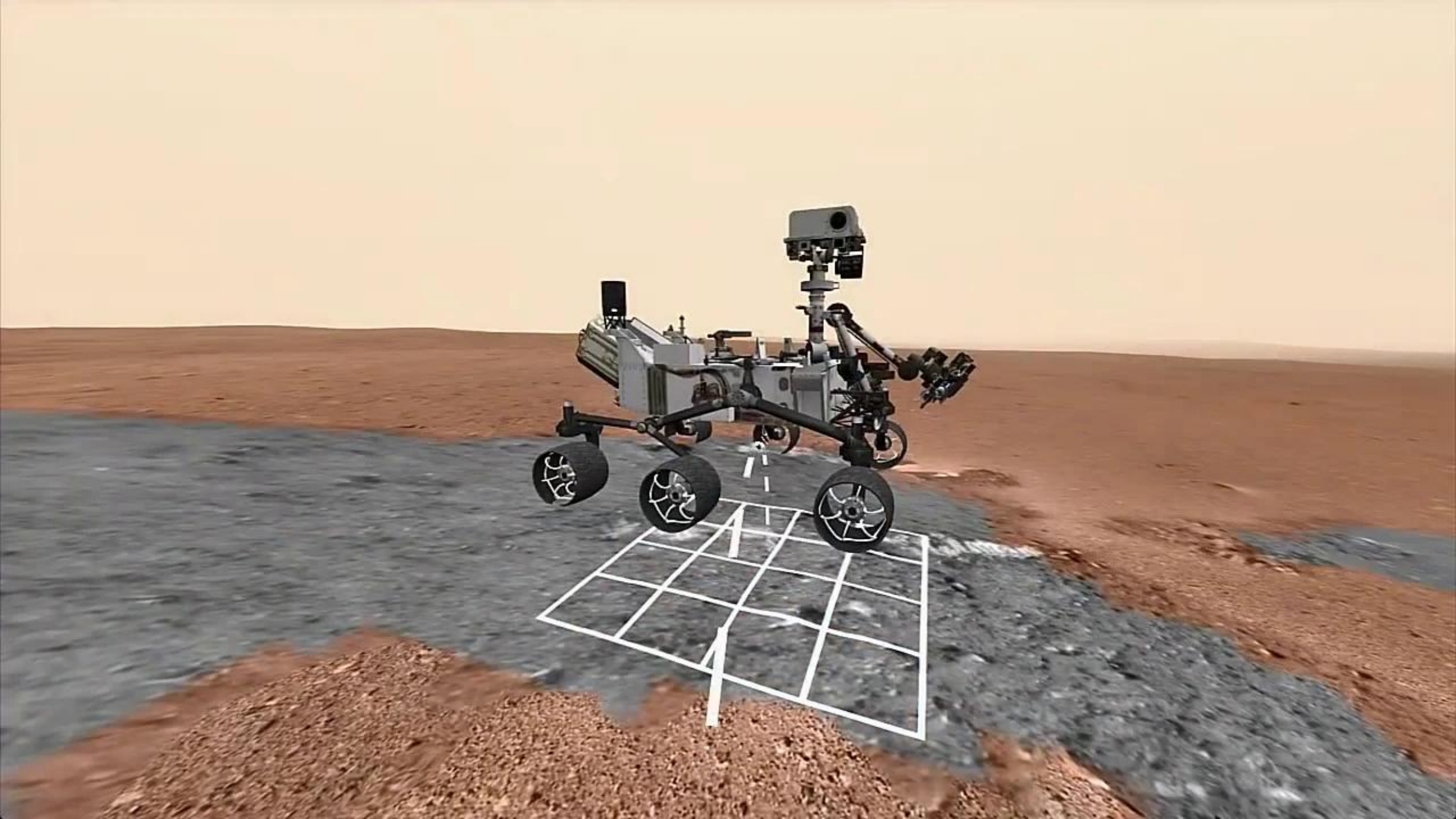

1
00:00:02,690 --> 00:00:00,020
[Music]

2
00:00:04,820 --> 00:00:02,700
the von Karman lecture a series of talks

3
00:00:07,820 --> 00:00:04,830
by scientists and engineers who are

4
00:00:09,800 --> 00:00:07,830
exploring our planet our solar system

5
00:00:20,170 --> 00:00:09,810
and all that lies beyond

6
00:00:22,280 --> 00:00:20,180
[Music]

7
00:00:24,970 --> 00:00:22,290
hey good evening ladies and gentlemen

8
00:00:27,170 --> 00:00:24,980
how's everyone doing tonight

9
00:00:30,800 --> 00:00:27,180
good well thanks for coming up joining

10
00:00:33,170 --> 00:00:30,810
us in the enjoy the AC while you can so

11
00:00:34,880 --> 00:00:33,180
virtual and augmented reality promised

12
00:00:37,220 --> 00:00:34,890
to transport us to places that we can

13
00:00:39,320 --> 00:00:37,230

only imagine when joined with spacecraft

14
00:00:41,240 --> 00:00:39,330
and robots these technologies will

15
00:00:43,450 --> 00:00:41,250
extend humanity's presence to real

16
00:00:46,610 --> 00:00:43,460
destinations that are equally fantastic

17
00:00:48,590 --> 00:00:46,620
NASA's operations laboratory at JPL is

18
00:00:50,330 --> 00:00:48,600
spearheading several ambitious projects

19
00:00:53,380 --> 00:00:50,340
applying virtual and augmented reality

20
00:00:55,430 --> 00:00:53,390
to the challenges of space exploration

21
00:00:57,740 --> 00:00:55,440
tonight's guests will share their

22
00:00:59,690 --> 00:00:57,750
progress so far the challenges that lie

23
00:01:03,440 --> 00:00:59,700
ahead and their vision for the future of

24
00:01:05,359 --> 00:01:03,450
VR and AR and space exploration as lead

25
00:01:07,190 --> 00:01:05,369
for the operations laboratory at JPL

26
00:01:09,320 --> 00:01:07,200
tonight's speakers developing highly

27
00:01:11,749 --> 00:01:09,330
innovative and effective space Mission

28
00:01:14,270 --> 00:01:11,759
Operations products with an emphasis on

29
00:01:16,850 --> 00:01:14,280
human-computer interactions and natural

30
00:01:18,740 --> 00:01:16,860
user interfaces he produced the first

31
00:01:21,350 --> 00:01:18,750
applications on the microsoft hololens

32
00:01:23,149 --> 00:01:21,360
platform for mars rover operations

33
00:01:24,590 --> 00:01:23,159
astronaut assistants on the

34
00:01:27,950 --> 00:01:24,600
International Space Station and

35
00:01:30,230 --> 00:01:27,960
spacecraft mechanical design and through

36
00:01:31,870 --> 00:01:30,240
key relationships with industry he is

37
00:01:34,460 --> 00:01:31,880
applying pre-market technologies

38
00:01:36,350 --> 00:01:34,470

influencing future technology roadmaps

39
00:01:38,359 --> 00:01:36,360
and establishing a leadership position

40
00:01:41,390 --> 00:01:38,369
for NASA in the application of virtual

41
00:01:43,130 --> 00:01:41,400
and augmented technologies for space he

42
00:01:45,080 --> 00:01:43,140
is also managing industry partnerships

43
00:01:47,030 --> 00:01:45,090
that are bringing NASA's mission of

44
00:01:49,609 --> 00:01:47,040
exploration to the public and a stem

45
00:01:50,960 --> 00:01:49,619
audiences worldwide here to lead our

46
00:01:54,090 --> 00:01:50,970
discussion tonight please welcome

47
00:02:01,190 --> 00:01:54,100
tonight's guest mr. Victor Liu

48
00:02:07,340 --> 00:02:01,200
[Applause]

