electronic system of claim 17, wherein the speakers in the WED play the binaural sound that emanates from one of the SLPs in empty space in response to the WED determining that the PED is pointed to the one of the SLPs in empty space, and"

728. For the same reasons as I describe for limitation 1[b] and claim 2, limitation 20[a] would have been obvious to a person of ordinary skill in the art. *See* Sections XI.A.1.c, XI.A.2.a.

(2) 20[b]: "the zone is shaped as a 3D cylinder with the user being centered in the 3D cylinder."

729. For the same reasons as I provided for claim 7, limitation 20[b] would have been obvious to a person of ordinary skill in the art. *See* Section XI.A.2.f.

* * *

730. For the reasons discussed above, every limitation in claims 1-20 of the '316 patent, and each of claims 1-20 as a whole, would have been obvious over Pedrotti in view of Jang, and further in view of Begault.

B. Ground 2: Claims 1-20 Are Unpatentable Over McCulloch In View Of Pedrotti, And Further In View Of Flaks

731. In this section, I explain why every limitation of claims 1-20 of the '316 patent, and each of claims 1-20 as a whole, would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, and further in view of Flaks.

1. Independent Claim 1

a. 1[pre]: "A method comprising:"

732. Both McCulloch and Pedrotti disclose methods.

733. McCulloch discloses a "method for controlling a virtual object" involving a HMD ("head mounted display device 2") and tracked HPEDs ("real controller device(s) 21"). McCulloch (Ex.1008) at 1:34-36, 4:49-55 (discussing HMD), 6:55-61 (discussing HPEDs), 12:41-48 ("requested actions indicated by real controller device commands being applied and displayed from the user perspective" in the "display field of view"), Figs. 1A-1B.

734. Pedrotti also discloses a "method" of providing "visual assistance to a user in a virtual reality environment." Pedrotti (Ex.1005) at 2:27-59; *see* Section XI.A.1.a.

b. 1[a]: "dividing, with a portable electronic device (PED) held in a hand of a user, an area around the user into a zone that extends around the user and that includes a sound localization point (SLP) from where binaural sound in empty space originates to the user;"

735. Limitation 1[a] would have been obvious to persons of ordinary skill in the art over McCulloch, either alone or with Flaks, in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section XI.A.1.b (Ground 1, limitation 1[a]).

736. As I discussed above for Ground 1, 8K contends that limitation 1[a] requires only that there be an area, or zone, defined for gameplay, as 8K contends that any area defined for game play will subsequently include binaural sound. *See* '316 8K Infringement Contentions (Ex.1130) at 4. Under this interpretation,

limitation 1[a] would have been obvious over McCulloch in view of Pedrotti, and over McCulloch in view of Pedrotti and further in view of Flaks, for the following reasons.

737. Persons of ordinary skill in the art would have recognized that McCulloch's system, which includes functionalities for tracking a controller held in the hand of a user (PED), could and would be used to implement Pedrotti's method of defining a zone for gameplay with a PED, or "divid[ing] … an area around the user into a zone that extends around the user."

738. McCulloch discloses a "display device system 8" that comprises a "head mounted display device 2":

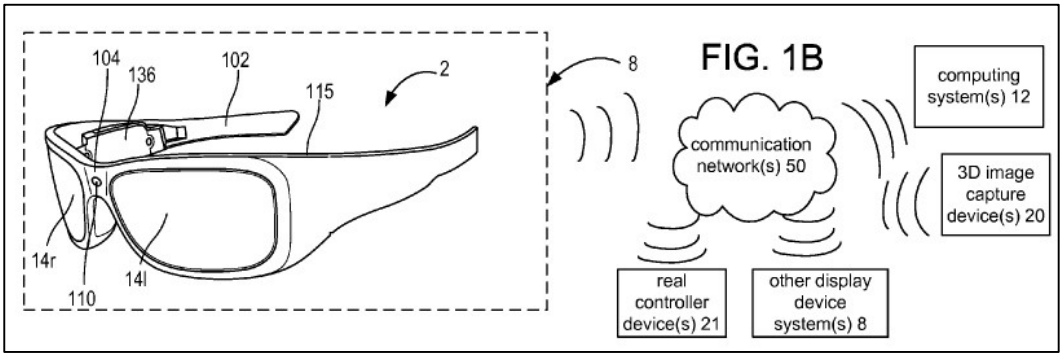


FIG. 1B

McCulloch (Ex.1008) at Fig. 1B; *see also* McCulloch (Ex.1008) at 4:49-55, 8:1-46 (describing control circuity 136 of the display device 2 and sensors, including an inertial sensing unit 132 and location or proximity sensors). McCulloch's HMD has "[c]ontrol circuitry 136" including a "processing unit 210," which "may comprise

one or more processors including a central processing unit (CPU) and a graphics processing unit (GPU)" and "memory 244":

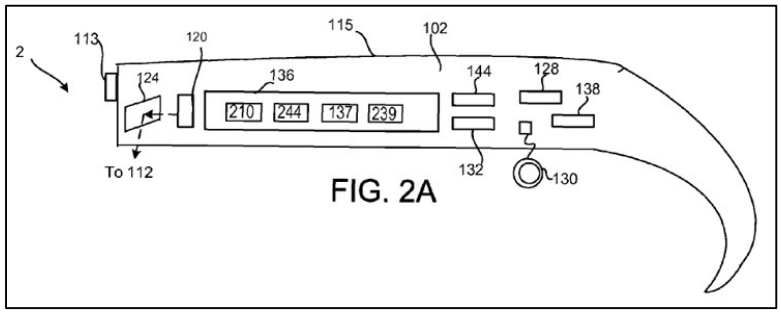


FIG. 2A

McCulloch (Ex.1008) at Fig. 2A, 8:1-16; *see also* McCulloch (Ex.1008) at 5:32-35 ("the functionality of companion processing module 4 may be integrated in software and hardware components of the display device 2 as in FIG. 1B"), Fig. 1B, 7:4-23. And the "computing environment" for McCulloch's "display device system 8," which includes the HMD, comprises an "image and audio processing engine 191" that "processes image data… and audio data." McCulloch (Ex.1008) at Fig. 4A, 13:52-18:7 (depicting and describing "computing environment 54" for McCulloch's HMD).

739. The computing environment also receives inertial and positional data from "handheld IMU controller[s]," which are PEDs held in the hands of the user. McCulloch (Ex.1008) at 4:25-31 (describing variants of controllers), 28:63-66 ("Joe is holding a handheld IMU real controller device 19 in this example"). "[C]hanges in position and orientation of [a] handheld controller cause its inertial motion unit to generate one or more signals which are converted by the handheld IMU real

controller device 19 to be user input requesting display of an action by [a] virtual object," such as a virtual basketball. McCulloch (Ex.1008) at 29:4-11. And as I explained above for Ground 1, Pedrotti also discloses a handheld PED. Pedrotti (Ex.1005) at 1:40-45, Figs. 2-5, 7; *see also* Section XI.A.1.b.

740. Because McCulloch also discloses, or at a minimum renders obvious, tracking the movement of its real controller device—and specifically tracking the movement with its HMD—persons of ordinary skill would have known that McCulloch's system could and would have been used to implement Pedrotti's method to divide an area around the user into a zone for gameplay. For example, McCulloch teaches that its controllers are tracked relative to the HMD and surrounding environment using image and depth data. *See* McCulloch (Ex.1008) at 7:34-59, 8:17-30. McCulloch also discloses tracking the translation and rotation of the handheld controller, e.g., the handheld IMU real controller device 19, via its inertial sensors. McCulloch (Ex.1008) at 29:4-36 ("changes in position and orientation of the handheld controller causes its inertial motion unit to generate one or more signals which are converted by the handheld IMU real controller device 19 to be user input requesting display of an action by the virtual object 30_2"), 29:36-63 ("Inertial motion sensors ['IMU'] in the handheld real controller device 19 identify parameters like speed, acceleration and direction of motion of the device 19 which is sent as data to the display device system 8."), 29:6-12 (similar), 24:28-35

(describing real controller device interface software 188), Figs. 8B, 8D; *see also* McCulloch (Ex.1008) at 28:63-66 (explaining that the "handheld IMU real controller device 19" "establishe[s] communication with [] display device system 8 (e.g., 2 and 4)"), 25:25-28. ("In other examples, non-NUI input like moving a displayed selection arrow with the real controller device may be used to identify a user selected object for control or force feedback as discussed below.").

741. Furthermore, persons of ordinary skill in the art would have understood that determining the handheld IMU device was being moved "in the direction of the television 16 [such] that the virtual basketball 303 collides with the display of the television" as disclosed by McCulloch ((Ex.1008) at 29:44-46) would require the dynamic determination of the position and orientation of the handheld IMU device relative to the McCulloch's HMD and the world. McCulloch teaches this relative position and orientation tracking as well because McCulloch's HMD is also tracked by the HMD itself, and the HMD provides image and depth data to track objects in front of the user, including the user's hands and controllers held in the user's hands. Persons of ordinary skill in the art would have known that determining the position and/or orientation of the handheld device, or PED held in the hand of the user, is a step in Pedrotti's method of defining a zone for gameplay.

742. Additionally, McCulloch's HMD also includes front-facing cameras to develop image and depth data to track objects in front of the user, including the

user's hands and controllers held in the user's hands. McCulloch (Ex.1008) at 12:18-21 ("the front facing capture devices 113 capture and provide image and depth data from which real objects are identified as well as their positions and often orientations relative to the display portion of the device"), 7:57-59 ("capture devices 113 are also referred to as outward facing capture devices meaning facing outward from the user's head"), 7:34-37 ("the capture devices 113 may also be depth sensitive, for example, they may be depth sensitive cameras which transmit and detect infrared light from which depth data may be determined"), 22:4-8 ("gesture recognition engine 193 can identify actions performed by a user indicating a control or command to an executing application," including actions "performed by a body part of a user, e.g. a hand or finger"), 28:5-11 ("the capture devices 113 can capture data of the user's hand and finger pointing to different objects and identifying them as a control object or a force feedback object or both, and the image and depth data is processed by the gesture recognition engine 193 for identifying a pointing selection gesture").

743. And, McCulloch discloses that the HMD includes absolute position and orientation tracking of the HMD through various sensors and transceivers, which provides information that can be combined with the HMD's image and depth data for the tracking of controllers. *See, e.g.*, McCulloch (Ex.1008) at 8:17-30 ("Inside, or mounted to temple 102, are an earphone of a set of earphones 130, an inertial sensing unit 132 including one or more inertial sensors, a location sensing unit 144

including one or more location or proximity sensors, some examples of which are a GPS transceiver, an infrared (IR) transceiver, or a radio frequency transceiver for processing RFID data. Optional electrical impulse sensing unit 128 detects commands via eye movements. In one embodiment, inertial sensing unit 132 includes as sensors a three axis magnetometer, a three axis gyro, and a three axis accelerometer. The inertial sensors are for sensing position, orientation, and sudden accelerations of head mounted display device 2. From these movements, head position, and thus orientation of the display device, may also be determined."), Fig. 2A.

744. Persons of ordinary skill in the art also would have understood that the camera-based absolute position and orientation of the handheld IMU real controller device 19 (held in the user's hand) supplements the IMU information about velocities and accelerations received from the IMU real controller device. As I discussed above, a "hybrid method of integrating multiple technologies together (sensor fusion)" can "provide both high precision and accuracy." Jerald, THE VR BOOK (Ex.1063) at 315. As such, persons of ordinary skill in the art would have known, or at minimum found it obvious, to use sensor fusion methods to combine the camera-based absolute position and orientation of the handheld IMU real controller device 19 (held in the user's hand) with the IMU-based derivative signals (e.g., velocities and accelerations) from the IMU real controller device 19.

745. McCulloch further teaches defining boundaries for a zone that extends around the user, or "identifying boundaries for a playspace in which virtual objects can be positioned." McCulloch (Ex.1008) at 20:11-13, 15:48-16:41, Fig. 4A. As the user is also located within the playspace, the boundaries define a zone that extends around the user.

