

SILICON
VALLEY

IV



COUNTDOWN TO 2024

DAYS

HOURS

MIN

SEC

1585 07:58:10

1
00:00:00,829 --> 00:00:11,600
nine eight seven six five four three two

2
00:00:31,820 --> 00:00:28,600
[Music]

3
00:00:35,300 --> 00:00:31,830
hi everybody welcome to another episode

4
00:00:38,000 --> 00:00:35,310
of NASA in Silicon Valley live I am your

5
00:00:41,060 --> 00:00:38,010
host Tiffany Blake if this is your first

6
00:00:43,430 --> 00:00:41,070
time tuning in to the show the NASA and

7
00:00:45,229 --> 00:00:43,440
Silicon Valley live is a conversational

8
00:00:48,290 --> 00:00:45,239
show out of NASA's Ames Research Center

9
00:00:50,930 --> 00:00:48,300
or we talk about all the nerdy NASA news

10
00:00:52,280 --> 00:00:50,940
you need to know today with me I have

11
00:00:55,460 --> 00:00:52,290
the awesome

12
00:00:57,320 --> 00:00:55,470
Abbie Tabor hello Tiffany yes hi

13
00:00:59,840 --> 00:00:57,330

everybody I'm your co-host today Abbie

14

00:01:03,020 --> 00:00:59,850

Tabor and we are simultaneously live

15

00:01:05,509 --> 00:01:03,030

right now on twitch YouTube Facebook and

16

00:01:07,160 --> 00:01:05,519

periscope but if you want to join in the

17

00:01:08,390 --> 00:01:07,170

chat and leave questions for our awesome

18

00:01:13,730 --> 00:01:08,400

guest today you need to do that on

19

00:01:15,890 --> 00:01:13,740

Twitch so go to www.twitch.tv/esa so

20

00:01:21,950 --> 00:01:15,900

today I'm really excited we're talking

21

00:01:24,590 --> 00:01:21,960

about space robot space we have a couple

22

00:01:25,850 --> 00:01:24,600

of amazing guests here today so why

23

00:01:28,040 --> 00:01:25,860

don't we go ahead and meet them can you

24

00:01:31,100 --> 00:01:28,050

guys tell us your name what you do here

25

00:01:34,160 --> 00:01:31,110

at Ames um I'm really I'm a robotics

26
00:01:37,670 --> 00:01:34,170
engineer and I build space robots pretty

27
00:01:39,560 --> 00:01:37,680
sweet all right yeah I'm Terry Fong I'm

28
00:01:41,510 --> 00:01:39,570
the chief roboticist here at NASA Ames

29
00:01:43,880 --> 00:01:41,520
and I dream up the robots that Maria

30
00:01:47,179 --> 00:01:43,890
then has to go build awesome job

31
00:01:49,190 --> 00:01:47,189
description thanks for joining

32
00:01:50,779 --> 00:01:49,200
before we get into the show and one

33
00:01:53,870 --> 00:01:50,789
remind our audience about this really

34
00:01:56,510 --> 00:01:53,880
cool clock we have here yes exactly

35
00:01:59,270 --> 00:01:56,520
this lovely item that we have for you

36
00:02:02,660 --> 00:01:59,280
today is our moon countdown clock so

37
00:02:04,819 --> 00:02:02,670
fires from now in 2024 we're planning to

38
00:02:07,130 --> 00:02:04,829

send humans to the moon as part of our

39

00:02:09,800 --> 00:02:07,140

Artemis program and this clock is

40

00:02:12,920 --> 00:02:09,810

counting down the days hours minutes and

41

00:02:14,810 --> 00:02:12,930

seconds until 2024 when the first woman

42

00:02:17,330 --> 00:02:14,820

and the next man will walk on the moon

43

00:02:18,890 --> 00:02:17,340

south pole so pretty exciting we'll talk

44

00:02:21,140 --> 00:02:18,900

more about that later in the show but if

45

00:02:26,000 --> 00:02:21,150

you want to learn more meanwhile you can

46

00:02:29,690 --> 00:02:26,010

visit www.nasa.gov slash artemis okay

47

00:02:31,610 --> 00:02:29,700

let's get started okay I'm excited I

48

00:02:33,530 --> 00:02:31,620

think let's start with just the basics

49

00:02:36,500 --> 00:02:33,540

like what's the history of you know

50

00:02:37,759 --> 00:02:36,510

humans and robots in space sorry can you

51
00:02:40,339 --> 00:02:37,769
tell us a little bit sure you know I

52
00:02:41,390 --> 00:02:40,349
mean NASA has used robots in space for a

53
00:02:43,160 --> 00:02:41,400
long time to carry out

54
00:02:45,289 --> 00:02:43,170
