

Live from NASA /JPL

# NASA Game Tech

September 13, 2013



Jet Propulsion Laboratory  
California Institute of Technology



1  
00:00:13,430 --> 00:00:11,270  
hey good evening ladies and gentlemen

2  
00:00:14,910 --> 00:00:13,440  
how's everyone tonight

3  
00:00:17,269 --> 00:00:14,920  
good thanks for coming out to join us

4  
00:00:19,429 --> 00:00:17,279  
tonight what would it be like to swim in

5  
00:00:22,310 --> 00:00:19,439  
the oceans of europa and what would it

6  
00:00:23,750 --> 00:00:22,320  
feel like to climb olympus mons on mars

7  
00:00:25,910 --> 00:00:23,760  
and would it be possible for all of us

8  
00:00:28,150 --> 00:00:25,920  
to experience these journeys together

9  
00:00:30,230 --> 00:00:28,160  
the goal of the tele exploration program

10  
00:00:31,830 --> 00:00:30,240  
is to make us better explorers by

11  
00:00:33,910 --> 00:00:31,840  
building immersive environments that

12  
00:00:35,670 --> 00:00:33,920  
feel like we're really there

13  
00:00:37,670 --> 00:00:35,680

by drawing together technologies from

14

00:00:38,869 --> 00:00:37,680

sources as unlikely as the video game

15

00:00:40,150 --> 00:00:38,879

industry

16

00:00:41,830 --> 00:00:40,160

and

17

00:00:44,229 --> 00:00:41,840

advancing the state of the art pardon me

18

00:00:46,630 --> 00:00:44,239

in a human system interaction we are

19

00:00:48,709 --> 00:00:46,640

working towards low-cost holodecks not

20

00:00:50,310 --> 00:00:48,719

only for every nasa mission scientist

21

00:00:52,470 --> 00:00:50,320

but for every person who longs to

22

00:00:53,990 --> 00:00:52,480

explore space with us

23

00:00:55,750 --> 00:00:54,000

this presentation will describe our

24

00:00:58,470 --> 00:00:55,760

progress towards these ambitious goals

25

00:01:00,389 --> 00:00:58,480

as well as the challenges that are ahead

26

00:01:02,470 --> 00:01:00,399

tonight's guest received his bachelor's

27

00:01:05,109 --> 00:01:02,480

and master's degrees in computer science

28

00:01:06,149 --> 00:01:05,119

from mit and a phd in computer science

29

00:01:07,350 --> 00:01:06,159

from the university of southern

30

00:01:09,270 --> 00:01:07,360

california

31

00:01:11,030 --> 00:01:09,280

today he leads mission operations

32

00:01:12,390 --> 00:01:11,040

innovation at nasa's jet propulsion

33

00:01:14,950 --> 00:01:12,400

laboratory

34

00:01:17,350 --> 00:01:14,960

he is also the founder and lead of the

35

00:01:19,350 --> 00:01:17,360

jpl operations laboratory and the

36

00:01:21,350 --> 00:01:19,360

principal investigator for a variety of

37

00:01:23,190 --> 00:01:21,360

projects focused on the control of

38

00:01:25,030 --> 00:01:23,200

spacecraft and robots

39

00:01:27,350 --> 00:01:25,040

previously he was a section manager

40

00:01:30,070 --> 00:01:27,360

group supervisor and lead for control

41

00:01:32,870 --> 00:01:30,080

tools on the spirit opportunity and

42

00:01:34,149 --> 00:01:32,880

curiosity mars rover missions ladies and

43

00:01:43,910 --> 00:01:34,159

gentlemen please help me welcome

44

00:01:48,069 --> 00:01:45,990

good evening thank you it's a real

45

00:01:50,550 --> 00:01:48,079

pleasure to come and talk tonight about

46

00:01:52,469 --> 00:01:50,560

a subject of great

47

00:01:55,749 --> 00:01:52,479

personal interest of mine i'm quite

48

00:01:57,270 --> 00:01:55,759

passionate about this concept of using

49

00:02:00,630 --> 00:01:57,280

technologies that are finally coming

50

00:02:02,310 --> 00:02:00,640

together i believe now to enable

51  
00:02:05,510 --> 00:02:02,320  
not just scientists and engineers to be

52  
00:02:07,510 --> 00:02:05,520  
better explorers but also to include the

53  
00:02:09,990 --> 00:02:07,520  
public in the journeys that we're taking

54  
00:02:12,150 --> 00:02:10,000  
right now within nasa

55  
00:02:15,270 --> 00:02:12,160  
so the vision that i want to describe to

56  
00:02:17,830 --> 00:02:15,280  
you today put simply is

57  
00:02:19,270 --> 00:02:17,840  
based on this

58  
00:02:22,630 --> 00:02:19,280  
this is how

59  
00:02:25,350 --> 00:02:22,640  
human beings explore the world

60  
00:02:27,350 --> 00:02:25,360  
we are all gifted with an amazing innate

61  
00:02:29,190 --> 00:02:27,360  
ability to extract a great deal of

62  
00:02:32,070 --> 00:02:29,200  
information from an environment and

63  
00:02:33,509 --> 00:02:32,080

understand it just by being present in

64

00:02:35,030 --> 00:02:33,519

it

65

00:02:37,830 --> 00:02:35,040

now scientists and engineers like the

66

00:02:40,150 --> 00:02:37,840

ones that operate our missions build

67

00:02:42,390 --> 00:02:40,160

upon those innate abilities with a lot

68

00:02:44,229 --> 00:02:42,400

of specialized training and learning

69

00:02:44,949 --> 00:02:44,239

until they can read an environment like

70

00:02:46,949 --> 00:02:44,959

this

71

00:02:49,350 --> 00:02:46,959

like a book in fact i've heard

72

00:02:50,949 --> 00:02:49,360

geologists tell me before that every

73

00:02:52,710 --> 00:02:50,959

environment that they go and explore on

74

00:02:54,150 --> 00:02:52,720

earth has a story to tell

75

00:02:55,910 --> 00:02:54,160

and that their

76

00:02:58,150 --> 00:02:55,920

study of that environment is trying to

77

00:03:00,150 --> 00:02:58,160

learn what that story is

78

00:03:03,030 --> 00:03:00,160

that gives me a little bit of a concern

79

00:03:04,470 --> 00:03:03,040

though when you consider that right now

80

00:03:07,110 --> 00:03:04,480

we're asking many of these scientists

81

00:03:09,270 --> 00:03:07,120

and engineers to explore other planets

82

00:03:11,509 --> 00:03:09,280

like this

83

00:03:13,990 --> 00:03:11,519

peering at little pictures

84

00:03:16,470 --> 00:03:14,000

on a flat computer screen

85

00:03:18,710 --> 00:03:16,480

trying to piece together in their minds

86

00:03:19,910 --> 00:03:18,720

a complete model of this distant

87

00:03:21,030 --> 00:03:19,920

environment that they're trying to

88

00:03:22,869 --> 00:03:21,040

explore

89

00:03:26,309 --> 00:03:22,879

understand and study

90

00:03:27,350 --> 00:03:26,319

this is very challenging to accomplish

91

00:03:29,190 --> 00:03:27,360

part of the reason why it's so

92

00:03:30,550 --> 00:03:29,200

challenging is all those wonderful

93

00:03:31,430 --> 00:03:30,560

innate abilities that i just talked

94

00:03:34,070 --> 00:03:31,440

about

95

00:03:36,149 --> 00:03:34,080

are actually working against you here

96

00:03:39,430 --> 00:03:36,159

because you're not accustomed to seeing

97

00:03:41,270 --> 00:03:39,440

the world in this way

98

00:03:43,270 --> 00:03:41,280

the work the problem gets even a little

99

00:03:45,430 --> 00:03:43,280

bit worse when you consider that our

100

00:03:47,990 --> 00:03:45,440

missions are often operated by groups of

101  
00:03:49,670 --> 00:03:48,000  
scientists and engineers so imagine

102  
00:03:52,070 --> 00:03:49,680  
all these different people each forming

103  
00:03:54,070 --> 00:03:52,080  
their own mental model of an environment

104  
00:03:55,589 --> 00:03:54,080  
each flawed in a different way

105  
00:03:57,830 --> 00:03:55,599  
and then coming together and trying to

106  
00:04:01,270 --> 00:03:57,840  
discuss those mental models and come to

107  
00:04:03,830 --> 00:04:01,280  
a consensus about what we should do next

108  
00:04:06,630 --> 00:04:03,840  
very challenging

109  
00:04:09,190 --> 00:04:06,640  
this is what i believe that we need

110  
00:04:10,789 --> 00:04:09,200  
we need to surround our scientists and

111  
00:04:12,470 --> 00:04:10,799  
engineers in environments that allow

112  
00:04:14,470 --> 00:04:12,480  
their innate abilities and their

113  
00:04:16,469 --> 00:04:14,480

training and learning

114

00:04:19,030 --> 00:04:16,479

to work in their advantage to help them

115

00:04:20,949 --> 00:04:19,040

understand environments like mars and

116

00:04:22,469 --> 00:04:20,959

other bodies in our solar system and

117

00:04:24,390 --> 00:04:22,479

beyond

118

00:04:25,670 --> 00:04:24,400

we need to immerse them in these

119

00:04:27,590 --> 00:04:25,680

environments

120

00:04:29,110 --> 00:04:27,600

to make them better decision makers and

121

00:04:31,510 --> 00:04:29,120

better explorers

122

00:04:33,510 --> 00:04:31,520

and i can think of a few people

123

00:04:36,390 --> 00:04:33,520

perhaps some folks here today would like

124

00:04:39,510 --> 00:04:36,400

to join them there as well

125

00:04:42,390 --> 00:04:40,870

what's in the way

126  
00:04:43,990 --> 00:04:42,400  
what's preventing us from building that

127  
00:04:45,510 --> 00:04:44,000  
right now what's what are the challenges

128  
00:04:47,110 --> 00:04:45,520  
we have to deal with well there are two

129  
00:04:49,510 --> 00:04:47,120  
that i'm going to focus on a lot this

130  
00:04:51,270 --> 00:04:49,520  
evening the first one is pretty basic

131  
00:04:53,590 --> 00:04:51,280  
it's distance

132  
00:04:55,189 --> 00:04:53,600  
the places we want to explore are far

133  
00:04:56,469 --> 00:04:55,199  
away now i'm going to focus a little bit

134  
00:04:58,070 --> 00:04:56,479  
on mars tonight that doesn't mean that

135  
00:04:59,510 --> 00:04:58,080  
what i'm talking about doesn't apply to

136  
00:05:00,950 --> 00:04:59,520  
other planets as well we're just going

137  
00:05:03,030 --> 00:05:00,960  
to stick with mars

138  
00:05:06,950 --> 00:05:03,040

for most of our examples so let's take

139

00:05:09,110 --> 00:05:06,960

mars mars is between 40 and 400 million

140

00:05:10,950 --> 00:05:09,120

kilometers away from earth depending on

141

00:05:13,510 --> 00:05:10,960

the time of year depending on where the

142

00:05:16,390 --> 00:05:13,520

planets are in their orbits

143

00:05:19,350 --> 00:05:16,400

that translates to a one-way signal

144

00:05:22,150 --> 00:05:19,360

delay of 5-20 minutes so

145

00:05:24,390 --> 00:05:22,160

a signal transmitted from earth

146

00:05:25,749 --> 00:05:24,400

from us takes five to 20 minutes to

147

00:05:27,830 --> 00:05:25,759

reach the robot that we're trying to

148

00:05:29,909 --> 00:05:27,840

control on mars

149

00:05:31,909 --> 00:05:29,919

now this seems like

150

00:05:33,510 --> 00:05:31,919

an incredibly challenging problem if

151  
00:05:35,990 --> 00:05:33,520  
you've ever had a conversation over a

152  
00:05:38,070 --> 00:05:36,000  
bad phone call overseas then you may

153  
00:05:40,070 --> 00:05:38,080  
have experienced just a fraction of a

154  
00:05:41,590 --> 00:05:40,080  
second of time delay and it's irritating

155  
00:05:45,350 --> 00:05:41,600  
it's hard the conversation starts to

156  
00:05:47,909 --> 00:05:45,360  
break down this is far longer than that

157  
00:05:49,909 --> 00:05:47,919  
in fact it seems so long that

158  
00:05:52,390 --> 00:05:49,919  
at times people have suggested that the

159  
00:05:54,469 --> 00:05:52,400  
way to overcome it is to just move the

160  
00:05:56,790 --> 00:05:54,479  
people closer so we'll leave the robot

161  
00:05:59,430 --> 00:05:56,800  
on mars but we'll put the human in orbit

162  
00:06:01,430 --> 00:05:59,440  
around mars and so by doing so

163  
00:06:04,309 --> 00:06:01,440

we'll have a time delay that's only

164

00:06:06,070 --> 00:06:04,319

going to be around a second or less

165

00:06:07,270 --> 00:06:06,080

i agree this would be a great thing to

166

00:06:09,350 --> 00:06:07,280

have it would certainly make those

167

00:06:11,590 --> 00:06:09,360

robots easier to control

168

00:06:13,510 --> 00:06:11,600

however this would also be

169

00:06:14,870 --> 00:06:13,520

extremely expensive to accomplish and i

170

00:06:18,550 --> 00:06:14,880

believe

171

00:06:20,790 --> 00:06:18,560

unsustainable in the long term

172

00:06:22,870 --> 00:06:20,800

i also don't think it is the best way

173

00:06:25,029 --> 00:06:22,880

that our astronauts can spend their time

174

00:06:27,670 --> 00:06:25,039

contributing to exploration

175

00:06:29,590 --> 00:06:27,680

so let's come back to that five to

176

00:06:31,189 --> 00:06:29,600

twenty minute delay that seemed like

177

00:06:33,430 --> 00:06:31,199

such a barrier

178

00:06:35,909 --> 00:06:33,440

i'm gonna say instead that this seems

179

00:06:38,469 --> 00:06:35,919

like a luxuriously short amount of time

180

00:06:41,510 --> 00:06:38,479

to deal with and here's why because

181

00:06:44,070 --> 00:06:41,520

today when we operate rovers like spirit

182

00:06:45,830 --> 00:06:44,080

opportunity rather and curiosity we're

183

00:06:48,390 --> 00:06:45,840

really dealing with a much longer time

184

00:06:50,390 --> 00:06:48,400

delay and here's why we send commands to

185

00:06:52,150 --> 00:06:50,400

a robot like opportunity typically once

186

00:06:53,189 --> 00:06:52,160

per day in the morning when the robot

187

00:06:55,270 --> 00:06:53,199

wakes up

188

00:06:57,510 --> 00:06:55,280

the robot then spends its whole day

189

00:06:59,510 --> 00:06:57,520

executing all of those commands taking

190

00:07:01,430 --> 00:06:59,520

pictures driving places things like that

191

00:07:03,189 --> 00:07:01,440

and then at the end of its day sends its

192

00:07:05,589 --> 00:07:03,199

information back to us

193

00:07:07,350 --> 00:07:05,599

we then work all night all the march and

194

00:07:10,070 --> 00:07:07,360

night again

195

00:07:11,830 --> 00:07:10,080

to send it a new set of commands on its

196

00:07:14,309 --> 00:07:11,840

following morning and at that point

197

00:07:16,950 --> 00:07:14,319

that's 24 hours later than our last

198

00:07:18,950 --> 00:07:16,960

transmission so i will contend that we

199

00:07:20,469 --> 00:07:18,960

are not in fact dealing with a 5 to 20

200

00:07:22,790 --> 00:07:20,479

minute time delay when we operate a

201  
00:07:25,430 --> 00:07:22,800  
robot on mars today we're in fact

202  
00:07:27,270 --> 00:07:25,440  
dealing with a 12 hour time delay

203  
00:07:29,830 --> 00:07:27,280  
because it's 24 hours between each of

204  
00:07:32,309 --> 00:07:29,840  
our transmissions

205  
00:07:33,830 --> 00:07:32,319  
interestingly 12 hours it's about how

206  
00:07:36,790 --> 00:07:33,840  
long it would take us to bounce our

207  
00:07:39,510 --> 00:07:36,800  
signal off of pluto

208  
00:07:41,430 --> 00:07:39,520  
at its furthest distance from the sun

209  
00:07:43,350 --> 00:07:41,440  
and then back to mars again

210  
00:07:45,189 --> 00:07:43,360  
so this doesn't seem like the best way

211  
00:07:46,629 --> 00:07:45,199  
we could imagine operating a robot on

212  
00:07:49,029 --> 00:07:46,639  
mars

213  
00:07:50,950 --> 00:07:49,039

how would we fix this what would we do

214

00:07:52,710 --> 00:07:50,960

to correct this issue so that we could

215

00:07:54,469 --> 00:07:52,720

deal with only five to 20 minutes of

216

00:07:57,029 --> 00:07:54,479

time to like well we know how to fix it

217

00:07:58,950 --> 00:07:57,039

we need something approximating

218

00:08:01,029 --> 00:07:58,960

continuous or near continuous

219

00:08:02,150 --> 00:08:01,039