746. Tracking the controller takes places entirely within McCulloch's HMD. The computing environment 54 is contained within the HMD, or device display system 8, which includes head mounted display device 2 and companion processing module 4. *See, e.g.*, McCulloch (Ex.1008) at 28:63-66 (referring to "display device system 8 (e.g., 2 and 4)"), 5:32-36 ("the functionality of the companion processing module 4 may be integrated in software and hardware components of the display device 2 as in FIG. 1B"), 7:14-16 ("control circuitry 136 of the display device 2 incorporates the functionality which a companion processing module provides in FIG. 1A"), 13:56-60 ("Fig. 4A illustrates a computing environment embodiment 54 from a software perspective which may be implemented by a system like display device system 8"), Fig. 4A (arrow showing item 8 pointing to computing environment 54).

747. The HMD, which contains the companion processing module, is in communication with the real controller devices in order to track the real controller devices and receive user input, as described above. *See* McCulloch (Ex.1008) at

5:19-36 ("[t]he companion processing module 4 may communicate wired or wirelessly" with "one or more real controller devices"), 24:28-30 (explaining that real controller device interface software 188, which is part of the computing environment 54 of the HMD, "communicates over a network 50 with the device interface software 189 of a real controller device 21"). And, as noted above, the changes in position and orientation of the handheld controller, which are "user input requesting display of an action," is the input data is provided to the real controller device interface software 188, which is part of the HMD's computing environment. McCulloch (Ex.1008) at 29:6-11, 25:29-33 ("the real controller device interface software 188 receives user input data from a real controller device"), 24:47-54 ("real controller device interface software 188 identifies a virtual object for control" and "applies the user input from the controller 21 requesting an action to be performed from the user perspective by indicating display instructions to the virtual data engine 195 or the application 166").

748. In addition to receiving information provided by the real controller devices, the computing environment 54 also receives device data 198, which includes data from the HMD itself, e.g., "data from sensors or sensing units" such as "the orientation sensors in inertial sensing unit 132" and "location and proximity transceivers in location sensing unit 144." McCulloch (Ex.1008) at 24:14-21. Additionally, the computing environment 54 of McCulloch's HMD includes image

and audio processing engine 191, which displays a user's actions (e.g., controlling a virtual object by real controller device 21) on the HMD. McCulloch (Ex.1008) at 13:64-14:11, 24:47-54 ("real controller device interface software 188 identifies a virtual object for control … applies the user input from the controller 21 requesting an action to be performed from the user perspective by indicating display instructions to the virtual data engine 195 or the application 166"); *see* Section IX.D (overview of McCulloch).

749. Also, persons of ordinary skill in the art would have known that McCulloch's controllers are tracked (or at a minimum could obviously be tracked) because, as I have explained, this was a common setup, particularly for gaming applications. *See* Section VII.D (discussing tracking). And, persons of ordinary skill in the art would have known that tracking these controllers include determining their position and orientation in space (e.g., where they are, or where they are pointed), and receiving information regarding a zone definition according to Pedrotti's method.

750. Accordingly, persons of ordinary skill in the art would have known and been motivated to use Pedrotti's method of defining a boundary for a safe area (a zone that extends around the user) with McCulloch's system. *See also* Section X.B.1 (reasons to combine McCulloch and Pedrotti).

751. In addition, McCulloch discloses that "a gaming application may receive user input identifying boundaries for a playspace," but offered one example of user input—gaze tracking with voice command. McCulloch (Ex.1008) at 20:11-18. Persons of ordinary skill in the art would have known and understood that Pedrotti's method, which uses HMD-tracked handheld controllers to draw a boundary, is advantageous, efficient, and accurate, and thus would have been motivated to use it.

752. With a handheld controller, as taught in Pedrotti, the user can more readily and accurately ensure that hazardous conditions are sufficiently outside the boundaries by a simple action of pointing or moving the controller along the desired boundaries. Jerald, THE VR BOOK (Ex.1063) at 282 ("hand-tracked devices work well … for pointing"), 327 ("[p]ointing is faster when speed of remote selection is important, but is also often used for precisely selecting close objects") (internal citations omitted). In comparison, skilled artisans would have understood that gaze tracking is resource-intensive and imprecise when used alone. Jerald, THE VR BOOK (Ex.1063) at 318-19 ("Interacting via eye tracking alone is usually not a good idea—eye tracking works better with multimodal input."), 319 ("Gaze data is noisy."), 328 ("eye gaze selection is typically not a good selection technique"). Additionally, even if gaze tracking were supplemented with voice commands for demarcating boundary points for better precision, persons of ordinary skill in the art would have been

motivated to pursue a simpler approach, especially when McCulloch's HMD already tracks the controller using the real controller device or IMU, with comparable hardware as disclosed in Pedrotti and consistent with how boundaries were defined in many safety and chaperone systems before February 2016. *See* Section X.B.1 (discussing McCulloch's and Pedrotti's HMDs and controllers among reasons to combine McCulloch and Pedrotti); Section VII.G (summary of safety and chaperone systems).

753. Further, because McCulloch's zone is "for a playspace in which virtual objects can be positioned" (McCulloch (Ex.1008) at 20:11-23), persons of ordinary skill in the art would have known to use McCulloch's system to implement Pedrotti's method, which renders obvious "dividing, with a portable electronic device (PED) held in a hand of a user, an area around the user into a zone." *See* Section XI.A.1.b (Ground 1, limitation 1[a]).

754. Persons of ordinary skill in the art would have understood that Pedrotti's method that divides an area around the user into a zone that extends around the user creates a zone that would subsequently "include a sound localization point (SLP) from where binaural sound in empty space originates to the user." Indeed, McCulloch discloses that the virtual "playspace" is an area "in which virtual objects can be positioned," which confirms that it would have been obvious for the area to subsequently contain an SLP, reflecting the location of a binaural sound-producing

virtual object. McCulloch (Ex.1008) at 20:11-23. In fact, McCulloch provides several examples of sound-producing virtual objects. McCulloch (Ex.1008) at 26:7-19 (flying helicopter that crashes into wall), 29:3-30:3 (bouncing basketball that crashes into television), 25:6-26:34, Fig. 5 (describing "play[ing] audio for the virtual object projected from a 3D space position of the virtual object"), Figs. 8A-8D, 24:67-25:3.

755. Persons of ordinary skill in the art also would have known and understood that the SLP in a McCulloch-Pedrotti system would be locations for "binaural sound in empty space" that "originates to the user" for the reasons that follow.

756. McCulloch further teaches that localized sound, such as binaural sound, originates from these virtual objects because McCulloch's 3D audio engine produces audio "projected from a 3D space position of the virtual object." McCulloch (Ex.1008) at 26:7-9. McCulloch also incorporates Flaks for implementation details for its 3D audio engine, including that the 3D audio engine's sound is generated using HRTFs, which POSAs would have understood are used to produce binaural sound. McCulloch (Ex.1008) at 14:53-67 (sounds can be "identified to the 3D audio engine 304 with data identifying from which direction or position to make the sound seem to come from"), 16:58-63 (similar), 21:21-54 (describing the 3D audio engine as a "positional 3D audio engine" where "[a]udio data for virtual objects generated

by an application can be output to the earphones to sound as if coming from the direction of the virtual object"), 29:43-57 (describing a basketball colliding with a television screen). Flaks discloses that its 3D audio engine "applies a head related transfer function (HRTF) for the listener to each of the components of the 3D audio signal, and provides the 3D audio signal." Flaks (Ex.1009) at 2:6-20; *see also* Flaks (Ex.1009) at 4:10-15 (describing generating sound that originates from a virtual sound source). Such components can reflect a right and left HRTF to provide binaural sound to the user, which was a common technique well known in the art. *See* Section VII.E (summary of binaural sound).

757. And, Flaks explains that binaural sound is generated "by comparing cues received at both ears (difference cues or binaural cues)" and that sound "appear[ing] to come from a particular location in 3-dimensional space" can be achieved through a technique where "one audio-speaker is placed over or near each ear" and "creating an audio signal using a 'head-related transfer function' (HRTF) to create the illusion that sound is originating from a location in 3D space." Flaks (Ex.1009) at 1:9-12, 1:17-28.

758. As further evidence that Flaks' audio engine generates binaural sound, Flaks discloses that, as part of its "process 600 of determining a listener's location and rotation in the room," the model of the human target "include[s] information that describes the rotation of the user's head such that the orientation of the user's

ears is known." Flaks (Ex.1009) at 10:5-9, 11:22-24. As part of Flaks' process of determining HRTFs for a particular listener, Flaks explains "if the system was expecting data for a right ear, then the system determines whether the data matches what is expected for a right ear." Flaks (Ex.1009) at 11:61-65. Because binaural sound accounts for both ears, persons of ordinary skill in the art would have understood these express statements to show that Flaks' 3D audio engine generates binaural sound. *See also* Section VII.E (discussing background for binaural sound).

759. McCulloch further teaches that the binaural sound is "in empty space" through its examples. For example, McCulloch's virtual basketball replaces a "real" basketball in the physical world, and is therefore in "empty space." McCulloch (Ex.1008) at Fig. 8B, 29:4-17 (actions are applied to "basketball virtual object 30_2" and "real basketball 30 has been erased"). Similarly, persons of ordinary skill in the art would have known and understood that McCulloch's other virtual objects such as the virtual helicopter and its associated binaural sound could and would be in "empty space." McCulloch (Ex.1008) at 25:8-11, 26:12-19.

760. For these reasons, limitation 1[a] would have been obvious over McCulloch, either alone or with Flaks, in view of Pedrotti under 8K's apparent interpretation of this limitation.

761. Additionally, if limitation 1[a] is interpreted to require a zone that "includes" an SLP from where binaural sound in empty space originates to the user

when the area around the user is divided by a PED, limitation 1[a] also would have been obvious over McCulloch, either alone or with Flaks, in view of Pedrotti.

762. As I discussed above, McCulloch discloses that the virtual "playspace" is an area "in which virtual objects can be positioned." McCulloch (Ex.1008) at 20:11-13. Additionally, McCulloch taught that its system uses a 3D audio engine that "plays audio data for [a] virtual object projected from a 3D space position," i.e., an SLP. McCulloch (Ex.1008) at 26:7-9. McCulloch explains that "[a]udio data for virtual objects … can be output to the earphones to sound as if coming from the direction of [a] virtual object projected into the display field of view." McCulloch (Ex.1008) at 21:25-29. Thus, McCulloch teaches that its virtual environment, or virtual playspace, includes multiple virtual objects—including when that space is divided into a zone according to Pedrotti's method, which persons of ordinary skill in the art would have been motivated to use with McCulloch's virtual environment. *See* Section X.B.1 (motivations to combine McCulloch and Pedrotti). These virtual objects in the McCulloch environment and also in the Pedrotti zone are "positioned" at "3D space positions" for "3D audio," or at multiple locations where sound localizes—i.e., multiple SLPs. And, in accordance with the teachings in Flaks providing details of the audio generated by the 3D audio engine, persons of ordinary skill in the art would have understood that the sound produced from those virtual objects, or at the respective SLPs, is binaural sound in empty space.

763. For these reasons limitation 1[a] would have been obvious over McCulloch, either alone or with Flaks, in view of Pedrotti if limitation 1[a] requires a zone that "includes" an SLP from where binaural sound in empty space originates to the user when the area around the user is divided by a PED.

c. 1[b]: "playing, with speakers in a wearable electronic device (WED) worn on a head of the user, the binaural sound that originates from the SLP in empty space;"

764. For the reasons I discussed above for limitations 1[a], limitation 1[b] would have been obvious to persons of ordinary skill in the art over McCulloch, either alone or with Flaks, in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section XI.A.1.c (Ground 1, limitation 1[b]). *See* Section XI.B.1.b.