planetary exploration we've sent robots

55
00:02:47,630 --> 00:02:45,299
to Mars and we still have robots on Mars

56
00:02:49,850 --> 00:02:47,640
today of course but in parallel to that

57
00:02:51,320 --> 00:02:49,860
there's been this real development for

58
00:02:55,100 --> 00:02:51,330
actually for a long time of robots that

59
00:02:56,990 --> 00:02:55,110
work with humans and they are used you

60
00:02:59,330 --> 00:02:57,000
know outside of spacecraft like outside

61
00:03:00,649 --> 00:02:59,340
of the space station and more recently

62
00:03:02,600 --> 00:03:00,659
we've been working with robots inside a

63
00:03:04,039 --> 00:03:02,610

spacecraft as well right we're going a

64

00:03:04,610 --> 00:03:04,049

little bit closer together right yeah

65

00:03:07,850 --> 00:03:04,620

really

66

00:03:09,619 --> 00:03:07,860

awesome so how about we talk a little

67

00:03:13,339 --> 00:03:09,629

bit about you know how they work

68

00:03:16,430 --> 00:03:13,349

together yeah how exactly do robots and

69

00:03:18,380 --> 00:03:16,440

humans interact yeah I think a great

70

00:03:20,660 --> 00:03:18,390

thing about when you talk about robots

71

00:03:22,339 --> 00:03:20,670

and humans together it's this not just

72

00:03:23,990 --> 00:03:22,349

oh how how do I make that robot you know

73

00:03:26,000 --> 00:03:24,000

just go off and do something but this

74

00:03:28,130 --> 00:03:26,010

whole notion of you know humans and

75

00:03:29,839 --> 00:03:28,140

robots working as a team and as

76
00:03:31,190 --> 00:03:29,849
something I think we're gonna see much

77
00:03:34,430 --> 00:03:31,200
more of as we go forward in the future

78
00:03:37,399 --> 00:03:34,440
this whole idea that we can use robots

79
00:03:39,710 --> 00:03:37,409
to work together with humans to perform

80
00:03:42,259 --> 00:03:39,720
work in space or on planetary surfaces

81
00:03:43,880 --> 00:03:42,269
and the idea is you might have all kinds

82
00:03:45,229 --> 00:03:43,890
of different robots and all kinds of

83
00:03:45,710 --> 00:03:45,239
humans working together with those

84
00:03:48,170 --> 00:03:45,720
robots

85
00:03:50,089 --> 00:03:48,180
right and the same way that a team for

86
00:03:52,009 --> 00:03:50,099
example a football team has specialists

87
00:03:53,599 --> 00:03:52,019
yeah you play to the strengths of the

88
00:03:55,309 --> 00:03:53,609

different members of the team so in this

89

00:03:58,580 --> 00:03:55,319

case you'd play the strengths of the

90

00:04:05,869 --> 00:03:58,590

humans versus the robots certain things

91

00:04:10,490 --> 00:04:05,879

humans are better yeah you were telling

92

00:04:13,580 --> 00:04:10,500

us earlier about the 3ds pretty common

93

00:04:16,400 --> 00:04:13,590

phrase and in robotics the 3ds which is

94

00:04:18,339 --> 00:04:16,410

dull dirty and dangerous those are the

95

00:04:21,229 --> 00:04:18,349

cases where you want to send a robot in

96

00:04:22,640 --> 00:04:21,239

rather than a human yeah you know if

97

00:04:24,260 --> 00:04:22,650

it's something really boring to do you

98

00:04:26,000 --> 00:04:24,270

gotta take a whole bunch of measurements

99

00:04:30,860 --> 00:04:26,010

it's probably better to sense a robot

100

00:04:32,810 --> 00:04:30,870

who doesn't mind do you know if it's if

101
00:04:35,750 --> 00:04:32,820
it's something where it's a dangerous

102
00:04:42,810 --> 00:04:35,760
situation again you it's sad but you

103
00:04:49,060 --> 00:04:46,840
far less than losing a human yeah so

104
00:04:51,400 --> 00:04:49,070
could a dangerous to be something out in

105
00:04:53,920 --> 00:04:51,410
space like leaving oh sure yeah yeah I

106
00:04:55,390 --> 00:04:53,930
mean I think beyond just dangerous I

107
00:04:57,220 --> 00:04:55,400
mean there are some things you know like

108