49
00:02:10,249 --> 00:02:07,350
thanks mark this is the first image back

50
00:02:12,610 --> 00:02:10,259
for Mars sent back from the Mariner 4

51
00:02:15,170 --> 00:02:12,620
spacecraft more than 50 years ago in

52
00:02:17,570 --> 00:02:15,180
1965 and I know it doesn't look super

53
00:02:19,670 --> 00:02:17,580
impressive by today's standards but back

54
00:02:22,370 --> 00:02:19,680
then can you imagine it was the first

55
00:02:24,740 --> 00:02:22,380
spacecraft that got to another planet

56
00:02:28,250 --> 00:02:24,750
and the scientists the engineers are so

57
00:02:30,140 --> 00:02:28,260
excited to look at what the camera has

58
00:02:31,520 --> 00:02:30,150
captured they couldn't wait for the

59
00:02:33,890 --> 00:02:31,530
image to come back so they started

60
00:02:36,380 --> 00:02:33,900
taking the bits of data and plotting it

61
00:02:38,390 --> 00:02:36,390
on a grid right so this is the result of

62
00:02:40,370 --> 00:02:38,400
that grid is a color by numbers thing

63
00:02:42,530 --> 00:02:40,380

they color that in they filled it in and

64
00:02:46,490 --> 00:02:42,540
this is the first glimpse of the Red

65
00:02:48,410 --> 00:02:46,500
Planet 10 years later we set foot on

66
00:02:51,590 --> 00:02:48,420
Mars for the first time with a Viking

67
00:02:53,690 --> 00:02:51,600
one robot Lander and you know it took a

68
00:02:56,539 --> 00:02:53,700
little selfie of its foot and the rocks

69
00:02:58,640 --> 00:02:56,549
around it it's real pretty ever since

70
00:03:02,000 --> 00:02:58,650
then we've sent over a dozen successful

71
00:03:04,190 --> 00:03:02,010
missions to Mars Col mating and the

72
00:03:06,229 --> 00:03:04,200
curiosity mission in 2012

73
00:03:08,060 --> 00:03:06,239
now when the 2012 when the Curiosity

74
00:03:10,069 --> 00:03:08,070
rover landed the first image that it

75
00:03:12,740 --> 00:03:10,079
took was this one yeah it's a little bit

76
00:03:15,199 --> 00:03:12,750
blurry it's these are taken from the

77
00:03:17,270 --> 00:03:15,209
hazard cameras of the rover so there's a

78
00:03:20,539 --> 00:03:17,280
front image and the back image they

79
00:03:23,060 --> 00:03:20,549
don't look very fancy but for us on the

80
00:03:24,979 --> 00:03:23,070
mission it was a critical moment because

81
00:03:28,069 --> 00:03:24,989
it's the first time we recognized that

82
00:03:29,780 --> 00:03:28,079
the mission had been successful it's

83
00:03:33,110 --> 00:03:29,790
safe it was able to communicate with us

84
00:03:37,099 --> 00:03:33,120
and send these images back so these

85
00:03:39,680 --> 00:03:37,109
three images depict a great story of how

86
00:03:43,280 --> 00:03:39,690
we've spent the last 50 60 years

87
00:03:45,789 --> 00:03:43,290
exploring Mars but the one problem here

88
00:03:48,410 --> 00:03:45,799

is we as humans don't fundamentally

89
00:03:50,930 --> 00:03:48,420
explore this way we all walk around our

90
00:03:53,569 --> 00:03:50,940
world looking at pictures right this is

91
00:03:56,180 --> 00:03:53,579
how we explore and we run around our

92
00:03:58,160 --> 00:03:56,190
world we immerse ourselves in our

93
00:04:00,979 --> 00:03:58,170
environments and we share those

94
00:04:03,140 --> 00:04:00,989
experiences with those around us and

95
00:04:05,180 --> 00:04:03,150
it's a wonderful feeling to be able to

96
00:04:08,090 --> 00:04:05,190
share that with other people but for

97
00:04:09,349 --> 00:04:08,100
Mars we have many challenges and so

98
00:04:11,629 --> 00:04:09,359
today I want to spend some time talking

99
00:04:13,460 --> 00:04:11,639
about those challenges why is it so hard

100
00:04:15,590 --> 00:04:13,470
for us to drive over

101
00:04:17,930 --> 00:04:15,600
on Mars what are the challenges and what

102
00:04:19,190 --> 00:04:17,940
can we do with these new technologies

103
00:04:21,020 --> 00:04:19,200
have been hearing about virtual and

104
00:04:22,970 --> 00:04:21,030
augmented reality how can we take those

105
00:04:25,150 --> 00:04:22,980
elements and improve the way our

106
00:04:27,800 --> 00:04:25,160
scientists explore this foreign planet

107
00:04:29,330 --> 00:04:27,810
and we'll start with the first challenge

108
00:04:31,460 --> 00:04:29,340
and this is the one we kind of touched

109
00:04:33,800 --> 00:04:31,470
upon already we've got these images

110
00:04:35,810 --> 00:04:33,810
these 2d images that's all we have from

111
00:04:37,370 --> 00:04:35,820
the rover you've heard about these fancy

112
00:04:39,860 --> 00:04:37,380
cars like Tesla and then Google

113
00:04:42,170 --> 00:04:39,870

self-driving cars they got fancy lasers

114
00:04:44,150 --> 00:04:42,180
and radars and all these gizmos we don't

115
00:04:47,690 --> 00:04:44,160
have that all we have are these camera

116
00:04:50,180 --> 00:04:47,700
images and from that we have to you know

117
00:04:51,740 --> 00:04:50,190
depict in the entire 3d environment for

118
00:04:53,840 --> 00:04:51,750
our scientists so that's the challenge

119
00:05:03,500 --> 00:04:53,850
the limited types of data the second

120
00:05:06,890 --> 00:05:03,510
issue is this so half of you guys in the

121
00:05:08,960 --> 00:05:06,900
audience know what that is I apologize

122
00:05:11,870 --> 00:05:08,970
that you didn't experience that for the

123
00:05:14,090 --> 00:05:11,880
rest of you guys this is a 56k modem

124
00:05:15,770 --> 00:05:14,100
this is how we used to connect to the

125
00:05:17,240 --> 00:05:15,780
internet it would take about five

126
00:05:18,980 --> 00:05:17,250
minutes to do that and then it would

127
00:05:23,480 --> 00:05:18,990
take 30 minutes to down your favorite

128
00:05:25,700 --> 00:05:23,490
music song those were tough times

129
00:05:27,050 --> 00:05:25,710
we use the Deep Space Network to

130
00:05:28,820 --> 00:05:27,060
communicate with our spacecraft and it's

131
00:05:31,340 --> 00:05:28,830
not this bad it's actually a pretty

132
00:05:33,440 --> 00:05:31,350
strong pipeline a pretty broad bandwidth

133
00:05:35,780 --> 00:05:33,450
the challenge is that each mission only

134
00:05:37,880 --> 00:05:35,790
has a small segment of the day that they

135
00:05:39,830 --> 00:05:37,890
have control over that network to

136
00:05:42,560 --> 00:05:39,840
communicate with their spacecraft so for

137
00:05:44,840 --> 00:05:42,570
Mars for example we get a few you know a

138
00:05:46,430 --> 00:05:44,850

chunk of that that's bandwidth and so if

139
00:05:49,520 --> 00:05:46,440
you spread that out averaged it across a

140
00:05:51,320 --> 00:05:49,530
day you get something like 56 K which is

141
00:05:53,690 --> 00:05:51,330
the challenge right not only can we only

142
00:05:55,760 --> 00:05:53,700
take pictures but we can only select us

143
00:05:57,530 --> 00:05:55,770
a portion of those to send back so if

144
00:06:03,710 --> 00:05:57,540
they'd be really careful but the data we

145
00:06:06,590 --> 00:06:03,720
get back here's the third issue some of

146
00:06:08,450 --> 00:06:06,600
you guys may recognize this as lag we in

147
00:06:11,180 --> 00:06:08,460
the business call time delay all right

148
00:06:14,720 --> 00:06:11,190
if you're a gamer 500 milliseconds of

149
00:06:17,600 --> 00:06:14,730
lag is horrible and you can't even play

150
00:06:20,450 --> 00:06:17,610
a game with that much lag for us on Mars

151
00:06:22,430 --> 00:06:20,460
we have a 15 minute time delay one-way

152
00:06:24,620 --> 00:06:22,440
right so that means it takes 30 minutes

153
00:06:27,200 --> 00:06:24,630
before we even understand if the thing

154
00:06:29,060 --> 00:06:27,210
we send it send a command to do actually

155
00:06:31,040 --> 00:06:29,070
happen so what that means is we can't

156
00:06:33,470 --> 00:06:31,050
joystick the rover here on earth we have

157
00:06:35,510 --> 00:06:33,480
to send it a block of a commands every

158
00:06:36,710 --> 00:06:35,520
single day and we only get one shot at

159
00:06:39,230 --> 00:06:36,720
that right so we've been very careful

160
00:06:40,940 --> 00:06:39,240
about what we want it to do every single

161
00:06:42,470 --> 00:06:40,950
day here's the last thing that we don't

162
00:06:44,630 --> 00:06:42,480
really think about all right this is

163
00:06:46,670 --> 00:06:44,640

something we take for granted and that's

164
00:06:48,110 --> 00:06:46,680
collaboration all right we're doing that

165
00:06:51,380 --> 00:06:48,120
right now all right we're having this

166
00:06:53,120 --> 00:06:51,390
conversation together and we can do out

167
00:06:54,230 --> 00:06:53,130
on earth very easily but it's very hard

168
00:06:56,530 --> 00:06:54,240
to do on Mars

169
00:06:59,450 --> 00:06:56,540
it's your scientists they're primarily

170
00:07:01,460 --> 00:06:59,460
geologists right so honor that's what

171
00:07:03,410 --> 00:07:01,470
they do is they walk around on these

172
00:07:05,240 --> 00:07:03,420
outcrops these hills these mountains

173
00:07:07,880 --> 00:07:05,250
they study the rocks that pick them up

174
00:07:10,850 --> 00:07:07,890
the user tools and they talk with each

175
00:07:12,500 --> 00:07:10,860
other in the same location right when we

176
00:07:14,210 --> 00:07:12,510
tell them to study Mars they don't have

177
00:07:17,180 --> 00:07:14,220
any of those capabilities anymore

178
00:07:19,100 --> 00:07:17,190
they're behind a computer screen

179
00:07:21,260 --> 00:07:19,110
they're usually distributed all around

180
00:07:23,960 --> 00:07:21,270
the world and they don't get to talk to

181
00:07:26,000 --> 00:07:23,970
each other over digital means so we took

182
00:07:28,580 --> 00:07:26,010
a look at this challenge right of this

183
00:07:31,130 --> 00:07:28,590
is the data set we get back how can we

184
00:07:33,800 --> 00:07:31,140
take this and transform the way they do

185
00:07:37,159 --> 00:07:33,810
their everyday jobs and our team at JPL

186
00:07:40,489 --> 00:07:37,169
we took that problem and we made this

187
00:07:42,559 --> 00:07:40,499
this is what Mars looks like today every

188
00:07:44,809 --> 00:07:42,569

pixel in that image in this video you

189
00:07:46,969 --> 00:07:44,819
see here is real there's no computer

190
00:07:49,459 --> 00:07:46,979
graphics generated it's all automated

191
00:07:51,589 --> 00:07:49,469
pipeline we're taking our 2d images and

192
00:07:53,540 --> 00:07:51,599
building this 3d world that our

193
00:07:55,939 --> 00:07:53,550
scientists get to explore it's it's the

194
00:07:56,420 --> 00:07:55,949
best rendering of Mars that we have

195
00:07:58,519 --> 00:07:56,430
today

196
00:08:00,140 --> 00:07:58,529
and I could go on and on about how we're

197
00:08:03,379 --> 00:08:00,150
doing this so I'll just go quickly

198
00:08:04,909 --> 00:08:03,389
through it all we're doing is we're

199
00:08:07,040 --> 00:08:04,919
taking these 2d images we're building a

200
00:08:09,140 --> 00:08:07,050
3d model we're applying the colored

201
00:08:12,739 --> 00:08:09,150
textures on top of it chopping into

202
00:08:15,170 --> 00:08:12,749
these 3d 3d squares or tiles and then

203
00:08:16,429 --> 00:08:15,180
streaming it into mobile devices so we

204
00:08:17,899 --> 00:08:16,439
have an experience that works on the

205
00:08:20,239 --> 00:08:17,909
phone we have experience that works on

206
00:08:22,640 --> 00:08:20,249
the web and web experience that works on

207
00:08:25,100 --> 00:08:22,650
these AR devices these augmented reality

208
00:08:27,649 --> 00:08:25,110
devices but what that really means is

209
00:08:30,050 --> 00:08:27,659
for the first time our scientists get to

210
00:08:32,750 --> 00:08:30,060
get up from their desks and walk around

211
00:08:34,490 --> 00:08:32,760
on Mars and they get to do that together

212
00:08:36,889 --> 00:08:34,500
with their colleagues all around the

213
00:08:40,159 --> 00:08:36,899

world and if you really get to explore

214
00:08:41,959 --> 00:08:40,169
Mars in the way that they explore earth

215
00:08:43,909 --> 00:08:41,969
all right thank you we're giving them

216
00:08:46,460 --> 00:08:43,919
their natural capabilities back and

217
00:08:47,960 --> 00:08:46,470
that's super powerful for them but we

218
00:08:49,819 --> 00:08:47,970
didn't want to stop here right our

219
00:08:51,889 --> 00:08:49,829
scientists get really excited about

220
00:08:53,870 --> 00:08:51,899
using this but what about everybody else

221
00:08:56,060 --> 00:08:53,880
and so we partner with our friends at

222
00:08:58,850 --> 00:08:56,070
Google and we build this experience

223
00:09:00,980 --> 00:08:58,860
called access Mars now access Mars uses

224
00:09:03,740 --> 00:09:00,990
a technology called web VR which means

225
00:09:05,449 --> 00:09:03,750
it works on any device with a browser so

226
00:09:10,060 --> 00:09:05,459
it works on your phone your browser and

227
00:09:14,509 --> 00:09:10,070
your VR headset let's take a quick look

228
00:09:17,300 --> 00:09:14,519
on November 26th 2011 NASA and JPL

229
00:09:18,949 --> 00:09:17,310
launched the Curiosity rover on its

230
00:09:21,900 --> 00:09:18,959
mission to find out if Mars has ever

231
00:09:23,400 --> 00:09:21,910
been suitable for life

232
00:09:27,460 --> 00:09:23,410
[Music]