765. As discussed for limitation 1[a], McCulloch, either alone or with Flaks, teaches SLPs from where binaural sound in empty space originates to the user. McCulloch's HMD plays binaural sound through speakers in its HMD (WED). *See* Section XI.B.1.b. And, as I discussed for limitation 1[a], McCulloch's HMD, is a WED worn on the head of the user. *See, e.g.*, McCulloch (Ex.1008) at 8:17-30 ("Inside, or mounted to temple 102, are an earphone of a set of earphones 130, an inertial sensing unit 132 including one or more inertial sensors, a location sensing unit 144 including one or more location or proximity sensors, some examples of which are a GPS transceiver, an infrared (IR) transceiver, or a radio frequency

transceiver for processing RFID data. Optional electrical impulse sensing unit 128 detects commands via eye movements. In one embodiment, inertial sensing unit 132 includes as sensors a three axis magnetometer, a three axis gyro, and a three axis accelerometer. The inertial sensors are for sensing position, orientation, and sudden accelerations of head mounted display device 2. From these movements, head position, and thus orientation of the display device, may also be determined."), Fig. 2A.

766. McCulloch's HMD plays a binaural sound emanating from the SLP using Flaks' 3D audio engine, "which receives input audio data and outputs audio data for the earphones 130 or other output audio devices like speakers." McCulloch (Ex.1008) at 21:21-38. Additionally, McCulloch's HMD plays sound through its earphones, which include speakers for each ear. McCulloch (Ex.1008) at 8:17-22 ("[i]nside, or mounted to temple 102, are an earphone of a set of earphones 130"), 21:21-38 ("The 3D audio engine 304 is a positional 3D audio engine which receives input audio data and outputs audio data for the earphones 130"), Fig. 2A (item 130).

d. 1[c]: "tracking, with one or more sensors in the WED worn on the head of the user, the PED to determine when the PED held in the hand of the user is moving outside the zone that extends around the user; and"

767. Limitation 1[c] would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti.

768. McCulloch discloses, or at a minimum renders obvious to a person of ordinary skill in the art, tracking the handheld controller device (PED) with the HMD (WED worn on the head of the user) for the reasons I discussed above for limitation 1[a]. *See* Section XI.B.1.b.

769. Further, McCulloch discloses that its HMD contains capture devices, including cameras and infrared transceivers (sensors) that detect and track infrared light that may be emitted by a controller (i.e., one or more sensors in the WED). McCulloch (Ex.1008) at 7:34-67 (describing capture devices), 8:7-39 (describing multiple types of "sensors" in the HMD, including transceivers), 5:19-36 (describing "companion processing module 4," which "may be integrated in" "display device 2," that communicates with the "controller devices 21" through infrared light). And McCulloch's processor stores the information needed compare the PED's or HMD's location with the zone's boundaries in view of McCulloch's shared coordinate system. McCulloch (Ex.1008) at 15:48-54, 16:18-21. Further, methods of using sensors on HMDs to track controllers such as controllers that emit infrared light that is captured by the HMD, were well known and widely used—either alone or in combination—because they were very accurate for tracking. *See* Section VII.D; Jerald, THE VR BOOK (Ex.1063) at 315 ("Hand-held tracked devices typically use inertial, electromagnetic, ultrasonic, or optical (camera) technologies."). Persons of ordinary skill in the art would have known that optical tracking systems, such as

those described in McCulloch, offer advantages, such as "accurate measurements of both position and orientation over relatively large working volumes, without many of the problems inherent in magnetic or acoustic tracking systems." Welch 1995 (Ex.1119) at 1 (also discussing disadvantages of mechanical tracking systems and acoustic tracking systems).

770. Additionally, using Pedrotti's method of determining when the PED moves outside the zone through McCulloch's system with its HMD-tracked controllers would render obvious limitation 1[c]'s "determin[ing] when the PED held in the hand of the user is moving outside the zone that extends around the user" in view of Pedrotti's disclosures discussed for this limitation in Ground 1. *See* Section XI.A.1.d. Pedrotti discloses tracking the PED's location in relation to the boundary; therefore, Pedrotti's method can determine when the PED is moving outside the zone that extends around the user. Pedrotti (Ex.1005) at 2:44-59 (describing "determin[ing] from the position of the handheld controller that the handheld controller is within a first preselected distance from the boundary"), 12:31-50 ("tracking the position and orientation of the user's hand if the user is holding a controller with a tracker," and explaining that "the processor knows where the user's head and hands are located" and "when the user's head and/or hand approaches the boundary"), 13:44-14:5 (describing warning "when the user's head or hands are approaching the boundary as determined by the trackers on the user's head or hands"

and "if the user's head or hands go beyond the boundary as determined by the trackers"); *see also* Section XI.A.1.d.

771. Persons of ordinary skill in the art would have known that McCulloch's system would have been able to implement Pedrotti's method, especially in view of McCulloch's teaching regarding a scene mapping engine, which "identifies the position and tracks the movement of real and virtual objects," which can include the PED held in the hand of the user. *See* McCulloch (Ex.1008) at 15:30-16:62, 8:1-11 (describing "memory 244" in HMD 2 that stores information regarding maps). Accordingly, it would have been straightforward to compare the positional and inertial information from the real controller device (McCulloch's tracked controller, or PED) against the boundaries of the Pedrotti-type zone in order to determine whether the PED is moving outside the zone.

772. And, persons of ordinary skill in the art would have readily understood how to carry out the very basic steps of testing whether the position (x, y, z coordinates) of McCulloch's tracked handheld controller device (PED) is moving outside a zone, for example a zone defined by a set of connected vertices or a parametric equation for a geometric primitive (similar to Pedrotti's zone).

773. Further, McCulloch discloses "collision processing" to determine when virtual objects come into contact (collide) with real or virtual objects, which persons of ordinary skill in the art would have understood could be used to determine when

a tracked handheld controller device (PED) moves outside a zone. McCulloch (Ex.1008) at 23:62-63 (disclosing the existence of collision processing: "The virtual images include any modifications to virtual image data based on collision processing."), 27:39-54 (disclosing examples of collision processing: "In step 508, a collision is identified between the virtual object under control of the real controller and the user selected force feedback object. Either the scene mapping engine 306 or an application 166 may identify the collision based on object 3D space position data for the virtual object and the user selected force feedback object from a 3D mapping of the user environment tracking the positions of the objects. The collision may occur inside or outside the display field of view but one or more forces associated with the collision may be modeled by the physics engine 308 based on the properties of the virtual object and the force feedback object and collision parameters like the speed and acceleration of each object. Based on the collision modeling performed by the physics engine 308 and the collision being in the display field of view, the virtual data engine 195 displays the collision from the user perspective.") Persons of ordinary skill in the art would have understood that such collision processing includes the very basic processing to determine whether a collision between two objects have occurred, e.g., whether the vertices of one object penetrate the surface of another object, and that this processing could also be used to determine when a tracked handheld controller device (PED) moves outside a zone.

e. 1[d]: "displaying, with the WED worn on the head of the user a virtual reality (VR) image that shows the zone in response to the WED determining that the PED is moving outside the zone."

774. Limitation 1[d] would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section XI.A.1.e (Ground 1, limitation 1[d]).

775. Further, McCulloch's system is capable of displaying virtual reality (VR) images, and persons of ordinary skill in the art would have known and understood that the HMD could and would display a Pedrotti-type zone as a VR image. McCulloch (Ex.1008) at 16:58-63 (describing multiple of McCulloch's engines working together to position, track, and generate virtual objects); *see also* McCulloch (Ex.1008) at 8:40-49 ("Mounted to or inside temple 102 is an image source of image generation unit 120 which produces visible light representing images."), 9:17-35 ("FIG. 3B is a top view of an embodiment of one side of an optical see-through, near-eye, augmented reality display device including a display optical system 14," which "is an integrated eye tracking and display system."), Figs. 2B, 4A.

776. Persons of ordinary skill in the art would have known and understood that the HMD could and would display a Pedrotti-type zone as a VR image as well, such as incorporating Pedrotti's visual warnings, which are rendered as a warning

fence or grid, into the McCulloch HMD's image and audio processing engine and virtual data engine. This is because McCulloch's HMD is already capable of rendering virtual surfaces such as walls using a 3D mesh similar to Pedrotti's grid-shaped virtual fence. *See* McCulloch (Ex.1008) at 17:14-31 (describing "3D mapping of an environment" including by using a "mesh" for "things like walls and floors"); *see also* McCulloch (Ex.1008) at 17:47-48 ("[a] polygon mesh may also be used to represent the object's boundary"), 23:25-56 (describing McCulloch's virtual data engine that "processes virtual objects and register the 3D position and orientation of virtual objects or imagery in relation to one or more coordinate systems" and that provides "a target 3D space position of where to insert the virtual object"). Indeed, McCulloch discloses examples of the user wearing McCulloch's HMD while engaged in a virtual environment or game where VR images are rendered (e.g., virtual helicopter, virtual basketball). *See, e.g.*, McCulloch (Ex.1008) at Figs. 8A-8D; Mount 350 (Ex.1027) at [0042], [0049].

777. It would have been obvious to persons of ordinary skill in the art to use McCulloch's HMD to display VR images. As discussed, AR and VR share similarities, with AR technologies almost always the more complex of the two since AR can be thought of as supplementing reality with virtual objects. *See, e.g.*, Azuma (Ex.1112) at 355-56 ("Augmented reality (AR) is a variation of virtual environments (VE), or virtual reality as it is more commonly called. VE technologies completely

immerse a user inside a synthetic environment. While immersed, the user cannot see the real world around him. In contrast, AR allows the user to see the real world, with virtual objects super-imposed upon or composited with the real world. Therefore, AR supplements reality, rather than completely replacing it.") (emphasis in original omitted); Jerald, THE VR BOOK (Ex.1063) at 32-33 (functionalities and qualities associated with an HMD, such as "accurate tracking, low latency, and careful calibration" apply equally to all HMDs), 484 ("[a]ugmented reality and virtual reality" have "many similarities and the two will likely converge," including because "the same hardware might be used for both"; "the convergence of AR and VR is not new from a research perspective"); U.S. Patent No. 8,884,984 ("Flaks 984") (Ex.1013) at Background ("One of the harder problems to solve with augmented reality is the ability to overlay virtual objects on top of real objects.") (incorporated by reference as U.S. Patent Application No. 12/905,952 in McCulloch (Ex.1008) at 10:66-11:2); Billinghurst 2015 (Ex.1049) at 80-81 ("[a]s more or less virtual content is added to the AR scene the interface moves closer or further away from the VE [virtual environment] or RE [real environment]").

778. Thus, persons of ordinary skill in the art would have known AR systems and methods (such as McCulloch's) are frequently, and at a minimum obviously, applicable in a VR context and are used to display VR images. *See* Zhou (Ex.1107) at 1006-09 (describing an exemplary game where two users occupying the same

physical 3-meter by 3-meter region explore a virtual land augmented on the physical ground, which then transitions into a completely virtual scene when the players have located a virtual princess), Figs. 9-11; Billinghurst, *The MagicBook – Moving Seamlessly Between Reality and Virtuality* (2001) ("Billinghurst 2001") (Ex.1123) at 6 (users turning the physical pages of MagicBook "can fly into the page and experience the story as an immersive virtual environment"), 7 ("[w]he users see an augmented reality scene they wish to explore, flicking the switch on the handle will transition them into the immersive environment" where "[t]he real world is no longer visible"), Figs. 2A-2C (showing how to "us[e] the MagicBook interface to move between reality and virtual reality); Billinghurst 2015 (Ex.1049) at 227 (describing another system where users "[w]earing see-through HMDs" and "using a 3D wand [] can also pull the content off the screen and see it as a 3D AR object floating in space in front of them").