00:04:59,470 --> 00:04:57,230
Maria was saying that you know really

109
00:05:00,970 --> 00:04:59,480
plays to the strengths of robots you

110
00:05:04,000 --> 00:05:00,980
know there are some things that require

111
00:05:06,790 --> 00:05:04,010
moving very large pieces of equipment or

112
00:05:09,790 --> 00:05:06,800
other things in space that are just too

113
00:05:12,360 --> 00:05:09,800

massive or too heavy for human to move

114

00:05:16,930 --> 00:05:12,370

yeah and sometimes take longer yeah

115

00:05:18,880 --> 00:05:16,940

precise placement right place the items

116

00:05:21,040 --> 00:05:18,890

very precisely with a robot but just

117

00:05:23,710 --> 00:05:21,050

like in any any team you know I think if

118

00:05:25,390 --> 00:05:23,720

you have a combination of humans and

119

00:05:26,710 --> 00:05:25,400

robots that can work well together I

120

00:05:28,540 --> 00:05:26,720

mean you know that allows you to do much

121

00:05:31,950 --> 00:05:28,550

more than just you know any individual

122

00:05:35,080 --> 00:05:31,960

thing one person by themselves yeah and

123

00:05:36,490 --> 00:05:35,090

an example I think of the precision that

124

00:05:37,930 --> 00:05:36,500

you're talking about you guys told us

125

00:05:48,580 --> 00:05:37,940

the International Space Station was

126

00:05:50,800 --> 00:05:48,590

assembled by robots right yeah cool so

127

00:05:52,750 --> 00:05:50,810

we have robots working outside of

128

00:05:55,090 --> 00:05:52,760

spacecraft robots working inside a

129

00:05:57,280 --> 00:05:55,100

spacecraft right so let's talk about

130

00:05:59,440 --> 00:05:57,290

some of those what are some historical

131

00:06:05,800 --> 00:05:59,450

robots that have worked on Space Station

132

00:06:08,770 --> 00:06:05,810

or Canada arm Space Shuttle 50 foot

133

00:06:10,360 --> 00:06:08,780

robot arm that was used for things like

134

00:06:12,550 --> 00:06:10,370

which we see right now

135

00:06:17,500 --> 00:06:12,560

I used to deploy things like satellites

136

00:06:20,860 --> 00:06:17,510

to very precisely place equipment for

137

00:06:22,900 --> 00:06:20,870

example when when we were integrating

138

00:06:24,730 --> 00:06:22,910

the space station yeah this was actually

139

00:06:27,060 --> 00:06:24,740

a pretty big arm it's like a 50 foot

140

00:06:29,350 --> 00:06:27,070

long arm Wow and I was able to move

141

00:06:32,980 --> 00:06:29,360

32,000 pounds that's basically like

142

00:06:39,400 --> 00:06:32,990

moving a school bus in position a school

143

00:06:41,050 --> 00:06:39,410

bus that's a pretty big robot benefit

144

00:06:43,990 --> 00:06:41,060

you know to building something like you

145

00:06:46,630 --> 00:06:44,000

know how long a station is also able to

146

00:06:48,400 --> 00:06:46,640

bolt to hold astronauts in place yeah

147

00:06:49,460 --> 00:06:48,410

really - Oh like well they're working

148

00:07:00,320 --> 00:06:49,470

ones are working right

149

00:07:07,850 --> 00:07:00,330

funny go floating off of the things you

150

00:07:11,110 --> 00:07:07,860

never think about here's the cool one

151
00:07:14,780 --> 00:07:13,070
mentioned earlier that robots can work

152
00:07:17,780 --> 00:07:14,790
outside or inside a spacecraft so

153
00:07:19,460 --> 00:07:17,790
Robonaut 2 was a humanoid robot that

154
00:07:21,410 --> 00:07:19,470
we sent up a few years ago to the space

155
00:07:22,970 --> 00:07:21,420
station in the picture you can see here

156
00:07:25,520 --> 00:07:22,980
it's holding something which looks like

157
00:07:29,480 --> 00:07:25,530
a magic wand but that's actually an air

158
00:07:30,890 --> 00:07:29,490
flow measurement device has a great name

159
00:07:32,570 --> 00:07:30,900
what the device actually is called the

160
00:07:35,690 --> 00:07:32,580
the sensor is actually called a velocity