233
00:09:34,060 --> 00:09:30,790
since then it's taken over 200,000

234
00:09:36,250 --> 00:09:34,070
photographs used by NASA JPL scientists

235
00:09:40,390 --> 00:09:36,260
to create the most realistic 3d model of

236
00:09:46,000 --> 00:09:40,400
Mars ever seen today it's yours to

237
00:09:48,760 --> 00:09:46,010
explore on a computer phone or in VR the

238
00:09:54,730 --> 00:09:48,770

real surface of Mars photographed by the

239
00:09:56,830 --> 00:09:54,740
Curiosity rover now in your browser so

240
00:09:58,680 --> 00:09:56,840
that's life today a Texas Mars comm

241
00:10:01,090 --> 00:09:58,690
encourage you to go try it out later

242
00:10:03,610 --> 00:10:01,100
we're gonna update it over time as

243
00:10:08,290 --> 00:10:03,620
Ciotti curiosity continued its journey

244
00:10:09,910 --> 00:10:08,300
on Mars so before we move on I would

245
00:10:12,310 --> 00:10:09,920
like to actually show you a little bit

246
00:10:15,850 --> 00:10:12,320
about how this is being used by science

247
00:10:17,350 --> 00:10:15,860
to scientists today and I can't get the

248
00:10:18,790 --> 00:10:17,360
headset out and make make you guys all

249
00:10:21,310 --> 00:10:18,800
experienced and augmented reality so

250
00:10:24,700 --> 00:10:21,320
I'll do the next best thing and show it

251
00:10:27,640 --> 00:10:24,710
to you on the web so this is the tool

252
00:10:30,910 --> 00:10:27,650
that our scientists use on the regular

253
00:10:33,490 --> 00:10:30,920
to explore this 3d Mars experience and

254
00:10:34,960 --> 00:10:33,500
you'll see initially it looks very much

255
00:10:39,280 --> 00:10:34,970
like the images that showed you right

256
00:10:42,970 --> 00:10:39,290
but what we can do is back out of this

257
00:10:45,760 --> 00:10:42,980
image and you'll see that were actually

258
00:10:48,250 --> 00:10:45,770
in a 3d environment with the rover and

259
00:10:51,370 --> 00:10:48,260
just like the video shows you earlier

260
00:10:53,590 --> 00:10:51,380
everything is here is real not

261
00:10:55,900 --> 00:10:53,600
computer-generated and it's running in

262
00:10:57,190 --> 00:10:55,910
real time in your browser so what's cool

263
00:11:00,070 --> 00:10:57,200

is we can click on any of those rocks

264
00:11:01,780 --> 00:11:00,080
that we care about it shows you a list

265
00:11:03,460 --> 00:11:01,790
of images here on the left there was

266
00:11:05,260 --> 00:11:03,470
either raw images that were taken by the

267
00:11:07,780 --> 00:11:05,270
rover and when you click on them it

268
00:11:10,120 --> 00:11:07,790
changes the to the perspective of which

269
00:11:13,050 --> 00:11:10,130
that image was taken and you'll see that

270
00:11:16,120 --> 00:11:13,060
it almost lines up perfectly with the 3d

271
00:11:18,400 --> 00:11:16,130
environment so it really gives the the

272
00:11:21,040 --> 00:11:18,410
the scientists that the credibility the

273
00:11:24,100 --> 00:11:21,050
confidence to then go operate the rover

274
00:11:26,530 --> 00:11:24,110
on Mars so this is the basic

275
00:11:28,240 --> 00:11:26,540
functionality for for how we're changing

276
00:11:31,510 --> 00:11:28,250
the way that people are operating there

277
00:11:33,130 --> 00:11:31,520
over on Mars but this technology is not

278
00:11:34,240 --> 00:11:33,140
just limited to Mars right if we can do

279
00:11:37,240 --> 00:11:34,250
this for Mars we can really do it for

280
00:11:38,950 --> 00:11:37,250
any remote environment and so we've

281
00:11:40,410 --> 00:11:38,960
already started to do that and today I

282
00:11:42,690 --> 00:11:40,420
want to show you guys a sneak peak

283
00:11:44,069 --> 00:11:42,700
of another product that we're working on

284
00:11:46,110 --> 00:11:44,079
and this is in conjunction with the

285
00:11:48,060 --> 00:11:46,120
Japanese Space Agency so there's a

286
00:11:50,850 --> 00:11:48,070
mission called Hayabusa - it's a very

287
00:11:53,360 --> 00:11:50,860
ambitious mission it's going to

288
00:11:56,879 --> 00:11:53,370

rendezvous at this asteroid called ryugu

289
00:11:59,879 --> 00:11:56,889
survey it for two months take three soil

290
00:12:01,230 --> 00:11:59,889
samples and land for Rovers on it and

291
00:12:03,660 --> 00:12:01,240
then it's going to deliver those samples

292
00:12:05,340 --> 00:12:03,670
back to earth all no matter of two years

293
00:12:06,900 --> 00:12:05,350
and so it's a very challenging mission

294
00:12:08,519 --> 00:12:06,910
and we really want to help the scientist

295
00:12:11,160 --> 00:12:08,529
in that short amount of time get the

296
00:12:12,750 --> 00:12:11,170
most science out of the time they have

297
00:12:15,689 --> 00:12:12,760
so I'm going to show you a preview of

298
00:12:16,829 --> 00:12:15,699
what we can do with that data set but we

299
00:12:18,150 --> 00:12:16,839
don't have that new data set yet so I'm

300
00:12:19,680 --> 00:12:18,160
going to show you what we did with the

301
00:12:22,259 --> 00:12:19,690
previous data set which is from the

302
00:12:25,560 --> 00:12:22,269
Hayabusa one mission this is it okawa

303
00:12:29,490 --> 00:12:25,570
right so initially here you can see this

304
00:12:31,560 --> 00:12:29,500
ring around this asteroid and these are

305
00:12:34,019 --> 00:12:31,570
actually each one of these squares it's

306
00:12:35,699 --> 00:12:34,029
an image of the asteroid and if I click

307
00:12:38,579 --> 00:12:35,709
on one of these images on the bottom as

308
00:12:41,160 --> 00:12:38,589
you can see it kind of highlights it

309
00:12:42,900 --> 00:12:41,170
takes you to that image overlaid on that

310
00:12:45,900 --> 00:12:42,910
asteroid so you get a again this

311
00:12:47,550 --> 00:12:45,910
representation of the raw image on top

312
00:12:49,050 --> 00:12:47,560
of this 3d environment give you a little

313
00:12:52,439 --> 00:12:49,060

bit of that context that spatial

314
00:12:54,689 --> 00:12:52,449
awareness so where we're going next with

315
00:12:56,939 --> 00:12:54,699
this stuff right what's what's next for

316
00:12:59,880 --> 00:12:56,949
Mars exploration well the next thing we

317
00:13:01,410 --> 00:12:59,890
have is the 2020 Rover there's a rope

318
00:13:03,750 --> 00:13:01,420
there's another Rover we're launching in

319
00:13:06,410 --> 00:13:03,760
2020 and on that rover there's something

320
00:13:10,050 --> 00:13:06,420
new there's going to be a helicopter

321
00:13:13,410 --> 00:13:10,060
it's gonna be the first interplanetary

322
00:13:16,970 --> 00:13:13,420
aerial vehicle right super exciting it's

323
00:13:20,310 --> 00:13:16,980
a 2 meter blade one kilogram payload

324
00:13:23,250 --> 00:13:20,320
we're just super excited about what this

325
00:13:25,800 --> 00:13:23,260
new capability brings to our sensor

326
00:13:27,960 --> 00:13:25,810
package you know we were able to get

327
00:13:29,490 --> 00:13:27,970
these 2d images we're able to send them

328
00:13:31,170 --> 00:13:29,500
down but what would if now we can get

329
00:13:33,210 --> 00:13:31,180
video but what if we get the third

330
00:13:35,579 --> 00:13:33,220
person view what if we could really map

331
00:13:38,550 --> 00:13:35,589
it and and walk around and fly around

332
00:13:39,780 --> 00:13:38,560
the the way we do here on earth so we're

333
00:13:42,600 --> 00:13:39,790
super excited about this mission

334
00:13:47,790 --> 00:13:42,610
but even further out we're gonna send

335
00:13:50,550 --> 00:13:47,800
humans to Mars and you know whether we

336
00:13:53,220 --> 00:13:50,560
do it or China does it or SpaceX does it

337
00:13:55,470 --> 00:13:53,230
we're gonna do it someday soon

338
00:13:57,180 --> 00:13:55,480

and when we do that you know it's going

339
00:13:59,850 --> 00:13:57,190
to be an a really exciting time it's

340
00:14:00,710 --> 00:13:59,860
gonna be a global event just like the

341
00:14:04,860 --> 00:14:00,720
World Cup

342
00:14:06,740 --> 00:14:04,870
everyone's gonna be tuned in but instead

343
00:14:09,300 --> 00:14:06,750
of watching it on their TVs this time

344
00:14:11,430 --> 00:14:09,310
instead of just the scientists and the

345
00:14:14,670 --> 00:14:11,440
engineers and the astronauts that get to

346
00:14:17,550 --> 00:14:14,680
go to Mars we will all be there already

347
00:14:19,830 --> 00:14:17,560
virtually exploring Mars and welcoming

348
00:14:23,210 --> 00:14:19,840
the astronauts as they take the first

349
00:14:32,410 --> 00:14:23,220
steps on the future of Mars exploration

350
00:14:37,910 --> 00:14:36,110
before I open it up to general QA I'd

351
00:14:39,590 --> 00:14:37,920
like to welcome a few my colleagues up

352
00:14:41,060 --> 00:14:39,600
on this stage these are the experts that

353
00:14:44,000 --> 00:14:41,070
worked on these technologies and these

354
00:14:46,100 --> 00:14:44,010
missions to answer a few questions we're

355
00:14:55,970 --> 00:14:46,110
gonna have a little discussion so please

356
00:14:59,570 --> 00:14:55,980
come on the stage so we have Alice

357
00:15:02,000 --> 00:14:59,580
winter who's our user researcher on this

358
00:15:04,070 --> 00:15:02,010
walk on Mars experience we've got Parker

359
00:15:06,020 --> 00:15:04,080
Abercrombie who's a project lead on the

360
00:15:08,720 --> 00:15:06,030
walk on Mars experience and Abigail

361
00:15:10,900 --> 00:15:08,730
Freeman an avid user of our tool as well

362
00:15:15,110 --> 00:15:10,910
as a scientist on the curiosity mission

363
00:15:18,140 --> 00:15:15,120

so since the topic of the lecture today

364
00:15:20,690 --> 00:15:18,150
is walking on Mars let's start with

365
00:15:23,540 --> 00:15:20,700
walking on Mars Abby how did it feel to

366
00:15:26,420 --> 00:15:23,550
walk on Mars for the first time oh it

367
00:15:28,820 --> 00:15:26,430
was it was almost surreal so I'm a

368
00:15:32,150 --> 00:15:28,830
scientist on the curiosity mission team

369
00:15:34,040 --> 00:15:32,160
and I spend hours and hours looking at

370
00:15:36,170 --> 00:15:34,050
these two-dimensional pictures and I

371
00:15:38,300 --> 00:15:36,180
spend so much time I'm almost imagining

372
00:15:41,000 --> 00:15:38,310
I'm there but the first time I put on

373
00:15:43,040 --> 00:15:41,010
the headset I really did feel like I was

374
00:15:44,810 --> 00:15:43,050
standing in a place that I already knew

375
00:15:46,880 --> 00:15:44,820
but I'd never actually gotten to visit

376
00:15:49,340 --> 00:15:46,890
it was this really awesome magical

377
00:15:51,980 --> 00:15:49,350
feeling and then once I got over that I

378
00:15:53,750 --> 00:15:51,990
was really excited and I you know just

379
00:15:55,820 --> 00:15:53,760
wanted to run around I wanted to run to

380
00:15:58,640 --> 00:15:55,830
the top of the highest hill in the scene

381
00:16:00,740 --> 00:15:58,650
I wanted to run along the Traverse for

382
00:16:02,690 --> 00:16:00,750
kilometres it was really a great

383
00:16:05,660 --> 00:16:02,700
experience and it's been really helpful

384
00:16:07,700 --> 00:16:05,670
to to do science as a geologist it's

385
00:16:09,470 --> 00:16:07,710
important to be able to see the rocks

386
00:16:10,910 --> 00:16:09,480
that I'm looking at in three dimensions

387
00:16:13,730 --> 00:16:10,920
it provides us important information

388
00:16:16,010 --> 00:16:13,740

about the environments that in place the

389
00:16:19,010 --> 00:16:16,020
rocks and the processes that shape them

390
00:16:21,560 --> 00:16:19,020
over time so again being able to now see

391
00:16:23,540 --> 00:16:21,570
them in the 3d environment stuffs just

392
00:16:25,190 --> 00:16:23,550
starts kind of clicking and you go hi I

393
00:16:27,620 --> 00:16:25,200
understand the relationship between this

394
00:16:30,320 --> 00:16:27,630
rock and this rock and now now I can see

395
00:16:35,480 --> 00:16:30,330
it immediately by being there that's

396
00:16:38,060 --> 00:16:35,490
great yeah it was incredible it was so I

397
00:16:40,940 --> 00:16:38,070
first tried on site just after I joined

398
00:16:43,040 --> 00:16:40,950
JPL four years ago and it was an amazing

399
00:16:44,570 --> 00:16:43,050
experience to to really feel like I was

400
00:16:45,500 --> 00:16:44,580
standing on Mars and to see Mars in a

401
00:16:49,040 --> 00:16:45,510
way that I had never seen

402
00:16:51,650 --> 00:16:49,050
for and I was struck by how how alien or

403
00:16:54,290 --> 00:16:51,660
different it looked but also how similar

404
00:16:56,210 --> 00:16:54,300
and then a couple weeks after I first

405
00:16:58,430 --> 00:16:56,220
tried on site I went camping that in the

406
00:17:00,140 --> 00:16:58,440
desert rounds of Borrego and I was

407
00:17:01,940 --> 00:17:00,150
struck by how how similar some things

408
00:17:03,530 --> 00:17:01,950
looked to areas on Mars and I realized

409
00:17:05,840 --> 00:17:03,540
that I had started thinking about Mars

410
00:17:07,790 --> 00:17:05,850
as more of a place than this this

411
00:17:09,650 --> 00:17:07,800
abstract dot in the sky or there's this

412
00:17:11,420 --> 00:17:09,660
place where images come back it really

413
00:17:16,100 --> 00:17:11,430

felt like like somewhere I had been at

414
00:17:18,439 --> 00:17:16,110
least virtually Alice your title as a

415
00:17:20,270 --> 00:17:18,449
user researcher for the audience here

416
00:17:21,710 --> 00:17:20,280
can you tell us what that means and what

417
00:17:24,470 --> 00:17:21,720
do you what do you do for walking on

418
00:17:26,480 --> 00:17:24,480
Mars yeah so my role can be described

419
00:17:28,700 --> 00:17:26,490
with different titles so some people

420
00:17:32,090 --> 00:17:28,710
call it a product owner some people call

421
00:17:35,480 --> 00:17:32,100
it a user experience researcher but the

422
00:17:37,490 --> 00:17:35,490
core task is really to represent user

423
00:17:38,930 --> 00:17:37,500
interests and development decisions and

424
00:17:40,490 --> 00:17:38,940
to do that you've got to know your users

425
00:17:42,920 --> 00:17:40,500
you got to get out there you got to meet

426
00:17:45,260 --> 00:17:42,930
them you got to know their jobs you know

427
00:17:46,790 --> 00:17:45,270
learn a bit of what their the problems

428
00:17:49,610 --> 00:17:46,800
they're having see what you can do to

429
00:17:50,900 --> 00:17:49,620
solve that and then synthesize that and

430
00:17:52,280 --> 00:17:50,910
bring that back to the development team

431
00:17:53,990 --> 00:17:52,290
because they're working on really hard

432
00:17:56,450 --> 00:17:54,000
problems like how do we take all these

433
00:18:00,440 --> 00:17:56,460
images and reconstruct it into this 3d

434
00:18:01,820 --> 00:18:00,450
model and I'm bringing the geology

435
00:18:04,430 --> 00:18:01,830
perspective to them that I've learned

436
00:18:06,110 --> 00:18:04,440
from people like Allie or some of the

437
00:18:07,790 --> 00:18:06,120
challenges they've heard from the

438
00:18:09,950 --> 00:18:07,800

sciences and how are you able to improve

439
00:18:12,710 --> 00:18:09,960
you know the overall experience based on

440
00:18:14,780 --> 00:18:12,720
these interactions yeah so one really

441
00:18:17,000 --> 00:18:14,790
three dimensional problem is where has

442
00:18:19,070 --> 00:18:17,010
the rover been before like I'm standing

443
00:18:20,810 --> 00:18:19,080
in this environment I see the rover

444
00:18:22,520 --> 00:18:20,820
right there but at some point it was

445
00:18:24,380 --> 00:18:22,530
moving right where did it come from

446
00:18:26,360 --> 00:18:24,390
and there's a lot of ways you can

447
00:18:29,000 --> 00:18:26,370
display this depending on what you need

448
00:18:30,350 --> 00:18:29,010
to see like do you need to see where

449
00:18:31,790 --> 00:18:30,360
it's been since the beginning of the

450
00:18:33,980 --> 00:18:31,800
mission or maybe where it was yesterday

451
00:18:35,300 --> 00:18:33,990
so you got a so I went out there and I

452
00:18:37,910 --> 00:18:35,310
talk to people I'm like oh why do you

453
00:18:39,830 --> 00:18:37,920
want to know that you know why or what

454
00:18:41,870 --> 00:18:39,840
fidelity does that direction need to be

455
00:18:43,730 --> 00:18:41,880