779. Indeed, this is also the case for McCulloch. As discussed above, a video see-through AR system, which McCulloch discloses, could and would easily be used for VR to display VR images. The only difference is the content, as AR would encompass video with computer-generated virtual objects and portions of the real environment, whereas VR would primarily encompass only the former. McCulloch (Ex.1008) at 26:31-34 ("If the near-eye AR display device system includes a video-see display or is operating in a video-see mode, a virtual object representation of the

real object may already exist."). Notably, the real objects in McCulloch's video-see mode are rendered as image data in the video displayed to the user. *See* McCulloch (Ex.1008) at 3:61-67 (providing background on video-see display); Jerald, THE VR BOOK (Ex.1063) at 32-33 (similar). McCulloch specifically describes examples of this, such as replacing a physical basketball with a virtual one, or replacing characteristics of the real environment with those of a virtual game environment through sound modeling. McCulloch (Ex.1008) at 29:4-16 ("FIG. 8B illustrates an example of a virtual object representation of the user selected real object being controlled with the real controller device … The real basketball 30 has been erased in this example."); *see also* Flaks (Ex.1009) at 8:35-40 ("However, instead of using actual materials of the real objects, virtual characteristics may be used. For example, instead of an actual thick carpet, a cement floor could be modeled."). Thus, persons of ordinary skill in the art would have known that McCulloch's display displays VR images. Persons of ordinary skill in the art would have understood that any display intended to be used for AR can be used for VR by filling the field of view (FOV) with VR imagery or VR objects, as was done with the MagicBook I describe above.

2. Dependent Claims 2-8

a. Claim 2

(1) 2[a]: "The method of claim 1 further comprising: highlighting, while the user is located inside the zone and with a display of the

WED, a VR image at the SLP in the zone when the PED held in the hand of the user is pointed at the SLP in the zone; and"

780. Limitation 2[a] would have been obvious to persons of ordinary skill in the art over McCulloch, either alone or with Flaks, in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section XI.A.2.a(1) (Ground 1, limitation 2[a]).

781. Limitation 2[a]'s recitation of "while the user is located in the zone and with a display of the WED" would have been obvious because a user using McCulloch's system and Pedrotti's method would have used McCulloch's HMD (WED) while in the Pedrotti-type zone, which defines the user's area for gameplay or "safe area" zone. And as Pedrotti discloses, the tracked location of the user could and would be used to determine "when the user comes within a preselected distance of the boundary," which indicates when the user is within the zone. Pedrotti (Ex.1005) at 4:37-44. Pedrotti also discloses that the tracked location of the user can be used to take action if the user enters or exits a zone. Pedrotti (Ex.1005) at 13:63-67 ("If the user's head or hands go beyond the boundary as determined by the trackers, the processor can provide additional messaging or warning, such as text or auditory warnings, or an additional visual warning, that persists until the user returns to the selected area within the boundary.").

782. As discussed for limitation 1[d], McCulloch's HMD has a display that displays virtual images to the user in McCulloch's playspace including virtual objects, which could and would be inside Pedrotti's zone defining the area for gameplay. *See* Section XI.A.1.e (limitation 1[d]).

783. As discussed in the context of limitation 1[a], McCulloch discloses, or at a minimum renders obvious limitation 2[a]'s recitation of "the PED held in the hand of the user is pointed at the one of the multiple SLPs in the zone." *See* Section XI.B.1.b (limitation 1[a]). Moreover, McCulloch discloses, or at a minimum renders obvious, tracking the movement of the handheld, real controller device with its HMD such that the HMD is able to determine where the controller device is pointed. McCulloch (Ex.1008) at 24:28-35, 29:4-63, Figs. 8B, 8D; *see* Section XI.B.1.b (limitation 1[a]). Persons of ordinary skill in the art would have found this obvious as well, as this setup—where the controller is used to point at a virtual object—was common especially for gaming. *See* Yen (Ex.1041) at 19:67-11:5 (user waves motion controller to cause avatar to wave virtual object); Mullen (Ex.1029) at 11:18-26 (handheld controller acts as a pointer using a "virtual laser [that] emanates out of [the] controller."), 9:16-24 (user points motion controller to aim virtual gun at virtual objects), 14:26-15:6 (user presses button on motion controller to grab virtual objects and moves motion controller to move them); Pedrotti (Ex.1005) at 9:26-40 (user grabs virtual weapon by reaching for it with motion controller and "pressing a button

on the controller," and then moves the virtual weapon by moving the controller); Mine Exploiting Proprioception 1997 (Ex.1116) at 70-71 (describing "[o]bject selection/manipulation where "[u]sers select and manipulate objects with their dominant hand" and "[t]he default form of manipulation is unconstrained 6DoF manipulation"); *see also* Section VII.C (describing tracking of handheld PEDs for use in gaming). In addition, Pedrotti also teaches such tracking, and the processor responsible for tracking movement of Pedrotti's controller may be "in the HMD." Pedrotti (Ex.1005) at 16:22-24; Section XI.A.2.a(1) (Ground 1, limitation 2[a]).

784. Additionally, limitation 2[a]'s "pointed" PED would have been obvious over McCulloch because McCulloch discloses multiple examples in which movement of a handheld controller selects and moves a virtual object, such as by pointing at it. McCulloch (Ex.1008) at 12:49-13:51 ("FIGS. 3A and 3B illustrate a contextual example of a virtual object being controlled with a real controller device from a user perspective."), 25:6-26:34 (describing the process by which a user is able to control a virtual object using the real controller device), 25:25-27 (describing other inputs for controlling objects), 29:4-17 ("FIG. 8B illustrates an example of a virtual object representation of the user selected real object being controlled with the real controller device. The changes in position and orientation of the handheld controller causes its inertial motion unit to generate one or more signals which are converted by the handheld IMU real controller device 19"). And, with respect to

Figures 8B-8D, McCulloch depicts the user pointing the handheld IMU real controller device at the virtual basketball, which is a virtual object associated with an SLP.

785. Indeed, the title of McCulloch is "Controlling a Virtual Object with a Real Controller Device," and it disclosed multiple examples of controllers for controlling virtual objects, including "a joystick," "a pointing device," and the "handheld inertial motion unit (IMU)" discussed above, which obviously could be pointed. McCulloch (Ex.1008) at Title, 4:25-33, cl. 12, 6:55-66 (example "real controller device[s]" for providing "user input data" "for controlling an object"), 25:25-28 ("moving a displayed selection arrow with [a] real controller device may be used to identify a user selected object for control").

786. As discussed in the context of Ground 1, pointing is an obvious convention used to select and is rendered obvious by Pedrotti as well. *See* Sections Section VII.C (describing actions carried out by handheld controllers), XI.A.2.a(1) (Ground 1, limitation 2[a]); *see, e.g.*, Jerald, THE VR BOOK (Ex.1063) at 327 ("Pointing Pattern" is "fundamental" "for selection"). For example, Pedrotti discloses using Pedrotti's controller to define a boundary of "an area in the physical world to be defined within which the user should remain, for example to avoid physical obstacles." Pedrotti (Ex.1005) at Abstract, 2:27-33 ("One embodiment discloses a method of assisting a user wearing a head-mounted display (HMD) in

remaining within a selected area of the physical world, the user holding a handheld controller having a controller tracker which provides information regarding a position of the handheld controller, the method comprising: receiving, by a processor as an input, a definition of a boundary of the selected area;"), 2:44-51, 2:60-3:2. Persons of ordinary skill in the art would have understood that holding a handheld controller and using it to define a boundary of "an area in the physical world" would (or would obviously) include pointing the controller to trace out the intended boundary.

787. McCulloch also renders obvious limitation 2[a]'s recitation of "highlighting … a VR image at the SLP in the zone" when the PED is pointed at the SLP in the zone. McCulloch's HMD uses a "visual effects library [with] routines for animations, ***highlighting***, and other types of visual enhancements which may also be ***associated with particular actions***," such as pointing. McCulloch (Ex.1008) at 23:4-7 (emphasis added); *see also* McCulloch (Ex.1008) at 8:40-46 (describing the image generation unit of McCulloch's computing environment), 9:4-52 (describing the display optical system of the HMD), 11:42-46 (explaining that "commands from the real controller device are interpreted, applied and display[ed]").

788. As discussed in the context of Ground 1, highlighting is an obvious convention used to indicate selection or that a virtual object is being pointed at, and is rendered obvious by Pedrotti as well. *See* Sections VII.C (describing actions

carried out by handheld controllers), XI.A.2.a(1) (Ground 1, limitation 2[a]); *see, e.g.*, Jerald, THE VR BOOK (Ex.1063) at 281 ("objects can make a sound" or "become highlighted" "when … they have been selected"), 305 ("Highlighting" conveys "that an object is able to be selected or grabbed").

789. More generally, if the purpose of pointing to an object is to perform some action with or on it, persons of ordinary skill in the art would have understood the need to have some form of dynamic visual confirmation that a user is sufficiently pointing at (intersecting) the object at any given moment, e.g., the "highlighting" effect from McCulloch's visual effects library (McCulloch (Ex.1008) at 23:4-7), lest the user be forced to repeatedly point and click around the object until they can successfully carry out the action.

790. Thus, in view of McCulloch, persons of ordinary skill in the art would have understood that a user could and would take McCulloch's handheld controller device (PED) to point at a sound-producing virtual object, which is associated with an SLP, such as a "virtual basketball" or a "virtual remote helicopter," as described in McCulloch's examples, to select and move the virtual object and its associated SLP. A sound-producing virtual object, and its image, is associated with the SLP; likewise, a sound source in virtual space (e.g., the SLP) is just one kind of virtual object that a user could and would select and arrange in a virtual environment, and it would be obvious to display a VR image at the SLP to provide a visual indication

of the existence of the virtual object to the user. *See* Section XI.A.2.a(1) (Ground 1, limitation 2[a]).

791. For example, the user could select a virtual basketball and move the basketball to collide with a television display, which emits a crashing sound on collision. McCulloch (Ex.1008) at 29:36-63, Fig. 8D. Furthermore, in the process of pointing the controller device (PED) at the VR image of the virtual object, and its associated SLP, persons of ordinary skill in the art would have understood that McCulloch's display consequently would highlight the VR image of the sound-producing virtual object (here, highlighting the VR image of the virtual basketball) to indicate and facilitate user selection.

792. McCulloch's HMD displays "highlighting," or alteration of the visual image "when the PED … is pointed at" the SLP, or virtual object, because McCulloch's HMD is able to track the position and orientation of the handheld controller through a variety of means (e.g., inertial motion unit, image and depth data), and also identify gestures such as pointing by the user. McCulloch (Ex.1008) at 7:34-59 (describing McCulloch's capture devices providing depth and image data), 8:17-30 (describing sensing units on McCulloch's HMD), 12:18-21 ("capture devices [] capture and provide image and depth data from which real objects [such as the user's hands or controllers] are identified as well as their positions and often orientations relative to the display portion of the device"), 22:4-8 (describing gesture

recognition engine that "can identify actions performed by a user indicating a control of command" such actions "performed by a body part of a user, e.g., a hand or finger"), 28:5-11 ("capture devices [] can capture data of the user's hand and finger pointing to different objects" "and the image and depth data is processed by the gesture recognition engine [] for identifying a pointing selection gesture"); *see* Section XI.B.1.b (limitation 1[a]). As noted above, it would have been obvious that these actions take place while the user is in the Pedrotti-type zone.

(2) 2[b]: "playing, with the WED worn on the head of the user, the binaural sound that emanates from the SLP in response to the PED pointing at the SLP."

793. For the reasons discussed above for limitations 1[a] and 1[b], limitation 2[b] would have been obvious to persons of ordinary skill in the art over McCulloch (alone or with Flaks) in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section XI.A.2.a(2) (Ground 1, limitation 2[b]). *See* Sections XI.B.1.b (limitation 1[a]), XI.B.1.c (limitation 1[b]).

794. As explained above, McCulloch's HMD is able to determine when the user is pointing the real controller device at an SLP. *See* Section XI.B.2.a(1) (limitation 2[a]). Persons of ordinary skill in the art would have found it obvious to trigger an action based on pointing the PED at a VR image at an SLP (e.g., playing a binaural sound with McCulloch's HMD that includes "a set of earphones").