communication between earth and mars to

220

00:08:03,909 --> 00:08:02,160

fix this

221

00:08:06,629 --> 00:08:03,919

we already have half the problem pretty

222

00:08:08,950 --> 00:08:06,639

much fixed in that we've already arrayed

223

00:08:10,469 --> 00:08:08,960

the antennas of the deep space network

224

00:08:12,070 --> 00:08:10,479

at three locations around the earth so

225

00:08:13,909 --> 00:08:12,080

that they can talk pretty much anywhere

226

00:08:16,070 --> 00:08:13,919

in space at any time

227

00:08:18,309 --> 00:08:16,080

what we don't have on the other end is a

228

00:08:19,830 --> 00:08:18,319

telecom infrastructure to receive those

229

00:08:23,430 --> 00:08:19,840

signals and pass them on to surface

230

00:08:24,710 --> 00:08:23,440

spacecraft at any time of the day so

231

00:08:26,469 --> 00:08:24,720

we need those

232

00:08:28,230 --> 00:08:26,479

and if we had them

233

00:08:30,309 --> 00:08:28,240

we could send signals pretty much

234

00:08:31,990 --> 00:08:30,319

anytime we wanted to anything in the

235

00:08:34,310 --> 00:08:32,000

martian system

236

00:08:37,990 --> 00:08:34,320

this would be revolutionary for mars

237

00:08:39,909 --> 00:08:38,000

exploration and i would assert that

238

00:08:42,790 --> 00:08:39,919

if we're trying to bring around that

239

00:08:45,110 --> 00:08:42,800

revolution in mars exploration that

240

00:08:47,190 --> 00:08:45,120

a change in our telecom infrastructure

241

00:08:48,550 --> 00:08:47,200

is the first most modest and i think

242

00:08:50,150 --> 00:08:48,560

biggest bang for our buck we could

243

00:08:51,990 --> 00:08:50,160

imagine

244

00:08:53,829 --> 00:08:52,000

why well because it would allow us to

245

00:08:55,269 --> 00:08:53,839

start operating a robot in a very

246

00:08:58,470 --> 00:08:55,279

different way so instead of sending a

247

00:09:00,310 --> 00:08:58,480

full day's worth of commands all at once

248

00:09:01,990 --> 00:09:00,320

we could instead

249

00:09:03,670 --> 00:09:02,000

send a little bit of work for the robot

250

00:09:05,750 --> 00:09:03,680

to accomplish we could say

251

00:09:06,790 --> 00:09:05,760

drive a little bit of a waze

252

00:09:11,110 --> 00:09:06,800

and then

253

00:09:12,949 --> 00:09:11,120

little bit further take some pictures

254

00:09:15,509 --> 00:09:12,959

and tell us what happened again now

255

00:09:17,269 --> 00:09:15,519

because we're able to respond to things

256

00:09:18,870 --> 00:09:17,279

as they're developing meaning we can see

257

00:09:20,310 --> 00:09:18,880

how far it got and change our mind about

258

00:09:22,310 --> 00:09:20,320

what we want to do

259

00:09:24,070 --> 00:09:22,320

this would be a far more effective way

260

00:09:25,670 --> 00:09:24,080

to operate but there is another problem

261

00:09:27,670 --> 00:09:25,680

that i'm hiding in here

262

00:09:30,230 --> 00:09:27,680

this would be good but we can do much

263

00:09:32,230 --> 00:09:30,240

better and the research in my laboratory

264

00:09:34,870 --> 00:09:32,240

has been trying to make this kind of an

265

00:09:37,190 --> 00:09:34,880

operations model even better than this

266

00:09:38,949 --> 00:09:37,200

so here's the problem

267

00:09:40,550 --> 00:09:38,959

when you send that first command to the

268

00:09:42,389 --> 00:09:40,560

rover first of all we know we're already

269

00:09:43,910 --> 00:09:42,399

paying one time delay cost right it

270

00:09:46,150 --> 00:09:43,920

takes 5 to 20 minutes for that signal to

271

00:09:47,990 --> 00:09:46,160

get to mars in the first place

272

00:09:50,710 --> 00:09:48,000

what happens then though this human

273

00:09:52,949 --> 00:09:50,720

being starts to wait because we're

274

00:09:53,910 --> 00:09:52,959

waiting for the robot to do what it was

275

00:09:55,350 --> 00:09:53,920

told

276

00:09:57,030 --> 00:09:55,360

so it

277

00:09:58,949 --> 00:09:57,040

we wait while it completes those

278

00:10:01,269 --> 00:09:58,959

commands we wait for it to send the

279

00:10:03,910 --> 00:10:01,279

results back another 5-20 minutes

280

00:10:05,269 --> 00:10:03,920

and then what happens well now the robot

281

00:10:06,230 --> 00:10:05,279

has to start waiting

282

00:10:07,509 --> 00:10:06,240

because

283

00:10:08,870 --> 00:10:07,519

we have to think about what it's going

284

00:10:10,550 --> 00:10:08,880

to do next

285

00:10:13,030 --> 00:10:10,560

so someone's always waiting in fact when

286

00:10:13,910 --> 00:10:13,040

the signal's in transit both parties are

287

00:10:16,790 --> 00:10:13,920

waiting

288

00:10:18,710 --> 00:10:16,800

so we spend a lot of time with one part

289

00:10:20,069 --> 00:10:18,720

of this very important partnership

290

00:10:21,829 --> 00:10:20,079

waiting

291

00:10:23,590 --> 00:10:21,839

in fact this

292

00:10:25,910 --> 00:10:23,600

method of operations

293

00:10:28,150 --> 00:10:25,920

has been come to known in the time delay

294

00:10:29,509 --> 00:10:28,160

operations world as

295

00:10:31,670 --> 00:10:29,519

bump and weight

296

00:10:33,910 --> 00:10:31,680

because you bump the robot a little bit

297

00:10:35,190 --> 00:10:33,920

and then you wait to see what happened

298

00:10:36,710 --> 00:10:35,200

bump it forward a little bit more and

299

00:10:39,030 --> 00:10:36,720

wait to see what happened how can we get

300

00:10:40,790 --> 00:10:39,040

out of this where could we look for some

301  
00:10:42,150 --> 00:10:40,800  
inspiration well

302  
00:10:44,389 --> 00:10:42,160  
turns out

303  
00:10:46,230 --> 00:10:44,399  
that video games got to deal with a very

304  
00:10:47,829 --> 00:10:46,240  
similar problem and i'm going to explain

305  
00:10:49,990 --> 00:10:47,839  
how they deal with it

306  
00:10:51,990 --> 00:10:50,000  
and then how we're following a

307  
00:10:53,030 --> 00:10:52,000  
impressively similar result

308  
00:10:54,310 --> 00:10:53,040  
now

309  
00:10:55,750 --> 00:10:54,320  
many years ago

310  
00:10:57,829 --> 00:10:55,760  
some friends of mine and i just for a

311  
00:10:59,750 --> 00:10:57,839  
hobby wrote a modification to a very

312  
00:11:01,509 --> 00:10:59,760  
popular video game of the time and this

313  
00:11:03,590 --> 00:11:01,519

is actually actual speed it was a very

314

00:11:06,150 --> 00:11:03,600

fast-paced game you know explosions

315

00:11:08,310 --> 00:11:06,160

happening everywhere rockets flying lots

316

00:11:11,190 --> 00:11:08,320

of people running everywhere it was a

317

00:11:12,949 --> 00:11:11,200

bit chaotic and it's very challenging

318

00:11:14,870 --> 00:11:12,959

for a game like this to keep everything

319

00:11:16,630 --> 00:11:14,880

in sync because people are playing from

320

00:11:17,990 --> 00:11:16,640

all over the country and they need to

321

00:11:19,269 --> 00:11:18,000

all kind of have a consistent view of

322

00:11:20,949 --> 00:11:19,279

the world for this game to make any

323

00:11:24,470 --> 00:11:20,959

sense at all now i'm not going to

324

00:11:26,310 --> 00:11:24,480

explain how we resolved it in this game

325

00:11:27,509 --> 00:11:26,320

because it's a bit of a complicated game

326

00:11:29,590 --> 00:11:27,519

i'm going to reduce it to something a

327

00:11:31,430 --> 00:11:29,600

little more simple and perhaps familiar

328

00:11:32,630 --> 00:11:31,440

to some folks in this audience

329

00:11:36,069 --> 00:11:32,640

this

330

00:11:37,509 --> 00:11:36,079

is pitfall harry in the atari 2600 2600

331

00:11:39,110 --> 00:11:37,519

game pitfall

332

00:11:40,870 --> 00:11:39,120

very charming game

333

00:11:42,389 --> 00:11:40,880

played in many many living rooms

334

00:11:45,190 --> 00:11:42,399

including

335

00:11:46,790 --> 00:11:45,200

some that i have been in and the

336

00:11:48,150 --> 00:11:46,800

idea here is you run and jump and try to

337

00:11:49,509 --> 00:11:48,160

keep yourself safe now when you're

338

00:11:51,269 --> 00:11:49,519

playing this by yourself in your living

339

00:11:52,710 --> 00:11:51,279

room it's very easy for things to stay

340

00:11:54,150 --> 00:11:52,720

in sync because there's really only one

341

00:11:55,990 --> 00:11:54,160

version of the world it's the version

342

00:11:57,990 --> 00:11:56,000

that's being run on your atari inside

343

00:11:59,990 --> 00:11:58,000

your your living room so that that's

344

00:12:01,670 --> 00:12:00,000

easy imagine though if we were going to

345

00:12:02,790 --> 00:12:01,680

play a game like this across the

346

00:12:04,550 --> 00:12:02,800

internet

347

00:12:06,790 --> 00:12:04,560

suddenly there's not one version of the

348

00:12:09,269 --> 00:12:06,800

game there's actually two there's one

349

00:12:10,629 --> 00:12:09,279

running on you or your computer and then

350

00:12:12,150 --> 00:12:10,639

there's another one running on the

351

00:12:13,990 --> 00:12:12,160

server and the server's job is a

352

00:12:16,150 --> 00:12:14,000

computer that's responsible for making

353

00:12:17,750 --> 00:12:16,160

sure that your version of the world and

354

00:12:19,990 --> 00:12:17,760

all of the other people who are playing

355

00:12:21,990 --> 00:12:20,000

with you stay consistent and that

356

00:12:23,750 --> 00:12:22,000

certain rules are followed

357

00:12:25,030 --> 00:12:23,760

keeping these versions of the game in

358

00:12:26,470 --> 00:12:25,040

sync

359

00:12:29,269 --> 00:12:26,480

can be very challenging and i'm going to

360

00:12:30,710 --> 00:12:29,279

explain why with a very very simple

361

00:12:32,710 --> 00:12:30,720

example so

362

00:12:33,990 --> 00:12:32,720

simply running and trying to jump over

363

00:12:36,150 --> 00:12:34,000

that pit

364

00:12:37,590 --> 00:12:36,160

let's imagine that you know the server

365

00:12:39,350 --> 00:12:37,600

that's that computer that's responsible

366

00:12:41,910 --> 00:12:39,360

for keeping things in sync between the

367

00:12:43,269 --> 00:12:41,920

players has told us where pitfall harry

368

00:12:45,190 --> 00:12:43,279

is

369

00:12:46,790 --> 00:12:45,200

and we've decided we'd like to run

370

00:12:49,190 --> 00:12:46,800

towards that pit

371

00:12:50,550 --> 00:12:49,200

so we push the key in our computer that

372

00:12:52,470 --> 00:12:50,560

tells it to run

373

00:12:54,710 --> 00:12:52,480

and we have to send a command to the

374

00:12:58,069 --> 00:12:54,720

server telling it that we want to run

375

00:13:00,069 --> 00:12:58,079

because it's actually not okay for our

376

00:13:01,350 --> 00:13:00,079

computer to be completely in charge of

377

00:13:02,790 --> 00:13:01,360

what the world is like because if it

378

00:13:04,870 --> 00:13:02,800

were it would be very easy to cheat you

379

00:13:06,710 --> 00:13:04,880

could simply have your computer say well

380

00:13:08,150 --> 00:13:06,720

i can run 10 times as fast as everyone

381

00:13:10,069 --> 00:13:08,160

jumped 10 times as high and i got all

382

00:13:12,710 --> 00:13:10,079

the points i went right it wouldn't make

383

00:13:14,550 --> 00:13:12,720

it very much fun for the other people so

384

00:13:17,030 --> 00:13:14,560

what we have to do is basically request

385

00:13:18,870 --> 00:13:17,040

of the server that we want to run so

386

00:13:20,470 --> 00:13:18,880

imagine that command starts heading its

387

00:13:23,430 --> 00:13:20,480

way towards the server now the internet

388

00:13:24,790 --> 00:13:23,440

is fast but it is not instantaneous

389

00:13:26,949 --> 00:13:24,800

so

390

00:13:28,949 --> 00:13:26,959

if i if the computer that you're playing

391

00:13:31,430 --> 00:13:28,959

on were to wait around to hear back from

392

00:13:33,430 --> 00:13:31,440

the server saying yes you you're running

393

00:13:35,990 --> 00:13:33,440

then the game would be very stuttery

394

00:13:37,910 --> 00:13:36,000

very jerky very laggy

395

00:13:40,230 --> 00:13:37,920

to play so instead what your computer

396

00:13:42,230 --> 00:13:40,240

has to do is guess it guesses you know

397

00:13:43,509 --> 00:13:42,240

what i'm just going to assume that the

398

00:13:45,190 --> 00:13:43,519

server is going to tell me it's okay so

399

00:13:46,470 --> 00:13:45,200

we're going to start running and you

400

00:13:48,069 --> 00:13:46,480

know what you're about to get into that

401  
00:13:49,509 --> 00:13:48,079  
pit and you push the button that says

402  
00:13:51,430 --> 00:13:49,519  
jump you still haven't heard anything

403  
00:13:53,030 --> 00:13:51,440  
from the server yet and your character

404  
00:13:54,949 --> 00:13:53,040  
starts jumping and

405  
00:13:57,350 --> 00:13:54,959  
starts to grab onto that rope and then

406  
00:13:59,030 --> 00:13:57,360  
finally the server gets back to you

407  
00:14:00,550 --> 00:13:59,040  
about that command that you said i wanna

408  
00:14:02,949 --> 00:14:00,560  
i wanna start running

409  
00:14:05,430 --> 00:14:02,959  
so what are you supposed to do now

410  
00:14:07,990 --> 00:14:05,440  
how do you stay in sync well what

411  
00:14:10,230 --> 00:14:08,000  
happens is very very quickly in your

412  
00:14:12,150 --> 00:14:10,240  
game on your local computer it takes the

413  
00:14:14,710 --> 00:14:12,160

information that the server gave it

414

00:14:16,710 --> 00:14:14,720

rushes it back

415

00:14:18,870 --> 00:14:16,720

and says all right what if this is the

416

00:14:20,389 --> 00:14:18,880

way that that run actually turned down

417

00:14:21,750 --> 00:14:20,399

and then it plays forward all the

418

00:14:24,069 --> 00:14:21,760

commands that you

419

00:14:26,870 --> 00:14:24,079

used on your local computer since then

420

00:14:28,470 --> 00:14:26,880

to get a new version of reality and then

421

00:14:29,350 --> 00:14:28,480

when that happens small things might

422

00:14:31,910 --> 00:14:29,360

change

423

00:14:33,030 --> 00:14:31,920

enough

424

00:14:35,350 --> 00:14:33,040

that you don't really notice them when

425

00:14:37,350 --> 00:14:35,360

you're playing a game but your game your

426

00:14:39,189 --> 00:14:37,360

local computer is actually doing this

427

00:14:41,350 --> 00:14:39,199

over and over and over again very low

428

00:14:42,790 --> 00:14:41,360

very quickly locally it's receiving an

429

00:14:45,350 --> 00:14:42,800

updated piece of information from the

430

00:14:48,389 --> 00:14:45,360

server it's running forward from there

431

00:14:50,629 --> 00:14:48,399

to what now is on your computer and

432

00:14:52,150 --> 00:14:50,639

rendering a new version of now over and

433

00:14:53,350 --> 00:14:52,160

over again you just don't realize it's

434

00:15:00,949 --> 00:14:53,360

doing this and of course this is

435

00:15:05,430 --> 00:15:02,790

this dance continues when you're playing

436

00:15:08,470 --> 00:15:05,440

a game and all modern uh online games

437

00:15:10,829 --> 00:15:08,480

work off of a base a system that is like

438

00:15:12,710 --> 00:15:10,839

this now what does this mean for

439

00:15:14,470 --> 00:15:12,720

exploration

440

00:15:16,870 --> 00:15:14,480

well they get to cheat a little bit here

441