161
00:07:37,190 --> 00:07:35,700
elk it's really meant to be used

162
00:07:39,080 --> 00:07:37,200
inside a space station for monitoring

163
00:07:41,170 --> 00:07:39,090

airflow and here we were doing some

164

00:07:43,700 --> 00:07:41,180

experiments to see how a robot like

165

00:07:45,590 --> 00:07:43,710

Robonaut 2 could carry out tasks which

166

00:07:47,390 --> 00:07:45,600

are normally done by humans all right

167

00:07:49,820 --> 00:07:47,400

those humanoid robots can use the same

168

00:07:52,870 --> 00:07:49,830

tools as astronauts so you don't have to

169

00:07:55,159 --> 00:07:52,880

retool everything that vilasa calc

170

00:07:57,980 --> 00:07:55,169

instrument is usually used by the

171

00:07:59,780 --> 00:07:57,990

astronauts so Robonaut because it has

172

00:08:01,640 --> 00:07:59,790

hands can actually hold it and use it

173

00:08:03,140 --> 00:08:01,650

the same way an astronaut would and the

174

00:08:04,880 --> 00:08:03,150

benefit of course of you know a robot

175

00:08:06,800 --> 00:08:04,890

for doing this kind of jobs it doesn't

176

00:08:08,900 --> 00:08:06,810

get tired of holding something and if

177

00:08:16,010 --> 00:08:08,910

you do it many times over and over and

178

00:08:17,840 --> 00:08:16,020

it's not going to complain I was in

179

00:08:25,420 --> 00:08:17,850

space I wouldn't care what I would be as

180

00:08:34,240 --> 00:08:28,370

what about some current robots in space

181

00:08:38,149 --> 00:08:34,250

that we have so there's spheres which a

182

00:08:40,130 --> 00:08:38,159

testbed actually I have a model here and

183

00:08:44,960 --> 00:08:40,140

this one's near and dear to our heart

184

00:08:47,450 --> 00:08:44,970

here at Ames of course right it is so

185

00:08:49,670 --> 00:08:47,460

this is a model of the spheres which are

186

00:08:52,370 --> 00:08:49,680

currently on orbit there's three of them

187

00:08:55,040 --> 00:08:52,380

on the space station and they've been

188

00:08:58,840 --> 00:08:55,050

used as a testbed for guest scientists

189

00:09:00,879 --> 00:08:58,850

so developers technology developers on

190

00:09:03,819 --> 00:09:00,889

on earth like from academia from

191

00:09:05,050 --> 00:09:03,829

commercial from inside of NASA have

192

00:09:07,629 --> 00:09:05,060

developed technologies that they would

193

00:09:10,090 --> 00:09:07,639

like to fly in zero-g and so they can

194

00:09:12,160 --> 00:09:10,100

actually deploy it on a spheres which

195

00:09:14,530 --> 00:09:12,170

would then fly them around inside a

196

00:09:16,120 --> 00:09:14,540

space station so what we see here is

197

00:09:20,110 --> 00:09:16,130

actually the mounting point where you

198

00:09:21,160 --> 00:09:20,120

can put a payload on oh yeah yeah you

199

00:09:23,259 --> 00:09:21,170

know one interesting thing about these

200

00:09:25,090 --> 00:09:23,269

is that they fly around by using

201
00:09:27,069 --> 00:09:25,100
actually carbon dioxide so there's

202
00:09:29,650 --> 00:09:27,079
normally a tank that plugs into these

203
00:09:32,259 --> 00:09:29,660
and they have little little nozzles

204
00:09:35,079 --> 00:09:32,269
basically which release controlled puffs

205
00:09:38,920 --> 00:09:35,089
of carbon dioxide yeah basically these

206
00:09:40,360 --> 00:09:38,930
little circular basically its way around

207
00:09:43,780 --> 00:09:40,370
inside a space station

208
00:09:46,540 --> 00:09:43,790
oh cool very cool they've been on orbit

209
00:09:53,980 --> 00:09:46,550
for over a decade yeah well yes held an

210
00:09:55,870 --> 00:09:53,990
astronaut for over a decade you know yes

211
00:09:59,170 --> 00:09:55,880
kind of the size of a volleyball we've

212
00:10:01,480 --> 00:09:59,180
been saying rise it self around it holds

213
00:10:04,240 --> 00:10:01,490