McCulloch (Ex.1008) at 8:17-22, 11:42-46, 21:21-38 ("The 3D audio engine 304 is a positional 3D audio engine which receives input audio data and outputs audio data for the earphones 130"). This type of control and manipulation in game play where an action of a PED, i.e., selecting, causes something else to occur in the game, i.e., making a noise or emitting a crashing sound due to a collision between moved virtual objects, was well known well before February 2016. *See* Section XI.B.2.a(1) (limitation 2[a]); *see also* Jerald, THE VR BOOK (Ex.1063) at 281 ("objects can make a sound" or "become highlighted" "when … they have been selected"), 356 ("use audio and highlighting to signify touching of objects"). Finally, as described above for limitation 1[a], McCulloch's HMD plays a binaural sound emanating from the SLP using Flaks' 3D audio engine. *See* Section XI.B.1.b (limitation 1[a]).

b. Claim 3: "The method of claim 1 further comprising: displaying, with the WED worn on the head of the user, the VR image that shows a size and a shape of the zone in response to the WED determining that the PED is moving outside the zone."

795. For the same reasons as I described for limitations 1[c] and 1[d], claim 3 would have been obvious over the Pedrotti disclosures discussed in Section XI.A.2.b (Ground 1, claim 3). *See* Sections XI.B.1.d (limitation 1[c]), XI.B.1.e (limitation 1[d]).

796. Claim 3 additionally recites that the VR image shows "a size and shape of the zone," in comparison to limitation 1[d]. Persons of ordinary skill in the art

would have understood that displaying a VR image of the Pedrotti-type zone, indicates the size and shape of the zone since the Pedrotti fence follows the shape of boundary defined by the user and is sized accordingly to the boundary defined by the user. *See* Section XI.A.2.b (Ground 1, claim 3).

c. Claim 4

(1) 4[a]: "The method of claim 1 further comprising: storing, in memory of the WED, a location of the zone, a size and a shape of the zone, and a location of the SLP in the zone from where the binaural sound originates to the user; and"

797. Limitation 4[a] would have been obvious over Pedrotti, including based on the Pedrotti disclosures discussed in Section XI.A.2.c(1) (Ground 1, limitation 4[a]).

798. As a preliminary matter, persons of ordinary skill in the art would have known and understood that data representing "a location of the zone, a size and a shape of the zone, and locations of the multiple SLPs in the zone from where the binaural sound originates to the user" is no different than any other data used by the system in that it is stored in memory to be used, acted upon, rendered, and displayed in the user's HMD when appropriate.

799. Limitation 4[a] also would have been obvious over McCulloch in view of Pedrotti. Persons of ordinary skill in the art would have known and understood

that a McCulloch system implementing Pedrotti's method would have to (or at a minimum would obviously) store the zone's location, size, and shape because that information is necessary for Pedrotti's method of determining when a user approaches a zone boundary or leaves the zone.

800. And persons of ordinary skill in the art also would have understood that such information could advantageously be stored in memory in an HMD, consistent with McCulloch's teachings (*see* McCulloch (Ex.1008) at 8:1-11 ("memory 244"), 19:8-21, 19:51-62, Fig. 2A (depicting same), 20:22-27 (McCulloch's system utilizes "adaptive virtual environment rules … based on the real objects and real features mapped in the user environment" including "size dimensions"), to allow the HMD's processor to access that information without the need to connect it to an external or remote memory.

801. Additionally, McCulloch teaches storing the location and size and shape of a zone because McCulloch teaches generating and storing 3D maps of environments, and it would have been obvious to store the Pedrotti-type zone in relation to McCulloch's mapped environments. *See* McCulloch (Ex.1008) at 15:48-54 ("The scene mapping engine 306 can also use a view independent coordinate system for 3D mapping. ***The map can be stored in the view independent coordinate system in a storage location (e.g. 324)*** accessible as well by other display device systems 8, other computer systems 12 or both, ***be retrieved from memory and be***

updated over time as one or more users enter or ***re-enter the environment***.") (emphasis added), 15:63-67 ("When a user enters an environment, the scene mapping engine 306 may first search for a pre-generated 3D map identifying 3D space positions and identification data of objects stored locally or accessible from another display device system 8 or a network accessible computer system 12."). For example, if a user enters a new environment (e.g., moves into a different room or a different part of the room), persons of ordinary skill in the art would have understood to retrieve the stored 3D map and the associated boundary in order to apply the appropriate or updated boundary for that user's location. As McCulloch indicates, location information can be based not only on a relative coordinate system, but also an absolute location, such as based on GPS information retrieved from the HMD's sensors. McCulloch (Ex.1008) at 8:17-22.

802. Furthermore, storing the location of an SLP in the zone would have been equally straightforward and obvious because McCulloch taught that its system stores the location of virtual objects and generates binaural sound for those objects, from their locations (SLPs). McCulloch (Ex.1008) at 15:48-54 (storing maps in memory), 19:8-27 (storage of virtual object properties), 19:51-62 (using stored properties to "update a 3D space position or position volume for an object"), 21:21-39 (McCulloch's 3D audio engine outputs "[a]udio data for virtual objects" "as if coming from the direction of [a] virtual object projected into the display field of

view"). Thus, from these disclosures, persons of ordinary skill in the art would have known that a virtual object location, including one from which binaural sound originates (i.e., location of an SLP) are, or obviously could and would be, stored in McCulloch's HMD memory.

(2) 4[b]: "retrieving, from the memory of the WED, the size and the shape of the zone in response to the WED determining that the user is in the location of the zone."

803. For the same reasons as I described for limitation 4[a], limitation 4[b] would have been obvious over McCulloch in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section XI.A.2.c(2) (Ground 1, limitation 4[b]). *See* Section XI.B.2.c(1) (limitation 4[a]).

804. As discussed for limitation 4[a], McCulloch discloses generating and storing 3D environment maps, so it would have been obvious to store the size and shape of a Pedrotti-type zone applicable to such an environment. *See* Section XI.B.2.c(1) (limitation 4[a]). Consequently, this information would have been retrieved when a user "enter[s] or re-enter[s] the environment" (i.e., in response to determining that the user is located in the zone), to give the user a sense of the zone's boundaries. McCulloch (Ex.1008) at 15:48-54, 15:63-67.

805. And, as explained, McCulloch's system implementing Pedrotti's method is able to determine when the user is located in the zone. *See* Sections

XI.B.1.b (limitation 1[a]), XI.B.1.d (limitation 1[c]) (describing McCulloch's HMD determining the location of the user through either the location of the HMD or handheld controller devices); Pedrotti (Ex.1005) at 12:31-41 ("processor knows where the user's head and hands are located" and "determine[s] when the user's head and/or hands approaches the boundary").

d. Claim 5

(1) 5[a]: "The method of claim 1 further comprising: designating, with the PED held in the hand of the user, locations of multiple SLPs in empty space in the zone from where the binaural sound originates to the user; and"

806. Limitation 5[a] would have been obvious to persons of ordinary skill in the art over McCulloch, either alone or with Flaks, in view of Pedrotti.

807. I understand that 8K contends with respect to similar claim language that two images of a game character "taken from a video depicting the user experience with the 'Bogo' application" show the character in different locations, and this satisfies the claim language requiring "designating, with the HPED held in the hand of a user, a sound localization point (SLP) in empty space in the zone above the physical floor from where the binaural sound originates to the user":



’737 8K Infringement Contentions (Ex.1121) at 4.

808. Consequently, it appears that, in 8K’s view, limitation 5[a] merely requires a game character that can be “moved by direction of the HPED” because, as a result, an “SLP will likewise move along with the corresponding location of the game character.” *See* ’737 8K Infringement Contentions (Ex.1121) at 4.

809. If 8K’s interpretation applies and limitation 5[a] requires only moving sound-producing virtual objects, such as game characters, this limitation would have been basic, straightforward, and of course obvious to persons of ordinary skill in the art long before February 2016, over numerous AR and VR references, including McCulloch, Pedrotti, and Flaks. *See* Section XI.A.2.d(1) (Ground 1, limitation 5[a]); *see also* Section VII.F.

810. As I discussed, persons of ordinary skill in the art would have understood having SLPs move with their corresponding virtual image is the essence of creating a realistic virtual environment. To summarize, having a virtual object's sound move with it, including in response to user manipulation, was a fundamental, "extremely important" feature of AR and VR, long before February 2016. *See* Brungart (Ex.1050) at 9 ("realistic near-field audio cues are extremely important" "where listeners are able to grab virtual sound sources and move them around the head"). It was also well known that sounds in these settings are associated with sound sources, which provide cues of characters' or objects' locations. Indeed, McCulloch discloses that localized sound emanates from the virtual object, indicating that the virtual object is associated with the SLP in empty space. McCulloch (Ex.1008) at 14:53-64 ("sound to be played … [is] identified to the 3D audio engine 304 with data identifying from which direction or position to make the sound seem to come from").

811. McCulloch discloses multiple examples in which movement of a handheld controller moves a virtual object, or SLP in empty space. McCulloch (Ex.1008) at 12:49-13:51 ("FIGS. 3A and 3B illustrate a contextual example of a virtual object being controlled with a real controller device from a user perspective."), 25:6-26:34 (describing the process by which a user is able to control a virtual object using the real controller device), 25:25-27 (describing other inputs

for controlling objects), 29:4-17 ("FIG. 8B illustrates an example of a virtual object representation of the user selected real object being controlled with the real controller device …."), Figs. 3A-3E, 8B. And, with respect to Figure 8B, McCulloch explains controlling virtual objects with movement of the controller, including changes in its position and orientation: "[t]he changes in position and orientation of the handheld controller causes its inertial motion unit to generate one or more signals which are converted by the handheld IMU real controller device 19 to be user input." McCulloch (Ex.1008) at 29:6-9.

812. As one example, McCulloch discloses that "the movement of the real controller device 19 up by the user has translated into an up action to be applied to the basketball virtual object 30_2, which the user sees from his perspective as he is looking straight at the virtual basketball 30_2":

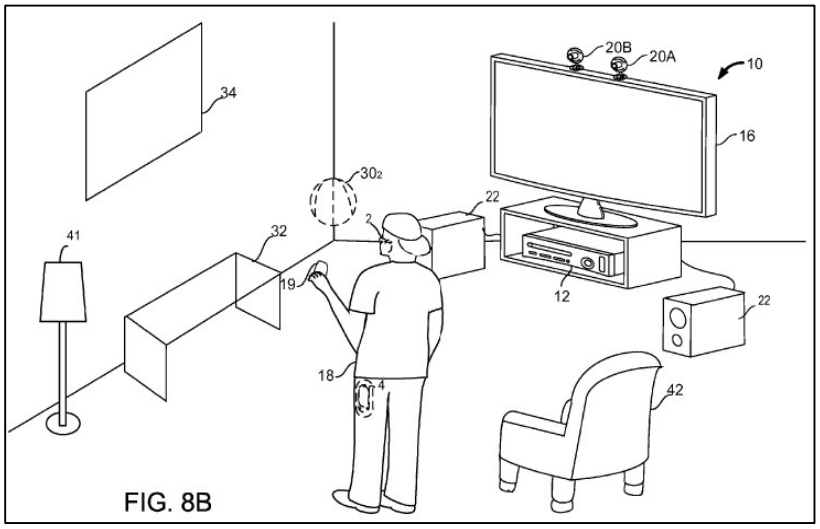


FIG. 8B

McCulloch (Ex.1008) at Fig. 8B, 29:12-16.