does it need to be a video of the rover

456
00:18:46,640 --> 00:18:43,740
driving or maybe could we show arrows

457
00:18:48,410 --> 00:18:46,650
what does it help you do and it helps

458
00:18:50,180 --> 00:18:48,420
them get a perspective of where we're

459
00:18:52,820 --> 00:18:50,190
going on the next day or perhaps where

460
00:18:54,590 --> 00:18:52,830
we've been before so we can see what

461
00:18:58,249 --> 00:18:54,600
data we have collected and maybe

462
00:19:01,870 --> 00:18:58,259
data we're going to collect and Parker

463
00:19:04,639 --> 00:19:01,880

you know for the developers out there

464
00:19:05,659 --> 00:19:04,649
how is it building these experiences

465
00:19:07,850 --> 00:19:05,669
what are some of the challenges of

466
00:19:08,899 --> 00:19:07,860
building in augmented reality maybe tell

467
00:19:11,779 --> 00:19:08,909
us a little bit what that means

468
00:19:13,159 --> 00:19:11,789
absolutely well on the one hand I think

469
00:19:14,749 --> 00:19:13,169
it's it's easier just to build these

470
00:19:16,730 --> 00:19:14,759
sorts of experiences than it ever has

471
00:19:18,830 --> 00:19:16,740
been which is great the gaming and

472
00:19:20,720 --> 00:19:18,840
entertainment industries are generating

473
00:19:22,310 --> 00:19:20,730
a lot of this technology the headsets

474
00:19:23,389 --> 00:19:22,320
are becoming more capable and more

475
00:19:25,669 --> 00:19:23,399
readily available and more affordable

476
00:19:27,649 --> 00:19:25,679
and the development tools are continuing

477
00:19:29,330 --> 00:19:27,659
to improve but there's there's still a

478
00:19:31,940 --> 00:19:29,340
lot of challenges because the medium is

479
00:19:34,070 --> 00:19:31,950
so new the main ones that come to my

480
00:19:36,889 --> 00:19:34,080
mind are the technical challenges

481
00:19:39,590 --> 00:19:36,899
because the headsets especially the the

482
00:19:41,960 --> 00:19:39,600
fully mobile had headsets are not as

483
00:19:44,600 --> 00:19:41,970
capable as a desktop workstation or a

484
00:19:47,060 --> 00:19:44,610
traditional gaming PC so getting the the

485
00:19:49,610 --> 00:19:47,070
software to run formally on the headsets

486
00:19:51,440 --> 00:19:49,620
can be challenging there are user

487
00:19:53,419 --> 00:19:51,450
interface and perception challenges

488
00:19:54,379 --> 00:19:53,429

because the immersive interfaces are so

489
00:19:56,240 --> 00:19:54,389
different

490
00:19:58,190 --> 00:19:56,250
there's not a lot of examples to look to

491
00:19:59,869 --> 00:19:58,200
like even the car even simple things

492
00:20:01,129 --> 00:19:59,879
like what should menu look like or how

493
00:20:04,610 --> 00:20:01,139
should the user interact with the system

494
00:20:06,619 --> 00:20:04,620
are are not not totally solved problems

495
00:20:07,820 --> 00:20:06,629
so you have you can look at a few

496
00:20:09,110 --> 00:20:07,830
examples of how other people have done

497
00:20:12,350 --> 00:20:09,120
it but there's there's something like a

498
00:20:13,970 --> 00:20:12,360
clear answer and making that usable and

499
00:20:17,539 --> 00:20:13,980
learn about for new users can be

500
00:20:19,730 --> 00:20:17,549
challenging and there can be a human

501
00:20:21,710 --> 00:20:19,740
comfort issues with what the

502
00:20:23,269 --> 00:20:21,720
head-mounted display if you if you don't

503
00:20:25,070 --> 00:20:23,279
pay attention to the user experience you

504
00:20:26,960 --> 00:20:25,080
can make people feel motion sick which i

505
00:20:28,610 --> 00:20:26,970
think is kind of the worst the worst

506
00:20:32,330 --> 00:20:28,620
experience a user can have using your

507
00:20:35,210 --> 00:20:32,340
software and finally I think one of the

508
00:20:37,190 --> 00:20:35,220
challenges of immersion is that it's

509
00:20:39,649 --> 00:20:37,200
it's really cool they're really easy to

510
00:20:41,960 --> 00:20:39,659
put together a cool demo they get people

511
00:20:44,119 --> 00:20:41,970
excited but it's much harder to build a

512
00:20:45,919 --> 00:20:44,129
tool in an immersive tool that people

513
00:20:47,899 --> 00:20:45,929

will really pick up and use as part of

514
00:20:49,700 --> 00:20:47,909
their day to day take jobs and provide

515
00:20:51,200 --> 00:20:49,710
enough value that a user is willing to

516
00:20:53,240 --> 00:20:51,210
put to put on the headset each day and

517
00:20:55,519 --> 00:20:53,250
one of the big challenge is developing

518
00:20:57,049 --> 00:20:55,529
on site has been making the the software

519
00:20:59,029 --> 00:20:57,059
is streamlined enough that scientists

520
00:21:00,889 --> 00:20:59,039
can effectively fit into their workflow

521
00:21:01,970 --> 00:21:00,899
and that it's a it's another tool that

522
00:21:03,769 --> 00:21:01,980
we're giving them that that's actually

523
00:21:06,080 --> 00:21:03,779
adding to their to their capabilities

524
00:21:07,600 --> 00:21:06,090
and it's not something that's a little

525
00:21:11,169 --> 00:21:07,610
too cumbersome to actually you

526
00:21:12,850 --> 00:21:11,179
on the job thanks for her so I just add

527
00:21:14,740 --> 00:21:12,860
to that I think the work that Alice does

528
00:21:16,900 --> 00:21:14,750
is is really key to understanding

529
00:21:18,070 --> 00:21:16,910
they're the users pain points what's

530
00:21:19,539 --> 00:21:18,080
working out for them and what needs to

531
00:21:21,039 --> 00:21:19,549
be improved so that we can make the

532
00:21:22,930 --> 00:21:21,049
software as streamlined as possible so

533
00:21:26,950 --> 00:21:22,940
it at the end of the day it's our users

534
00:21:29,620 --> 00:21:26,960
problems and as one of our favorite

535
00:21:31,120 --> 00:21:29,630
users Abbie how has how do you think

536
00:21:32,740 --> 00:21:31,130
this these kind of tools have changed

537
00:21:34,810 --> 00:21:32,750
the way you guys think about science

538
00:21:36,970 --> 00:21:34,820

planning as a whole yeah you know a

539
00:21:38,980 --> 00:21:36,980
couple ways one of my favorite

540
00:21:41,230 --> 00:21:38,990
experiences when kind of on site was

541
00:21:42,789 --> 00:21:41,240
first coming on we were as a day I'm

542
00:21:44,440 --> 00:21:42,799
planning and we wanted to image a

543
00:21:46,270 --> 00:21:44,450
certain feature and we were wondering

544
00:21:47,770 --> 00:21:46,280
okay should we take it here should we

545
00:21:50,049 --> 00:21:47,780
wait till we drive well we have a better

546
00:21:51,730 --> 00:21:50,059
view and you know we have tools we can

547
00:21:53,590 --> 00:21:51,740
put it in we can calculate you sheds

548
00:21:55,450 --> 00:21:53,600
that's all cumbersome but I said wait a

549
00:21:56,620 --> 00:21:55,460
minute why don't I just look and I could

550
00:21:58,000 --> 00:21:56,630
put on the headset and I could look

551
00:21:59,500 --> 00:21:58,010
around and say okay this looks pretty

552
00:22:01,690 --> 00:21:59,510
good and then I ran over to where we

553
00:22:04,480 --> 00:22:01,700
were driving and I said oh this looks

554
00:22:06,250 --> 00:22:04,490
much better so I mean I could tell and

555
00:22:07,630 --> 00:22:06,260
kind of intuitively we should wait we

556
00:22:09,580 --> 00:22:07,640
should wait to take this picture we'll

557
00:22:11,409 --> 00:22:09,590
get a better image after our drive and

558
00:22:14,380 --> 00:22:11,419
so in that sense it's really helpful for

559
00:22:16,630 --> 00:22:14,390
planning it's also helpful for planning

560
00:22:19,299 --> 00:22:16,640
and helping us understand the safety of

561
00:22:20,919 --> 00:22:19,309
our drives some of the things that we do

562
00:22:22,780 --> 00:22:20,929
as scientists is work with the rover

563
00:22:24,610 --> 00:22:22,790

drivers to understand is this terrain

564
00:22:27,130 --> 00:22:24,620
gonna be treacherous are these rocks

565
00:22:29,350 --> 00:22:27,140
gonna be a problem so again being able

566
00:22:31,780 --> 00:22:29,360
to see that in 3d and even walk the

567
00:22:33,970 --> 00:22:31,790
Traverse before the rover even drives

568
00:22:35,710 --> 00:22:33,980
the Traverse is so helpful in just

569
00:22:38,230 --> 00:22:35,720
getting this intuitive sense of what's

570
00:22:40,060 --> 00:22:38,240
gonna happen yeah tell us a little bit

571
00:22:42,010 --> 00:22:40,070
more about that planning cycle how do

572
00:22:43,780 --> 00:22:42,020
you work with your colleagues around the

573
00:22:45,549 --> 00:22:43,790
world and make sure you come to the same

574
00:22:48,190 --> 00:22:45,559
consensus and such a limited amount of

575
00:22:50,919 --> 00:22:48,200
time yeah usually the way we operate the

576
00:22:52,720 --> 00:22:50,929
rover is we play on a day at a time and

577
00:22:54,820 --> 00:22:52,730
we'll plan a day we'll send the

578
00:22:56,710 --> 00:22:54,830
instructions to the rover it will run it

579
00:22:58,120 --> 00:22:56,720
stuff while we sleep at night and then

580
00:22:59,770 --> 00:22:58,130
we'll come in the next morning and we'll

581
00:23:01,960 --> 00:22:59,780
have all of the data that we collected

582
00:23:04,120 --> 00:23:01,970
that day before and we have a very small

583
00:23:06,220 --> 00:23:04,130
window of time where we need to make the

584
00:23:08,140 --> 00:23:06,230
plan for the next day before we hit our

585
00:23:10,270 --> 00:23:08,150
deadline when we need to uplink it to

586
00:23:12,100 --> 00:23:10,280
the rover so we're compressed and we're

587
00:23:13,450 --> 00:23:12,110
also located around the world we have

588
00:23:14,680 --> 00:23:13,460

the science team around the world so we

589
00:23:16,270 --> 00:23:14,690
all have to come to an agreement about

590
00:23:18,700 --> 00:23:16,280
what we want to do in this compressed

591
00:23:20,340 --> 00:23:18,710
period of time so again being able to

592
00:23:22,350 --> 00:23:20,350
visualize the data

593
00:23:24,210 --> 00:23:22,360
we intuitively have tools that we can

594
00:23:26,100 --> 00:23:24,220
just fire up right away is so important

595
00:23:27,930 --> 00:23:26,110
and helping us all get on the same page

596
00:23:30,210 --> 00:23:27,940
and really understand what's going on

597
00:23:33,930 --> 00:23:30,220
and come to consensus and enough time

598
00:23:35,159 --> 00:23:33,940
that we can make a plan Parker

599
00:23:38,610 --> 00:23:35,169
we've been working on this stuff for

600
00:23:40,680 --> 00:23:38,620
four years now and what do you think the

601
00:23:43,620 --> 00:23:40,690
next four years looks like for this kind

602
00:23:45,210 --> 00:23:43,630
of work well one of the the immediate

603
00:23:46,680 --> 00:23:45,220
things on our roadmap is building the

604
00:23:48,600 --> 00:23:46,690
next generation of this tool for the

605
00:23:50,039 --> 00:23:48,610
upcoming Mars 2020 mission where we'll

606
00:23:52,320 --> 00:23:50,049
be taking all of the experience of the

607
00:23:54,570 --> 00:23:52,330
previous four years extending it and

608
00:23:56,549 --> 00:23:54,580
making it even more integrated into the

609
00:23:58,169 --> 00:23:56,559
the science planning process where as

610
00:23:59,880 --> 00:23:58,179
on-site came in to the Curiosity rover

611
00:24:02,340 --> 00:23:59,890
mission kind of late in the game as an

612
00:24:04,260 --> 00:24:02,350
additional experimental tool our next

613
00:24:06,360 --> 00:24:04,270

tool called Astro will be about a

614
00:24:09,299 --> 00:24:06,370
fundamental part of the tactical process

615
00:24:11,640 --> 00:24:09,309
used by the science team but but

616
00:24:14,430 --> 00:24:11,650
thinking beyond Mars really what on-site

617
00:24:16,470 --> 00:24:14,440
provides is immersion and situational

618
00:24:18,240 --> 00:24:16,480
awareness of a remote environment maybe

619
00:24:20,279 --> 00:24:18,250
with a robotic vehicle or maybe not and

620
00:24:21,510 --> 00:24:20,289
Mars is kind of an extreme example of

621
00:24:22,890 --> 00:24:21,520
that if a place that you can't

622
00:24:24,779 --> 00:24:22,900
physically visit but this will allows

623
00:24:26,940 --> 00:24:24,789
you to virtually visit but there's a lot

624
00:24:29,130 --> 00:24:26,950
of other applications that could benefit

625
00:24:30,950 --> 00:24:29,140
from the same capabilities including

626
00:24:33,720 --> 00:24:30,960
exploring the seafloor here on earth

627
00:24:36,480 --> 00:24:33,730
exploring a lunar surfaces or asteroid

628
00:24:39,480 --> 00:24:36,490
surfaces the the upcoming Europa clipper

629
00:24:40,649 --> 00:24:39,490
mission or even exploring the areas on

630
00:24:44,039 --> 00:24:40,659
earth that are just difficult to get to

631
00:24:46,289 --> 00:24:44,049
like volcano craters lava tubes areas in

632
00:24:48,000 --> 00:24:46,299
the Arctic or remote field you know

633
00:24:49,440 --> 00:24:48,010
geology field sites we've had a lot of

634
00:24:52,310 --> 00:24:49,450
interest from from terrestrial

635
00:24:55,260 --> 00:24:52,320
geologists in that kind of capability

636
00:24:57,049 --> 00:24:55,270
alright I just have one final question

637
00:24:59,760 --> 00:24:57,059
for you guys before I open up the public

638
00:25:01,310 --> 00:24:59,770

with these types of virtual augmented

639
00:25:02,520 --> 00:25:01,320
reality technologies we're hearing about

640
00:25:04,980 --> 00:25:02,530
everywhere

641
00:25:07,169 --> 00:25:04,990
what other things in everyday life do

642
00:25:11,190 --> 00:25:07,179
you think it's gonna change I'll start

643
00:25:12,779 --> 00:25:11,200
with you Ellis hmm well I think it

644
00:25:17,490 --> 00:25:12,789
really has the power to connect people

645
00:25:19,799 --> 00:25:17,500
to places or people where we are you

646
00:25:22,860 --> 00:25:19,809
know not physically co-located so we've

647
00:25:25,049 --> 00:25:22,870
seen some I mean I've heard of some

648
00:25:26,649 --> 00:25:25,059
experiences in the news where people can

649
00:25:29,469 --> 00:25:26,659
go to a museum or

650
00:25:31,899 --> 00:25:29,479
go to another you know place or visit

651
00:25:33,749 --> 00:25:31,909
people in a way that you know they

652
00:25:36,249 --> 00:25:33,759
couldn't do because they were physically

653
00:25:38,019 --> 00:25:36,259
separated Mars is the furthest place

654
00:25:40,080 --> 00:25:38,029
Mars is the furthest place definitely

655
00:25:42,779 --> 00:25:40,090
but like Parker said I feel like

656
00:25:44,680 --> 00:25:42,789
education is going to be a big big

657
00:25:47,979 --> 00:25:44,690
beneficiary of these kind of

658
00:25:49,869 --> 00:25:47,989
technologies there you know and you

659
00:25:52,419 --> 00:25:49,879
could be in a classroom learning about

660
00:25:54,339 --> 00:25:52,429
you know the ocean floor but then you

661
00:25:56,339 --> 00:25:54,349
could all Don your headset and then go

662
00:25:58,539 --> 00:25:56,349
walk around and do like these virtual

663
00:26:00,999 --> 00:25:58,549

geology field trips while you're still

664
00:26:02,339 --> 00:26:01,009
in grad school and I think an education

665
00:26:04,659 --> 00:26:02,349
is probably going to be the biggest

666
00:26:06,789 --> 00:26:04,669
connecting the students to those remote

667
00:26:10,060 --> 00:26:06,799
environments that they're studying is

668
00:26:13,359 --> 00:26:10,070
gonna be the biggest I hope that's the

669
00:26:15,489 --> 00:26:13,369
biggest change Parker what about you

670
00:26:17,379 --> 00:26:15,499
what other applications do you see I

671
00:26:18,969 --> 00:26:17,389
think that the these capabilities are

672
00:26:20,200 --> 00:26:18,979
going to become more more tightly

673
00:26:22,269 --> 00:26:20,210
integrated with tools that we already

674
00:26:24,430 --> 00:26:22,279
use and especially the tools we already

675
00:26:26,619 --> 00:26:24,440
use I think that will come to a point

676
00:26:28,389 --> 00:26:26,629
where the the headset is not a

677
00:26:30,909 --> 00:26:28,399
completely separate application but it's

678
00:26:32,680 --> 00:26:30,919
it's another view of your computer and

679
00:26:34,389 --> 00:26:32,690
the applications you normally use on

680
00:26:35,979 --> 00:26:34,399
your computer throughout your day will