experiments okay and as as if that

214

00:10:08,259 --> 00:10:04,250

wasn't enough you guys upgraded your

215

00:10:11,980 --> 00:10:08,269

spheres at one point right yes we have a

216

00:10:13,389 --> 00:10:11,990

project called smart spheres where we we

217

00:10:16,210 --> 00:10:13,399

wanted to see what we could do to

218

00:10:19,030 --> 00:10:16,220

improve the the compute power on board

219

00:10:21,120 --> 00:10:19,040

the sensing power on board because these

220

00:10:25,480 --> 00:10:21,130

were built you know 14 15 years ago so

221

00:10:27,910 --> 00:10:25,490

so the sensors the the computer very old

222

00:10:29,610 --> 00:10:27,920

very out of date and so we want to be

223

00:10:33,129 --> 00:10:29,620

able to kind of speed them up and try

224

00:10:35,740 --> 00:10:33,139

some robotics experiments on board and

225

00:10:39,699 --> 00:10:35,750

so we actually flew this which I'm sure

226

00:10:41,470 --> 00:10:39,709

do you want to this is yeah this is you

227

00:10:44,199 --> 00:10:41,480

might recognize this as a smartphone and

228

00:10:50,600 --> 00:10:44,209

this is actually a Nexus S smartphone

229

00:10:56,280 --> 00:10:55,019

back in like 2010 and you know we had to

230

00:10:57,900 --> 00:10:56,290

make some modifications it doesn't look

231

00:11:00,239 --> 00:10:57,910

like the off-the-shelf thing although I

232

00:11:01,619 --> 00:11:00,249

will say this started off you know at a

233

00:11:14,970 --> 00:11:01,629

local electronics store was actually

234

00:11:16,920 --> 00:11:14,980

purchased and you know you know you

235

00:11:18,509 --> 00:11:16,930

worry about obviously people worried

236

00:11:20,429 --> 00:11:18,519

about breaking their smartphones and you

237

00:11:22,049 --> 00:11:20,439

know they cover their screens and of

238

00:11:23,460 --> 00:11:22,059

course we worry about that but we didn't

239

00:11:25,110 --> 00:11:23,470

want the shards if they were I need to

240

00:11:27,569 --> 00:11:25,120

fly off right so this there's actually

241

00:11:29,280 --> 00:11:27,579

some teflon tape on here it's got this

242

00:11:30,480 --> 00:11:29,290

very you know sort of sleek battery pack

243

00:11:35,579 --> 00:11:30,490

here because we have some concerns about

244

00:11:36,840 --> 00:11:35,589

putting of lithium you know but the

245

00:11:40,710 --> 00:11:36,850

great thing about this is it's very

246

00:11:42,840 --> 00:11:40,720

compact it gave us cameras and built-in

247

00:11:48,900 --> 00:11:42,850

accelerometers and has high bandwidth

248

00:11:55,199 --> 00:11:48,910

wireless data transfer so the ultimate

249

00:12:01,319 --> 00:11:55,209

brain upgrade next time on pimp your

250

00:12:04,799 --> 00:12:01,329

robot also the fun fact about spheres is

251

00:12:08,669 --> 00:12:04,809

that it was based on an idea from Star

252

00:12:11,369 --> 00:12:08,679

Wars right that's right based on the

253

00:12:13,799 --> 00:12:11,379

training droid in the first Star Wars

254

00:12:24,480 --> 00:12:13,809

movie when Luke is learning how to use a

255

00:12:26,069 --> 00:12:24,490

lightsaber this actually came up you

256

00:12:27,689 --> 00:12:26,079

know from the original place where

257

00:12:29,970 --> 00:12:27,699

Spears was developed and that was at MIT

258

00:12:32,280 --> 00:12:29,980

and professor Dave Miller challenged his

259

00:12:34,049 --> 00:12:32,290

you know his his engineering class yeah

260

00:12:41,400 --> 00:12:34,059

yeah you know here's here's the thing

261

00:12:42,600 --> 00:12:41,410

and Star Wars can you build me one all

262

00:12:45,569 --> 00:12:42,610

right so that's one that we particularly

263

00:12:48,030 --> 00:12:45,579

love there are a few others that are

264

00:12:49,739 --> 00:12:48,040

currently I think on the station that we

265