00:15:19,509 --> 00:15:16,880

because in order to make the predictions

442

00:15:22,150 --> 00:15:19,519

pretty good they actually run a copy of

443

00:15:24,949 --> 00:15:22,160

the code that the server has

444

00:15:26,310 --> 00:15:24,959

on your local computer so it's kind of

445

00:15:28,470 --> 00:15:26,320

running through the same rule book to

446

00:15:29,910 --> 00:15:28,480

figure out what the server is likely to

447

00:15:31,750 --> 00:15:29,920

predict now i can't predict everything

448

00:15:32,949 --> 00:15:31,760

because for one thing your computer

449

00:15:35,670 --> 00:15:32,959

can't predict the actions of other

450

00:15:37,670 --> 00:15:35,680

players but it can get pretty good

451  
00:15:39,110 --> 00:15:37,680  
imagine now that what's on the other end

452  
00:15:41,030 --> 00:15:39,120  
of the time delay

453  
00:15:43,509 --> 00:15:41,040  
is mars

454  
00:15:45,110 --> 00:15:43,519  
it's not a computer not a simulation

455  
00:15:47,590 --> 00:15:45,120  
so we can't run

456  
00:15:50,150 --> 00:15:47,600  
mars locally we can't run a copy of that

457  
00:15:51,509 --> 00:15:50,160  
locally so we have to make our best

458  
00:15:53,269 --> 00:15:51,519  
predictions our best guesses about

459  
00:15:55,189 --> 00:15:53,279  
what's going to happen but we're going

460  
00:15:57,110 --> 00:15:55,199  
to be wrong more often we're going to

461  
00:15:58,790 --> 00:15:57,120  
have more uncertainty

462  
00:16:01,030 --> 00:15:58,800  
so that comes to

463  
00:16:02,550 --> 00:16:01,040

how the research in my lab is trying to

464

00:16:04,790 --> 00:16:02,560

address this particular challenge

465

00:16:06,550 --> 00:16:04,800

because the concept of predicting what

466

00:16:09,269 --> 00:16:06,560

is going to happen in order to mitigate

467

00:16:11,110 --> 00:16:09,279

the effects of time delay is not new but

468

00:16:13,189 --> 00:16:11,120

what we believe is new is providing a

469

00:16:14,470 --> 00:16:13,199

way to reason upon the uncertainty that

470

00:16:16,389 --> 00:16:14,480

that introduces

471

00:16:18,790 --> 00:16:16,399

so a member of our lab alex menzies

472

00:16:20,870 --> 00:16:18,800

actually went so far as to write a video

473

00:16:22,710 --> 00:16:20,880

game version of what it would be like to

474

00:16:24,150 --> 00:16:22,720

drive a robot with time delay and this

475

00:16:25,189 --> 00:16:24,160

is what it looks like so let me explain

476  
00:16:27,590 --> 00:16:25,199  
a couple of things that you're seeing

477  
00:16:29,269 --> 00:16:27,600  
here this

478  
00:16:31,030 --> 00:16:29,279  
black circular robot down here at the

479  
00:16:32,870 --> 00:16:31,040  
bottom well that is a robot and the red

480  
00:16:34,710 --> 00:16:32,880  
thing is which way it's facing

481  
00:16:36,710 --> 00:16:34,720  
and these green dots that are being laid

482  
00:16:38,470 --> 00:16:36,720  
up here at the top those are waypoints

483  
00:16:41,269 --> 00:16:38,480  
those are places that you want the robot

484  
00:16:42,550 --> 00:16:41,279  
to go these dark blue lines here these

485  
00:16:45,110 --> 00:16:42,560  
are walls these are things that you're

486  
00:16:47,749 --> 00:16:45,120  
not allowed to bump into

487  
00:16:49,590 --> 00:16:47,759  
this blue haze that surrounds these

488  
00:16:51,430 --> 00:16:49,600

waypoints is what we call the

489

00:16:53,350 --> 00:16:51,440

uncertainty volume

490

00:16:55,829 --> 00:16:53,360

this represents

491

00:16:57,990 --> 00:16:55,839

how unsure you are about where the robot

492

00:17:00,150 --> 00:16:58,000

will actually end up if you tell it to

493

00:17:02,069 --> 00:17:00,160

go to those locations and you'll notice

494

00:17:04,390 --> 00:17:02,079

it grows and shrinks

495

00:17:06,470 --> 00:17:04,400

if you get way out in advance of the

496

00:17:07,750 --> 00:17:06,480

robot which is down here this is where

497

00:17:12,549 --> 00:17:07,760

the robot

498

00:17:14,710 --> 00:17:12,559

was to get too far out in advance that

499

00:17:16,630 --> 00:17:14,720

uncertainty volume gets too big and you

500

00:17:18,949 --> 00:17:16,640

have to stop and wait for it to compress

501  
00:17:20,789 --> 00:17:18,959  
like right now the driver is waiting

502  
00:17:23,669 --> 00:17:20,799  
until that blue uncertainty volume gets

503  
00:17:24,470 --> 00:17:23,679  
small enough that it can fit through

504  
00:17:28,470 --> 00:17:24,480  
that

505  
00:17:30,870 --> 00:17:28,480  
passageway there so finally right there

506  
00:17:32,870 --> 00:17:30,880  
it the driver can see i have enough room

507  
00:17:34,870 --> 00:17:32,880  
to get through so i will

508  
00:17:36,549 --> 00:17:34,880  
issue those waypoints and the robot will

509  
00:17:37,669 --> 00:17:36,559  
start driving again and then he'll start

510  
00:17:39,430 --> 00:17:37,679  
quickly

511  
00:17:41,270 --> 00:17:39,440  
adding waypoints to move up to the next

512  
00:17:43,110 --> 00:17:41,280  
passageway and have to stop again

513  
00:17:44,390 --> 00:17:43,120

because now the uncertainty is getting a

514

00:17:46,230 --> 00:17:44,400

little bit too large again like we

515

00:17:47,750 --> 00:17:46,240

really need to wait again and let let

516

00:17:49,430 --> 00:17:47,760

the real robot catch up now why does

517

00:17:50,390 --> 00:17:49,440

that uncertainty volume get smaller when

518

00:17:53,110 --> 00:17:50,400

you wait

519

00:17:54,789 --> 00:17:53,120

it's because as it gets closer to where

520

00:17:56,950 --> 00:17:54,799

you're planning there are fewer and

521

00:17:59,029 --> 00:17:56,960

fewer ways that things can go wrong that

522

00:18:01,510 --> 00:17:59,039

things can be unpredictable because it's

523

00:18:03,029 --> 00:18:01,520

close to to where the wave points are so

524

00:18:04,390 --> 00:18:03,039

it's not going to instantly jump 10 feet

525

00:18:07,669 --> 00:18:04,400

to the left it's going to make small

526

00:18:12,390 --> 00:18:09,669

what we're trying to do is to allow a

527

00:18:15,029 --> 00:18:12,400

person to stay ahead of the robot while

528

00:18:17,029 --> 00:18:15,039

managing risk by understanding the

529

00:18:18,310 --> 00:18:17,039

uncertainty that that introduces there's

530

00:18:20,390 --> 00:18:18,320

one last thing i want to point out which

531

00:18:23,029 --> 00:18:20,400

is this special orange little version of

532

00:18:24,789 --> 00:18:23,039

the robot here that's something we call

533

00:18:29,669 --> 00:18:24,799

the committed state

534

00:18:31,510 --> 00:18:29,679

you think the robot would be if you said

535

00:18:33,350 --> 00:18:31,520

stop everything right now

536

00:18:34,789 --> 00:18:33,360

so you can't stop the robot instantly on

537

00:18:37,669 --> 00:18:34,799

mars because it takes 5 to 20 minutes

538

00:18:39,510 --> 00:18:37,679

for your stop message to get there

539

00:18:41,590 --> 00:18:39,520

where that orange little robot is is

540

00:18:44,070 --> 00:18:41,600

where you would expect it to stop

541

00:18:46,070 --> 00:18:44,080

if that stop command were sent right now

542

00:18:47,510 --> 00:18:46,080

what's also really important about it is

543

00:18:49,350 --> 00:18:47,520

if you can stay

544

00:18:52,230 --> 00:18:49,360

ahead

545

00:18:54,950 --> 00:18:52,240

of that little orange robot

546

00:18:57,110 --> 00:18:54,960

then you're in in fact not paying any

547

00:18:59,190 --> 00:18:57,120

penalty for the time delay because if

548

00:19:01,350 --> 00:18:59,200

you're dropping waypoints in in front of

549

00:19:03,909 --> 00:19:01,360

these in front in front of this orange

550

00:19:06,230 --> 00:19:03,919

robot it means that the robot will get

551  
00:19:09,110 --> 00:19:06,240  
that instruction before it stops

552  
00:19:11,669 --> 00:19:09,120  
so this game becomes about can you plan

553  
00:19:12,549 --> 00:19:11,679  
waypoints in in front of the committed

554  
00:19:14,549 --> 00:19:12,559  
state

555  
00:19:17,669 --> 00:19:14,559  
while being very careful never to let

556  
00:19:19,590 --> 00:19:17,679  
your blue uncertainty volume intersect

557  
00:19:22,310 --> 00:19:19,600  
with something that you don't want to

558  
00:19:24,710 --> 00:19:22,320  
come into contact with

559  
00:19:26,710 --> 00:19:24,720  
if you can do that there's actually no

560  
00:19:28,630 --> 00:19:26,720  
difference between operating that robot

561  
00:19:31,110 --> 00:19:28,640  
two feet away or 400 million kilometers

562  
00:19:34,710 --> 00:19:32,630  
so let's look at how we've tried

563  
00:19:37,270 --> 00:19:34,720

applying this to a real robot because

564

00:19:38,789 --> 00:19:37,280

that's just a simulation

565

00:19:42,070 --> 00:19:38,799

this robot

566

00:19:44,549 --> 00:19:42,080

is just a basic off-the-shelf uh

567

00:19:46,870 --> 00:19:44,559

robot that we've outfitted with some

568

00:19:49,510 --> 00:19:46,880

range sensors on top and so those range

569

00:19:50,870 --> 00:19:49,520

sensors allow the robot to keep track of

570

00:19:52,549 --> 00:19:50,880

where things are in the environment in

571

00:19:53,909 --> 00:19:52,559

addition to what they look like and

572

00:19:56,070 --> 00:19:53,919

we've set up a little obstacle course

573

00:19:58,390 --> 00:19:56,080

for it with those red boxes so you can

574

00:20:00,470 --> 00:19:58,400

see the the sensors up top complete with

575

00:20:02,630 --> 00:20:00,480

googly eyes

576  
00:20:05,110 --> 00:20:02,640  
so this is remember the old way right so

577  
00:20:08,150 --> 00:20:05,120  
we issue a waypoint and then we wait

578  
00:20:09,990 --> 00:20:08,160  
until the robot arrives at that spot

579  
00:20:11,510 --> 00:20:10,000  
and when it gets there and tells us i've

580  
00:20:13,110 --> 00:20:11,520  
gotten there then we put another

581  
00:20:15,270 --> 00:20:13,120  
waypoint and then we wait again so

582  
00:20:16,630 --> 00:20:15,280  
that's bump and weight right

583  
00:20:19,029 --> 00:20:16,640  
so here is the interface that we've

584  
00:20:21,830 --> 00:20:19,039  
built that allows us to go beyond that

585  
00:20:24,390 --> 00:20:21,840  
this is a rendering of the environment

586  
00:20:25,909 --> 00:20:24,400  
as sensed by those sensors on top of the

587  
00:20:28,149 --> 00:20:25,919  
robot

588  
00:20:30,310 --> 00:20:28,159

and then when we plan a path through

589

00:20:32,870 --> 00:20:30,320

this little obstacle course of red robot

590

00:20:34,470 --> 00:20:32,880

of red boxes you'll see that uncertainty

591

00:20:36,710 --> 00:20:34,480

volume appear

592

00:20:38,710 --> 00:20:36,720

and as we drop additional waypoints we

593

00:20:40,070 --> 00:20:38,720

have to be careful if we ever see the

594

00:20:42,549 --> 00:20:40,080

blue

595

00:20:44,549 --> 00:20:42,559

hazy part come into contact with the box

596

00:20:46,310 --> 00:20:44,559

because that would mean we might crash

597

00:20:48,149 --> 00:20:46,320

we might bump into something so that

598

00:20:49,909 --> 00:20:48,159

situation you see right there is is not

599

00:20:52,230 --> 00:20:49,919

good you'd have to pull that waypoint

600

00:20:53,270 --> 00:20:52,240

back a little bit and that ghosted robot

601  
00:20:54,870 --> 00:20:53,280  
you saw on the interface and we're

602  
00:20:56,710 --> 00:20:54,880  
giving you just an idea of what it would

603  
00:20:58,310 --> 00:20:56,720  
look like if it existed in real life

604  
00:21:00,470 --> 00:20:58,320  
that's that magical state called the

605  
00:21:02,390 --> 00:21:00,480  
committed state that if you're planning

606  
00:21:05,029 --> 00:21:02,400  
in front of that you're not paying any

607  
00:21:06,789 --> 00:21:05,039  
penalty for time delay

608  
00:21:08,789 --> 00:21:06,799  
so we've had some encouraging results

609  
00:21:10,630 --> 00:21:08,799  
with this interface we're about to start

610  
00:21:12,870 --> 00:21:10,640  
some experiments where we hope we'll be

611  
00:21:14,630 --> 00:21:12,880  
able to show some quantitative benefits

612  
00:21:15,590 --> 00:21:14,640  
to people who choose to drive robots

613  
00:21:21,110 --> 00:21:15,600

this way

614

00:21:27,510 --> 00:21:23,590

what would it enable if we could drive a

615

00:21:29,110 --> 00:21:27,520

robot that way on mars

616

00:21:30,710 --> 00:21:29,120

well saw what it looked like with bump

617

00:21:33,270 --> 00:21:30,720

and weight you saw what it looked like

618

00:21:34,950 --> 00:21:33,280

when you just kept uh when you had

619

00:21:36,390 --> 00:21:34,960

shorter bump in weights right when you

620

00:21:38,070 --> 00:21:36,400

gave it just a few things to do and then

621

00:21:39,350 --> 00:21:38,080

a few more things to do

622

00:21:41,510 --> 00:21:39,360

if we could drive it the way that i just

623

00:21:43,669 --> 00:21:41,520

showed you would be more like this we

624

00:21:45,270 --> 00:21:43,679

would send commands to tell the robot to

625

00:21:46,950 --> 00:21:45,280

move it would be

626  
00:21:49,270 --> 00:21:46,960  
reporting back to us about how things

627  
00:21:51,909 --> 00:21:49,280  
are happening and we would be passing

628  
00:21:53,510 --> 00:21:51,919  
out new waypoints to it kind of right in

629  
00:21:55,510 --> 00:21:53,520  
front of it

630  
00:21:57,029 --> 00:21:55,520  
far enough out where we're managing our

631  
00:21:59,270 --> 00:21:57,039  
uncertainty so that we're not doing

632  
00:22:01,029 --> 00:21:59,280  
anything dangerous

633  
00:22:02,789 --> 00:22:01,039  
but still we're trying to keep the robot

634  
00:22:04,390 --> 00:22:02,799  
from sitting idle and waiting for a

635  
00:22:06,549 --> 00:22:04,400  
command

636  
00:22:09,430 --> 00:22:06,559  
this would be a dramatic benefit to

637  
00:22:11,430 --> 00:22:09,440  
operations and to exploration because

638  
00:22:12,950 --> 00:22:11,440

it would allow us to not only

639

00:22:14,230 --> 00:22:12,960

react quickly to things as they're

640

00:22:15,430 --> 00:22:14,240

changing meaning that you could drive a

641

00:22:17,110 --> 00:22:15,440

little bit see what you see and then

642

00:22:18,870 --> 00:22:17,120

choose where to drive or take a big

643

00:22:20,470 --> 00:22:18,880

picture at low resolution and then pick

644

00:22:22,630 --> 00:22:20,480

an area to take a higher resolution

645

00:22:24,549 --> 00:22:22,640

interactively right then

646

00:22:26,870 --> 00:22:24,559

but

647

00:22:28,549 --> 00:22:26,880

it would also allow us to manage the

648

00:22:32,549 --> 00:22:28,559

risks associated with getting too far

649

00:22:37,430 --> 00:22:35,510

so we'll go on to something else now

650

00:22:40,070 --> 00:22:37,440

distance was one of the barriers in

651  
00:22:42,310 --> 00:22:40,080  
front of the tele exploration project

652  
00:22:44,149 --> 00:22:42,320  
immersion is another challenge what do

653  
00:22:45,350 --> 00:22:44,159  
we do with the information that comes

654  
00:22:47,110 --> 00:22:45,360  
back from these robots when we're

655  
00:22:48,630 --> 00:22:47,120  
controlling them how do we present it to

656  
00:22:50,630 --> 00:22:48,640  