681
00:26:38,049 --> 00:26:35,989
have augmented reality or virtual

682
00:26:39,969 --> 00:26:38,059
reality you know views what it makes

683
00:26:42,009 --> 00:26:39,979
sense to have them that fully immersive

684
00:26:43,599 --> 00:26:42,019
stereo 3d and capability and I think

685
00:26:45,249 --> 00:26:43,609
will be a very normal streamlined part

686
00:26:47,469 --> 00:26:45,259
of working with computers in the future

687
00:26:48,879 --> 00:26:47,479
and maybe maybe even beyond that when

688
00:26:52,269 --> 00:26:48,889

you're not in a computer when once the

689
00:26:53,409 --> 00:26:52,279
the the display technology is portable

690
00:26:56,049 --> 00:26:53,419
enough that you can carry it with you

691
00:27:00,269 --> 00:26:56,059
every day it will be as ubiquitous as

692
00:27:02,529 --> 00:27:00,279
ubiquitous as a smartphone mm-hmm I mean

693
00:27:04,570 --> 00:27:02,539
yeah I think my answer is actually very

694
00:27:06,810 --> 00:27:04,580
similar to Alice's but I'll say it

695
00:27:09,249 --> 00:27:06,820
anyway you know one of my favorite

696
00:27:10,899 --> 00:27:09,259
aspects of using on site for Mars rover

697
00:27:12,249 --> 00:27:10,909
operations is the fact that as a science

698
00:27:14,320 --> 00:27:12,259
team it makes it so easy to collaborate

699
00:27:16,299 --> 00:27:14,330
so one of the features of the software

700
00:27:17,919 --> 00:27:16,309
is that we can actually all beam onto

701
00:27:19,719 --> 00:27:17,929
the surface of Mars together and we have

702
00:27:21,310 --> 00:27:19,729
these little avatars that show up and

703
00:27:24,489 --> 00:27:21,320
walk around and we're all connected

704
00:27:25,839 --> 00:27:24,499
through audio as well and it's amazing

705
00:27:27,849 --> 00:27:25,849
how much you really start to feel like

706
00:27:31,149 --> 00:27:27,859
you're actually in a field site with

707
00:27:33,759 --> 00:27:31,159
these people who might be in Denmark or

708
00:27:35,440 --> 00:27:33,769
Great Britain or Australia but you

709
00:27:37,149 --> 00:27:35,450
really feel like you're in a room you're

710
00:27:40,169 --> 00:27:37,159
walking around your avatar can interact

711
00:27:42,279 --> 00:27:40,179
with their avatar and I think just the

712
00:27:44,019 --> 00:27:42,289
capability for this to bring people

713
00:27:46,060 --> 00:27:44,029

together you know if they're just

714
00:27:48,039 --> 00:27:46,070
families and loved ones across the globe

715
00:27:49,899 --> 00:27:48,049
if there are different researchers who

716
00:27:52,629 --> 00:27:49,909
are interested in a common goal any

717
00:27:54,789 --> 00:27:52,639
sorts of thing it just you feel so much

718
00:27:56,619 --> 00:27:54,799
more together than you do over a WebEx

719
00:27:58,899 --> 00:27:56,629
telecon or something like that it's

720
00:28:00,789 --> 00:27:58,909
really interesting to me yeah I think

721
00:28:03,399 --> 00:28:00,799
overall it's gonna transform the way we

722
00:28:05,080 --> 00:28:03,409
capture and tell stories right right now

723
00:28:09,669 --> 00:28:05,090
we capture them with these little things

724
00:28:12,099 --> 00:28:09,679
and it's a very linear timeline right

725
00:28:14,859 --> 00:28:12,109
but imagine an environment where you

726
00:28:17,080 --> 00:28:14,869
know it's so it's a concert or the World

727
00:28:19,299 --> 00:28:17,090
Cup or like a football game and you can

728
00:28:21,070 --> 00:28:19,309
replay that from any angle any time

729
00:28:22,810 --> 00:28:21,080
right and walk through the field as

730
00:28:24,159 --> 00:28:22,820
they're playing these type of

731
00:28:27,219 --> 00:28:24,169
technologies are we're gonna really

732
00:28:29,560 --> 00:28:27,229
enable and open up a whole several

733
00:28:31,450 --> 00:28:29,570
different dimensions of interactions and

734
00:28:31,989 --> 00:28:31,460
it's super exciting to see what comes

735
00:28:33,999 --> 00:28:31,999
next

736
00:28:36,609 --> 00:28:34,009
all right so what's that we'll open it

737
00:28:38,049 --> 00:28:36,619
up to questions here I think if you guys

738
00:28:45,450 --> 00:28:38,059

can line up to the mic so that we can

739
00:28:52,239 --> 00:28:50,200
there's a mic in the middle if you can't

740
00:29:03,279 --> 00:28:52,249
get to it feel free to shout out and I

741
00:29:05,259 --> 00:29:03,289
can always a my first yes excellent okay

742
00:29:07,599 --> 00:29:05,269
my question is not so much about virtual

743
00:29:09,519 --> 00:29:07,609
reality but augmented reality so I

744
00:29:11,349 --> 00:29:09,529
understand that the heads-up display in

745
00:29:12,639 --> 00:29:11,359
aircraft especially for fighter pilots

746
00:29:15,460 --> 00:29:12,649
has been really revolutionary in terms

747
00:29:17,229 --> 00:29:15,470
of extending human capabilities in a

748
00:29:19,570 --> 00:29:17,239
partnership with the machine do you

749
00:29:21,639 --> 00:29:19,580
envision having astronaut spacesuit

750
00:29:23,529 --> 00:29:21,649
helmets having full functionality like

751
00:29:25,149 --> 00:29:23,539
that and being able to overlay

752
00:29:26,680 --> 00:29:25,159
instructions and navigational

753
00:29:28,659 --> 00:29:26,690
information things like that is there in

754
00:29:30,729 --> 00:29:28,669
the field and also safety like their

755
00:29:31,749 --> 00:29:30,739
oxygen level or something so it can let

756
00:29:34,839 --> 00:29:31,759
them know if there's a problem very

757
00:29:36,399 --> 00:29:34,849
quickly yeah we have technologists at

758
00:29:38,409 --> 00:29:36,409
Johnson Space Center in Houston working

759
00:29:40,239 --> 00:29:38,419
on that problem right now the one thing

760
00:29:43,180 --> 00:29:40,249
to think about it's it's a unique

761
00:29:45,430 --> 00:29:43,190
challenge both for fighter jet pilots

762
00:29:47,889 --> 00:29:45,440
and astronauts is that you can't have a

763
00:29:49,810 --> 00:29:47,899

screen that's the only rule because if

764
00:29:51,729 --> 00:29:49,820
the screen breaks you know what happens

765
00:29:53,230 --> 00:29:51,739
right it's a huge safety race so to

766
00:29:55,390 --> 00:29:53,240
figure out how to get the projection

767
00:29:57,850 --> 00:29:55,400
on the screen in a way that it feels

768
00:29:59,440 --> 00:29:57,860
like it's the right depth cue but also

769
00:30:01,600 --> 00:29:59,450
doesn't obscure their everyday tasks

770
00:30:03,460 --> 00:30:01,610
that's an integer challenge we're just

771
00:30:09,820 --> 00:30:03,470
starting that it's a it makes perfect

772
00:30:12,880 --> 00:30:09,830
sense okay thank you all right thank you

773
00:30:14,590 --> 00:30:12,890
you've spoken a lot about how these

774
00:30:17,460 --> 00:30:14,600
technologies can help people feel more

775
00:30:20,550 --> 00:30:17,470
connected with places they haven't been

776
00:30:23,980 --> 00:30:20,560
how do you think this could apply to

777
00:30:26,170 --> 00:30:23,990
also helping people connect with places

778
00:30:29,230 --> 00:30:26,180
they haven't been through things like

779
00:30:31,000 --> 00:30:29,240
robots on earth because for example here

780
00:30:34,030 --> 00:30:31,010
you're showing a lot of visualization of

781
00:30:36,400 --> 00:30:34,040
remote environments and particularly

782
00:30:39,400 --> 00:30:36,410
with your delay in communicating with

783
00:30:41,530 --> 00:30:39,410
Mars you can't exactly joystick robot as

784
00:30:43,270 --> 00:30:41,540
you said but there are a lot of places

785
00:30:44,680 --> 00:30:43,280
on earth where you could actually start

786
00:30:46,750 --> 00:30:44,690
to interact back the other direction

787
00:30:48,910 --> 00:30:46,760
again with the world so have you started

788
00:30:49,690 --> 00:30:48,920

to think about that yet and what might

789
00:30:52,900 --> 00:30:49,700
that look like

790
00:30:54,820 --> 00:30:52,910
Thanks yeah this actually ties in nicely

791
00:30:58,750 --> 00:30:54,830
with the previous gentleman's question

792
00:31:01,240 --> 00:30:58,760
of how can I can augmented reality play

793
00:31:04,390 --> 00:31:01,250
into these sorts of tools so in the

794
00:31:05,920 --> 00:31:04,400
context of visualizing environments that

795
00:31:07,450 --> 00:31:05,930
a Rovers and navigating through the

796
00:31:09,580 --> 00:31:07,460
Curiosity rover is going to one extreme

797
00:31:10,750 --> 00:31:09,590
where you have a large time delay but

798
00:31:12,490 --> 00:31:10,760
there are other cases especially

799
00:31:14,740 --> 00:31:12,500
terrestrially where you might have

800
00:31:18,010 --> 00:31:14,750
Rovers they're in the same field site as

801
00:31:20,410 --> 00:31:18,020
you so there we we see being able to

802
00:31:22,210 --> 00:31:20,420
overlay into the real world information

803
00:31:23,890 --> 00:31:22,220
about the where the vehicle is if you

804
00:31:25,690 --> 00:31:23,900
can't see it for example if it if you're

805
00:31:28,390 --> 00:31:25,700
in an ice field and the vehicles under

806
00:31:30,220 --> 00:31:28,400
the water or under the ice and visualize

807
00:31:32,260 --> 00:31:30,230
sensor feeds showing you what the robot

808
00:31:34,090 --> 00:31:32,270
is sensing you know as if you were

809
00:31:35,950 --> 00:31:34,100
seeing kind of you know visualizations

810
00:31:37,570 --> 00:31:35,960
on top of the rover in the field and

811
00:31:39,640 --> 00:31:37,580
helping you understand what the Machine

812
00:31:41,140 --> 00:31:39,650
is sensing in a way that that you're

813
00:31:43,990 --> 00:31:41,150

you're not really able to in the same

814
00:31:47,380 --> 00:31:44,000
way with from a screen and how would

815
00:31:49,990 --> 00:31:47,390
that extend to control I think that that

816
00:31:51,670 --> 00:31:50,000
could that could be used by an operator

817
00:31:54,250 --> 00:31:51,680
controlling the robot giving them a view

818
00:31:55,810 --> 00:31:54,260
into the into the vehicle and it's its

819
00:31:57,520 --> 00:31:55,820
surroundings and its interaction with

820
00:31:59,830 --> 00:31:57,530
the surroundings in a way that we don't

821
00:32:03,389 --> 00:31:59,840
have with with current interfaces thank

822
00:32:08,940 --> 00:32:07,289
hi um I noticed or I heard earlier you

823
00:32:11,190 --> 00:32:08,950
were mentioning about the motion

824
00:32:13,349 --> 00:32:11,200
sickness palm with a VR and AR which is

825
00:32:16,320 --> 00:32:13,359
definitely very prevalent and kind of

826
00:32:17,969 --> 00:32:16,330
prevented the use of Xbox controllers

827
00:32:22,049 --> 00:32:17,979
and joysticks nowadays for moving around

828
00:32:24,299 --> 00:32:22,059
and I was just curious if specific to

829
00:32:27,180 --> 00:32:24,309
your projects you have come up have you

830
00:32:29,129 --> 00:32:27,190
come up with any innovative ways that we

831
00:32:30,810 --> 00:32:29,139
could minimize motion sickness such as

832
00:32:34,379 --> 00:32:30,820
ways that we can move around the

833
00:32:36,930 --> 00:32:34,389
environment in I guess that we haven't

834
00:32:38,969 --> 00:32:36,940
heard of before I think right now we're

835
00:32:40,079 --> 00:32:38,979
really in a discovery phase because you

836
00:32:41,489 --> 00:32:40,089
know the web has been around for a long

837
00:32:43,289 --> 00:32:41,499
time so there are standards for

838
00:32:45,539 --> 00:32:43,299

developing you know stuff and no

839
00:32:46,829 --> 00:32:45,549
nothing's gonna make people motion sick

840
00:32:49,769 --> 00:32:46,839
on the web but there are certain things

841
00:32:51,539 --> 00:32:49,779
that we know confuse people so I think

842
00:32:53,639 --> 00:32:51,549
we're now in a stage where the whole

843
00:32:57,629 --> 00:32:53,649
industry is discovering like what are

844
00:32:59,639 --> 00:32:57,639
the standards for UX design and VR so we

845
00:33:01,589 --> 00:32:59,649
found a few things in our application

846
00:33:03,839 --> 00:33:01,599
that we know cause motion sickness so we

847
00:33:05,579 --> 00:33:03,849
don't display them or you know we'll

848
00:33:07,229 --> 00:33:05,589
have a feature in our web viewer but not

849
00:33:10,320 --> 00:33:07,239
in our hololens viewer because we know

850
00:33:12,989 --> 00:33:10,330
like if you control the camera angle on

851
00:33:14,519 --> 00:33:12,999
a halt like on the web you can change

852
00:33:16,019 --> 00:33:14,529
the camera however you want that's why

853
00:33:17,969 --> 00:33:16,029
we can all watch movies without getting

854
00:33:20,729 --> 00:33:17,979
motion sick but if you're watching a

855
00:33:22,589 --> 00:33:20,739
movie in your VR device your body knows

856
00:33:24,509 --> 00:33:22,599
it's not moving so when your visual

857
00:33:26,669 --> 00:33:24,519
feedback tells you that it's you're

858
00:33:29,430 --> 00:33:26,679
moving that can cause motion sickness

859
00:33:31,680 --> 00:33:29,440
and on top of that there's a tremendous

860
00:33:32,999 --> 00:33:31,690
amount of individual variability so I

861
00:33:35,399 --> 00:33:33,009
think we're just discovering those

862
00:33:38,190 --> 00:33:35,409
standards on our own and just sort of

863
00:33:39,899 --> 00:33:38,200

sharing them with other people who are

864
00:33:41,249 --> 00:33:39,909
discovering VR applications we're always

865
00:33:43,769 --> 00:33:41,259
interested to learn what people in the

866
00:33:48,659 --> 00:33:43,779
gaming industry have found makes their

867
00:33:50,969 --> 00:33:48,669
users motion sick or not thoughts to

868
00:33:52,469 --> 00:33:50,979
that I think Alex Ellis hit on the big

869
00:33:54,539 --> 00:33:52,479
one don't don't move the camera if the

870
00:33:57,629 --> 00:33:54,549
users heads not moving that's soon that

871
00:33:58,829 --> 00:33:57,639
gets you most of the way there don't do

872
00:34:00,749 --> 00:33:58,839
things that you can't do in the real

873
00:34:02,879 --> 00:34:00,759
world I think especially things that

874
00:34:04,799 --> 00:34:02,889
make your brain feel it will feel

875
00:34:06,450 --> 00:34:04,809
strange like flying can be problematic

876
00:34:08,129 --> 00:34:06,460
not having something that at the ground

877
00:34:09,829 --> 00:34:08,139
level to feel like you're you're

878
00:34:12,389 --> 00:34:09,839
floating in space can be problematic

879
00:34:14,579 --> 00:34:12,399
I'll give you one that's kind of unique

880
00:34:16,470 --> 00:34:14,589
to the to the Mars case as you're

881
00:34:16,950 --> 00:34:16,480
walking virtually on Mars you're on a

882
00:34:21,089 --> 00:34:16,960
flat

883
00:34:22,889 --> 00:34:21,099
we're continually having to adjust the

884
00:34:24,809 --> 00:34:22,899
height of the terrain to make it feel

885
00:34:26,609 --> 00:34:24,819
like you're standing on the surface we

886
00:34:28,819 --> 00:34:26,619
found that it as you're walking uphill

887
00:34:31,950 --> 00:34:28,829
if you continually bring the world down

888
00:34:33,359 --> 00:34:31,960

that makes people feel motion sick so we

889
00:34:34,619 --> 00:34:33,369
actually let you walk a little bit into

890
00:34:36,750 --> 00:34:34,629
the hill and then we bring the world up

891
00:34:38,490 --> 00:34:36,760
when you stop but interestingly when you

892
00:34:41,399 --> 00:34:38,500
walk downhill it's it's fine to bring

893
00:34:42,899 --> 00:34:41,409
the world up continually so it's really

894
00:34:44,940 --> 00:34:42,909
just been kind of a process of trial and

895
00:34:46,589 --> 00:34:44,950
error of trying things out and then when

896
00:34:48,480 --> 00:34:46,599
one doesn't feel right trying to tweak

897
00:34:50,460 --> 00:34:48,490
it until it feels okay and it's very

898
00:34:52,769 --> 00:34:50,470
non-intuitive sometimes what what those

899
00:34:54,990 --> 00:34:52,779
things are that that cause problems yeah

900
00:34:58,319 --> 00:34:55,000
one of the things I will add that Parker

901
00:35:01,200 --> 00:34:58,329
touched on is the flying thing because a

902
00:35:03,120 --> 00:35:01,210
lot of people want to look at the the

903
00:35:04,620 --> 00:35:03,130
terrain from an orbital view to get a

904
00:35:07,140 --> 00:35:04,630
bigger picture but we found that when we