813. And persons of ordinary skill in the art would have known and understood that sound associated with a virtual object moves with the object. Thus, with respect to McCulloch's example, sound associated with the virtual basketball moves with the basketball (e.g., the ball bouncing on the floor or whooshing through the air). As McCulloch explains, "the 3D audio engine 304 plays audio data for the virtual object projected from a 3D space position of the virtual object relative to a 3D space position and orientation identified for the display device which is used to approximate the position and orientation of the user's head supporting the display device." McCulloch (Ex.1008) at 26:7-12. In another of McCulloch's example concerning a virtual helicopter, the user's input using the controller "caus[es] the display to show the tail rotors going down and the pulling effect this has on the rest of the helicopter"; and, when the user is not paying attention and the helicopter crashes into a wall behind the user, "the 3D audio engine 304 plays the audio of the virtual crash to project from a position of the wall behind the user." McCulloch (Ex.1008) at 13:24-48, 26:12-19; *see also* Section XI.A.2.a(1) (Ground 1, limitation 2[a] providing additional examples of sound associated with a virtual object moving with the object). Persons of ordinary skill in the art would have known that such sounds could and would be implemented in any of McCulloch's examples. McCulloch (Ex.1008) at 24:58-25:5 ("The technology may be embodied in other specific forms without departing from the spirit or essential characteristics thereof

… the method embodiments are not limited to operating in the system embodiments described" and "may be implemented in other system embodiments.").

814. Persons of ordinary skill in the art would have known this is how McCulloch's system works because McCulloch discloses storing input audio data with respect to virtual objects, and incorporates by reference Flaks' disclosure of a positional 3D audio engine. McCulloch(Ex.1008) at 21:21-38 (incorporating Flaks), 14:21-22 ("sound effects for an application from the 3D audio engine 304 to be output to the user via earphones 130"), 14:53-67 (scene mapping engine 305 combines information regarding position and movement of virtual objects with the image and audio processing engine 191); *see also* Flaks (Ex.1009) at 1:9-11 (explaining "[h]umans estimate the location of a source by taking cues derived from one ear, and by comparing cues received at both ears (difference cues or binaural cues)"), 1:44-46 (disclosing HRTF processing to "localize a sound as coming from a virtual sound source"), 1:62-67 (indicating that Flaks' invention is directed to binaural sound because "[a] realistic 3D audio signal may be generated based on the data collected from sensors," where the data "describes physical characteristics of the listener (e.g., head and pinna shape and size) in order to determine a suitable HRTF for that listener"), 13:55-14:4. And, as I have explained above in Ground 1, it was well known, straightforward, and basic (and, of course, obvious) that virtual characters or objects, including characters and objects that can be controlled and

moved by a handheld controller, are programmed to be associated with their sounds in AR and VR settings, such that sounds emanate from the locations for the virtual characters' and objects' images. *See* Section XI.A.2.a(1) (Ground 1, limitation 2[a]).

815. Persons of ordinary skill in the art would have understood from McCulloch's (and Flaks') disclosures that binaural sound for McCulloch's bouncing (and crashing) basketball will (or at a minimum will obviously) track the basketball's virtual image, e.g., for "realistic 3D audio" improving a user's experience. McCulloch (Ex.1008) at 1:62-64.

(2) 5[b]: "displaying, with the WED, VR images at the locations of the multiple SLPs in empty space in the zone."

816. Limitation 5[b] would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, including based on Pedrotti's disclosures discussed in Section XI.A.2.d(2) (Ground 1, limitation 5[b]).

817. As discussed for limitation 2[a], McCulloch discloses an HMD that displays VR images, and so does Pedrotti. *See* McCulloch (Ex.1008) at Fig. 8B, 8:40-46, Fig. 4A; Pedrotti (Ex.1005) at Abstract ("processor causes the HMD to display a virtual world"); *see* Section XI.B.2.a(1) (limitation 2[a]). For example, as noted, McCulloch's HMD displays a virtual basketball to the user. McCulloch (Ex.1008) at Fig. 8B-8D.

818. Additionally, McCulloch discloses (or at a minimum renders obvious), displaying VR images at the locations of the respective multiple SLPs, or sound sources of the binaural sounds. For example, McCulloch describes a virtual basketball smashing into a virtual television that shatters or a virtual helicopter crashing into a wall where both the VR image (i.e., the basketball or helicopter) and the associated sound (smashing and crashing sounds, respectively) are provided to the user. McCulloch (Ex.1008) at Figs. 3A-3E, 8A-8D.

819. McCulloch discloses a scene mapping engine 306 that "identifies the position and tracks the movement of real and virtual objects in [a] volumetric space," and McCulloch's HMD's image generation unit 120 "display[s] a virtual object" such that it appears "at a designated depth location in a field of view to provide a realistic, in-focus three dimensional display of a virtual object." McCulloch (Ex.1008) at 8:40-46, 16:58-63, 13:52-14:5 (describing associated software components), Fig. 4A. McCulloch also teaches linking visual and audio data, e.g., with collision-related events:

> The sound library … may also store audio data for sound effects to be played by the 3D audio engine 304 and which may be linked with different simulated actions, pre-collision events and collision events. Similarly, a visual effects library may store routines for animations, highlighting, and other types of visual enhancements which may also be associated with particular actions, pre-collision events and collision

> effects … An application can register virtual objects and pre-collision events and the associated visual effects, sound effects, and collision effects …

McCulloch (Ex.1008) at 22:66-23:20.

820. Additionally, Flaks discloses that "[a]s one example, the virtual sound source 29a could be an object being displayed on the display 196." Flaks (Ex.1009) at 4:10-20, 1:17-28 (similar).

821. Persons of ordinary skill in the art would have understood that the VR image that is displayed by McCulloch's HMD is displayed "at the locations of the multiple SLPs in the zone," as required by limitation 5[b]. This would have been obvious over McCulloch, including because it expressly incorporates Flaks or in view of Flaks, since both McCulloch and Flaks disclose associating the audio data from a virtual object with the VR display of the virtual object or sound source, i.e., SLP. *See, e.g.*, McCulloch (Ex.1008) at 21:25-28 ("Audio data for virtual objects generated by an application can be output to the earphones to sound as if coming from the direction of the virtual object projected into the display field of view."); Flaks (Ex.1009) at 4:10-20 ("the sound in the 3D audio signal may appear to be originating from some virtual sound source," which "could be an object being displayed on the display"). For example, if the basketball crashed into the monitor, persons of ordinary skill in the art would have known, including based on

McCulloch's and Flaks' disclosures, that sound for that crash should be perceived to originate from the point of the collision, not from any other object in the room. McCulloch (Ex.1008) at 29:46-55 ("[t]he physics engine 308 models the collision and the virtual data engine 195 displays a collision effect"), 21:35-38 ("Audio data from a sound library 312 may be associated with one or more collisions or actions" "so that the 3D audio engine 304 will play the audio data during display of one or more collisions or actions.").

e. Claim 6

(1) 6[a]: "The method of claim 1 further comprising: selecting one of multiple SLPs in the zone when the PED held in the hand of the user is pointed at the one of the multiple SLPs in the zone; and"

822. For the same reasons as I describe for limitation 1[a], 2[a], and 5[a], limitation 6[a] would have been obvious over McCulloch in view of Pedrotti. *See* Sections XI.B.1.b, XI.B.2.a(1), XI.B.2.d(1).

823. McCulloch discloses that objects can be selected. For example, McCulloch (Ex.1008) at 1:21-23 ("The technology described herein provides for controlling an object displayed by a near-eye, augmented reality display with a real controller device. The object may be selected based on user input, often input captured via a natural user interface (NUI)."), 4:14-15 ("A user may select an object for control by a real controller device."), and 26:20-21 ("A user may select a real

object to be controlled by the real controller device 21."). McCulloch discloses multiple methods of selection that involve pointing. McCulloch (Ex.1008) at 25:18-28 ("For example, a selection gesture like pointing one's finger may be identified by the gesture recognition engine 193 and a notification sent to the operating system identifying the selection gesture and the object to which it is related.").

824. Persons of ordinary skill in the art would have known and understood that it was common to use a handheld controller to select, move, and control virtual objects by pointing at them. *See* Section VII.D (discussing tracking handheld controllers); *see, e.g.*, Jerald, THE VR BOOK (Ex.1063) at 314-15 ("Tracked hand-held controllers are typically 6DoF devices (known as 'wands' in the VR research community where they have been used for decades) and can also contain functionality offered by non-tracked hand-held controllers. Tracked hand-held controllers are currently the best option for a majority of interactive VR applications. ***Tracked hand-held controllers are easy to use for many 3D tasks due to their natural, direct mapping to hand motion***.") (emphasis added), 327 ("[T]he Pointing Pattern is one of the most fundamental and often-used patterns for selection."); Ross (Ex.1125) at 22:17-29 ("[a] user, content creator, and/or other persons may create, customize, and/or adjust using a controller").

825. Thus, because pointing as a method of selecting an object in virtual environments, as well as highlighting to indicate those selections were made, were

well known before February 2016, selecting an SLP when a PED (e.g., McCulloch's controller) is pointed at the SLP would have been obvious over McCulloch (alone or with Flaks) and Pedrotti.

(2) 6[b]: "displaying, with the WED worn on the head of the user, a VR image at the one of the multiple SLPs in response to the one of the multiple SLPs being pointed at by the PED held in the hand of the user."

826. For the same reasons as I described for limitations 1[a], 5[a], 5[b] and 6[a], limitation 6[b] would have been obvious over McCulloch, either alone or with Flaks, in view of Pedrotti. *See* Sections XI.B.1.b (limitation 1[a]), XI.B.2.d(1) (limitation 5[a]), XI.B.2.d(2) (limitation 5[b]), XI.B.2.e(1) (limitation 6[a]), XI.A.6.b (Ground 1, claim 19).

827. Persons of ordinary skill in the art would have known and understood that a McCulloch-Pedrotti or McCulloch-Flaks-Pedrotti system could and would display, using McCulloch's HMD, a VR image associated with an SLP, when a user points McCulloch's controller at the image (and thus the associated SLP). For example, when a user points at and selects at a virtual helicopter (a virtual object associated with an SLP), the helicopter's VR image is displayed and also moves with that virtual helicopter. McCulloch (Ex.1008) at 26:7-19 (describing the virtual helicopter crashing into a wall based on the user's input dictating its path), Figs. 3A-3E. Both the corresponding image and sound would move together and be displayed

at a different location, in response to the user's pointing and under the user's direction. The same is true for McCulloch's virtual basketball. McCulloch (Ex.1008) at 30:36-63 (describing the virtual basketball moving as directed by the user and colliding with the display of the television); Figs. 8B-8D.

f. Claim 7: "The method of claim 1, wherein the zone has one of a three-dimensional (3D) shape of a cylinder and a 3D shape of a rectangle, and the user is centered in the zone."

828. Claim 7 would have been obvious in view of the Pedrotti disclosures discussed in Section XI.A.2.f (Ground 1, claim 7).

829. Pedrotti discloses an example of a circular boundary defining a zone with a 3D shape of a cylinder where the user is centered in the cylinder. *See* Section XI.A.2.f (Ground 1, claim 7). In addition, this is consistent with McCulloch, which does not restrict the zone for game play to any particular shape. *See* McCulloch (Ex.1008) at 20:11-18.

g. Claim 8: "The method of claim 1 further comprising: playing, with the speakers in the WED worn on the head of the user, an audio warning in response to the WED determining that the PED is moving outside the zone."

830. Claim 8 would have been obvious in view of the Pedrotti disclosures discussed in Section XI.A.2.g (Ground 1, claim 8).

831. Specifically, Pedrotti discloses "it may [] be appropriate to generate an audio warning … instead of, the visual warning" to alert the user. Pedrotti (Ex.1005) at 2:44-59, 4:37-44 (explaining that the processor tracks the position and orientation of trackers in the HMD and controllers), 12:31-50 (same). Pedrotti's warning indicates the user should move back into the zone so as not "to move out of the selected area," and can take the form of a verbal instruction as was a common technique for chaperone systems. *See* Section XI.A.2.g (Ground 1, claim 8).