the people who are responsible for

657  
00:22:52,549 --> 00:22:50,640  
driving them so that they have an

658  
00:22:54,470 --> 00:22:52,559  
intuitive understanding of the

659  
00:22:58,950 --> 00:22:54,480  
environment of the robot and can make

660  
00:23:03,669 --> 00:23:02,470  
imagine yourself as a mars scientist

661  
00:23:05,990 --> 00:23:03,679  
who's trying to help control the

662  
00:23:10,070 --> 00:23:06,000  
curiosity rover you are inundated with a

663  
00:23:11,590 --> 00:23:10,080

torrent of imagery and other data

664

00:23:14,549 --> 00:23:11,600

you're trying to put together a mental

665

00:23:15,990 --> 00:23:14,559

model of the scene around the robot

666

00:23:18,630 --> 00:23:16,000

we've come up with some tools to help

667

00:23:20,230 --> 00:23:18,640

ourselves do this we build maps

668

00:23:22,230 --> 00:23:20,240

we take the pictures and we stitch them

669

00:23:23,909 --> 00:23:22,240

together into larger pictures and then

670

00:23:25,990 --> 00:23:23,919

we reproject them from interesting

671

00:23:29,510 --> 00:23:26,000

angles to try to get it all in our head

672

00:23:32,390 --> 00:23:29,520

about what the scene really looks like

673

00:23:34,950 --> 00:23:32,400

sometimes we put the robot

674

00:23:36,310 --> 00:23:34,960

as a 3d model into a scene in a computer

675

00:23:38,390 --> 00:23:36,320

and then fly around it to try to

676  
00:23:39,909 --> 00:23:38,400  
understand where the terrain is and how

677  
00:23:41,909 --> 00:23:39,919  
big the robot is relative to some of the

678  
00:23:44,230 --> 00:23:41,919  
things in it but we spend quite a lot of

679  
00:23:46,310 --> 00:23:44,240  
time looking at images like this this is

680  
00:23:48,710 --> 00:23:46,320  
a panorama one of my favorites acquired

681  
00:23:50,390 --> 00:23:48,720  
by the spirit rover around a thousand

682  
00:23:52,549 --> 00:23:50,400  
days into its mission

683  
00:23:54,230 --> 00:23:52,559  
i want you to study with it study it

684  
00:23:55,510 --> 00:23:54,240  
with me for a moment

685  
00:23:57,990 --> 00:23:55,520  
try to get a feeling for this

686  
00:23:59,830 --> 00:23:58,000  
environment that the rover is exploring

687  
00:24:02,549 --> 00:23:59,840  
now try to imagine yourself as an

688  
00:24:04,470 --> 00:24:02,559

astronaut there with it

689

00:24:06,230 --> 00:24:04,480

perhaps you've come over here to study a

690

00:24:07,909 --> 00:24:06,240

rock that looks interesting over there

691

00:24:09,830 --> 00:24:07,919

and you decide that you'd like to go to

692

00:24:11,190 --> 00:24:09,840

another place perhaps over there where

693

00:24:12,950 --> 00:24:11,200

there's a patch of soil that looks

694

00:24:14,630 --> 00:24:12,960

interesting

695

00:24:17,029 --> 00:24:14,640

look at this picture and tell me how you

696

00:24:19,269 --> 00:24:17,039

would get there

697

00:24:21,430 --> 00:24:19,279

it seems reasonable that you would just

698

00:24:23,669 --> 00:24:21,440

follow that path

699

00:24:24,870 --> 00:24:23,679

seems very reasonable but incorrect

700

00:24:26,470 --> 00:24:24,880

because if you were there people would

701  
00:24:28,070 --> 00:24:26,480  
probably start laughing at you because

702  
00:24:29,430 --> 00:24:28,080  
you would have turned around and walked

703  
00:24:31,909 --> 00:24:29,440  
directly away from where you wanted to

704  
00:24:34,230 --> 00:24:31,919  
go because this is a panoramic image

705  
00:24:36,230 --> 00:24:34,240  
this is the fastest way to get from

706  
00:24:37,990 --> 00:24:36,240  
point a to point b

707  
00:24:40,470 --> 00:24:38,000  
much faster in fact those spots are only

708  
00:24:42,070 --> 00:24:40,480  
a few feet apart

709  
00:24:44,070 --> 00:24:42,080  
and although those little silhouettes

710  
00:24:45,590 --> 00:24:44,080  
look kind of reasonable right now if you

711  
00:24:46,950 --> 00:24:45,600  
really were standing there on mars

712  
00:24:48,549 --> 00:24:46,960  
studying that rock

713  
00:24:49,990 --> 00:24:48,559

you wouldn't be that big you'd be that

714

00:24:51,750 --> 00:24:50,000

big

715

00:24:54,230 --> 00:24:51,760

and unless you grew to about 20 feet

716

00:24:56,470 --> 00:24:54,240

tall while you walked you'd be that big

717

00:24:58,070 --> 00:24:56,480

over on the other side

718

00:25:00,710 --> 00:24:58,080

i tried very hard to make these

719

00:25:03,269 --> 00:25:00,720

measurements it's even hard to

720

00:25:04,789 --> 00:25:03,279

produce an accurate size when you're

721

00:25:06,630 --> 00:25:04,799

working with data that's only rendered

722

00:25:07,990 --> 00:25:06,640

this way now when you first looked at

723

00:25:09,750 --> 00:25:08,000

that image

724

00:25:11,669 --> 00:25:09,760

you probably didn't see anything that

725

00:25:13,350 --> 00:25:11,679

looked peculiar it probably looked

726

00:25:14,950 --> 00:25:13,360

normal probably looked like something

727

00:25:17,750 --> 00:25:14,960

you would just see outside your window

728

00:25:19,029 --> 00:25:17,760

if you were sitting there on mars

729

00:25:20,470 --> 00:25:19,039

if i had shown you a picture of

730

00:25:21,350 --> 00:25:20,480

something a little more familiar like

731

00:25:24,070 --> 00:25:21,360

this

732

00:25:26,390 --> 00:25:24,080

you which by the way is the exact same

733

00:25:27,590 --> 00:25:26,400

kind of image

734

00:25:29,110 --> 00:25:27,600

you would have instantly noticed that

735

00:25:31,029 --> 00:25:29,120

there was something a little bit odd

736

00:25:33,830 --> 00:25:31,039

because you've seen cities

737

00:25:35,909 --> 00:25:33,840

and they don't usually look like this

738

00:25:36,950 --> 00:25:35,919

now let me ask you a question a little

739

00:25:39,990 --> 00:25:36,960

quiz

740

00:25:41,590 --> 00:25:40,000

if you're there and you want to go there

741

00:25:42,950 --> 00:25:41,600

how would you do it and i'm going to

742

00:25:45,110 --> 00:25:42,960

pause for a second let you think about

743

00:25:47,110 --> 00:25:45,120

it how do you get from the arrow on the

744

00:25:48,230 --> 00:25:47,120

right to the arrow that's kind of in the

745

00:25:49,669 --> 00:25:48,240

middle there

746

00:25:51,590 --> 00:25:49,679

what's the path it would you would take

747

00:25:55,110 --> 00:25:51,600

where would you have to turn

748

00:25:59,350 --> 00:25:57,029

okay it's a trick question you would

749

00:26:01,830 --> 00:25:59,360

walk in a straight line it is on the

750

00:26:02,870 --> 00:26:01,840

same street you would walk directly down

751  
00:26:04,789 --> 00:26:02,880  
the street

752  
00:26:06,789 --> 00:26:04,799  
not turn at all and you would arrive

753  
00:26:08,149 --> 00:26:06,799  
immediately at your destination

754  
00:26:10,630 --> 00:26:08,159  
and if you were there you would

755  
00:26:12,149 --> 00:26:10,640  
certainly do just that

756  
00:26:13,110 --> 00:26:12,159  
how about an inside environment like

757  
00:26:16,149 --> 00:26:13,120  
this

758  
00:26:18,470 --> 00:26:16,159  
assembly room if you want to walk from

759  
00:26:21,269 --> 00:26:18,480  
that aisle over to that aisle no it's

760  
00:26:24,230 --> 00:26:21,279  
the same aisle same trick right

761  
00:26:26,070 --> 00:26:24,240  
it is really if you can see the footpath

762  
00:26:28,149 --> 00:26:26,080  
down across the bottom there see that

763  
00:26:33,190 --> 00:26:28,159

little curve

764

00:26:37,110 --> 00:26:34,710

when we see things that are familiar to

765

00:26:38,789 --> 00:26:37,120

us projected this way we immediately

766

00:26:40,470 --> 00:26:38,799

recognize that they're not an accurate

767

00:26:43,110 --> 00:26:40,480

representation of the way the world

768

00:26:45,110 --> 00:26:43,120

really is they're still challenging to

769

00:26:47,269 --> 00:26:45,120

interpret even when we do know even if

770

00:26:48,310 --> 00:26:47,279

you know that this room actually looks

771

00:26:50,390 --> 00:26:48,320

like that

772

00:26:53,430 --> 00:26:50,400

it's still really hard to try to map

773

00:26:55,190 --> 00:26:53,440

those things to each other to each other

774

00:26:56,789 --> 00:26:55,200

it gets even worse if things are moving

775

00:26:57,909 --> 00:26:56,799

good thing we don't do extreme sports

776

00:26:59,990 --> 00:26:57,919

this way right

777

00:27:02,549 --> 00:27:00,000

watch your friend on the red jacket here

778

00:27:07,669 --> 00:27:02,559

does that make sense

779

00:27:11,430 --> 00:27:09,350

that's pretty peculiar

780

00:27:13,909 --> 00:27:11,440

what's going on here

781

00:27:15,990 --> 00:27:13,919

the bottom line is is that we are not

782

00:27:17,590 --> 00:27:16,000

evolved or taught

783

00:27:18,549 --> 00:27:17,600

to view and understand the world this

784

00:27:21,269 --> 00:27:18,559

way

785

00:27:23,990 --> 00:27:21,279

and even with great mental effort

786

00:27:26,149 --> 00:27:24,000

we cannot enforce a model of the world

787

00:27:27,590 --> 00:27:26,159

that makes sense on the data that looks

788

00:27:30,870 --> 00:27:27,600

like that

789

00:27:35,269 --> 00:27:33,350

so what are we going to do about it

790

00:27:37,269 --> 00:27:35,279

how can we show things to people what

791

00:27:38,870 --> 00:27:37,279

kind of an environment can you put them

792

00:27:40,310 --> 00:27:38,880

in that would make them feel a little

793

00:27:43,190 --> 00:27:40,320

bit more like they're there who could we

794

00:27:46,630 --> 00:27:45,350

video games again

795

00:27:49,350 --> 00:27:46,640

so i wish i could tell you that this was

796

00:27:50,870 --> 00:27:49,360

a video of me you know out snowboarding

797

00:27:52,310 --> 00:27:50,880

although

798

00:27:54,950 --> 00:27:52,320

i hope there's no one in this audience

799

00:27:56,549 --> 00:27:54,960

that snowboards this way

800

00:27:57,909 --> 00:27:56,559

i've forgotten the name of this this

801  
00:27:59,669 --> 00:27:57,919  
snowboarding game but i put it here to

802  
00:28:01,190 --> 00:27:59,679  
make a point which is that video game

803  
00:28:02,950 --> 00:28:01,200  
industry

804  
00:28:05,190 --> 00:28:02,960  
is all about immersion

805  
00:28:06,950 --> 00:28:05,200  
it's about trying to make you feel like

806  
00:28:09,110 --> 00:28:06,960  
you're in a place that either doesn't

807  
00:28:11,110 --> 00:28:09,120  
exist or a place that you would never go

808  
00:28:12,950 --> 00:28:11,120  
in your right mind

809  
00:28:15,990 --> 00:28:12,960  
and give imbue you with powers that you

810  
00:28:18,549 --> 00:28:16,000  
would never have in those environments

811  
00:28:22,149 --> 00:28:18,559  
i'll also point out that they build

812  
00:28:24,389 --> 00:28:22,159  
immersion with a budget that far exceeds

813  
00:28:27,990 --> 00:28:24,399

all of the world's space exploration

814

00:28:31,750 --> 00:28:28,830

no

815

00:28:33,510 --> 00:28:31,760

jokes so

816

00:28:35,750 --> 00:28:33,520

they don't only do it with

817

00:28:37,510 --> 00:28:35,760

cool renderings like that they also do

818

00:28:39,669 --> 00:28:37,520

it with amazing devices

819

00:28:40,549 --> 00:28:39,679

so here are just a few examples

820

00:28:46,070 --> 00:28:40,559

of

821

00:28:47,190 --> 00:28:46,080

many millions into usability and human

822

00:28:49,110 --> 00:28:47,200

interaction

823

00:28:51,590 --> 00:28:49,120

controllers that sort of just beg to be

824

00:28:53,909 --> 00:28:51,600

held head mounted displays body tracking

825

00:28:56,389 --> 00:28:53,919

systems motion tracking systems these

826

00:28:59,750 --> 00:28:56,399

are all tools to try to make you feel

827

00:29:01,750 --> 00:28:59,760

more like you're in the game

828

00:29:02,549 --> 00:29:01,760

okay so you may be looking at this and

829

00:29:03,590 --> 00:29:02,559

saying

830

00:29:04,789 --> 00:29:03,600

gimmicks

831

00:29:06,710 --> 00:29:04,799

these don't really make that big of a

832

00:29:08,230 --> 00:29:06,720

difference well i'm going to make a

833

00:29:09,909 --> 00:29:08,240

pretty impassioned argument to the

834

00:29:12,070 --> 00:29:09,919

contrary starting with just a very

835

00:29:14,149 --> 00:29:12,080

simple example

836

00:29:15,510 --> 00:29:14,159

if you don't like roller coasters you

837

00:29:17,430 --> 00:29:15,520

might want to close your eyes for just a

838

00:29:18,870 --> 00:29:17,440

second because we're going to go on a

839

00:29:20,310 --> 00:29:18,880

little bit of a ride

840

00:29:22,549 --> 00:29:20,320

there's nothing really magical here

841

00:29:24,789 --> 00:29:22,559

we've just stuck a camera on the front

842

00:29:27,110 --> 00:29:24,799

of using a roller coaster here and we're

843

00:29:28,789 --> 00:29:27,120

going to see what it feels like to go

844

00:29:30,470 --> 00:29:28,799

down this now

845

00:29:33,590 --> 00:29:30,480

all right here we go

846

00:29:33,600 --> 00:29:37,909

do you feel something

847

00:29:42,950 --> 00:29:39,669

do you feel

848

00:29:46,230 --> 00:29:44,470

why

849

00:29:47,909 --> 00:29:46,240

you're sitting in an auditorium you're

850

00:29:49,269 --> 00:29:47,919

looking at a screen that's 30 40 feet

851  
00:29:51,269 --> 00:29:49,279  
away from some of you

852  
00:29:52,389 --> 00:29:51,279  
why does it feel like you might be

853  
00:29:53,750 --> 00:29:52,399  
moving

854  
00:29:55,190 --> 00:29:53,760  
why did it feel more like you were

855  
00:29:56,230 --> 00:29:55,200  
moving when i made it just a little bit

856  
00:29:58,389 --> 00:29:56,240  
bigger

857  
00:30:00,470 --> 00:29:58,399  
this is first in a number of examples

858  
00:30:01,269 --> 00:30:00,480  
i'm going to give that i would say are

859  
00:30:03,750 --> 00:30:01,279  
just

860  
00:30:05,430 --> 00:30:03,760  
sort of a little bit of a funny proof of

861  
00:30:07,190 --> 00:30:05,440  
the fact that we are a little more

862  
00:30:09,269 --> 00:30:07,200  
simple than any of us really want to

863  
00:30:11,350 --> 00:30:09,279

believe

864

00:30:12,470 --> 00:30:11,360

just by covering a little bit more of

865

00:30:14,230 --> 00:30:12,480

your retina

866

00:30:15,909 --> 00:30:14,240

and making things go rush past you like

867

00:30:20,070 --> 00:30:15,919

that you get a little feeling in your

868

00:30:24,549 --> 00:30:22,149

now let's take this a step further what

869

00:30:26,470 --> 00:30:24,559

if you take a person who's a little bit

870

00:30:28,230 --> 00:30:26,480

afraid of roller coasters

871

00:30:30,310 --> 00:30:28,240

and you put them inside a head-mounted

872

00:30:32,230 --> 00:30:30,320

display

873

00:30:43,950 --> 00:30:32,240

in which they ride a roller coaster

874

00:30:43,960 --> 00:31:01,990

oh my gosh

875

00:31:06,310 --> 00:31:03,430

i don't want to play anymore he just

876  
00:31:06,320 --> 00:31:13,110  
it's great to have friends

877  
00:31:13,120 --> 00:31:15,669  
listen

878  
00:31:20,310 --> 00:31:17,430  
get this off again

879  
00:31:22,230 --> 00:31:20,320  
he's hyperventilating at the end okay

880  
00:31:23,669 --> 00:31:22,240  
so you know we can wonder whether it was