905
00:35:08,970 --> 00:35:07,150
did that you're it's too high above the

906
00:35:11,039 --> 00:35:08,980
terrain and it makes people feel motion

907
00:35:13,859 --> 00:35:11,049
sickness or an unsteady so we actually

908
00:35:16,140 --> 00:35:13,869
put a floor like a fake floor under

909
00:35:18,960 --> 00:35:16,150
there where it appears your feet are and

910
00:35:22,380 --> 00:35:18,970
then people were fine and we just

911
00:35:23,819 --> 00:35:22,390
discovered that that works so those are

912
00:35:25,730 --> 00:35:23,829
the kind of things we're just testing

913
00:35:33,180 --> 00:35:25,740

out every time we develop new features

914
00:35:35,940 --> 00:35:33,190
that's really cool thank you hi in

915
00:35:40,319 --> 00:35:35,950
reality what role did the impact craters

916
00:35:42,359 --> 00:35:40,329
play in making an even terrain whereby

917
00:35:46,349 --> 00:35:42,369
are there adjustments that have to be

918
00:35:47,970 --> 00:35:46,359
made we know we don't make adjustments

919
00:35:49,980 --> 00:35:47,980
for the impact craters what we'd want to

920
00:35:51,720 --> 00:35:49,990
do is capture the craters as you know as

921
00:35:53,190 --> 00:35:51,730
accurately as we're able to so we take

922
00:35:54,990 --> 00:35:53,200
the images that the rubber sends back

923
00:35:57,510 --> 00:35:55,000
and from stereo correlation of the rover

924
00:35:59,430 --> 00:35:57,520
imagery we can drive the 3d geometry in

925
00:36:01,769 --> 00:35:59,440
this case the the geometry of the impact

926
00:36:03,450 --> 00:36:01,779
craters and then we'll build that into

927
00:36:05,160 --> 00:36:03,460
our integrated mesh reconstruction in

928
00:36:06,870 --> 00:36:05,170
fact some of our users are specifically

929
00:36:10,529 --> 00:36:06,880
looking for the impact crater so it's an

930
00:36:12,480 --> 00:36:10,539
area of interest for them they're

931
00:36:15,000 --> 00:36:12,490
nature's drills man they drill in and

932
00:36:17,160 --> 00:36:15,010
they expose the 3d stratigraphy of the

933
00:36:20,329 --> 00:36:17,170
rocks so what a great rate of view it in

934
00:36:24,170 --> 00:36:20,339
3d with the MRO

935
00:36:26,510 --> 00:36:24,180
constantly discovering impact craters

936
00:36:30,400 --> 00:36:26,520
say for example 2010

937
00:36:34,760 --> 00:36:30,410
most recently in 2012-2013 there's a

938
00:36:38,870 --> 00:36:34,770

frequency of the impact craters to allow

939
00:36:43,010 --> 00:36:38,880
to substantiate the even ground or to

940
00:36:45,560 --> 00:36:43,020
compensate for it so so Mars is pretty

941
00:36:47,600 --> 00:36:45,570
heavily cratered but I mean as you can

942
00:36:49,250 --> 00:36:47,610
see in the images it's it's a big planet

943
00:36:51,700 --> 00:36:49,260
so there's a lot of craters but there's

944
00:36:56,810 --> 00:36:51,710
even more ground to drive around on

945
00:36:58,760 --> 00:36:56,820
thank you hi

946
00:37:01,040 --> 00:36:58,770
I understand the concept where you have

947
00:37:02,600 --> 00:37:01,050
the helicopter you know in the future

948
00:37:05,180 --> 00:37:02,610
you're going to have the helicopter

949
00:37:07,430 --> 00:37:05,190
could go up but what if the helicopter

950
00:37:09,740 --> 00:37:07,440
is sort of a mothership and has four or

951
00:37:12,350 --> 00:37:09,750
five little drones on it

952
00:37:14,210 --> 00:37:12,360
and they could go low or high and

953
00:37:16,490 --> 00:37:14,220
they're going in five different

954
00:37:20,210 --> 00:37:16,500
directions without a very expensive

955
00:37:23,870 --> 00:37:20,220
hardware and just you since we have so

956
00:37:26,180 --> 00:37:23,880
much technology now sort of to split out

957
00:37:29,510 --> 00:37:26,190
and go in different directions you may

958
00:37:32,870 --> 00:37:29,520
have saved a lot of time one day going

959
00:37:35,270 --> 00:37:32,880
up here and one day yeah just running by

960
00:37:36,620 --> 00:37:35,280
you yeah that's an excellent comment and

961
00:37:38,570 --> 00:37:36,630
actually something that we've been

962
00:37:40,520 --> 00:37:38,580
talking about here at JPL quite a lot

963
00:37:42,680 --> 00:37:40,530

you know this first helicopter is gonna

964
00:37:44,720 --> 00:37:42,690
be a great technology demonstration of

965
00:37:46,700 --> 00:37:44,730
how it will work and now we're starting

966
00:37:49,099 --> 00:37:46,710
to think beyond wow you know if this

967
00:37:50,599 --> 00:37:49,109
works what else can we do and ideas of

968
00:37:53,990 --> 00:37:50,609
multiple helicopter there's a single

969
00:37:57,790 --> 00:37:54,000
site to explore vast areas is something

970
00:38:02,810 --> 00:38:00,380
hi I was just curious if you've been

971
00:38:04,970 --> 00:38:02,820
approached by any film makers you know

972
00:38:07,700 --> 00:38:04,980
instead of sitting in the future in a

973
00:38:09,770 --> 00:38:07,710
theater looking at a screen people could

974
00:38:12,650 --> 00:38:09,780
sit with their VR headset anywhere and

975
00:38:16,910 --> 00:38:12,660
be part of the film with a lot of the

976
00:38:19,040 --> 00:38:16,920
studios here you know Fox Disney they

977
00:38:20,390 --> 00:38:19,050
have some of those innovative solutions

978
00:38:22,490 --> 00:38:20,400
like you mentioned you know kind of a

979
00:38:24,650 --> 00:38:22,500
green screen before you get to do it

980
00:38:26,480 --> 00:38:24,660
right what if you could be on Mars and

981
00:38:28,730 --> 00:38:26,490
act there and then actually do your

982
00:38:30,440 --> 00:38:28,740
action action what's really interesting

983
00:38:33,880 --> 00:38:30,450
I think is and then relates to the

984
00:38:39,859 --> 00:38:33,890
previous question is how entertainment

985
00:38:42,950 --> 00:38:39,869
you know excites things that we do here

986
00:38:45,349 --> 00:38:42,960
and back and forth and and so it's this

987
00:38:46,999 --> 00:38:45,359
you know the movie studios the

988
00:38:49,460 --> 00:38:47,009

entertainment they create these crazy

989
00:38:51,710 --> 00:38:49,470
visions of the future and then we built

990
00:38:53,059 --> 00:38:51,720
them right and then when we built them

991
00:38:55,190 --> 00:38:53,069
they gets excited and I think about a

992
00:38:57,049 --> 00:38:55,200
future future and then it just keeps

993
00:38:59,329 --> 00:38:57,059
feeding into the loop so I think it is

994
00:39:01,700 --> 00:38:59,339
very exciting for us we do talk a lot

995
00:39:03,739 --> 00:39:01,710
with these these studios not only about

996
00:39:07,930 --> 00:39:03,749
the technology but about what that

997
00:39:10,309 --> 00:39:07,940
allows us to create excellent thank you

998
00:39:12,259 --> 00:39:10,319
hello do you have any plans to

999
00:39:16,130 --> 00:39:12,269
open-source these core components of

1000
00:39:17,599 --> 00:39:16,140
your technology we don't have the

1001
00:39:19,460 --> 00:39:17,609
immediate plans to open source the

1002
00:39:21,529 --> 00:39:19,470
on-site technology however we are

1003
00:39:22,759 --> 00:39:21,539
working on open sourcing the the terrain

1004
00:39:25,609 --> 00:39:22,769
rendering engine that we've built to

1005
00:39:28,069 --> 00:39:25,619
render the the Mars terrain that's not

1006
00:39:30,650 --> 00:39:28,079
quite ready yet I've checked back with

1007
00:39:32,450 --> 00:39:30,660
with that the ops lab page later on it

1008
00:39:35,029 --> 00:39:32,460
should be coming online probably in the

1009
00:39:36,920 --> 00:39:35,039
next half year so okay so the

1010
00:39:38,150 --> 00:39:36,930
information will be on the website and

1011
00:39:40,370 --> 00:39:38,160
then we'll be able to check it here the

1012
00:39:46,400 --> 00:39:40,380
ops lab website up top slab JPL the NASA

1013
00:39:48,349 --> 00:39:46,410

don't go okay yeah thanks you mentioned

1014
00:39:50,900 --> 00:39:48,359
briefly that I like it especially as a

1015
00:39:53,839 --> 00:39:50,910
scientists that the whole environment

1016
00:39:55,479 --> 00:39:53,849
feels very much like a feel like you're

1017
00:39:59,930 --> 00:39:55,489
going on into the field is going on Mars

1018
00:40:02,839 --> 00:39:59,940
and so it's kind of curious into if you

1019
00:40:04,479 --> 00:40:02,849
see any future improvements in terms I

1020
00:40:06,410 --> 00:40:04,489
feel like there's gonna be some sort of

1021
00:40:08,989 --> 00:40:06,420
disconnect between obviously you can

1022
00:40:11,870 --> 00:40:08,999
make a direct observation on the

1023
00:40:15,229 --> 00:40:11,880
material but I mean do you have direct

1024
00:40:17,479 --> 00:40:15,239
access to maybe your your data on you

1025
00:40:19,130 --> 00:40:17,489
know its composition or obviously you

1026
00:40:20,720 --> 00:40:19,140
can't like actually engage with the

1027
00:40:23,809 --> 00:40:20,730
material to see like maybe how brittle

1028
00:40:25,339 --> 00:40:23,819
it is and on top of that have you guys

1029
00:40:29,420 --> 00:40:25,349
actually dealt with the issue in terms

1030
00:40:31,880 --> 00:40:29,430
of taking field notes is that you going

1031
00:40:34,220 --> 00:40:31,890
in and out of the VR which I feel it

1032
00:40:35,839 --> 00:40:34,230
might be a little disorienting or can

1033
00:40:38,749 --> 00:40:35,849
you actually take field notes while

1034
00:40:40,249 --> 00:40:38,759
being in the environment yeah so those

1035
00:40:41,989 --> 00:40:40,259
are great questions and something that

1036
00:40:43,670 --> 00:40:41,999
we worked closely with Alice actually

1037
00:40:45,440 --> 00:40:43,680
when we were developing it how much data

1038
00:40:46,970 --> 00:40:45,450

should we show should be be able to

1039
00:40:49,970 --> 00:40:46,980
click on a rock and have a composition

1040
00:40:51,910 --> 00:40:49,980
come up and what we found was sometimes

1041
00:40:53,890 --> 00:40:51,920
too much as too much

1042
00:40:55,180 --> 00:40:53,900
and it just overwhelmed the interface

1043
00:40:57,160 --> 00:40:55,190
I'm sure you can talk more about that

1044
00:40:59,500 --> 00:40:57,170
but in the end we do we have multiple

1045
00:41:01,510 --> 00:40:59,510
tools so we can use the on-site to

1046
00:41:03,640 --> 00:41:01,520
orient ourselves give the basic lay of

1047
00:41:05,770 --> 00:41:03,650
the land give the basic geology and then

1048
00:41:07,000 --> 00:41:05,780
when we need to go deeper into you know

1049
00:41:08,830 --> 00:41:07,010
what is the composition of this

1050
00:41:10,570 --> 00:41:08,840
particular rock we can then go to our

1051
00:41:14,200 --> 00:41:10,580
computer screen and look at those data

1052
00:41:16,060 --> 00:41:14,210
in that medium yeah we have a lot of the

1053
00:41:18,370 --> 00:41:16,070
capabilities to display that data but

1054
00:41:21,730 --> 00:41:18,380
it's just what is useful in the moment

1055
00:41:23,350 --> 00:41:21,740
so what we found is that people kind of

1056
00:41:26,020 --> 00:41:23,360
just want to walk around on Mars you get

1057
00:41:28,360 --> 00:41:26,030
just so much information by walking

1058
00:41:31,090 --> 00:41:28,370
around as because the geologists who are

1059
00:41:33,190 --> 00:41:31,100
walking around on Mars in our in on-site

1060
00:41:34,570 --> 00:41:33,200
trained to be geologists on earth where

1061
00:41:37,510 --> 00:41:34,580
they were used to collecting data

1062
00:41:39,190 --> 00:41:37,520
you know spatially by walking around so

1063
00:41:42,460 --> 00:41:39,200

we found that that's the most useful

1064
00:41:46,630 --> 00:41:42,470
thing for them but to your points I know

1065
00:41:48,040 --> 00:41:46,640
that one of our users he would look he

1066
00:41:49,450 --> 00:41:48,050
would Don the headset and then look

1067
00:41:52,000 --> 00:41:49,460
around and then go to the highest hill

1068
00:41:55,150 --> 00:41:52,010
and start drawing maps you know because

1069
00:41:57,190 --> 00:41:55,160
you could see the whole terrain so that

1070
00:41:59,830 --> 00:41:57,200
was his version of field notes as you

1071
00:42:01,900 --> 00:41:59,840
say so there are ways to do it it's just

1072
00:42:05,140 --> 00:42:01,910
you know using it as a window into

1073
00:42:07,030 --> 00:42:05,150
another world and then you know

1074
00:42:10,270 --> 00:42:07,040
whatever's useful to you in this case

1075
00:42:12,160 --> 00:42:10,280
maps you know when we first started this

1076
00:42:14,920 --> 00:42:12,170
project we drew out these storyboards

1077
00:42:18,130 --> 00:42:14,930
much like in film and the last

1078
00:42:20,770 --> 00:42:18,140
storyboard we had was two scientists

1079
00:42:23,680 --> 00:42:20,780
picking up a rock together with their

1080
00:42:25,690 --> 00:42:23,690
hands and studying it feeling it getting

1081
00:42:28,540 --> 00:42:25,700
some statistics out of it and putting in

1082
00:42:31,060 --> 00:42:28,550
their virtual pouch right and the

1083
00:42:33,820 --> 00:42:31,070
technology today is not quite there yet

1084
00:42:35,950 --> 00:42:33,830
but we do see a roadmap for that to be

1085
00:42:37,780 --> 00:42:35,960
possible now imagine you you you see

1086
00:42:41,650 --> 00:42:37,790
this rock you really love a be picks it

1087
00:42:44,080 --> 00:42:41,660
up she studies it and then weeks months

1088
00:42:46,030 --> 00:42:44,090

down the line you feel deja vu I saw

1089
00:42:47,320 --> 00:42:46,040
that before right and and and with

1090
00:42:49,900 --> 00:42:47,330
machine learning AI these new

1091
00:42:52,210 --> 00:42:49,910
technologies it recognizes every past

1092
00:42:54,670 --> 00:42:52,220
rock that you studied or have not

1093
00:42:56,830 --> 00:42:54,680
studied and recommends you know just

1094
00:42:59,170 --> 00:42:56,840
like Amazon does and recommends other

1095
00:43:01,790 --> 00:42:59,180
rocks you might be interested in

1096
00:43:05,359 --> 00:43:01,800
it makes perfect sense right we do it

1097
00:43:07,160 --> 00:43:05,369
every day today why not for Mars so yes

1098
00:43:10,339 --> 00:43:07,170
we're thinking about all sorts of cool

1099
00:43:12,470 --> 00:43:10,349
technologies but relating it back to the

1100
00:43:16,250 --> 00:43:12,480
user and what's most effective in their

1101
00:43:17,570 --> 00:43:16,260
use case I like one more point here your

1102
00:43:19,339 --> 00:43:17,580
question you mentioned that might be

1103
00:43:22,010 --> 00:43:19,349
disorienting to pop in and out of the

1104
00:43:24,020 --> 00:43:22,020
virtual environment but the hololens is

1105
00:43:26,000 --> 00:43:24,030
is not a completely vr device so you

1106
00:43:27,830 --> 00:43:26,010
have some peripheral vision left over

1107
00:43:30,410 --> 00:43:27,840
which allows you to take notes on pen

1108
00:43:32,540 --> 00:43:30,420
and paper fairly effectively and we it

1109
00:43:34,670 --> 00:43:32,550
originally played with some ideas to

1110
00:43:36,920 --> 00:43:34,680
make that even more integrated with your

1111
00:43:38,540 --> 00:43:36,930
desktop tools where we would recognize

1112
00:43:40,370 --> 00:43:38,550
where your computer monitor was in the

1113
00:43:41,450 --> 00:43:40,380

world and cut that out of mars so as he

1114
00:43:42,950 --> 00:43:41,460
looked around you would see Mars

1115
00:43:45,830 --> 00:43:42,960
everywhere and then your computer screen

1116
00:43:47,510 --> 00:43:45,840
on Mars and that's that's something that

1117
00:43:50,150 --> 00:43:47,520
I would like to pursue in the future to

1118
00:43:51,980 --> 00:43:50,160
make these emergent immersive tools more

1119
00:43:54,320 --> 00:43:51,990
tightly connected with the tools that

1120
00:43:55,849 --> 00:43:54,330
scientists or nearly use as we found

1121
00:43:57,380 --> 00:43:55,859
that some things work really well in

1122
00:43:59,720 --> 00:43:57,390
immersive environments like looking at

1123
00:44:01,700 --> 00:43:59,730
3d data from multiple perspectives and

1124
00:44:03,589 --> 00:44:01,710
other things actually don't work all

1125
00:44:05,810 --> 00:44:03,599
that well like looking at bar graphs or

1126
00:44:07,670 --> 00:44:05,820
text that works pretty well on a 2d

1127
00:44:09,770 --> 00:44:07,680
screen and putting a 2d screen into an