00:12:51,269 --> 00:12:49,749

could talk about and share some pictures

266

00:12:55,139 --> 00:12:51,279

on you showed us before Canada arm

267

00:13:00,299 --> 00:12:55,149

there's Canada arm - that's right 58

268

00:13:02,860 --> 00:13:00,309

foot robotic arm on the outside of the

269

00:13:04,990 --> 00:13:02,870

space station and it's used for multiple

270

00:13:08,350 --> 00:13:05,000

purposes but it also it's used to dock

271

00:13:10,900 --> 00:13:08,360

the commercial commercial cargo vehicles

272

00:13:15,340 --> 00:13:10,910

so what we see here is it it's being

273

00:13:17,740 --> 00:13:15,350

used to dock the the SpaceX Dragon yeah

274

00:13:18,820 --> 00:13:17,750

and this arm is is even as Maria said

275

00:13:21,010 --> 00:13:18,830

it's even longer than the original

276

00:13:23,019 --> 00:13:21,020

Canada arm which was on the on this

277

00:13:25,269 --> 00:13:23,029

Space Shuttle this one

278

00:13:37,110 --> 00:13:25,279

also it's a really big arm it can

279

00:13:44,050 --> 00:13:42,400

Space Station modules it's really cool

280

00:13:45,700 --> 00:13:44,060

the way it can inchworm around the

281

00:13:47,650 --> 00:13:45,710

station so it can wherever it needs to

282

00:13:50,650 --> 00:13:47,660

be deployed they sort of it there are

283

00:13:58,560 --> 00:13:50,660

holding spots around the outside of the

284

00:14:02,710 --> 00:14:00,610

robot because it's actually a collection

285

00:14:04,480 --> 00:14:02,720

of you know a bunch of different robots

286

00:14:08,170 --> 00:14:04,490

that fit together and there's the big

287

00:14:10,480 --> 00:14:08,180

arm itself but there's also a separate

288

00:14:13,060 --> 00:14:10,490

set of robot arms that can attach the

289

00:14:15,880 --> 00:14:13,070

end and those those arms form the system

290

00:14:18,490 --> 00:14:15,890

called Dexter or if you like acronyms

291

00:14:26,769 --> 00:14:18,500

it's the the spdm the special purpose

292

00:14:29,530 --> 00:14:26,779

dexterous manipulator basically allows

293

00:14:30,519 --> 00:14:29,540

this large arm to have the ability to to

294

00:14:32,530 --> 00:14:30,529

do fine

295

00:14:34,750 --> 00:14:32,540

quote fine dexterous motion so you have

296

00:14:36,940 --> 00:14:34,760

two smaller arms attached to this bigger

297

00:14:39,250 --> 00:14:36,950

arm and those go on to a mobile base and

298

00:14:40,870 --> 00:14:39,260

so now you have this big large system

299

00:14:43,480 --> 00:14:40,880

that can really move all kinds of things

300

00:14:49,510 --> 00:14:43,490

around outside of the space station Wow

301
00:14:52,570 --> 00:14:49,520
pretty handy yeah what about Simon Simon

302
00:14:55,300 --> 00:14:52,580
with a seat Simon with the sea yes that

303
00:15:00,310 --> 00:14:55,310
was built by the German space agency and

304
00:15:04,600 --> 00:15:00,320
an Airbus there we see it Simon

305
00:15:07,840 --> 00:15:04,610
it's meant to be a personal assistant to

306
00:15:10,030 --> 00:15:07,850
astronauts on the station so we see him

307
00:15:12,220 --> 00:15:10,040
there with Alexander Gerst who was a

308
00:15:13,670 --> 00:15:12,230
commander on station about a year ago

309
00:15:16,220 --> 00:15:13,680
last summer

310
00:15:19,850 --> 00:15:16,230
they ran the experiment Simon actually

311
00:15:23,150 --> 00:15:19,860
runs Watson so it's similar to you know

312
00:15:34,369 --> 00:15:23,160
the smart speakers that you know add

313
00:15:36,889 --> 00:15:34,379

something to my shopping list or it can

314

00:15:39,829 --> 00:15:36,899

be helpful you know if they need to have

315

00:15:41,840 --> 00:15:39,839

a procedure brought up so you know help

316

00:15:44,509 --> 00:15:41,850

them with different tasks that they're

317

00:15:48,889 --> 00:15:44,519

doing and yeah your personal robotic

318