881  
00:31:25,350 --> 00:31:23,679  
really particularly kind of his friends

882  
00:31:27,510 --> 00:31:25,360  
to put him through that but let's take a

883  
00:31:29,350 --> 00:31:27,520  
look here these are grown adults

884  
00:31:30,789 --> 00:31:29,360  
they know where they are they know that

885  
00:31:32,230 --> 00:31:30,799  
they're sitting in a chair in their home

886  
00:31:34,470 --> 00:31:32,240  
they know that just 30 seconds ago they

887  
00:31:36,389 --> 00:31:34,480  
were talking with their friends

888  
00:31:37,990 --> 00:31:36,399

why are they reacting this way

889

00:31:40,389 --> 00:31:38,000

why are they scared of something that

890

00:31:41,990 --> 00:31:40,399

they know isn't a rollercoaster

891

00:31:43,590 --> 00:31:42,000

again i think it's because we're a

892

00:31:45,430 --> 00:31:43,600

little more simple than any of us want

893

00:31:47,269 --> 00:31:45,440

to really think that we are

894

00:31:49,909 --> 00:31:47,279

let's look at one other example

895

00:31:51,269 --> 00:31:49,919

continuing with the theme of terror

896

00:31:54,070 --> 00:31:51,279

here is a

897

00:31:55,830 --> 00:31:54,080

scary game played by more grown adults

898

00:31:57,430 --> 00:31:55,840

who are used to scary movies and scary

899

00:32:10,870 --> 00:31:57,440

video games all is going to happen is

900

00:32:16,149 --> 00:32:12,950

i don't want to be

901  
00:32:17,509 --> 00:32:16,159  
anymore man

902  
00:32:29,350 --> 00:32:17,519  
i don't want to be in here anymore is

903  
00:32:29,360 --> 00:32:34,870  
oh my god

904  
00:32:40,230 --> 00:32:37,590  
no no no no no no no no no no

905  
00:32:42,470 --> 00:32:40,240  
no no no no no no no no

906  
00:32:45,750 --> 00:32:42,480  
no no no no no

907  
00:32:58,870 --> 00:32:48,470  
okay

908  
00:33:01,269 --> 00:32:58,880  
oh i'm done all right these

909  
00:33:03,669 --> 00:33:01,279  
i love these examples

910  
00:33:06,230 --> 00:33:03,679  
how can grown men

911  
00:33:07,509 --> 00:33:06,240  
be terrified of a video game like this

912  
00:33:09,669 --> 00:33:07,519  
well

913  
00:33:11,350 --> 00:33:09,679

i incidentally this last person here

914

00:33:13,830 --> 00:33:11,360

wrote in his comments on his youtube

915

00:33:15,990 --> 00:33:13,840

video that this was the most terrifying

916

00:33:17,590 --> 00:33:16,000

video game movie book whatever

917

00:33:19,509 --> 00:33:17,600

experience that he'd ever had in his

918

00:33:20,870 --> 00:33:19,519

life

919

00:33:22,630 --> 00:33:20,880

there's some critical things that are

920

00:33:25,190 --> 00:33:22,640

happening here complete

921

00:33:26,470 --> 00:33:25,200

isolation of the visual field of the

922

00:33:27,430 --> 00:33:26,480

player

923

00:33:28,950 --> 00:33:27,440

audio

924

00:33:33,430 --> 00:33:28,960

three-dimensional isolation of their

925

00:33:38,630 --> 00:33:36,310

there are factors here working together

926  
00:33:39,830 --> 00:33:38,640  
to make these people willing to accept

927  
00:33:42,149 --> 00:33:39,840  
the environment that they're being

928  
00:33:44,230 --> 00:33:42,159  
presented with this is what immersion

929  
00:33:47,430 --> 00:33:44,240  
looks like and here it's being used for

930  
00:33:51,509 --> 00:33:47,440  
entertainment to scare to shock

931  
00:33:53,509 --> 00:33:51,519  
how can we use it for exploration

932  
00:33:56,630 --> 00:33:53,519  
i'm going to contend that when you

933  
00:33:58,950 --> 00:33:56,640  
accomplish this kind of immersion

934  
00:34:00,950 --> 00:33:58,960  
you are making it possible for humans to

935  
00:34:02,549 --> 00:34:00,960  
use those innate abilities that i was

936  
00:34:04,830 --> 00:34:02,559  
talking about at the beginning of the

937  
00:34:10,869 --> 00:34:04,840  
talk so i'm going to give

938  
00:34:23,270 --> 00:34:13,190

of how my lab is using these kinds of

939

00:34:27,750 --> 00:34:24,869

okay

940

00:34:29,829 --> 00:34:27,760

so what i have here is an oculus rift it

941

00:34:31,270 --> 00:34:29,839

is a head mounted display

942

00:34:33,190 --> 00:34:31,280

in active development right now by a

943

00:34:35,109 --> 00:34:33,200

team in long beach we've been partnering

944

00:34:36,069 --> 00:34:35,119

with them for some time

945

00:34:37,829 --> 00:34:36,079

may have seen some of them on the

946

00:34:39,990 --> 00:34:37,839

internet

947

00:34:42,230 --> 00:34:40,000

it's a couple of screens placed very

948

00:34:43,829 --> 00:34:42,240

close to your eyes with optics in front

949

00:34:46,230 --> 00:34:43,839

of them

950

00:34:48,230 --> 00:34:46,240

and a device in here that is keeping

951  
00:34:50,790 --> 00:34:48,240  
track of which way it's facing so as i

952  
00:34:52,790 --> 00:34:50,800  
turn it i've got a scene

953  
00:34:55,190 --> 00:34:52,800  
that was taken shortly after curiosity's

954  
00:34:56,310 --> 00:34:55,200  
landing up there so if i put this on my

955  
00:34:58,950 --> 00:34:56,320  
face here

956  
00:35:00,150 --> 00:34:58,960  
i also see it in stereo

957  
00:35:01,910 --> 00:35:00,160  
so that means that i'm getting a

958  
00:35:03,990 --> 00:35:01,920  
different version on my left eye than my

959  
00:35:05,510 --> 00:35:04,000  
right eye and it helps me to sense how

960  
00:35:07,349 --> 00:35:05,520  
far things are away

961  
00:35:08,550 --> 00:35:07,359  
i can actually go to a few other places

962  
00:35:11,430 --> 00:35:08,560  
on mars here

963  
00:35:13,030 --> 00:35:11,440

and i want to talk about what happens

964

00:35:14,230 --> 00:35:13,040

in a system like this

965

00:35:18,069 --> 00:35:14,240

because

966

00:35:23,430 --> 00:35:19,270

is

967

00:35:25,670 --> 00:35:23,440

on the screens

968

00:35:27,589 --> 00:35:25,680

this sense of which way i'm turning my

969

00:35:30,150 --> 00:35:27,599

head it's often called the kinesthetic

970

00:35:31,670 --> 00:35:30,160

or somatosensory sense it's the part of

971

00:35:33,349 --> 00:35:31,680

our brain that's responsible for knowing

972

00:35:36,150 --> 00:35:33,359

where our body is

973

00:35:38,310 --> 00:35:36,160

when you synchronize that sense with

974

00:35:40,870 --> 00:35:38,320

what's coming into your eyes

975

00:35:42,630 --> 00:35:40,880

your brain immediately takes a jump in

976  
00:35:44,550 --> 00:35:42,640  
how it can put an environment like this

977  
00:35:48,550 --> 00:35:44,560  
together

978  
00:35:52,150 --> 00:35:49,829  
i want to show you one thing it doesn't

979  
00:35:53,510 --> 00:35:52,160  
do remember this because i'll

980  
00:35:54,710 --> 00:35:53,520  
give you an example later about how

981  
00:35:56,710 --> 00:35:54,720  
we're dealing with it

982  
00:36:00,390 --> 00:35:56,720  
so i can turn it keeps track of which

983  
00:36:02,150 --> 00:36:00,400  
way it's facing but if i slide it

984  
00:36:03,829 --> 00:36:02,160  
hard to hold it still enough

985  
00:36:05,910 --> 00:36:03,839  
nothing changes

986  
00:36:07,190 --> 00:36:05,920  
so it's not actually keeping track of

987  
00:36:10,829 --> 00:36:07,200  
its position

988  
00:36:14,150 --> 00:36:10,839

it's keeping track of its orientation

989

00:36:16,470 --> 00:36:14,160

okay what's the next step

990

00:36:18,150 --> 00:36:16,480

we've got

991

00:36:21,750 --> 00:36:18,160

our eyes

992

00:36:28,390 --> 00:36:22,790

neck

993

00:36:33,589 --> 00:36:29,990

but we're not able to move around in the

994

00:36:36,630 --> 00:36:33,599

environment we're only able to

995

00:36:37,910 --> 00:36:36,640

control which way we're facing

996

00:36:40,310 --> 00:36:37,920

so the next demonstration i'm going to

997

00:36:41,750 --> 00:36:40,320

show you

998

00:36:43,750 --> 00:36:41,760

allows us to start moving around

999

00:36:48,150 --> 00:36:43,760

although in a basic way in a different

1000

00:36:53,430 --> 00:36:50,150

okay have a second for this data to load

1001  
00:36:55,109 --> 00:36:53,440  
in the data that you're going to see

1002  
00:36:56,230 --> 00:36:55,119  
here

1003  
00:36:57,510 --> 00:36:56,240  
is all acquired from the mars

1004  
00:36:58,870 --> 00:36:57,520  
reconnaissance orbiter so it's going to

1005  
00:37:00,390 --> 00:36:58,880  
look a little bit blurry but it's real

1006  
00:37:01,750 --> 00:37:00,400  
data of marsh

1007  
00:37:03,109 --> 00:37:01,760  
and i'm going to put on this headset and

1008  
00:37:09,589 --> 00:37:03,119  
i'm going to really put it on this time

1009  
00:37:13,990 --> 00:37:11,510  
the way i'm going to move around is with

1010  
00:37:15,430 --> 00:37:14,000  
this joystick this game pad so i can

1011  
00:37:16,790 --> 00:37:15,440  
look

1012  
00:37:18,710 --> 00:37:16,800  
and see things in different directions

1013  
00:37:20,550 --> 00:37:18,720

just like i could before but now i can

1014

00:37:22,790 --> 00:37:20,560

also move

1015

00:37:24,150 --> 00:37:22,800

so i'm going to move over here to

1016

00:37:26,550 --> 00:37:24,160

where we have the curiosity rover

1017

00:37:28,870 --> 00:37:26,560

waiting for me

1018

00:37:30,710 --> 00:37:28,880

looking around it's like a nice place

1019

00:37:31,670 --> 00:37:30,720

this is in gale crater incidentally this

1020

00:37:33,109 --> 00:37:31,680

is in

1021

00:37:35,030 --> 00:37:33,119

curiosity's landing site although it's

1022

00:37:37,910 --> 00:37:35,040

not currently located right here

1023

00:37:39,510 --> 00:37:37,920

and i can look around this robot now in

1024

00:37:41,990 --> 00:37:39,520

different directions from different

1025

00:37:43,829 --> 00:37:42,000

directions i'm using this gamepad here

1026

00:37:45,510 --> 00:37:43,839

to pick where i'm standing

1027

00:37:48,829 --> 00:37:45,520

and then i'm using

1028

00:37:53,270 --> 00:37:51,750

checking to decide where i'm looking so

1029

00:37:55,510 --> 00:37:53,280

i can you know get up here and take a

1030

00:37:57,109 --> 00:37:55,520

closer look at the mast

1031

00:37:59,670 --> 00:37:57,119

now what happened there you see me

1032

00:38:01,990 --> 00:37:59,680

trying to slide my head again

1033

00:38:03,270 --> 00:38:02,000

nothing's happening right because again

1034

00:38:04,470 --> 00:38:03,280

it's tracking the direction that i'm

1035

00:38:06,230 --> 00:38:04,480

looking

1036

00:38:08,230 --> 00:38:06,240

but not the position the only position

1037

00:38:10,230 --> 00:38:08,240

control i have is here there's another

1038

00:38:12,710 --> 00:38:10,240

problem though which is that

1039

00:38:15,670 --> 00:38:12,720

you and i do not move through the world

1040

00:38:16,829 --> 00:38:15,680

using a thumb stick

1041

00:38:18,870 --> 00:38:16,839

we

1042

00:38:21,349 --> 00:38:18,880

walk so another thing that's kind of

1043

00:38:23,750 --> 00:38:21,359

interesting about this is that i find

1044

00:38:26,150 --> 00:38:23,760

moving around in an environment

1045

00:38:28,069 --> 00:38:26,160

wearing a head-mounted display

1046

00:38:30,950 --> 00:38:28,079

using a controller like this fairly

1047

00:38:34,310 --> 00:38:30,960

disorienting and the reason why is that

1048

00:38:36,550 --> 00:38:34,320

the motion of my virtual body is not in

1049

00:38:38,069 --> 00:38:36,560

sync with what i'm seeing on the goggles

1050

00:38:39,670 --> 00:38:38,079

anymore

1051

00:38:41,589 --> 00:38:39,680

so remember that kinesthetic sense i was

1052

00:38:43,270 --> 00:38:41,599

talking about when the neck and what you

1053

00:38:45,190 --> 00:38:43,280

see in your eyes is in sync well all of

1054

00:38:46,790 --> 00:38:45,200

a sudden now what i'm seeing in my eyes

1055

00:38:48,390 --> 00:38:46,800

is out of sync with my body because my

1056

00:38:50,550 --> 00:38:48,400

kinesthetic sense says you are standing

1057

00:38:52,630 --> 00:38:50,560

still your legs are not moving

1058

00:38:54,150 --> 00:38:52,640

but the scene is moving this is why

1059

00:38:55,670 --> 00:38:54,160

sometimes people get motion sick in a

1060

00:38:57,510 --> 00:38:55,680

situation like this because actually

1061

00:38:58,790 --> 00:38:57,520

what your brain is saying is this does

1062

00:39:00,470 --> 00:38:58,800

not make sense

1063

00:39:02,390 --> 00:39:00,480

and i think you may have ingested some

1064

00:39:04,550 --> 00:39:02,400

kind of poison which is making you

1065

00:39:05,990 --> 00:39:04,560

hallucinogenic and so maybe it should

1066

00:39:06,870 --> 00:39:06,000

all come out of your stomach now which

1067

00:39:08,710 --> 00:39:06,880

is why

1068

00:39:09,589 --> 00:39:08,720

you start to feel sick to your stomach

1069

00:39:12,150 --> 00:39:09,599

so

1070

00:39:19,910 --> 00:39:12,160

we don't want that to happen of course

1071

00:39:24,069 --> 00:39:21,829

well we could allow ourselves to move

1072

00:39:25,670 --> 00:39:24,079

around by walking

1073

00:39:28,710 --> 00:39:25,680

this is an omnidirectional treadmill

1074

00:39:31,109 --> 00:39:28,720

called the virtuex omni and was in our

1075

00:39:33,670 --> 00:39:31,119

lab recently and that's brian duran one

1076

00:39:35,030 --> 00:39:33,680

of the members of our lab uh walking

1077

00:39:36,150 --> 00:39:35,040

around in that same scene that i was

1078

00:39:37,910 --> 00:39:36,160

just in

1079

00:39:40,550 --> 00:39:37,920

so the omni is kind of interesting it

1080

00:39:43,589 --> 00:39:40,560

accomplishes this feat by really being a

1081

00:39:45,670 --> 00:39:43,599

carefully engineered slippery bowl

1082

00:39:47,589 --> 00:39:45,680

it's really that

1083

00:39:49,670 --> 00:39:47,599

so you wear special shoes and when you

1084

00:39:51,109 --> 00:39:49,680

step outside the center you kind of

1085

00:39:53,510 --> 00:39:51,119

slide back towards the middle i'll show

1086

00:39:54,390 --> 00:39:53,520

it to you here again in a second

1087

00:39:56,150 --> 00:39:54,400

so

1088

00:39:57,270 --> 00:39:56,160

there's nothing no motorized no motors

1089

00:39:58,310 --> 00:39:57,280

or anything down there you're just

1090

00:40:00,310 --> 00:39:58,320

sliding back to the center and you're

1091

00:40:02,710 --> 00:40:00,320

balancing yourself a little bit on that

1092

00:40:04,069 --> 00:40:02,720

that waistband thing to uh because it's

1093

00:40:05,750 --> 00:40:04,079

sort of slippery

1094

00:40:08,150 --> 00:40:05,760

you can also wear a belt that will you

1095

00:40:11,430 --> 00:40:08,160

know keep you uh supported on that ring

1096

00:40:14,390 --> 00:40:11,440

that's around your waist

1097

00:40:16,069 --> 00:40:14,400

if you use a system like this one

1098

00:40:17,670 --> 00:40:16,079

i think that you would find

1099

00:40:20,150 --> 00:40:17,680

that that effect i was talking about

1100

00:40:22,790 --> 00:40:20,160

about moving around with a joystick is

1101  
00:40:27,030 --> 00:40:22,800  
less because now the scene moves when

1102  
00:40:29,270 --> 00:40:27,040  
your body moves so as you walk

1103  
00:40:31,030 --> 00:40:29,280  
the scene moves as if you're walking and

1104  
00:40:33,270 --> 00:40:31,040  
your body feels your legs moving and

1105  
00:40:34,950 --> 00:40:33,280  
sees the scene moving so less of that