1128
00:44:12,050 --> 00:44:09,780
immersive displays is kind of missing

1129
00:44:13,730 --> 00:44:12,060
the point so I'd like to see all of

1130
00:44:15,530 --> 00:44:13,740
these tools working seamlessly together

1131
00:44:17,450 --> 00:44:15,540
so that you can use the immersion to get

1132
00:44:19,400 --> 00:44:17,460
the context you know click click on a

1133
00:44:21,890 --> 00:44:19,410
rock see that rock pop up in all of your

1134
00:44:23,390 --> 00:44:21,900
other science tools let me dial in in a

1135
00:44:24,680 --> 00:44:23,400
little bit and see that point change in

1136
00:44:26,480 --> 00:44:24,690
the immersion and again seamlessly go

1137
00:44:28,280 --> 00:44:26,490
back and forth as really as if you're

1138
00:44:36,140 --> 00:44:28,290

just using one tool that's part of

1139
00:44:37,550 --> 00:44:36,150
mersive in part 2d thank you so

1140
00:44:39,440 --> 00:44:37,560
currently you're using the tool with

1141
00:44:40,730 --> 00:44:39,450
existing data sets which are images

1142
00:44:42,560 --> 00:44:40,740
which is also pretty cool because

1143
00:44:44,930 --> 00:44:42,570
presumably you could integrate that with

1144
00:44:46,849 --> 00:44:44,940
all previously existing data sets as

1145
00:44:48,410 --> 00:44:46,859
well but none of the technologies

1146
00:44:49,700 --> 00:44:48,420
developed and shown I'm wondering if you

1147
00:44:52,010 --> 00:44:49,710
have considered adding additional

1148
00:44:55,730 --> 00:44:52,020
sensors like maybe temperature or

1149
00:44:58,670 --> 00:44:55,740
perhaps ambient noise and creating like

1150
00:45:01,700 --> 00:44:58,680
a more full experience there to capture

1151
00:45:04,160 --> 00:45:01,710
more of the senses yeah so in the case

1152
00:45:06,020 --> 00:45:04,170
of the of Mars exploration word we are

1153
00:45:09,440 --> 00:45:06,030
limited to the sensors already onboard

1154
00:45:10,660 --> 00:45:09,450
the vehicles we focused mainly on the

1155
00:45:12,860 --> 00:45:10,670
visual imaging that there are

1156
00:45:15,260 --> 00:45:12,870
scientific datasets they're collected

1157
00:45:17,300 --> 00:45:15,270
too we we have looked at a few ways that

1158
00:45:19,280 --> 00:45:17,310
we could bring those also into the the

1159
00:45:21,020 --> 00:45:19,290
immersive environment and the cases

1160
00:45:23,570 --> 00:45:21,030
where it makes sense is where the data

1161
00:45:25,010 --> 00:45:23,580
is going to inherently 3d actually one

1162
00:45:27,440 --> 00:45:25,020
that is kind of interesting they were

1163
00:45:28,850 --> 00:45:27,450

were considering for 2020 is there's an

1164
00:45:30,860 --> 00:45:28,860
instrument called grim facts that's the

1165
00:45:32,900 --> 00:45:30,870
ground-penetrating radar that's going to

1166
00:45:34,670 --> 00:45:32,910
sense beneath the surface of Mars has

1167
00:45:36,770 --> 00:45:34,680
the rover drives and we've thought a

1168
00:45:40,520 --> 00:45:36,780
little bit about how could we have

1169
00:45:42,110 --> 00:45:40,530
visualized subsurface in for meetings in

1170
00:45:43,910 --> 00:45:42,120
an immersive environment and would there

1171
00:45:45,320 --> 00:45:43,920
be additional information that

1172
00:45:50,770 --> 00:45:45,330
scientists could derive from looking at

1173
00:45:56,540 --> 00:45:53,980
hi you guys put a lot of emphasis on

1174
00:45:59,570 --> 00:45:56,550
when building your environment that you

1175
00:46:02,750 --> 00:45:59,580
use the pictures from curiosity and no

1176
00:46:07,640 --> 00:46:02,760
computer generation so my question is

1177
00:46:09,170 --> 00:46:07,650
how do you tell curiosity where to take

1178
00:46:10,970 --> 00:46:09,180
pictures so that it doesn't most

1179
00:46:12,410 --> 00:46:10,980
efficiently since I doubt taking a

1180
00:46:15,620 --> 00:46:12,420
picture of every inch of Mars would be

1181
00:46:18,530 --> 00:46:15,630
very efficient but then also be able to

1182
00:46:20,540 --> 00:46:18,540
combine all those pictures into the 3d

1183
00:46:24,110 --> 00:46:20,550
environment without any loss of data in

1184
00:46:27,410 --> 00:46:24,120
certain areas where there's just not

1185
00:46:29,120 --> 00:46:27,420
enough to make a full picture

1186
00:46:31,070 --> 00:46:29,130
that's a great question how about I'll

1187
00:46:32,960 --> 00:46:31,080
address that from the technical side and

1188
00:46:36,710 --> 00:46:32,970

then have a maybe you can add some some

1189
00:46:38,480 --> 00:46:36,720
science insights so the way that we

1190
00:46:40,880 --> 00:46:38,490
approach 3d reconstruction is to take

1191
00:46:42,290 --> 00:46:40,890
the images that the rover sends back use

1192
00:46:46,510 --> 00:46:42,300
the stereo correlation between the

1193
00:46:49,160 --> 00:46:46,520
pictures to derive 3d geometry and then

1194
00:46:51,200 --> 00:46:49,170
kind of a big research area for us has

1195
00:46:52,790 --> 00:46:51,210
been finding very accurate solves

1196
00:46:54,230 --> 00:46:52,800
between positions where the rover

1197
00:46:55,790 --> 00:46:54,240
captured imagery so that we can combine

1198
00:46:57,170 --> 00:46:55,800
imagery from different points of view

1199
00:46:59,330 --> 00:46:57,180
and get a more complete view of the

1200
00:47:01,010 --> 00:46:59,340
environment we do that with with a

1201
00:47:03,170 --> 00:47:01,020
variety of computer vision techniques

1202
00:47:04,910 --> 00:47:03,180
that we've tuned for this particular use

1203
00:47:06,740 --> 00:47:04,920
case and there are a number of

1204
00:47:08,780 --> 00:47:06,750
off-the-shelf tools that can do similar

1205
00:47:10,490 --> 00:47:08,790
things but we found that they don't work

1206
00:47:13,040 --> 00:47:10,500
particularly well for the context of

1207
00:47:15,020 --> 00:47:13,050
Mars reconstruction because if you're

1208
00:47:16,490 --> 00:47:15,030
doing this on earth you you can capture

1209
00:47:18,320 --> 00:47:16,500
a lot of images you can throw fly a

1210
00:47:20,090 --> 00:47:18,330
drone around and capture a bunch of tons

1211
00:47:21,770 --> 00:47:20,100
of images or you can walk around with

1212
00:47:23,360 --> 00:47:21,780
your SLR and capture as much data as you

1213
00:47:24,560 --> 00:47:23,370

need but when we're trying to

1214
00:47:26,330 --> 00:47:24,570
reconstruct Mars we're

1215
00:47:29,960 --> 00:47:26,340
to the images that came back over that

1216
00:47:31,550 --> 00:47:29,970
56k modem connection and they tend to be

1217
00:47:33,320 --> 00:47:31,560
fewer in number than you would typically

1218
00:47:35,810 --> 00:47:33,330
have on earth they tend to be captured

1219
00:47:38,300 --> 00:47:35,820
from farther apart and with less overlap

1220
00:47:40,220 --> 00:47:38,310
so a lot of the the custom work that's

1221
00:47:41,960 --> 00:47:40,230
gone into this reconstruction pipeline

1222
00:47:45,200 --> 00:47:41,970
has been developing heuristics that can

1223
00:47:47,240 --> 00:47:45,210
can make useful reconstructions even

1224
00:47:48,770 --> 00:47:47,250
when you have limited data and will use

1225
00:47:50,990 --> 00:47:48,780
as much or as little tool data as we

1226
00:47:53,210 --> 00:47:51,000
have so when we just arrived at a new

1227
00:47:54,380 --> 00:47:53,220
place we may we may only have two

1228
00:47:56,210 --> 00:47:54,390
pictures of the ground in front of the

1229
00:47:58,160 --> 00:47:56,220
rover and everything else will just fill

1230
00:47:59,660 --> 00:47:58,170
in from adorable base map and then we'll

1231
00:48:01,880 --> 00:47:59,670
add more as the rover down likes more

1232
00:48:03,970 --> 00:48:01,890
imagery so we tried to eke out as much

1233
00:48:06,320 --> 00:48:03,980
as we can from the images that we have

1234
00:48:08,180 --> 00:48:06,330
and then to answer the question of how

1235
00:48:09,710 --> 00:48:08,190
do we figure out what pictures to take

1236
00:48:11,660 --> 00:48:09,720
with the rover that's something that the

1237
00:48:13,700 --> 00:48:11,670
science team gets together kind of first

1238
00:48:15,500 --> 00:48:13,710

thing in the morning and we all fight it

1239
00:48:17,630 --> 00:48:15,510
out to figure out given the amount of

1240
00:48:19,400 --> 00:48:17,640
time we have every day and what our data

1241
00:48:21,530 --> 00:48:19,410
volume for that day is what is

1242
00:48:23,290 --> 00:48:21,540
reasonable to take pictures of so we

1243
00:48:25,910 --> 00:48:23,300
often start with lower resolution

1244
00:48:28,430 --> 00:48:25,920
grayscale images that cover wide areas

1245
00:48:30,500 --> 00:48:28,440
and then we kind of use our geology eyes

1246
00:48:32,420 --> 00:48:30,510
and say that rock looks particularly

1247
00:48:34,520 --> 00:48:32,430
interesting or that relationship we need

1248
00:48:35,960 --> 00:48:34,530
to image that and so we pick little

1249
00:48:38,720 --> 00:48:35,970
postage stamps that we want in high

1250
00:48:39,980 --> 00:48:38,730
resolution color images some spaces that

1251
00:48:42,050 --> 00:48:39,990
are really special or if we've been

1252
00:48:44,450 --> 00:48:42,060
driving for a while we'll take a 360

1253
00:48:46,160 --> 00:48:44,460
degree color panorama but those are very

1254
00:48:48,800 --> 00:48:46,170
large data products they take a really

1255
00:48:50,060 --> 00:48:48,810
long time so we don't take them all the

1256
00:48:52,820 --> 00:48:50,070
time but we often do have these

1257
00:48:57,800 --> 00:48:52,830
grayscale 360-degree coverage for most

1258
00:49:00,440 --> 00:48:57,810
of our spots hi

1259
00:49:03,440 --> 00:49:00,450
one and a half year ago at Kennedy Space

1260
00:49:07,310 --> 00:49:03,450
Center I had the opportunity to use the

1261
00:49:10,790 --> 00:49:07,320
hololens in one Mars environment hosted

1262
00:49:17,180 --> 00:49:10,800
by John Graham is it the same technology

1263
00:49:18,440 --> 00:49:17,190

with not what is the difference yeah so

1264
00:49:20,180 --> 00:49:18,450
the experience that you're referring to

1265
00:49:21,770 --> 00:49:20,190
is called destination Mars and that was

1266
00:49:24,650 --> 00:49:21,780
one of our first public outreach

1267
00:49:27,290 --> 00:49:24,660
spin-offs of on-site so we took the the

1268
00:49:28,820 --> 00:49:27,300
core technology behind on-site we took

1269
00:49:30,260 --> 00:49:28,830
out this the science plenty of features

1270
00:49:32,420 --> 00:49:30,270
and we replaced them with a wrapper that

1271
00:49:34,430 --> 00:49:32,430
turned it into a museum experience led

1272
00:49:36,710 --> 00:49:34,440
by a holographic capture of Buzz Aldrin

1273
00:49:37,960 --> 00:49:36,720
and ERISA Hines one of our Rover drivers

1274
00:49:40,329 --> 00:49:37,970
here at JPL

1275
00:49:42,280 --> 00:49:40,339
and you go on a guided tour of three

1276
00:49:43,599 --> 00:49:42,290
sites on Mars and learn about the

1277
00:49:45,339 --> 00:49:43,609
current Rover missions the history of

1278
00:49:47,410 --> 00:49:45,349
the planet and future human exploration

1279
00:49:49,390 --> 00:49:47,420
and I think what's really cool about

1280
00:49:51,250 --> 00:49:49,400
destination Mars and access Mars that

1281
00:49:53,170 --> 00:49:51,260
fiction Victor mentioned earlier is that

1282
00:49:54,700 --> 00:49:53,180
it's using all of the same terrain data

1283
00:49:56,319 --> 00:49:54,710
products that are scientists here at JPL

1284
00:49:58,059 --> 00:49:56,329
get to see so I think it's a great way

1285
00:49:59,290 --> 00:49:58,069
of letting the public kind of experience

1286
00:50:02,290 --> 00:49:59,300
that in the same way that our scientists

1287
00:50:06,849 --> 00:50:02,300
do yes to us thank you good to hear it

1288
00:50:09,640 --> 00:50:06,859

again I'm sure you probably thought

1289
00:50:12,130 --> 00:50:09,650
about this before but we're all under

1290
00:50:16,270 --> 00:50:12,140
budget constraints companies individuals

1291
00:50:18,819 --> 00:50:16,280
corporations even agencies the same way

1292
00:50:20,890 --> 00:50:18,829
pharmaceuticals to find out one more

1293
00:50:23,200 --> 00:50:20,900
thing to cure one little ailment they

1294
00:50:26,260 --> 00:50:23,210
may spend a hundred million dollars on

1295
00:50:29,170 --> 00:50:26,270
it is it possible and if you haven't

1296
00:50:31,569 --> 00:50:29,180
considered before that JPL go to the

1297
00:50:36,040 --> 00:50:31,579
different two company will Disney the

1298
00:50:38,400 --> 00:50:36,050
media companies and offer a sale like

1299
00:50:41,349 --> 00:50:38,410
put up the big billboard whatever it is

1300
00:50:43,780 --> 00:50:41,359
110 million here 100 million there it

1301
00:50:45,460 --> 00:50:43,790
starts adding up to money I'm sure it's

1302
00:50:47,829 --> 00:50:45,470
something you thought about seven

1303
00:50:50,890 --> 00:50:47,839
money's spent on a stadium or an

1304
00:50:53,740 --> 00:50:50,900
advertising it'll really be a big hit if

1305
00:50:56,670 --> 00:50:53,750
somehow you get media or some

1306
00:50:59,589 --> 00:50:56,680
corporation to sponsor or even to

1307
00:51:02,349 --> 00:50:59,599
concentrate and working on some type of

1308
00:51:07,050 --> 00:51:02,359
software or stuff instead of from your

1309
00:51:08,800 --> 00:51:07,060
part your budget let it be expanded and

1310
00:51:11,079 --> 00:51:08,810
so it's not me

1311
00:51:15,450 --> 00:51:11,089
let them get all the credit whatever it

1312
00:51:18,730 --> 00:51:15,460
is but it's the benefit of all to us our

1313
00:51:21,250 --> 00:51:18,740

commercial partnerships office works

1314
00:51:24,190 --> 00:51:21,260
with companies all around the country in

1315
00:51:25,540 --> 00:51:24,200
the world to figure out how to best

1316
00:51:27,550 --> 00:51:25,550
leverage our technology for their

1317
00:51:30,069 --> 00:51:27,560
individual fields so we do have a lot of

1318
00:51:31,960 --> 00:51:30,079
interaction with the commercial industry

1319
00:51:33,910 --> 00:51:31,970
not only leveraging their technology for

1320
00:51:36,280 --> 00:51:33,920
our applications but then sharing back

1321
00:51:40,540 --> 00:51:36,290
our work if it helps them do their work

1322
00:51:41,950 --> 00:51:40,550
more effectively access Mars experience

1323
00:51:44,620 --> 00:51:41,960
that Victor mentioned earlier was the

1324
00:51:48,990 --> 00:51:44,630
collaboration with Google and the

1325
00:51:51,600 --> 00:51:49,000
destination Mars or excuse me the Oh

1326
00:51:54,030 --> 00:51:51,610
actually on site itself I meant

1327
00:51:55,650 --> 00:51:54,040
was at first a collaboration with

1328
00:51:57,510 --> 00:51:55,660
Microsoft so we are interested in

1329
00:52:03,560 --> 00:51:57,520
leveraging commercial partnerships where

1330
00:52:06,030 --> 00:52:03,570
we can this question is for I think a B

1331
00:52:08,880 --> 00:52:06,040
what fraction of your day do you spend

1332
00:52:10,890 --> 00:52:08,890
using the on-site tool and do you see

1333
00:52:14,880 --> 00:52:10,900
that fraction increasing over time and

1334
00:52:17,310 --> 00:52:14,890
if so what features would be like most

1335
00:52:19,260 --> 00:52:17,320
useful I guess it really depends on the

1336
00:52:21,570 --> 00:52:19,270
day and what I'm doing on days when I'm

1337
00:52:22,910 --> 00:52:21,580
on shift you should only use it for 10

1338
00:52:25,440 --> 00:52:22,920

or 15 minutes you know walk around

1339
00:52:26,820 --> 00:52:25,450
orient myself figure out what's going on

1340
00:52:29,100 --> 00:52:26,830
there are some days when I use it for

1341
00:52:30,570 --> 00:52:29,110
longer especially some days we do

1342
00:52:33,120 --> 00:52:30,580
collaborative sessions where we call

1343
00:52:34,770 --> 00:52:33,130
them meet on Mars where we spend an hour

1344
00:52:36,510 --> 00:52:34,780
and we have team members from all over

1345
00:52:38,430 --> 00:52:36,520
the world you know dialing our avatars

1346
00:52:40,820 --> 00:52:38,440
come in and we talk about it's our

1347
00:52:43,050 --> 00:52:40,830
science discussion for the day on Mars

1348
00:52:44,790 --> 00:52:43,060
those are really fun and you know it's

1349
00:52:46,890 --> 00:52:44,800