00:15:57,410 --> 00:15:48,899

assistant you know its voice commanded

319

00:16:06,199 --> 00:15:57,420

yeah yeah yeah I think we have another

320

00:16:08,660 --> 00:16:06,209

here ant ball info was built by the

321

00:16:10,579 --> 00:16:08,670

Japanese space agency and it's meant to

322

00:16:12,259 --> 00:16:10,589

be basically a floating camera it can

323

00:16:15,079 --> 00:16:12,269

move around inside the Japanese

324

00:16:17,540 --> 00:16:15,089

experiment module and take over some of

325

00:16:20,989 --> 00:16:17,550

the sort of videography chores of

326

00:16:24,110 --> 00:16:20,999

astronauts so a lot of times astronauts

327

00:16:26,179 --> 00:16:24,120

need to document activities you know so

328

00:16:29,119 --> 00:16:26,189

they're filming other astronauts doing

329

00:16:33,559 --> 00:16:29,129

things and so this little robot can take

330

00:16:35,480 --> 00:16:33,569

the take over that job yeah I have a

331

00:16:37,340 --> 00:16:35,490

question here before we go to our

332

00:16:41,809 --> 00:16:37,350

rapid-fire questions we're gonna take as

333

00:16:43,160 --> 00:16:41,819

many as possible but Shamli wants to

334

00:16:44,720 --> 00:16:43,170

know would robots on the International

335

00:16:47,030 --> 00:16:44,730

Space Station be controlled by Houston

336

00:16:48,650 --> 00:16:47,040

or command here on earth or would they

337

00:16:54,710 --> 00:16:48,660

be in the hands of the astronaut aboard

338

00:16:57,019 --> 00:16:54,720

the station I mean just like there's no

339

00:16:59,030 --> 00:16:57,029

one perfect robot you know for

340

00:17:01,039 --> 00:16:59,040

everything there's there's not one you

341

00:17:03,019 --> 00:17:01,049

know a specific way that any of these

342

00:17:04,579 --> 00:17:03,029

robots would be operated you know they

343

00:17:07,579 --> 00:17:04,589

could be controlled from from the earth

344

00:17:09,470 --> 00:17:07,589

they could operate you know autonomously

345

00:17:13,420 --> 00:17:09,480

or they could be you know operated also

346

00:17:15,790 --> 00:17:13,430

by astronauts oh yes yes

347

00:17:17,650 --> 00:17:15,800

right and actually sis fears that we

348

00:17:19,000 --> 00:17:17,660

were looking at a minute ago it does do

349

00:17:22,660 --> 00:17:19,010

some things autonomously on Space

350

00:17:29,290 --> 00:17:22,670

Station right and we have video of it

351
00:17:30,250 --> 00:17:29,300
docking and undocking okay you know the

352
00:17:32,200 --> 00:17:30,260
some of the experiments that we've done

353
00:17:34,900 --> 00:17:32,210
with spheres you know we've tried to

354
00:17:37,750 --> 00:17:34,910
allow it to operate and fly around

355
00:17:39,340 --> 00:17:37,760
inside the space station by itself it

356
00:17:41,770 --> 00:17:39,350
can be used to carry out things like

357
00:17:44,620 --> 00:17:41,780
interior surveys they can fly back and

358
00:17:46,150 --> 00:17:44,630
forth to various specific locations Oh

359
00:17:48,880 --> 00:17:46,160
take readings at those locations and

360
00:17:50,050 --> 00:17:48,890
then fly on yeah do a video of that

361
00:17:51,730 --> 00:17:50,060
maybe that's what I was thinking of yes

362
00:17:55,870 --> 00:17:51,740
yeah yeah let's see if we get that

363
00:17:57,220 --> 00:17:55,880

spheres video so there you see a smart

364

00:17:59,470 --> 00:17:57,230

spheres this is yeah this was a

365

00:18:01,030 --> 00:17:59,480

different smartphone so we we work with

366

00:18:04,930 --> 00:18:01,040

not just the Nexus S but this was a

367

00:18:06,910 --> 00:18:04,940

project tango smartphone that we worked

368

00:18:09,250 --> 00:18:06,920

on in partnership with our friends next

369

00:18:10,630 --> 00:18:09,260

door over at Google and here is a

370

00:18:12,130 --> 00:18:10,640

picture this is a video here you