1106  
00:40:37,750 --> 00:40:34,960  
discontinuity you know where your brain

1107  
00:40:39,109 --> 00:40:37,760  
says this doesn't make sense

1108  
00:40:40,870 --> 00:40:39,119  
we still don't have the position of the

1109  
00:40:42,470 --> 00:40:40,880  
head though right turns out that the

1110  
00:40:45,030 --> 00:40:42,480  
position of the head is really really

1111  
00:40:46,310 --> 00:40:45,040  
important you're using it right now you

1112  
00:40:47,750 --> 00:40:46,320  
may not really realize it but you're

1113  
00:40:49,829 --> 00:40:47,760

pretty much spending your whole life

1114

00:40:51,589 --> 00:40:49,839

going like this

1115

00:40:53,910 --> 00:40:51,599

and by doing this you can start to get a

1116

00:40:55,829 --> 00:40:53,920

feeling for how far things are away how

1117

00:40:57,109 --> 00:40:55,839

much room there is you know could you

1118

00:40:58,470 --> 00:40:57,119

fit through there could you could you

1119

00:41:00,390 --> 00:40:58,480

make it out that door or something like

1120

00:41:03,190 --> 00:41:00,400

that

1121

00:41:04,710 --> 00:41:03,200

so here's what we can do to start also

1122

00:41:07,270 --> 00:41:04,720

tracking the head this is victor louelle

1123

00:41:09,190 --> 00:41:07,280

another member of our lab

1124

00:41:10,390 --> 00:41:09,200

he's got the oculus rift on again but

1125

00:41:13,190 --> 00:41:10,400

we're tracking it with these little

1126

00:41:15,589 --> 00:41:13,200

markers which are observed by these

1127

00:41:17,109 --> 00:41:15,599

cameras it's a vikon bonita system

1128

00:41:18,630 --> 00:41:17,119

same sort of like motion capture system

1129

00:41:19,910 --> 00:41:18,640

that they use in movies for character

1130

00:41:22,069 --> 00:41:19,920

animation

1131

00:41:23,510 --> 00:41:22,079

so using that we can not only keep track

1132

00:41:26,790 --> 00:41:23,520

of which way

1133

00:41:29,430 --> 00:41:26,800

the display is facing but also where the

1134

00:41:30,950 --> 00:41:29,440

display is within that space so we've

1135

00:41:32,630 --> 00:41:30,960

also dialed up the detail quite a lot

1136

00:41:34,230 --> 00:41:32,640

here we're also including the surface

1137

00:41:36,390 --> 00:41:34,240

detail in addition to orbital

1138

00:41:38,150 --> 00:41:36,400

information all blended in with pictures

1139

00:41:41,190 --> 00:41:38,160

taken by the robot as well

1140

00:41:43,349 --> 00:41:41,200

so when victor stands up looks around

1141

00:41:45,030 --> 00:41:43,359

when he starts walking in this

1142

00:41:46,550 --> 00:41:45,040

environment as he's going to do right

1143

00:41:49,190 --> 00:41:46,560

here

1144

00:41:51,910 --> 00:41:49,200

the scene changes as if he's walking

1145

00:41:54,230 --> 00:41:51,920

around in that same spot on mars he can

1146

00:41:55,349 --> 00:41:54,240

crouch down and take a new perspective

1147

00:41:57,190 --> 00:41:55,359

on the scene

1148

00:41:59,349 --> 00:41:57,200

study a wheel

1149

00:42:00,870 --> 00:41:59,359

he can use that head parallax that i was

1150

00:42:02,870 --> 00:42:00,880

talking about moving your head back and

1151  
00:42:04,230 --> 00:42:02,880  
forth to get a feeling for how are those

1152  
00:42:06,550 --> 00:42:04,240  
things really situated in the

1153  
00:42:08,309 --> 00:42:06,560  
environment how big are they how much

1154  
00:42:10,470 --> 00:42:08,319  
room is there in between them you can

1155  
00:42:12,390 --> 00:42:10,480  
really start to sort of feel how large

1156  
00:42:15,430 --> 00:42:12,400  
things are in the environment that he's

1157  
00:42:17,589 --> 00:42:15,440  
been asked to explore

1158  
00:42:19,349 --> 00:42:17,599  
so let's review those three ingredients

1159  
00:42:21,190 --> 00:42:19,359  
we put together there

1160  
00:42:23,190 --> 00:42:21,200  
we connected what you see with the

1161  
00:42:24,710 --> 00:42:23,200  
direction you're facing with where your

1162  
00:42:26,790 --> 00:42:24,720  
neck is pointing

1163  
00:42:28,150 --> 00:42:26,800

we made it possible for you to move by

1164

00:42:30,309 --> 00:42:28,160

walking

1165

00:42:33,030 --> 00:42:30,319

and we kept track of your point of view

1166

00:42:35,510 --> 00:42:33,040

by tracking the position of your head

1167

00:42:37,589 --> 00:42:35,520

those three ingredients turn out to be a

1168

00:42:39,109 --> 00:42:37,599

really really great combination

1169

00:42:40,950 --> 00:42:39,119

and then although the system is still

1170

00:42:42,150 --> 00:42:40,960

early and we still have more research to

1171

00:42:43,670 --> 00:42:42,160

do and we have some studies that we're

1172

00:42:45,829 --> 00:42:43,680

going to be doing testing the the

1173

00:42:47,829 --> 00:42:45,839

efficacy of this comparing it with other

1174

00:42:49,670 --> 00:42:47,839

means of trying to understand

1175

00:42:51,270 --> 00:42:49,680

an environment that's being explored

1176  
00:42:52,870 --> 00:42:51,280  
we're very encouraged by the results

1177  
00:42:55,430 --> 00:42:52,880  
that we're seeing so far

1178  
00:43:01,030 --> 00:42:55,440  
i'm really looking forward to sharing

1179  
00:43:05,270 --> 00:43:03,030  
i wish i could bring all of you up here

1180  
00:43:09,829 --> 00:43:05,280  
right now

1181  
00:43:10,829 --> 00:43:09,839  
and believe me

1182  
00:43:13,510 --> 00:43:10,839  
in my

1183  
00:43:15,910 --> 00:43:13,520  
hopes what we're on is a path towards

1184  
00:43:17,990 --> 00:43:15,920  
where these kinds of technologies are

1185  
00:43:19,750 --> 00:43:18,000  
going to make it possible for all of us

1186  
00:43:21,750 --> 00:43:19,760  
to experience that but i wanted to give

1187  
00:43:24,309 --> 00:43:21,760  
you a little bit of taste of it tonight

1188  
00:43:25,349 --> 00:43:24,319

so i love doing live demos in my talks

1189

00:43:26,790 --> 00:43:25,359

and if i'm going to try to do something

1190

00:43:28,069 --> 00:43:26,800

even a little crazier here which is that

1191

00:43:30,230 --> 00:43:28,079

i'm going to try to do a demo that

1192

00:43:31,670 --> 00:43:30,240

involves all of you right now and

1193

00:43:32,710 --> 00:43:31,680

everybody out there who's watching on

1194

00:43:34,470 --> 00:43:32,720

online

1195

00:43:36,069 --> 00:43:34,480

so if you'll pull out your phone right

1196

00:43:38,550 --> 00:43:36,079

now yes i'm actually telling you at a

1197

00:43:40,230 --> 00:43:38,560

talk to pull out your phone which i know

1198

00:43:43,510 --> 00:43:40,240

is a little bit rare a little bit out of

1199

00:43:46,790 --> 00:43:45,349

type in that url that's at the top into

1200

00:43:48,630 --> 00:43:46,800

the browser and i should warn you that

1201  
00:43:49,990 --> 00:43:48,640  
if you have an iphone 4 or 5 this is

1202  
00:43:51,990 --> 00:43:50,000  
going to work

1203  
00:43:54,309 --> 00:43:52,000  
really well if you have an android phone

1204  
00:43:55,910 --> 00:43:54,319  
it may not work quite as well turns out

1205  
00:43:58,870 --> 00:43:55,920  
that different phones have a different

1206  
00:44:00,790 --> 00:43:58,880  
amount of noise in the gyroscope which

1207  
00:44:03,030 --> 00:44:00,800  
is keeping track of which way the phone

1208  
00:44:04,710 --> 00:44:03,040  
is facing so if it starts to get really

1209  
00:44:05,750 --> 00:44:04,720  
jittery and shaky on you first of all

1210  
00:44:07,190 --> 00:44:05,760  
make sure that you've turned your phone

1211  
00:44:08,550 --> 00:44:07,200  
this way and that you're holding it sort

1212  
00:44:10,950 --> 00:44:08,560  
of like you would if you were taking a

1213  
00:44:13,430 --> 00:44:10,960

picture by the way stand up

1214

00:44:15,190 --> 00:44:13,440

because it's a lot easier when you can

1215

00:44:17,910 --> 00:44:15,200

look around behind you

1216

00:44:19,109 --> 00:44:17,920

look around this environment

1217

00:44:20,829 --> 00:44:19,119

if you're having troubles with your

1218

00:44:30,870 --> 00:44:20,839

phone borrow your

1219

00:44:34,069 --> 00:44:32,150

and then move your phone around as if

1220

00:44:35,349 --> 00:44:34,079

you were sort of taking a picture and as

1221

00:44:36,710 --> 00:44:35,359

you turn around it's going to change

1222

00:44:38,870 --> 00:44:36,720

your perspective and it should give you

1223

00:44:40,230 --> 00:44:38,880

just a little taste of what i'm talking

1224

00:44:42,470 --> 00:44:40,240

about here

1225

00:44:44,390 --> 00:44:42,480

it's the same panorama that i challenged

1226  
00:44:46,069 --> 00:44:44,400  
you with those questions about early on

1227  
00:44:47,589 --> 00:44:46,079  
in the presentation the one where i was

1228  
00:44:49,109 --> 00:44:47,599  
asking you which way you would walk it's

1229  
00:44:51,430 --> 00:44:49,119  
the same panorama shown down here at the

1230  
00:44:54,230 --> 00:44:51,440  
bottom if you look down you'll see the

1231  
00:44:55,750 --> 00:44:54,240  
rover underneath

1232  
00:44:57,349 --> 00:44:55,760  
if you look

1233  
00:44:59,670 --> 00:44:57,359  
try to find the rover tracks in the

1234  
00:45:01,829 --> 00:44:59,680  
environment

1235  
00:45:08,150 --> 00:45:01,839  
you can look and see the hills out in

1236  
00:45:13,349 --> 00:45:09,510  
and then i want you

1237  
00:45:14,870 --> 00:45:13,359  
to try and mentally extend

1238  
00:45:16,470 --> 00:45:14,880

how this feels

1239

00:45:17,829 --> 00:45:16,480

with how it would feel with even more

1240

00:45:19,750 --> 00:45:17,839

technology because really this is a

1241

00:45:21,990 --> 00:45:19,760

cheap little trick this is a tiny little

1242

00:45:25,030 --> 00:45:22,000

technological trick

1243

00:45:27,589 --> 00:45:25,040

imagine what where is possible with more

1244

00:45:31,990 --> 00:45:27,599

technology with more efforts put into

1245

00:45:35,829 --> 00:45:33,430

so here's what gets me kind of excited

1246

00:45:37,270 --> 00:45:35,839

about this because i would believe that

1247

00:45:39,510 --> 00:45:37,280

right now

1248

00:45:41,670 --> 00:45:39,520

all of us in this room

1249

00:45:44,150 --> 00:45:41,680

and the people who are watching online

1250

00:45:48,150 --> 00:45:44,160

are standing on mars together and we're

1251

00:45:52,710 --> 00:45:50,790

and it's my hope

1252

00:45:54,870 --> 00:45:52,720

that when we come to a day like the day

1253

00:45:56,550 --> 00:45:54,880

when we first put an astronaut's boot on

1254

00:45:58,470 --> 00:45:56,560

that planet

1255

00:46:01,589 --> 00:45:58,480

that they're going to be a billion

1256

00:46:03,349 --> 00:46:01,599

people in attendance for that event

1257

00:46:04,230 --> 00:46:03,359

that they're going to be standing beside

1258

00:46:06,230 --> 00:46:04,240

them

1259

00:46:08,230 --> 00:46:06,240

standing beside each other and alongside

1260

00:46:10,390 --> 00:46:08,240

that astronaut on mars

1261

00:46:12,230 --> 00:46:10,400

i hope to see you all there and i thank

1262

00:46:13,109 --> 00:46:12,240

you very much for your attention this

1263

00:46:24,870 --> 00:46:13,119

evening

1264

00:46:27,829 --> 00:46:26,309

and i've left time for questions so i'm

1265

00:46:29,190 --> 00:46:27,839

happy to take them i'm supposed to

1266

00:46:30,950 --> 00:46:29,200

remind you that if you have a question

1267

00:46:32,470 --> 00:46:30,960

to please come to this microphone here

1268

00:46:34,790 --> 00:46:32,480

so that everybody can hear the question

1269

00:46:38,309 --> 00:46:34,800

as well as the people who are watching

1270

00:46:46,550 --> 00:46:39,430

and i'll leave this running for a while

1271

00:46:52,470 --> 00:46:49,510

uh at the beginning you showed the

1272

00:46:53,750 --> 00:46:52,480

projection of the

1273

00:46:57,109 --> 00:46:53,760

model

1274

00:47:00,150 --> 00:46:57,119

vehicle ahead used in the uncertainty

1275

00:47:04,390 --> 00:47:02,230

how do you how accurately can you

1276

00:47:07,670 --> 00:47:04,400

actually calculate where the boundaries

1277

00:47:09,589 --> 00:47:07,680

of that uncertainty cloud are and how do

1278

00:47:12,069 --> 00:47:09,599

you do that so it's challenging of

1279

00:47:12,950 --> 00:47:12,079

course uh we make models

1280

00:47:13,750 --> 00:47:12,960

of

1281

00:47:18,950 --> 00:47:13,760

the

1282

00:47:20,710 --> 00:47:18,960

terrain that we're driving in and

1283

00:47:21,430 --> 00:47:20,720

those models are actually they're

1284

00:47:24,710 --> 00:47:21,440

they're

1285

00:47:28,069 --> 00:47:24,720

that challenge of simulating and

1286

00:47:31,030 --> 00:47:28,079

modeling the interactions of robots with

1287

00:47:33,670 --> 00:47:31,040

surfaces with so wheels on dirt and how

1288

00:47:36,230 --> 00:47:33,680

they react so the answer is we do our

1289

00:47:38,790 --> 00:47:36,240

best and that uncertainty

1290

00:47:41,030 --> 00:47:38,800

volume is really an expression of

1291

00:47:43,990 --> 00:47:41,040

how poorly really we're doing meaning

1292

00:47:46,150 --> 00:47:44,000

that the larger that volume is the

1293

00:47:47,430 --> 00:47:46,160

the more error there is in our guesses

1294

00:47:49,190 --> 00:47:47,440

about where the robot's going to be if

1295

00:47:50,550 --> 00:47:49,200

we could predict perfectly there would

1296

00:47:52,230 --> 00:47:50,560

be no uncertainty volume there would be

1297

00:47:53,109 --> 00:47:52,240

just a point the robot will be exactly

1298

00:47:56,309 --> 00:47:53,119

here

1299

00:47:58,069 --> 00:47:56,319

so uh i think the answer would be um i

1300

00:48:00,230 --> 00:47:58,079

think we do it adequately well to make

1301  
00:48:02,470 --> 00:48:00,240  
this mode of operations reasonable but

1302  
00:48:03,430 --> 00:48:02,480  
there is much more room for improvement

1303  
00:48:06,150 --> 00:48:03,440  
well like

1304  
00:48:08,309 --> 00:48:06,160  
for example would like if it if it uh

1305  
00:48:09,910 --> 00:48:08,319  
the wheel hit a slipped on a rock or

1306  
00:48:11,510 --> 00:48:09,920  
something would that

1307  
00:48:13,030 --> 00:48:11,520  
add to the uncertainty something like

1308  
00:48:14,790 --> 00:48:13,040  
that absolutely yeah it's a wheel

1309  
00:48:16,390 --> 00:48:14,800  
slipping in soft soil

1310  
00:48:17,109 --> 00:48:16,400  
falling off of a rock things like that

1311  
00:48:19,670 --> 00:48:17,119  
now

1312  
00:48:21,270 --> 00:48:19,680  
we have measures on the mars rovers for

1313  
00:48:22,790 --> 00:48:21,280

instance that we can use to counteract

1314

00:48:24,950 --> 00:48:22,800

that one of them is called visual

1315

00:48:27,829 --> 00:48:24,960

odometry so when we have this

1316

00:48:30,150 --> 00:48:27,839

capability running on the robots

1317

00:48:31,750 --> 00:48:30,160

they can keep track of

1318

00:48:33,750 --> 00:48:31,760

how things are moving past them in the

1319

00:48:35,670 --> 00:48:33,760

environment visually so the the

1320

00:48:38,790 --> 00:48:35,680

challenges is that if you're only using

1321

00:48:40,870 --> 00:48:38,800

the rover's uh inertial measurement and

1322

00:48:42,710 --> 00:48:40,880