832. In addition, persons of ordinary skill in the art would have known that audio warnings could and would be played through McCulloch's HMD's earphones, which include, or at a minimum obviously include, speakers that play audio. *See* Section XI.B.1.c (limitation 1[b]) (McCulloch's HMD's earphones play binaural sound); McCulloch (Ex.1008) at 8:17-22 (describing earphones); Flaks (Ex.1009) at 1:18-23. Indeed, audio warnings were commonly used in chaperone systems. *See* also Section VII.G (discussing safety and chaperone systems).

3. Independent Claim 9

a. 9[pre]: "A method comprising:"

833. Both McCulloch and Pedrotti disclose the preamble of claim 9. As explained for limitation 1[pre], both McCulloch and Pedrotti disclose methods. *See* Section XI.B.1.a (limitation 1[pre]).

b. 9[a]: "dividing, with a portable electronic device (PED) held in a hand of a user, an area around the user into a three-dimensional (3D) zone that extends around the user and that includes sound localization points (SLPs) from where binaural sound originates to the user;"

834. For the same reasons as I described for limitation 1[a], limitation 9[a] would have been obvious to persons of ordinary skill in the art over McCulloch, either alone or with Flaks, in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section XI.A.3.b (Ground 1, limitation 9[a]). *See* Section XI.B.1.b (limitation 1[a]).

835. As discussed, Pedrotti teaches a 3D zone because Pedrotti's method defines the user's 3D "safe area" playspace. This was a common principle applied to safety and chaperone systems. *See* Section VII.G (providing visual examples of boundaries existing in 3D space, and thereby defining a 3D zone). *See* Section XI.A.3.b (Ground 1, limitation 9[a]).

c. 9[b]: "determining, with a wearable electronic device (WED) worn on a head of the user, when the user is leaving the zone; and"

836. For the same reasons as I described for limitations 1[c] and 1[d], limitation 9[b] would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section XI.A.3.c (Ground 1, limitation 9[b]). *See* Sections XI.B.1.d (limitation 1[c]), XI.B.1.e (limitation 1[d]).

837. As a preliminary matter, persons of ordinary skill in the art would have understood that McCulloch's HMD (the claimed WED) is tracked, and hence the user's movement determined. McCulloch states "[t]he technology described herein provides for controlling an object displayed by a near-eye, augmented reality display with a real controller device." McCulloch (Ex.1008) at 1:18-20. Persons of ordinary skill in the art would understand that discussion of an HMD in the context of augmented reality includes this. Indeed, the view-dependent virtual imagery described throughout McCulloch would not be possible without the HMD being tracked.

838. McCulloch discloses that the HMD (the claimed WED) is tracked. McCulloch (Ex.1008) at 15:30-47 ("Mapping what is around the user in the user's environment can be aided with sensor data. Data from an orientation sensing unit 132, e.g. a three axis accelerometer and a three axis magnetometer, determines position changes of the user's head and correlation of those head position changes with changes in the image and depth data from the front facing capture devices 113 can identify positions of objects relative to one another and at what subset of an environment a user is looking. As mentioned above, depth map data of another HMD device, currently or previously in the environment, along with position and head orientation data for this other HMD device can also be used to map what is in the user environment. Shared real objects in their depth maps can be used for image

alignment and other techniques for image mapping. With the position and orientation data as well, what objects are coming into view can be predicted as well so physical interaction processing, occlusion and other processing can start even before the objects are in view.") McCulloch's HMD includes the "inertial sensors" (e.g., a three axis accelerometer) for "sensing position, orientation, and sudden accelerations of head mounted display device 2." McCulloch (Ex.1008) at 8:17-28; 24:14-21 ("device data may also include data from sensors or sensing units or determined from the sensors or sensing units like the orientation sensors in inertial sensing unit 132"). In other words, the sensors provided on McCulloch's HMD are used for tracking the user's head and thus can be used to track the location of the user, e.g., through position and orientation information; the same is true with respect to McCulloch's system's ability to track the handheld controllers, which are held in the hand of the user and therefore reflects the location of the user as well. *See also* Section XI.B.1.d (limitation 1[c]).

839. It would have been obvious to use McCulloch's system that includes information regarding the location of the user—whether via the HMD worn on the user's head or the controller held in the user's hand—to implement Pedrotti's method of displaying a warning when the user leaves the zone.

840. In addition, persons of ordinary skill in the art would have readily understood how "to determine when the user moves outside the zone" for the same

reasons I discuss for limitation 1[c], including for example their basic knowledge and McCulloch's disclosures of collision processing. *See* Section XI.B.1.d (limitation 1[c]).

d. 9[c]: "warning the user that the user is leaving the zone by displaying, with the WED worn on the head of the user, a 3D virtual reality (VR) image of the zone in response to the WED determining that the user is leaving the zone."

841. For the same reasons as limitation 1[d], limitation 9[c] would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section XI.A.3.d (Ground 1, limitation 9[c]). *See* Section XI.B.1.e.

4. Dependent Claims 10-16

842. I understand that claims 10-14 depend on independent claim 9.

843. Thus, it is my opinion that each of dependent claims 10-14 would have been obvious to persons of ordinary skill in the art for the same reasons as independent claim 9 and additionally for the reasons I discuss in the following subsections.

a. Claim 10

(1) 10[a]: "The method of claim 9 further comprising: determining, with the WED, when the PED is pointed at one of the SLPs while the user is located in the zone; and"

844. For the same reasons as I describe for limitations 1[a], 2[a], and 5[a], limitation 10[a] would have been obvious to persons of ordinary skill in the art over McCulloch, either alone or with Flaks, in view of Pedrotti. *See* Sections XI.B.1.b (limitation 1[a]), XI.B.2.a(1) (limitation 2[a]), XI.B.2.d(1) (limitation 5[a]).

(2) 10[b]: "playing the binaural sound that originates from the one of the SLPs in the zone in response to the WED determining that the PED is pointed at the one of the SLPs."

845. For the same reasons as I described for limitation 2[b], limitation 10[b] would have been obvious to persons of ordinary skill in the art over McCulloch, either alone or with Flaks, in view of Pedrotti. *See* Section XI.B.2.a(2) (limitation 2[b]).

846. Specifically, for the same reasons it would have been obvious to process sound with HRTFs to generate binaural sound originating from a designated SLP and sound-generating virtual objects, which I discussed above in the context of limitations 1[b] and 2[b], it would have been obvious to process sound with HRTFs to generate binaural sound in response to the WED determining that the PED is pointed at an SLP using McCulloch's 3D audio engine (the details of which are provided in Flaks), such as before or when the television is shattered by a basketball, as McCulloch describes. *See* Sections XI.B.1.c (limitation 1[b]), XI.B.2.a(2)

(limitation 2[b]). As noted, playing the binaural sound in response to pointing to a SLP is a common cause-and-effect in a virtual environment.

b. Claim 11: "The method of claim 9 further comprising: highlighting, while the user is located in the zone and with a display of the WED, color of a VR image at one of the SLPs in the zone when the PED held in the hand of the user points at the one of the SLPs in the zone."

847. For the same reasons as I described for limitation 2[a], claim 11 would have been obvious to persons of ordinary skill in the art over McCulloch, either alone or with Flaks, in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section XI.A.4.b (Ground 1, claim 11). *See* Section XI.B.2.a(1) (limitation 2[a]). In addition to "highlighting," McCulloch taught "other types of visual enhancements," which persons of ordinary skill in the art would have recognized would include emphasizing and changing color. *See* Section XI.B.2.a(1) (limitation 2[a]); McCulloch (Ex.1008) at 23:4-7.

848. Further, persons of ordinary skill in the art would have understood that VR images could be displayed in color, and one common manipulation of images is to highlight the color of an image. *See* McCulloch (Ex.1008) at 23:4-7 ("a visual effects library may store routines for animations, highlighting, and other types of visual enhancements"). Indeed, as I described in the State of the Art section, highlighting or changing the color of an object conveys a form of feedback to the user. *See* Jerald, THE VR BOOK (Ex.1063) at 356 (disclosing use of these forms of

feedback "to signify touching of objects"), 305 ("Highlighting is visually outlining or changing the color of an object … Highlighting is also used to convey that an object is able to be selected or grabbed when the hand is close even though a collision has not yet occurred,"), Fig. 26.5; Section VII.C (discussing standard conventions involving handheld controllers). Persons of ordinary skill would have found it obvious for the VR image to be displayed in color, such as through highlighting or by changing the color entirely, as a way of providing feedback to the user that the VR image (and its accompanying SLP) is being pointed at.

c. Claim 12

(1) 12[a]: "A method of claim 9, wherein the 3D VR image of the zone is shaped as a cylinder with the user being centered in the cylinder, and"

849. For the same reasons as I described for claim 7 and limitation 9[b], limitation 12[a] would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti. *See* Sections XI.B.2.f (claim 7), XI.B.3.b (limitation 9[b]).

850. Persons of ordinary skill in the art would have known and found it obvious for a cylindrical zone to be displayed as a 3D VR image that is also cylindrical in shape. *See also* Section XI.A.4.c(1) (Ground 1, limitation 12[a]).

(2) 12[b]: "the WED is a head mounted display that display[s] VR images and"

851. For the same reasons as I described for limitation 1[d], limitation 12[b] is disclosed by McCulloch, as McCulloch's HMD that displays VR images. *See* Section XI.B.1.e (limitation 1[d]); *see also* Sections XI.B.1.b (limitation 1[a]), XI.B.2.a(1) (limitation 2[a]), XI.B.2.d(2) (limitation 5[b]).

(3) 12[c]: "plays the binaural sound while the user plays a game."

852. For the same reasons as I described for limitations 1[a] and 1[b], claim limitation 12[c] would have been obvious to persons of ordinary skill in the art over McCulloch, either alone or with Flaks, in view of Pedrotti. *See* Sections XI.B.1.b (limitation 1[a]), XI.B.1.c (limitation 1[b]).

853. In addition, McCulloch and Pedrotti both disclose applying their systems to game play, including in VR environments. McCulloch (Ex.1008) at 6:29-33 (discussing "game applications" executed on display device system 8), 24:1-4 (describing video-see mode); Pedrotti (Ex.1005) at 1:40-44 (describing a "video game"), 9:24-40.

d. Claim 13

(1) 13[a]: "A method of claim 9, wherein the 3D VR image of the zone is shaped as a rectangle with the user being centered in the rectangle, and"

854. For the same reasons as I described for claim 7 and limitation 9[b], claim limitation 13[a] would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, including based on the Pedrotti disclosures

discussed in Section XI.A.4.d(1) (Ground 1, limitation 13[a]). *See* Sections XI.B.2.f (claim 7), XI.B.3.c (limitation 9[b]).

855. Persons of ordinary skill in the art would have known and found it obvious for a rectangular zone to be displayed as a 3D VR image that is also rectangular in shape.

856. Further, it would have been obvious for a person of ordinary skill in the art to have known that the 3D VR image of the zone could and would be shaped as a rectangle. For instance, Pedrotti does not limit the shape of the zone; rather, it is customizable and could be rectangular. Pedrotti (Ex.1005) at 14:56-15:3 (allowing definition of "an irregularly shaped area" and based on "sampling points as the user moves around the chosen perimeter"). In addition, rectangular shaped zones mirror both common physical and virtual environments (i.e., rooms). *See also* Section XI.A.4.d(1) (Ground 1, limitation 13[a]).

(2) 13[b]: "the WED is a head mounted display that displays VR images and"

857. For the same reasons as I described for limitation 1[d], limitation 13[b] is disclosed by McCulloch, as McCulloch's HMD that displays VR images. *See* Section XI.B.1.e (limitation 1[d]); *see also* Sections XI.B.1.b (limitation 1[a]), XI.B.2.a(1) (limitation 2[a]), XI.B.2.d(2) (limitation 5[b]).

(3) 13[c]: "plays the binaural sound while the user plays a game."