fun it's collaborative and you you work

1350
00:52:48,420 --> 00:52:46,900
as a team and you you bond kind of in

1351
00:52:50,190 --> 00:52:48,430
the field though there's Jon over on the

1352
00:52:51,900 --> 00:52:50,200
hill over there off on his own and we're

1353
00:52:55,110 --> 00:52:51,910
over looking at this rock over here so

1354
00:52:56,640 --> 00:52:55,120
yeah depends on the day but I don't know

1355
00:52:59,580 --> 00:52:56,650
if I see it increasing a whole lot in

1356
00:53:01,320 --> 00:52:59,590
the future um I think the way it's been

1357
00:53:03,150 --> 00:53:01,330
working has been been really good but

1358
00:53:05,070 --> 00:53:03,160
I'm excited to see how it turns out with

1359
00:53:06,780 --> 00:53:05,080
the next Rover because in that case the

1360
00:53:08,850 --> 00:53:06,790
tool have been integrated with the rover

1361
00:53:11,040 --> 00:53:08,860
when the science team gets brought on

1362
00:53:12,570 --> 00:53:11,050
initially so they might kind of view it

1363
00:53:15,780 --> 00:53:12,580

in a whole different way so looking

1364
00:53:18,480 --> 00:53:15,790
forward to how that's used yeah and one

1365
00:53:20,910 --> 00:53:18,490
point I wanted to mention is that I I

1366
00:53:22,770 --> 00:53:20,920
don't really think our scientists need

1367
00:53:24,450 --> 00:53:22,780
to use it more I guess because I think

1368
00:53:26,010 --> 00:53:24,460
the beautiful thing about is that they

1369
00:53:28,200 --> 00:53:26,020
can put it on they can look around and

1370
00:53:31,230 --> 00:53:28,210
go oh I get I get it now I see where we

1371
00:53:32,610 --> 00:53:31,240
are I don't need to spend you know 30

1372
00:53:34,680 --> 00:53:32,620
minutes looking at pictures on my

1373
00:53:36,780 --> 00:53:34,690
computer screen to get oriented about

1374
00:53:38,940 --> 00:53:36,790
where the rover is right now or where

1375
00:53:41,940 --> 00:53:38,950
we're going to go I really like that

1376
00:53:43,470 --> 00:53:41,950
it's a quick tool that quickly gives you

1377
00:53:45,060 --> 00:53:43,480
an intuitive understanding of where you

1378
00:53:46,890 --> 00:53:45,070
are so it might not ever increase it

1379
00:53:48,120 --> 00:53:46,900
might stay at ten minutes a day and

1380
00:53:50,070 --> 00:53:48,130
maybe that's where it's supposed to be

1381
00:53:52,110 --> 00:53:50,080
yeah I think it's likely that it also be

1382
00:53:53,400 --> 00:53:52,120
you kind of many short short sessions

1383
00:53:54,690 --> 00:53:53,410
throughout a day as you're switching

1384
00:53:57,840 --> 00:53:54,700
between different tools you're using

1385
00:53:59,280 --> 00:53:57,850
this to to get your initial context are

1386
00:54:01,230 --> 00:53:59,290
you going to add another tool coming

1387
00:54:03,090 --> 00:54:01,240
back to the immersive context later on

1388
00:54:05,370 --> 00:54:03,100

and throughout your day so I'd like to

1389
00:54:07,200 --> 00:54:05,380
see I yeah I told it become something

1390
00:54:08,970 --> 00:54:07,210
that's effortless to switch over to

1391
00:54:10,440 --> 00:54:08,980
whenever it's helpful to you yeah I

1392
00:54:12,059 --> 00:54:10,450
sometimes when there's a break in the

1393
00:54:15,410 --> 00:54:12,069
day it's kind of nice should just put it

1394
00:54:26,789 --> 00:54:15,420
on and be like man my job is really cool

1395
00:54:31,680 --> 00:54:26,799
really cool thank you are you thinking

1396
00:54:37,200 --> 00:54:31,690
about creating an avatar machine where

1397
00:54:39,859 --> 00:54:37,210
you actually go there that's right you

1398
00:54:42,530 --> 00:54:39,869
think it's impossible

1399
00:54:46,020 --> 00:54:42,540
leave this to the software developers

1400
00:54:49,170 --> 00:54:46,030
you actually could smell taste and feel

1401
00:54:51,180 --> 00:54:49,180
and actually be there with that kind of

1402
00:54:53,549 --> 00:54:51,190
technology yeah I think I would ever

1403
00:54:55,410 --> 00:54:53,559
thought of that this taking pictures is

1404
00:54:56,940 --> 00:54:55,420
not getting you anywhere it's definitely

1405
00:54:58,410 --> 00:54:56,950
something we've thought about I think

1406
00:55:00,270 --> 00:54:58,420
this is this is getting back to an

1407
00:55:02,010 --> 00:55:00,280
earlier gentleman's question of have we

1408
00:55:05,010 --> 00:55:02,020
thought of it of incorporating other

1409
00:55:07,980 --> 00:55:05,020
sensors data like you know sound in this

1410
00:55:09,270 --> 00:55:07,990
case smell you know again we're limited

1411
00:55:12,510 --> 00:55:09,280
to the data that we get back from the

1412
00:55:14,819 --> 00:55:12,520
rover so smell I think we might be a

1413
00:55:19,230 --> 00:55:14,829

couple Rover missions away from from

1414
00:55:20,609 --> 00:55:19,240
that one sounds yeah does have a

1415
00:55:24,780 --> 00:55:20,619
microphone so maybe we can bring in

1416
00:55:26,430 --> 00:55:24,790
sound so I think yeah you probably

1417
00:55:29,849 --> 00:55:26,440
probably not temperature more sparse

1418
00:55:31,440 --> 00:55:29,859
it's a little too cold we tried to we

1419
00:55:33,030 --> 00:55:31,450
try to find the kind of the happy medium

1420
00:55:35,750 --> 00:55:33,040
between feeling like you're on Mars but

1421
00:55:40,319 --> 00:55:35,760
not feeling too much like you're on Mars

1422
00:55:42,660 --> 00:55:40,329
well I think it's possible it's very

1423
00:55:47,549 --> 00:55:42,670
possible look what we look what we've

1424
00:55:48,960 --> 00:55:47,559
gone already look what we've done well I

1425
00:55:54,020 --> 00:55:48,970
think we ought to start thinking like

1426
00:55:59,849 --> 00:55:58,170
hi I think my question is to Abby is I

1427
00:56:02,670 --> 00:55:59,859
understand that you see you're saying

1428
00:56:04,950 --> 00:56:02,680
that each mission I say the karati have

1429
00:56:07,589 --> 00:56:04,960
a certain amount of like a window that

1430
00:56:09,480 --> 00:56:07,599
you can talk to and get datas so I'm

1431
00:56:11,819 --> 00:56:09,490
just wondering because it has something

1432
00:56:14,549 --> 00:56:11,829
to do with the direction that plan is

1433
00:56:17,309 --> 00:56:14,559
facing where the vehicle is as far as

1434
00:56:18,940 --> 00:56:17,319
all the other vehicles that is you know

1435
00:56:21,370 --> 00:56:18,950
in in the space so

1436
00:56:23,170 --> 00:56:21,380
if there are efforts being to like

1437
00:56:25,630 --> 00:56:23,180
increase the bandwidth so you can talk

1438
00:56:28,630 --> 00:56:25,640

to like a multiple emissions

1439
00:56:30,490 --> 00:56:28,640
simultaneously of oh you can only talk

1440
00:56:32,470 --> 00:56:30,500
to one mission at a time with the

1441
00:56:35,920 --> 00:56:32,480
technology that we have right now yeah

1442
00:56:37,420 --> 00:56:35,930
that's an excellent question and so one

1443
00:56:38,829 --> 00:56:37,430
of the biggest limiting factors I'm

1444
00:56:41,740 --> 00:56:38,839
communicating with the Rovers on the

1445
00:56:43,270 --> 00:56:41,750
surface of Mars is you know one pointing

1446
00:56:44,380 --> 00:56:43,280
we can't talk to the rover if we're on

1447
00:56:45,579 --> 00:56:44,390
the other side of the planet or it's

1448
00:56:47,859 --> 00:56:45,589
more importantly on the other side of

1449
00:56:49,630 --> 00:56:47,869
the planet is Earth but we almost always

1450
00:56:51,549 --> 00:56:49,640
talk to the rover's via the orbiters

1451
00:56:53,589 --> 00:56:51,559
that we have orbiting Mars it's a lot

1452
00:56:55,599 --> 00:56:53,599
easier for the Rovers to use their radio

1453
00:56:57,039 --> 00:56:55,609
to talk to an orbiter that's nearby then

1454
00:56:58,720 --> 00:56:57,049
to talk all the way back to earth and

1455
00:57:00,609 --> 00:56:58,730
the orbiters have much bigger antennas

1456
00:57:03,789 --> 00:57:00,619
and more powerful radios that they can

1457
00:57:05,650 --> 00:57:03,799
use to talk to earth so that's one of

1458
00:57:07,780 --> 00:57:05,660
the factors that limits how often we can

1459
00:57:09,760 --> 00:57:07,790
communicate but the idea of continually

1460
00:57:12,430 --> 00:57:09,770
improving these radios increasing our

1461
00:57:14,380 --> 00:57:12,440
data volume rates is something that the

1462
00:57:16,539 --> 00:57:14,390
engineers here are working on and also

1463
00:57:18,849 --> 00:57:16,549

considering your own 2020 we're going to

1464
00:57:20,319 --> 00:57:18,859
have a fleet of Rovers heading to the

1465
00:57:22,240 --> 00:57:20,329
surface of Mars and some of them might

1466
00:57:24,039 --> 00:57:22,250
land near each other insight is landing

1467
00:57:25,270 --> 00:57:24,049
pretty close to our curiosity is and

1468
00:57:28,210 --> 00:57:25,280
we're gonna have to start to share those

1469
00:57:29,500 --> 00:57:28,220
orbiter passes so absolutely thinking

1470
00:57:31,420 --> 00:57:29,510
about technology can you use your

1471
00:57:32,920 --> 00:57:31,430
orbiters to talk to multiple Rovers at

1472
00:57:34,900 --> 00:57:32,930
different places on the planet at the

1473
00:57:36,309 --> 00:57:34,910
same time as I hope something we're

1474
00:57:42,970 --> 00:57:36,319
gonna need to really worry about in the

1475
00:57:46,839 --> 00:57:42,980
future thank you hello first of all

1476
00:57:49,900 --> 00:57:46,849
pardon my English I understand that Mars

1477
00:57:52,630 --> 00:57:49,910
is really red because of the iron in it

1478
00:57:54,339 --> 00:57:52,640
how do you deal with the camera lenses

1479
00:57:56,829 --> 00:57:54,349
with that dust

1480
00:58:00,339 --> 00:57:56,839
Iren does that really sticks to the

1481
00:58:02,349 --> 00:58:00,349
lenses so some of the cameras have lens

1482
00:58:03,700 --> 00:58:02,359
caps and in fact those pictures that

1483
00:58:06,280 --> 00:58:03,710
Victor showed at the beginning of the

1484
00:58:07,630 --> 00:58:06,290
talk had the caps on them right before

1485
00:58:09,609 --> 00:58:07,640
they popped off so some of them we

1486
00:58:10,900 --> 00:58:09,619
covered lens caps some of them we make

1487
00:58:12,520 --> 00:58:10,910
sure at the end of the day we stow them

1488
00:58:14,319 --> 00:58:12,530

you know looking down so they don't get

1489
00:58:17,380 --> 00:58:14,329
dusty and in general they don't

1490
00:58:20,589 --> 00:58:17,390
accumulate too much dust over time and

1491
00:58:22,630 --> 00:58:20,599
the other thing is that you know I I'm

1492
00:58:25,539 --> 00:58:22,640
probably sure that there is more than

1493
00:58:28,569 --> 00:58:25,549
one person the likes to know where you

1494
00:58:30,670 --> 00:58:28,579
are exactly in the planet and most of

1495
00:58:31,280 --> 00:58:30,680
the time I see the pictures and I have

1496
00:58:33,860 --> 00:58:31,290
to do

1497
00:58:36,650 --> 00:58:33,870
where the shadows are coming from

1498
00:58:42,830 --> 00:58:36,660
because I I would love to know where is

1499
00:58:44,240 --> 00:58:42,840
north and south in in in in Mars yeah it

1500
00:58:46,070 --> 00:58:44,250
would be similar to Earth and you know

1501
00:58:47,690 --> 00:58:46,080
you can you can look at the shadows the

1502
00:58:50,000 --> 00:58:47,700
same way on Mars as you can on earth it

1503
00:58:51,920 --> 00:58:50,010
spins in the same direction as Earth so

1504
00:58:53,450 --> 00:58:51,930
you'll see the Sun rise and set the same

1505
00:58:56,210 --> 00:58:53,460
areas of the sky right

1506
00:58:58,910 --> 00:58:56,220
is there any map pardon my ignorance I

1507
00:59:01,280 --> 00:58:58,920
haven't followed this very much you can

1508
00:59:03,020 --> 00:59:01,290
just google both Rovers that we have on

1509
00:59:04,610 --> 00:59:03,030
Mars opportunity and curiosity you can

1510
00:59:06,290 --> 00:59:04,620
go to the websites you can look at their

1511
00:59:11,900 --> 00:59:06,300
traverse maps and it's all publicly

1512
00:59:13,640 --> 00:59:11,910
available thank you as someone who

1513
00:59:15,320 --> 00:59:13,650

really enjoys role playing games and

1514
00:59:17,960 --> 00:59:15,330
stuff online I was thinking that this is

1515
00:59:19,940 --> 00:59:17,970
an amazing educational tool for say

1516
00:59:22,730 --> 00:59:19,950
training graduate students or astronauts

1517
00:59:24,350 --> 00:59:22,740
especially in super exotic environments

1518
00:59:25,640 --> 00:59:24,360
so like I could foresee pain maybe you

1519
00:59:27,110 --> 00:59:25,650
could even have a grading system where

1520
00:59:28,970 --> 00:59:27,120
if they pick up the wrong rock you know

1521
00:59:31,280 --> 00:59:28,980
they lose ten percent maybe they'd hate

1522
00:59:32,600 --> 00:59:31,290
that but in all seriousness though I see

1523
00:59:34,820 --> 00:59:32,610
it as something where you could very

1524
00:59:36,260 --> 00:59:34,830
precisely train someone to work in a

1525
00:59:37,940 --> 00:59:36,270
specific environment because I mean

1526
00:59:39,920 --> 00:59:37,950
astronaut missions I believe they're

1527
00:59:41,780 --> 00:59:39,930
scheduled down to the minute ideally

1528
00:59:43,820 --> 00:59:41,790
because you have so little time in so

1529
00:59:45,830 --> 00:59:43,830
many science goals so to train people

1530
00:59:47,630 --> 00:59:45,840
how to work quickly and effectively it

1531
00:59:50,090 --> 00:59:47,640
seems like that's high potential so do

1532
00:59:52,430 --> 00:59:50,100
you see the ability to add I guess like

1533
00:59:53,720 --> 00:59:52,440
digital object like feedback to where

1534
00:59:55,280 --> 00:59:53,730
someone you can tell if someone's

1535
00:59:57,410 --> 00:59:55,290
understanding the concept you're trying

1536
01:00:00,290 --> 00:59:57,420
to teach them or if they're grasping the

1537
01:00:03,140 --> 01:00:00,300
right object that kind of thing we're

1538
01:00:04,820 --> 01:00:03,150

doing a lot in the area of training all

1539
01:00:07,070 --> 01:00:04,830
right both for astronauts and for

1540
01:00:08,900 --> 01:00:07,080
operators on the ground there's the

1541
01:00:12,620 --> 01:00:08,910
ability to do something before you do

1542
01:00:14,840 --> 01:00:12,630
something is super valuable and yes so

1543
01:00:17,210 --> 01:00:14,850
the technology is improving in terms of

1544
01:00:19,460 --> 01:00:17,220
recognition of your workspace and the

1545
01:00:21,770 --> 01:00:19,470
completion status of your workspace and

1546
01:00:24,830 --> 01:00:21,780
it's only gonna get better over time we

1547
01:00:28,190 --> 01:00:24,840
have a mission to test this out actually

1548
01:00:29,900 --> 01:00:28,200
at the NEEMO of this fall so Nemo is

1549
01:00:31,970 --> 01:00:29,910
NASA's extreme environment Mission

1550
01:00:33,470 --> 01:00:31,980
Operations is basically submarine off

1551
01:00:35,180 --> 01:00:33,480
the coast of Florida it's where the

1552
01:00:36,980 --> 01:00:35,190
astronauts train before they go to the

1553
01:00:38,930 --> 01:00:36,990
space station so we're gonna test some

1554
01:00:41,330 --> 01:00:38,940
of these capabilities what if you had

1555
01:00:43,310 --> 01:00:41,340
spatial procedures in your world that

1556
01:00:44,460 --> 01:00:43,320
tell you what to do in the same way that

1557
01:00:46,890 --> 01:00:44,470
you know you might want you

1558
01:00:48,780 --> 01:00:46,900
to show you how to tie a tie or fix some

1559
01:00:51,300 --> 01:00:48,790
plumbing what if those instructions were

1560
01:00:53,130 --> 01:00:51,310
in the world with you right how much

1561
01:00:54,990 --> 01:00:53,140
better would that experience be I think

1562
01:00:57,560 --> 01:00:55,000
this is going to be the future of how we

1563
01:01:01,980 --> 01:00:57,570

train everything especially in schools

1564
01:01:06,180 --> 01:01:01,990
thank you very much I noticed it is past

1565
01:01:07,920 --> 01:01:06,190
8:00 so if you guys do need to take off

1566
01:01:10,260 --> 01:01:07,930
we will be here for a little while

1567
01:01:11,700 --> 01:01:10,270
longer to answer your questions but I

1568
01:01:14,280 --> 01:01:11,710
just want to thank everybody for coming

1569
01:01:15,900 --> 01:01:14,290
today we had a great discussion and we

1570
01:01:29,400 --> 01:01:15,910
hope they'll talk to you guys