it's you know the turning of its wheels

1323

00:48:44,069 --> 00:48:42,720

there's a lot of drift is what we would

1324

00:48:45,750 --> 00:48:44,079

call there's a lot of error that builds

1325

00:48:47,910 --> 00:48:45,760

up over time something like visual

1326

00:48:50,069 --> 00:48:47,920

odometry reduces but doesn't eliminate

1327

00:48:52,069 --> 00:48:50,079

that error and also visual odometry at

1328

00:48:53,829 --> 00:48:52,079

times can be expensive to run it's a

1329

00:48:55,670 --> 00:48:53,839

computationally intensive task on the

1330

00:48:57,829 --> 00:48:55,680

robot so we don't always use it we

1331

00:48:58,950 --> 00:48:57,839

usually use it when we expect slip to be

1332

00:49:00,829 --> 00:48:58,960

very high

1333

00:49:03,270 --> 00:49:00,839

thank you

1334

00:49:07,349 --> 00:49:03,280

sure uh hello

1335

00:49:08,630 --> 00:49:07,359

uh was the dispute resolved between

1336

00:49:10,150 --> 00:49:08,640

uh jean

1337

00:49:12,309 --> 00:49:10,160

doggoff and

1338

00:49:14,470 --> 00:49:12,319

gene rotterdam

1339

00:49:17,670 --> 00:49:14,480

regarding the

1340

00:49:18,710 --> 00:49:17,680

control panel in the starship enterprise

1341

00:49:21,750 --> 00:49:18,720

when

1342

00:49:22,950 --> 00:49:21,760

rotterdam said well he couldn't really

1343

00:49:25,910 --> 00:49:22,960

get his

1344

00:49:27,990 --> 00:49:25,920

mind and the human brain around this

1345

00:49:30,150 --> 00:49:28,000

immersion

1346

00:49:32,950 --> 00:49:30,160

i really wish i could speak on that with

1347

00:49:35,670 --> 00:49:32,960

authority i you know although i uh you

1348

00:49:37,910 --> 00:49:35,680

know i'm a fan of the show i i can't say

1349

00:49:39,990 --> 00:49:37,920

that i remember that specific episode or

1350

00:49:45,270 --> 00:49:40,000

that specific question

1351  
00:49:48,950 --> 00:49:47,030  
um could you clarify a little bit on how

1352  
00:49:50,790 --> 00:49:48,960  
you plan on uh incorporating the two

1353  
00:49:52,309 --> 00:49:50,800  
technologies with like the movement

1354  
00:49:53,270 --> 00:49:52,319  
prediction and also the oculus rift

1355  
00:49:55,430 --> 00:49:53,280  
stuff

1356  
00:49:56,230 --> 00:49:55,440  
sure yeah so

1357  
00:49:59,670 --> 00:49:56,240  
um

1358  
00:50:00,870 --> 00:49:59,680  
when you consider that

1359  
00:50:02,710 --> 00:50:00,880  
observing the environment and

1360  
00:50:03,829 --> 00:50:02,720  
understanding is really understanding

1361  
00:50:05,349 --> 00:50:03,839  
the environment is really just sort of

1362  
00:50:07,829 --> 00:50:05,359  
part one of the challenge we also need

1363  
00:50:09,270 --> 00:50:07,839

to affect things in that environment uh

1364

00:50:11,030 --> 00:50:09,280

you can imagine that the second half of

1365

00:50:12,630 --> 00:50:11,040

the talk is sort of the observation and

1366

00:50:14,470 --> 00:50:12,640

understanding part and then the first

1367

00:50:17,510 --> 00:50:14,480

part of the talk is then how you then

1368

00:50:19,109 --> 00:50:17,520

begin to move in effect so you could

1369

00:50:21,430 --> 00:50:19,119

imagine

1370

00:50:23,750 --> 00:50:21,440

you know donning a system like this or

1371

00:50:25,829 --> 00:50:23,760

standing inside a you know a theater a

1372

00:50:28,470 --> 00:50:25,839

holodeck like theater planning where you

1373

00:50:30,150 --> 00:50:28,480

want to go and then using the time delay

1374

00:50:32,230 --> 00:50:30,160

mitigation strategies that i discussed

1375

00:50:33,910 --> 00:50:32,240

at the beginning to improve the

1376  
00:50:36,390 --> 00:50:33,920  
efficiency of what you're accomplishing

1377  
00:50:38,950 --> 00:50:36,400  
there so for instance being able to

1378  
00:50:40,710 --> 00:50:38,960  
direct it where to drive and then stay

1379  
00:50:43,829 --> 00:50:40,720  
ahead of it such that you're not wasting

1380  
00:50:45,589 --> 00:50:43,839  
a lot of time uh on mars i see would you

1381  
00:50:47,109 --> 00:50:45,599  
simulate like or

1382  
00:50:48,309 --> 00:50:47,119  
like a fake environment for the person

1383  
00:50:49,829 --> 00:50:48,319  
to see and then observe and then make

1384  
00:50:51,190 --> 00:50:49,839  
decisions that way

1385  
00:50:52,390 --> 00:50:51,200  
well you can fake something so for

1386  
00:50:54,470 --> 00:50:52,400  
instance like i showed with pitfall

1387  
00:50:56,390 --> 00:50:54,480  
harry right you and also with the

1388  
00:50:58,230 --> 00:50:56,400

committed state of the robot you would

1389

00:50:59,750 --> 00:50:58,240

certainly want to show them your best

1390

00:51:01,750 --> 00:50:59,760

guess about where the robot's going to

1391

00:51:03,750 --> 00:51:01,760

end up if you send those commands and i

1392

00:51:06,390 --> 00:51:03,760

think also it's a value to show them

1393

00:51:07,670 --> 00:51:06,400

that extra state the committed state of

1394

00:51:09,030 --> 00:51:07,680

where it would be if you stopped right

1395

00:51:10,470 --> 00:51:09,040

this moment

1396

00:51:12,790 --> 00:51:10,480

so you certainly want to fake those

1397

00:51:14,390 --> 00:51:12,800

things

1398

00:51:16,470 --> 00:51:14,400

i think that there's a trade-off when

1399

00:51:18,710 --> 00:51:16,480

you fake more that basically you're

1400

00:51:20,390 --> 00:51:18,720

trading the

1401  
00:51:21,589 --> 00:51:20,400  
efficiencies that you gain from being

1402  
00:51:23,910 --> 00:51:21,599  
able to get a little glimpse of what

1403  
00:51:25,829 --> 00:51:23,920  
might be coming with the risks that

1404  
00:51:27,510 --> 00:51:25,839  
you're taking if you're wrong and so i

1405  
00:51:29,270 --> 00:51:27,520  
would say you should predict as much as

1406  
00:51:31,349 --> 00:51:29,280  
you possibly can as long as you can

1407  
00:51:32,549 --> 00:51:31,359  
simultaneously communicate the

1408  
00:51:35,109 --> 00:51:32,559  
uncertainty you have in those

1409  
00:51:38,790 --> 00:51:35,119  
predictions so that people don't start

1410  
00:51:42,230 --> 00:51:38,800  
believing something that was only a gas

1411  
00:51:45,910 --> 00:51:44,230  
so the the fully immersive stuff is cool

1412  
00:51:46,870 --> 00:51:45,920  
but up into that point it seems like

1413  
00:51:48,630 --> 00:51:46,880

there's a

1414

00:51:51,109 --> 00:51:48,640

first step which is just generating that

1415

00:51:53,030 --> 00:51:51,119

sort of full 3d environment a prediction

1416

00:51:53,990 --> 00:51:53,040

of it about the rover how close are we

1417

00:51:55,190 --> 00:51:54,000

to being able to do that for mission

1418

00:51:56,549 --> 00:51:55,200

planning never mind the head mounted

1419

00:51:57,750 --> 00:51:56,559

displays but just

1420

00:51:59,829 --> 00:51:57,760

you know the

1421

00:52:02,309 --> 00:51:59,839

first person shooter style controls so

1422

00:52:04,710 --> 00:52:02,319

the 3d engineering environment yeah

1423

00:52:05,990 --> 00:52:04,720

okay uh

1424

00:52:08,470 --> 00:52:06,000

well first of all let's talk about the

1425

00:52:10,870 --> 00:52:08,480

sensors that we have on our robots to

1426  
00:52:14,390 --> 00:52:10,880  
feed such an environment so you know the

1427  
00:52:16,470 --> 00:52:14,400  
mars rovers for example have on them

1428  
00:52:18,309 --> 00:52:16,480  
a set of cameras on the mast which

1429  
00:52:20,870 --> 00:52:18,319  
points in different directions and it's

1430  
00:52:22,870 --> 00:52:20,880  
those images that we're using to render

1431  
00:52:25,030 --> 00:52:22,880  
the environment that you saw uh the one

1432  
00:52:27,349 --> 00:52:25,040  
where we were tracking the head position

1433  
00:52:28,710 --> 00:52:27,359  
uh the so the navigation camera pictures

1434  
00:52:29,990 --> 00:52:28,720  
were actually what we were showing there

1435  
00:52:31,910 --> 00:52:30,000  
we're not even actually showing the

1436  
00:52:33,910 --> 00:52:31,920  
highest resolution data that curiosity

1437  
00:52:35,510 --> 00:52:33,920  
can acquire which is with the mast cam

1438  
00:52:38,069 --> 00:52:35,520

we were just using the navigation images

1439

00:52:40,950 --> 00:52:38,079

which are good but lower resolution so i

1440

00:52:44,630 --> 00:52:40,960

think we are in a good place there we

1441

00:52:46,309 --> 00:52:44,640

um there are whole parts of jpl who have

1442

00:52:48,069 --> 00:52:46,319

really i think mastered the technique of

1443

00:52:49,910 --> 00:52:48,079

taking images

1444

00:52:51,829 --> 00:52:49,920

that are acquired in stereo so two

1445

00:52:54,549 --> 00:52:51,839

images and extracting ranged data from

1446

00:52:56,069 --> 00:52:54,559

it and then converting that into a

1447

00:52:58,870 --> 00:52:56,079

terrain model like the one that you were

1448

00:53:00,630 --> 00:52:58,880

seeing there now one challenge is then

1449

00:53:02,150 --> 00:53:00,640

effective rendering of that so i'll go

1450

00:53:03,349 --> 00:53:02,160

just a little bit more into depth about

1451  
00:53:04,470 --> 00:53:03,359  
some of the tricks we've been playing

1452  
00:53:05,589 --> 00:53:04,480  
there we had

1453  
00:53:07,270 --> 00:53:05,599  
actually a student who worked with us

1454  
00:53:08,790 --> 00:53:07,280  
this summer charlie goddard who did some

1455  
00:53:11,190 --> 00:53:08,800  
work in this area

1456  
00:53:14,710 --> 00:53:11,200  
and we're actually blending and i'll go

1457  
00:53:27,030 --> 00:53:14,720  
back to that video so you can see

1458  
00:53:34,390 --> 00:53:29,670  
okay so

1459  
00:53:39,109 --> 00:53:37,430  
okay um that's a little hard to see but

1460  
00:53:41,990 --> 00:53:39,119  
there's actually a couple kinds of data

1461  
00:53:45,270 --> 00:53:42,000  
being shown here up near the top are

1462  
00:53:46,710 --> 00:53:45,280  
two-dimensional images that are being so

1463  
00:53:48,390 --> 00:53:46,720

when the rover takes its pictures of

1464

00:53:50,790 --> 00:53:48,400

course it's just taking pictures you

1465

00:53:53,030 --> 00:53:50,800

know like photographs

1466

00:53:55,510 --> 00:53:53,040

we try to use those pictures as long as

1467

00:53:57,670 --> 00:53:55,520

we can because the date the detail that

1468

00:53:58,950 --> 00:53:57,680

a picture offers is very very high as

1469

00:54:00,630 --> 00:53:58,960

long as you're looking at the scene from

1470

00:54:02,230 --> 00:54:00,640

the same point of view as the picture

1471

00:54:04,230 --> 00:54:02,240

you can get a great deal of information

1472

00:54:06,069 --> 00:54:04,240

from from the photograph the problem is

1473

00:54:08,069 --> 00:54:06,079

when your head moves away from where

1474

00:54:09,990 --> 00:54:08,079

that picture was taken because that's

1475

00:54:11,750 --> 00:54:10,000

when the image no longer really makes

1476  
00:54:14,150 --> 00:54:11,760  
sense now one thing that charlie worked

1477  
00:54:16,710 --> 00:54:14,160  
on this summer was a way to use a

1478  
00:54:19,670 --> 00:54:16,720  
technique we were calling

1479  
00:54:21,430 --> 00:54:19,680  
disparity mapping to take pixels from

1480  
00:54:23,190 --> 00:54:21,440  
that image projected through the model

1481  
00:54:26,710 --> 00:54:23,200  
of the camera that we have

1482  
00:54:28,470 --> 00:54:26,720  
and shift them as your head moves and so

1483  
00:54:30,069 --> 00:54:28,480  
what that allows us to do is to hang on

1484  
00:54:32,309 --> 00:54:30,079  
to those images just a little bit longer

1485  
00:54:34,630 --> 00:54:32,319  
so if i move my head to the side we can

1486  
00:54:36,230 --> 00:54:34,640  
still show basically the right thing on

1487  
00:54:38,150 --> 00:54:36,240  
that image and if we go a little bit

1488  
00:54:40,230 --> 00:54:38,160

further we have to give up on the image

1489

00:54:42,870 --> 00:54:40,240

and we give up in favor of what you see

1490

00:54:45,109 --> 00:54:42,880

in the foreground of this video and that

1491

00:54:47,190 --> 00:54:45,119

is all point cloud data so point cloud

1492

00:54:49,510 --> 00:54:47,200

data is then taking those images which

1493

00:54:51,349 --> 00:54:49,520

give us information about how far away

1494

00:54:52,470 --> 00:54:51,359

things are in the environment and

1495

00:54:54,390 --> 00:54:52,480

rendering

1496

00:54:57,109 --> 00:54:54,400

a mesh you can think of it as a bunch of

1497

00:54:58,950 --> 00:54:57,119

dots connected together

1498

00:55:00,630 --> 00:54:58,960

that give you the the feeling that it's

1499

00:55:02,069 --> 00:55:00,640

a continuous scene we're actually using

1500

00:55:03,750 --> 00:55:02,079

a technique here called surfliit

1501

00:55:06,630 --> 00:55:03,760

rendering which another one of our

1502

00:55:07,349 --> 00:55:06,640

students dylan worked on this summer

1503

00:55:09,109 --> 00:55:07,359

and

1504

00:55:10,470 --> 00:55:09,119

the

1505

00:55:11,750 --> 00:55:10,480

interesting thing about surflit

1506

00:55:13,750 --> 00:55:11,760

rendering is that it's a little more

1507

00:55:15,109 --> 00:55:13,760

data efficient than other methods that

1508

00:55:17,030 --> 00:55:15,119

have been used so what we're looking for

1509

00:55:19,270 --> 00:55:17,040

actually is a great combination of all

1510

00:55:20,390 --> 00:55:19,280

these rendering techniques all used at

1511

00:55:23,190 --> 00:55:20,400

the same time

1512

00:55:25,589 --> 00:55:23,200

to give you the most complete scene that

1513

00:55:27,990 --> 00:55:25,599

uh that we can so i would say this is

1514

00:55:29,589 --> 00:55:28,000

close to is as good as we can do it

1515

00:55:30,470 --> 00:55:29,599

right now we hope to get further than

1516

00:55:32,150 --> 00:55:30,480

this

1517

00:55:33,910 --> 00:55:32,160

the next opportunity so the next

1518

00:55:35,190 --> 00:55:33,920

frontier would be thinking about new

1519

00:55:37,589 --> 00:55:35,200

instruments that could be put on a

1520

00:55:39,510 --> 00:55:37,599

future mission that are designed to

1521

00:55:42,230 --> 00:55:39,520

build environments like these

1522

00:55:43,750 --> 00:55:42,240

so not piecing together from images

1523

00:55:47,270 --> 00:55:43,760

necessarily but what other kinds of

1524

00:55:49,109 --> 00:55:47,280

instruments lidar-based instruments

1525

00:55:50,309 --> 00:55:49,119

things like that that could build up 3d

1526

00:55:51,750 --> 00:55:50,319

scenes

1527

00:55:53,190 --> 00:55:51,760

is most of the image data you get from

1528

00:55:54,549 --> 00:55:53,200

curiosity usable for something like this

1529

00:55:56,230 --> 00:55:54,559

or is it something you can only do with

1530

00:55:57,829 --> 00:55:56,240

the sort of stereo panoramas that you

1531

00:55:59,430 --> 00:55:57,839

get here really only the stereo

1532

00:56:01,990 --> 00:55:59,440

panoramas because

1533

00:56:04,230 --> 00:56:02,000

we need the the stereo information to

1534

00:56:06,470 --> 00:56:04,240

help us understand um

1535

00:56:08,549 --> 00:56:06,480

how far away things are on the scene in

1536

00:56:11,349 --> 00:56:08,559

some cases uh monoscopic you know just

1537

00:56:13,109 --> 00:56:11,359