858. For the same reasons as I described for limitations 1[a], 1[b], and 12[c], claim limitation 12[c] would have been obvious to persons of ordinary skill in the art over McCulloch, either alone or with Flaks, in view of Pedrotti. *See* Sections XI.B.1.b (limitation 1[a]), XI.B.1.c (limitation 1[b]), XI.B.4.c(3) (limitation 12[c]).

859. In addition, McCulloch and Pedrotti both disclose applying their systems to game play, including in VR environments. McCulloch (Ex.1008) at 6:29-33 (discussing "game applications" executed on display device system 8), 24:1-4 (describing video-see mode); Pedrotti (Ex.1005) at 1:40-44 (describing a "video game"), 9:24-40.

e. Claim 14: "The method of claim 9 further comprising: playing, with the WED worn on the head of the user an audio warning indicating the user should move back into the zone in response to the WED determining that the user is leaving the zone."

860. For the same reasons as I described for claim 8, claim 14 would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section XI.A.4.e (Ground 1, claim 14). *See* Sections XI.B.2.g. As discussed, Pedrotti's warning, which includes an audio warning, indicates that the user should move back into the zone so that the user does not move out of the selected area. Pedrotti (Ex.1005) at 4:37-44.

f. Claim 15: "The method of claim 9, wherein the 3D VR image of the zone is shaped as a cylinder that extends around the user."

861. For the same reasons as I described for claim 7 and limitation 12[a], claim 15 would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section XI.A.4.f (Ground 1, claim 15). *See* Sections XI.B.2.f (claim 7), XI.B.4.c(1) (limitation 12[a]).

g. Claim 16

(1) 16[a]: "The method of claim 9 further comprising: determining, with the WED worn on the head of the user when the PED is leaving the zone; and"

862. For the same reasons as I described for limitations 1[c] and 1[d] and as I described for Ground 1 of this claim, limitation 16[a] would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section XI.A.4.g(1) (Ground 1, limitation 16[a]). *See* Sections XI.B.1.d (limitation 1[c]), XI.B.1.e (limitation 1[d]).

(2) 16[b]: "warning the user that the PED is leaving the zone by displaying, with the WED worn on the head of the user, the 3D VR image of the zone in response to the WED determining that the PED is leaving the zone."

863. For the same reasons as I described for limitation 1[d], 9[c], and 16[a] and as I described for Ground 1 of this claim, limitation 16[b] would have been

obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section XI.A.4.g(2) (Ground 1, limitation 16[b]). *See* Sections XI.B.1.e (limitation 1[d]), XI.B.3.d (limitation 9[c]), XI.B.4.g(1) (limitation 16[a]).

5. Independent Claim 17

a. 17[pre]: "An electronic system comprising:"

864. Both McCulloch and Pedrotti disclose the preamble of claim 17. McCulloch discloses a "display device system," which is an electronic system. McCulloch (Ex.1008) at 4:43-49, Fig. 1; *see also* Section XI.A.5.a (Ground 1, 17[pre] for Pedrotti).

b. 17[a]: "a portable electronic device (PED) held in a hand of a user that divides an area around the user into a three-dimensional (3D) zone that extends around the user and includes sound localization points (SLPs) in empty space from where binaural sound originates to the user while the user is located inside the zone; and"

865. For the same reasons as I described for limitations 1[a] and 9[a], limitation 17[a] would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section XI.A.5.b (Ground 1, limitation 17[a]). *See* Sections XI.B.1.b (limitation 1[a]), XI.B.3.b (limitation 9[a]).

c. 17[b]: "a wearable electronic device (WED) that is worn on a head of the user,"

866. For the same reasons as I described for limitation 1[b], limitation 17[b] would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section XI.A.5.c (Ground 1, limitation 17[b]). *See* Section XI.B.1.c (limitation 1[b]).

d. 17[c]: "wirelessly communicates with the PED,"

867. Both McCulloch and Pedrotti disclose that the HMD is able to communicate wirelessly, and specifically with the PED. McCulloch (Ex.1008) at 5:19-36, 6:55-58 (real controller devices "coupled to the display device system" "via a wireless connection"); *see* Section XI.A.5.d (Ground 1, limitation 17[c] for Perotti).

e. 17[d]: "includes speakers that play to the user the binaural and that emanates from the SLPs in empty space in the zone,"

868. For the same reasons as I described for limitation 1[b], limitation 17[d] would have been obvious to persons of ordinary skill in the art over McCulloch, either alone or with Flaks, in view of Pedrotti. *See* Section XI.B.1.c (limitation 1[b]).

f. 17[e]: "includes one or more sensors that sense when the PED is leaving the zone,"

869. For the same reasons as I described for limitation 1[c], limitation 17[e] would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section XI.A.5.f (Ground 1, limitation 17[e]). *See* Sections XI.B.1.d (limitation 1[c]).

g. 17[f]: "and includes a display that displays a virtual reality (VR) image of the zone in response to sensing that the PED is leaving the zone,"

870. For the same reasons as I described for limitation 1[d], limitation 17[f] would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section XI.A.5.g (Ground 1, limitation 17[f]). *See* Sections XI.B.1.e (limitation 1[d]).

h. 17[g]: "wherein the display displays the VR image of the zone to warn the user that the user is leaving the zone."

871. For the same reasons as I described for limitations 1[d] and 9[c] and as I described for Ground 1 of this limitation, limitation 17[g] would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section XI.A.5.h (Ground 1, limitation 17[g]). *See* Sections XI.B.1.e (limitation 1[d]), XI.B.3.d (limitation 9[c]).

872. Specifically, Pedrotti discloses that its system "generates a warning" "when the user's head and/or hand approaches to within a preselected distance." Pedrotti (Ex.1005) at 12:40-50. Persons of ordinary skill in the art would have understood that "approach[ing] to within a preselected distance, for example, one foot … of the boundary" indicates that the user is leaving the zone, especially when that "preselected distance" is set to be a small number or zero. Pedrotti (Ex.1005) at 12:40-50.

6. Dependent Claim 18-20

873. I understand that claims 18-20 depend on independent claim 17.

874. Thus, it is my opinion that each of dependent claims 18-20 would have been obvious to persons of ordinary skill in the art for the same reasons as independent claim 17 and additionally for the reasons I discuss in the following subsections.

a. Claim 18: "The electronic system of claim 17, wherein the display of the WED highlights a color of a VR image at one of the SLPs in response to the WED determining that the PED is pointing to the VR image at the one of the SLPs."

875. For the same reasons as I described for limitation 2[a] and claim 11, claim 18 would have been obvious over McCulloch in view of Pedrotti. *See* Sections XI.B.2.a(1) (limitation 2[a]), XI.B.4.b (claim 11).

b. Claim 19: "The electronic system of claim 17, wherein the WED tracks a location of the user with respect to the SLPs, and automatically displays a VR image at a location of one of the SLPs in response to determining that the user is proximate to the location of the one of the SLPs."

876. For the same reasons as I describe for limitations 1[c], 1[d], 4[a], 5[b], 6[b], and claim 3, Claim 19 would have been obvious over McCulloch, either alone or with Flaks, in view of Pedrotti. *See* Sections XI.B.1.d (limitation 1[c]), XI.B.1.e (limitation 1[d]), XI.B.2.c(1) (limitation 4[a]), XI.B.2.d(2) (limitation 5[b]), XI.B.2.e(2) (limitation 6[b]), XI.B.2.b (claim 3).

877. In addition, McCulloch discloses storing virtual objects' locations, McCulloch (Ex.1008) at 19:8-21 (describing "data fields in an object physical properties data set" including "size," "shape," and "boundary data"), 19:51-62 ("scene mapping engine 306 can update a 3D space position or position volume for an object"). These virtual objects are associated with SLPs because McColluch describes sounds coming from the virtual objects such as a basketball smashing into a television or a helicopter. Thus, McCulloch also stores (or at a minimum obviously stores) SLP locations. McCulloch's system could and would then compare the user's location with those of SLPs to determine when the user is proximate thereto. McCulloch (Ex.1008) at 19:8-21, 19:51-62 (describing position history or motion path).

878. Persons of ordinary skill in the art would have understood that Pedrotti's system does in fact automatically displays the virtual fence when the condition that the PED is at the boundary of the 3D zone is met. *See* Pedrotti (Ex.1005) at 15:4-58 (explaining the flow chart shown in Fig. 15), Fig. 15. Furthermore, as discussed in Ground 1, it would have been obvious to persons of ordinary skill in the art to apply Pedrotti's logic for automatically displaying a fence's virtual image in response to determining that the user is in a specific location (i.e., when leaving or being outside the zone) to automatically displaying other virtual images at SLPs based on the user's location. Section XI.A.6.b (Ground 1,

claim 19); Pedrotti at 4:37-44 (explaining that the processor "tracks the position and orientation of the HMD track" and the "trackers in the physical controllers"). Automatically displaying images when users get close was a well-known effect in virtual environments (Section XI.A.6.b (Ground 1, claim 19)), e.g., to present content of interest to the user while pausing or not presenting content on which the user is not focused. *See* Ross (Ex.1125) at 2:32-67 ("The system may be configured such that primary virtual reality content may be displayed to a user, and, responsive to the user turning his view away from the primary virtual reality content; moving away from the primary virtual reality content; and/or taking other actions … The primary virtual reality content may resume (e.g., automatically) when the user returns his view.")

879. Furthermore, McCulloch's HMD supports this activity because its scene mapping engine "identifies the position and tracks the movement of real and virtual objects" McCulloch (Ex.1008) at 16:49-65 (describing "3D mapping" using "Depth images from multiple perspectives"), 4:4-15, 21:1-4 ("a 3D space position for each object may be defined by the scene mapping engine"), 28:23-25. Thus, McCulloch's HMD could and would compare a user's location with locations of virtual objects (as well as their SLPs), including to display VR images based on user proximity, as claimed.

c. Claim 20

(1) 20[a]: "The electronic system of claim 17, wherein the speakers in the WED play the binaural sound that emanates from one of the SLPs in empty space in response to the WED determining that the PED is pointed to the one of the SLPs in empty space, and"

880. For the same reasons I described for limitations 1[b] and 2[b], limitation 20[a] would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti. *See* Sections XI.B.1.c (limitation 1[b]), XI.B.2.a(2) (limitation 2[b]).

(2) 20[b]: "the zone is shaped as a 3D cylinder with the user being centered in the 3D cylinder."

881. For the same reasons as I described for claim 7, limitation 20[b] would have been obvious over Pedrotti, including based on the Pedrotti disclosures discussed in Section XI.A.6.c(2) (Ground 1, limitation 20[b]). *See* Section XI.B.2.f (claim 7).

* * *

882. Thus, every limitation in claims 1-20 of the '316 patent, and each of claims 1-20 as a whole, would have been obvious over McCulloch in view of Pedrotti, and further in view of Flaks.

XII. Conclusion

883. For the foregoing reasons, it is my opinion that claims 1-14 and 17-20 of the '509 patent and 1-20 of the '316 patent are unpatentable under 35 U.S.C. § 103.

884. To summarize, The challenged claims of the ’509 patent recite basic and straightforward systems and processes that, before February 2016, were used in virtual environments and well known to persons of ordinary skill in the art. Likewise, the challenged claims of the ’316 patent recite basic and straightforward systems and processes that, before February 2016, were used in virtual environments and well known to persons of ordinary skill in the art. Further, to the extent 8K argues that the challenged claims of either patent differ from the disclosures of the art relied on in the grounds of Petitioners’ petitions and discussed in detail above, it is my opinion that any such differences are trivial, including in view of the many additional prior art references I discussed in this declaration, which, among other things, demonstrate the level of knowledge persons of ordinary skill in the art would have possessed before the ’509 and ’316 patents earliest possible priority date.

All statements made herein of my own knowledge are true, and all statements made on information and belief are believed to be true. Further, I am aware that these statements are made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. § 1001. I declare under penalty of perjury that the foregoing is true and correct.

Executed on June 8, 2023 in Longwood, Florida.



Dr. Gregory F. Welch

Meta Platforms, Inc.
Exhibit 1003
Page 478