one eye image uh is is useful

1538

00:56:14,710 --> 00:56:13,119

another challenge is like right now like

1539

00:56:16,470 --> 00:56:14,720

we're only using one camera here we're

1540

00:56:19,270 --> 00:56:16,480

using well we're using a pair of cameras

1541

00:56:20,789 --> 00:56:19,280

but one type of camera on curiosity we

1542

00:56:23,270 --> 00:56:20,799

another interesting challenge is

1543

00:56:26,309 --> 00:56:23,280

integrating the other imaging sensors

1544

00:56:27,750 --> 00:56:26,319

like the mast cam or the hazard cameras

1545

00:56:29,109 --> 00:56:27,760

which are actually mounted on the body

1546

00:56:30,789 --> 00:56:29,119

of the vehicle

1547

00:56:31,670 --> 00:56:30,799

possibly even the camera that is on the

1548

00:56:35,190 --> 00:56:31,680

arm

1549

00:56:37,030 --> 00:56:35,200

the molle or the microscope basically

1550

00:56:38,309 --> 00:56:37,040

those all could produce useful data in

1551

00:56:39,510 --> 00:56:38,319

certain cases

1552

00:56:44,710 --> 00:56:39,520

that could help

1553

00:56:49,349 --> 00:56:47,510

hi um a couple of us were talking at

1554

00:56:50,630 --> 00:56:49,359

lunch about your talk we're excited to

1555

00:56:53,349 --> 00:56:50,640

come and uh

1556

00:56:54,870 --> 00:56:53,359

my friend asked me a question uh

1557

00:56:56,950 --> 00:56:54,880

you know when we're all standing in our

1558

00:56:58,710 --> 00:56:56,960

mars given the latency

1559

00:57:01,190 --> 00:56:58,720

how will we know what we're going to say

1560

00:57:02,870 --> 00:57:01,200

to one another or how we interact with

1561

00:57:04,470 --> 00:57:02,880

each other

1562

00:57:06,069 --> 00:57:04,480

we were wondering you know could you

1563

00:57:08,710 --> 00:57:06,079

build in some kind of predictive

1564

00:57:11,030 --> 00:57:08,720

modeling of of how i might react to you

1565

00:57:13,030 --> 00:57:11,040

and use some of the same techniques to

1566

00:57:15,270 --> 00:57:13,040

to convince this poor astronaut that may

1567

00:57:16,870 --> 00:57:15,280

have been out there for 500 days

1568

00:57:18,549 --> 00:57:16,880

or however long we're going to send him

1569

00:57:20,309 --> 00:57:18,559

out that maybe he's not alone in the

1570

00:57:21,190 --> 00:57:20,319

universe but that he has friends with

1571

00:57:23,349 --> 00:57:21,200

him

1572

00:57:25,750 --> 00:57:23,359

in a way that's a little bit more

1573

00:57:27,589 --> 00:57:25,760

instinctive than you know 25 minute

1574

00:57:28,789 --> 00:57:27,599

delay on how high are you doing

1575

00:57:30,230 --> 00:57:28,799

you know it's funny i don't think it's

1576

00:57:32,230 --> 00:57:30,240

so far fetched

1577

00:57:33,910 --> 00:57:32,240

so it kind of falls in that category of

1578

00:57:35,109 --> 00:57:33,920

of you know us all desperately wanting

1579

00:57:36,069 --> 00:57:35,119

to believe that we're more complicated

1580

00:57:37,430 --> 00:57:36,079

than we are

1581

00:57:39,430 --> 00:57:37,440

but uh if you look at for instance

1582

00:57:40,950 --> 00:57:39,440

something as simple as predictive

1583

00:57:42,390 --> 00:57:40,960

texting you know when you start typing

1584

00:57:43,910 --> 00:57:42,400

on your phone and it starts completing

1585

00:57:45,990 --> 00:57:43,920

the words for you

1586

00:57:48,150 --> 00:57:46,000

there is a lot of predictability it

1587

00:57:50,710 --> 00:57:48,160

turns out in in i think the way that

1588

00:57:51,750 --> 00:57:50,720

humans behave um i think there's a limit

1589

00:57:56,470 --> 00:57:51,760

you know we wouldn't be able to push

1590

00:57:58,069 --> 00:57:56,480

that too terribly far uh the

1591

00:57:59,430 --> 00:57:58,079

i think

1592

00:58:00,390 --> 00:57:59,440

predicting the directions that people

1593

00:58:02,069 --> 00:58:00,400

are going

1594

00:58:03,510 --> 00:58:02,079

the ways that they're going to interact

1595

00:58:05,990 --> 00:58:03,520

with objects in the environment things

1596

00:58:08,950 --> 00:58:06,000

like that seem like low-hanging fruit

1597

00:58:10,870 --> 00:58:08,960

conversations more difficult i hope i

1598

00:58:11,670 --> 00:58:10,880

hope i would not be so easily predicted

1599

00:58:13,190 --> 00:58:11,680

that

1600

00:58:15,109 --> 00:58:13,200

someone could uh could play out my

1601  
00:58:17,510 --> 00:58:15,119  
conversation before i said it only my

1602  
00:58:18,309 --> 00:58:17,520  
wife can do that

1603  
00:58:20,829 --> 00:58:18,319  
yes

1604  
00:58:23,670 --> 00:58:20,839  
um yeah in the beginning you showed like

1605  
00:58:26,470 --> 00:58:23,680  
um these different scenarios

1606  
00:58:28,230 --> 00:58:26,480  
with a like relay satellite in the in

1607  
00:58:29,190 --> 00:58:28,240  
the martian orbit

1608  
00:58:31,589 --> 00:58:29,200  
but

1609  
00:58:33,910 --> 00:58:31,599  
right now we don't have that one

1610  
00:58:36,470 --> 00:58:33,920  
can you anyhow already gain some

1611  
00:58:38,230 --> 00:58:36,480  
efficiencies or can you already use this

1612  
00:58:40,150 --> 00:58:38,240  
technology with the

1613  
00:58:41,270 --> 00:58:40,160

with this 24-hour

1614

00:58:43,829 --> 00:58:41,280

uh

1615

00:58:46,150 --> 00:58:43,839

time frame communications

1616

00:58:48,789 --> 00:58:46,160

it's a good question um

1617

00:58:50,069 --> 00:58:48,799

i would say that the operations process

1618

00:58:51,910 --> 00:58:50,079

that we've developed for controlling

1619

00:58:54,630 --> 00:58:51,920

robots on mars

1620

00:58:56,069 --> 00:58:54,640

today is very well suited to the amount

1621

00:58:58,069 --> 00:58:56,079

of time delay that we're dealing with

1622

00:58:59,430 --> 00:58:58,079

and with that cadence of operations

1623

00:59:01,510 --> 00:58:59,440

where we're

1624

00:59:04,950 --> 00:59:01,520

you know uplinking really at most once a

1625

00:59:07,270 --> 00:59:04,960

day often at times once every three days

1626

00:59:08,309 --> 00:59:07,280

in certain cases

1627

00:59:10,069 --> 00:59:08,319

uh

1628

00:59:12,630 --> 00:59:10,079

we do have orbiters around mars of

1629

00:59:14,870 --> 00:59:12,640

course and they are relaying almost all

1630

00:59:17,030 --> 00:59:14,880

of the data that comes back from from

1631

00:59:19,270 --> 00:59:17,040

the assets that are on the surface it's

1632

00:59:21,030 --> 00:59:19,280

that there are too few and they have

1633

00:59:22,789 --> 00:59:21,040

other jobs you know these these orbiters

1634

00:59:24,470 --> 00:59:22,799

are are still performing scientific

1635

00:59:25,990 --> 00:59:24,480

missions of their own so they can't

1636

00:59:28,069 --> 00:59:26,000

spend all their time just relaying

1637

00:59:30,150 --> 00:59:28,079

telemetry for us uh there have been

1638

00:59:32,069 --> 00:59:30,160

proposals of for instance a mars telecom

1639

00:59:34,470 --> 00:59:32,079

orbiter that was you know a few years

1640

00:59:37,510 --> 00:59:34,480

back to put an asset around mars that

1641

00:59:39,349 --> 00:59:37,520

would provide dedicated telemetry

1642

00:59:40,870 --> 00:59:39,359

i don't think we have to have that to

1643

00:59:43,510 --> 00:59:40,880

start making progress in this direction

1644

00:59:45,349 --> 00:59:43,520

but it would require

1645

00:59:46,549 --> 00:59:45,359

some pretty creative thinking about how

1646

00:59:49,270 --> 00:59:46,559

to increase the frequency of

1647

00:59:50,309 --> 00:59:49,280

communication with the robots another

1648

00:59:53,349 --> 00:59:50,319

challenge by the way is that

1649

00:59:55,270 --> 00:59:53,359

communication is expensive

1650

00:59:56,470 --> 00:59:55,280

in terms of power by the robot on the

1651  
00:59:58,150 --> 00:59:56,480  
surface so

1652  
01:00:00,710 --> 00:59:58,160  
we we also need to think about power

1653  
01:00:03,190 --> 01:00:00,720  
systems that can support more frequent

1654  
01:00:10,150 --> 01:00:03,200  
communication by robot on mars

1655  
01:00:12,630 --> 01:00:11,190  
oh

1656  
01:00:16,710 --> 01:00:12,640  
mark's bringing here a couple questions

1657  
01:00:23,030 --> 01:00:19,430  
so first one says can we use this

1658  
01:00:25,190 --> 01:00:23,040  
technology to fly an airplane on marsh

1659  
01:00:26,230 --> 01:00:25,200  
and i would say absolutely

1660  
01:00:29,829 --> 01:00:26,240  
actually the first thing that makes me

1661  
01:00:33,030 --> 01:00:29,839  
think of is

1662  
01:00:34,549 --> 01:00:33,040  
a titan airship actually one of my

1663  
01:00:36,950 --> 01:00:34,559

favorite ideas that has been floated

1664

01:00:39,510 --> 01:00:36,960

around jpl in the past but focusing on

1665

01:00:42,470 --> 01:00:39,520

mars for for a second uh

1666

01:00:44,470 --> 01:00:42,480

you're not going to control you know a

1667

01:00:46,390 --> 01:00:44,480

dog fighter right you know

1668

01:00:47,829 --> 01:00:46,400

banking and turning and looping and you

1669

01:00:49,190 --> 01:00:47,839

know that's obviously not something you

1670

01:00:52,230 --> 01:00:49,200

want to do with five to 20 minutes of

1671

01:00:54,150 --> 01:00:52,240

time delay however if your airplane

1672

01:00:55,589 --> 01:00:54,160

is really a robot which it would

1673

01:00:56,630 --> 01:00:55,599

absolutely have to be

1674

01:00:58,950 --> 01:00:56,640

then

1675

01:00:59,829 --> 01:00:58,960

what it should be accomplishing is all

1676

01:01:02,549 --> 01:00:59,839

of that

1677

01:01:04,710 --> 01:01:02,559

high frequency control itself so it's

1678

01:01:06,789 --> 01:01:04,720

reacting to the buffeting winds and it's

1679

01:01:09,750 --> 01:01:06,799

keeping itself level and what you're

1680

01:01:10,950 --> 01:01:09,760

giving it are longer range trajectories

1681

01:01:12,710 --> 01:01:10,960

for instance i want to i want to start

1682

01:01:15,270 --> 01:01:12,720

reducing my altitude now and coming

1683

01:01:16,870 --> 01:01:15,280

closer to you know this mountain or i

1684

01:01:18,789 --> 01:01:16,880

want to climb now or i want to head over

1685

01:01:20,870 --> 01:01:18,799

this way and so you can imagine you know

1686

01:01:23,109 --> 01:01:20,880

when we were plotting out those

1687

01:01:27,270 --> 01:01:23,119

paths

1688

01:01:31,510 --> 01:01:29,349

there's nothing about this approach

1689

01:01:34,150 --> 01:01:31,520

that doesn't scale to controlling

1690

01:01:36,069 --> 01:01:34,160

something in three dimensions uh

1691

01:01:37,589 --> 01:01:36,079

when you're plotting out a path on the

1692

01:01:39,670 --> 01:01:37,599

ground there you can just imagine also

1693

01:01:41,510 --> 01:01:39,680

plotting a path through the air

1694

01:01:43,829 --> 01:01:41,520

it's just that you're more supervising

1695

01:01:46,309 --> 01:01:43,839

the flight than you are actively

1696

01:01:49,829 --> 01:01:46,319

controlling and you know joysticking the

1697

01:01:54,549 --> 01:01:52,069

so the second question says is nasa

1698

01:01:56,710 --> 01:01:54,559

partnered with any gaming companies to

1699

01:01:59,349 --> 01:01:56,720

aid with exploration and the answer is

1700

01:02:01,589 --> 01:01:59,359

an emphatic yes

1701

01:02:04,710 --> 01:02:01,599

so we have a number of partnerships in

1702

01:02:06,710 --> 01:02:04,720

my lab the opslab with a variety of of

1703

01:02:09,190 --> 01:02:06,720

partners and you've seen some of the

1704

01:02:10,630 --> 01:02:09,200

examples of those partnerships today

1705

01:02:11,990 --> 01:02:10,640

there are others i'll mention just

1706

01:02:13,510 --> 01:02:12,000

briefly something that i wish i could

1707

01:02:15,670 --> 01:02:13,520

have squeezed into the talk today but

1708

01:02:16,710 --> 01:02:15,680

couldn't for time was that we actually

1709

01:02:19,430 --> 01:02:16,720

released

1710

01:02:21,829 --> 01:02:19,440

nasa's first game to a video

1711

01:02:23,589 --> 01:02:21,839

gaming console one year ago it's called

1712

01:02:26,230 --> 01:02:23,599

mars river landing and we released it

1713

01:02:29,910 --> 01:02:26,240

with microsoft to the xbox 360.

1714

01:02:31,270 --> 01:02:29,920

and with it people could land on mars

1715

01:02:33,190 --> 01:02:31,280

using

1716

01:02:34,390 --> 01:02:33,200

the connect in their their living room

1717

01:02:37,349 --> 01:02:34,400

and it was

1718

01:02:40,150 --> 01:02:37,359

actually really a phenomenal success and

1719

01:02:42,069 --> 01:02:40,160

i think those things absolutely aid with

1720

01:02:43,670 --> 01:02:42,079

exploration first of all it explains to

1721

01:02:45,510 --> 01:02:43,680

people what we're trying to accomplish

1722

01:02:47,670 --> 01:02:45,520

but i think also connects them in a way

1723

01:02:49,190 --> 01:02:47,680

that other media doesn't

1724

01:02:52,549 --> 01:02:49,200

one thing i'm really

1725

01:02:53,750 --> 01:02:52,559

fond of mentioning often is that 97

1726  
01:02:57,270 --> 01:02:53,760  
percent

1727  
01:03:00,069 --> 01:02:57,280  
of american teenagers play video games

1728  
01:03:02,390 --> 01:03:00,079  
97 this is the pew research center study

1729  
01:03:05,349 --> 01:03:02,400  
of 2008 called teens video games and

1730  
01:03:06,870 --> 01:03:05,359  
civics so that's in 2008 97 of them

1731  
01:03:08,950 --> 01:03:06,880  
played which let's just face it that's

1732  
01:03:11,910 --> 01:03:08,960  
just all right that's all

1733  
01:03:14,230 --> 01:03:11,920  
all teenagers play video games

1734  
01:03:16,069 --> 01:03:14,240  
how many people in this room remember

1735  
01:03:17,910 --> 01:03:16,079  
watching the apollo landing in their

1736  
01:03:19,829 --> 01:03:17,920  
living room

1737  
01:03:21,910 --> 01:03:19,839  
a lot of hands

1738  
01:03:24,069 --> 01:03:21,920

and i know from talking to a lot of

1739

01:03:26,150 --> 01:03:24,079

people about it that a lot of people who

1740

01:03:27,670 --> 01:03:26,160

work with me

1741

01:03:28,789 --> 01:03:27,680

trace their inspiration moment the

1742

01:03:31,190 --> 01:03:28,799

moment that made them want to go work

1743

01:03:33,270 --> 01:03:31,200

for nasa to that living room to that

1744

01:03:34,950 --> 01:03:33,280

moment

1745

01:03:36,710 --> 01:03:34,960

there's something very special about

1746

01:03:39,109 --> 01:03:36,720

experiencing something like that with

1747

01:03:40,630 --> 01:03:39,119

your family in your living room and

1748

01:03:43,589 --> 01:03:40,640

video games

1749

01:03:46,630 --> 01:03:43,599

are in the living room

1750

01:03:50,069 --> 01:03:46,640

so i see it as a great way for nasa to

1751

01:03:52,150 --> 01:03:50,079

be back there and again in the future so

1752

01:03:54,150 --> 01:03:52,160

yes emphatically we are partnered with

1753

01:03:55,670 --> 01:03:54,160

video game companies and i i really

1754

01:03:58,069 --> 01:03:55,680

dearly hope that we'll see even more of

1755

01:03:59,589 --> 01:03:58,079

that in the future

1756

01:04:00,789 --> 01:03:59,599

are there any final questions i'm happy

1757

01:04:02,630 --> 01:04:00,799

that if they're

1758

01:04:04,789 --> 01:04:02,640

get more on your minds come and find me