371

00:18:13,990 --> 00:18:12,140

actually see a smartphone on the front

372

00:18:15,550 --> 00:18:14,000

of spheres it's flying around inside of

373

00:18:17,380 --> 00:18:15,560

the space station it's actually going

374

00:18:19,300 --> 00:18:17,390

back and forward back and forth flying

375

00:18:20,950 --> 00:18:19,310

kind of a lawnmower pattern and this is

376

00:18:22,780 --> 00:18:20,960

what Mission Control sees so you can see

377

00:18:25,300 --> 00:18:22,790

video coming down from the smartphone

378

00:18:26,950 --> 00:18:25,310

cameras you can see what looks like a

379

00:18:29,140 --> 00:18:26,960

video game on the right side you can see

380

00:18:30,640 --> 00:18:29,150

the path that it's flying and the weight

381

00:18:32,110 --> 00:18:30,650

points that it's going back and forth

382

00:18:34,750 --> 00:18:32,120

between so here's flying towards point

383

00:18:36,760 --> 00:18:34,760

seven at the lower right there there's

384

00:18:38,770 --> 00:18:36,770

an image that shows the representation

385

00:18:40,810 --> 00:18:38,780

of what the camera seemed that kind of

386

00:18:42,250 --> 00:18:40,820

blue thing and this allows us to have a

387

00:18:44,320 --> 00:18:42,260

really good understanding of the robot

388

00:18:47,590 --> 00:18:44,330

in its environment and what it's doing

389

00:18:49,690 --> 00:18:47,600

at any given time oh yeah cool so

390

00:19:07,750 --> 00:18:49,700

there's your answer to that yeah we have

391

00:19:09,580 --> 00:19:07,760

a comic from snow the end says I quit we

392

00:19:13,870 --> 00:19:09,590

could jump right into our right hand

393

00:19:18,430 --> 00:19:13,880

fire let me start session emphasis on

394

00:19:21,010 --> 00:19:18,440

the creek all right Tiffany do that yes

395

00:19:22,870 --> 00:19:21,020

I have one so let's say four Spears how

396

00:19:26,210 --> 00:19:22,880

long did it take to actually create the

397

00:19:29,539 --> 00:19:26,220

robot actually designed that yeah

398

00:19:31,760 --> 00:19:29,549

well as I said this this was a a project

399

00:19:34,730 --> 00:19:31,770

that started MIT with with actually an

400

00:19:36,860 --> 00:19:34,740

undergraduate engineering class and so

401
00:19:38,539 --> 00:19:36,870
the students worked on that extensively

402
00:19:40,130 --> 00:19:38,549
that led to a number of different

403
00:19:42,890 --> 00:19:40,140
prototypes and eventually those were

404
00:19:44,390 --> 00:19:42,900
sent up to the space station but you

405
00:19:45,950 --> 00:19:44,400
know the reality is that it's hard to

406
00:19:47,899 --> 00:19:45,960
say exactly how long it takes to build

407
00:19:50,570 --> 00:19:47,909
something because you have to design it

408
00:19:51,950 --> 00:19:50,580
test it there are lot of things for the

409
00:19:53,450 --> 00:19:51,960
space station that we're concerned about

410
00:19:55,250 --> 00:19:53,460
in terms of making sure things are safe

411
00:19:57,080 --> 00:19:55,260
right of course in terms of like

412
00:19:59,360 --> 00:19:57,090
materials and how it operates and all

413
00:20:00,710 --> 00:19:59,370

those kinds of things so a fair amount

414

00:20:01,640 --> 00:20:00,720

of time especially with that and then of

415

00:20:02,930 --> 00:20:01,650

course once they get on the space

416

00:20:08,360 --> 00:20:02,940

station you know just because you get

417

00:20:10,190 --> 00:20:08,370

there done every single robot that goes

418

00:20:14,529 --> 00:20:10,200

up into space we're still learning how

419

00:20:17,510 --> 00:20:14,539

to improve and make them better a

420

00:20:27,740 --> 00:20:17,520

comment about int ball from airplane man

421

00:20:30,049 --> 00:20:27,750

1997 so cute yes the Jaypee guy has a

422

00:20:31,610 --> 00:20:30,059

question about learning and training to

423

00:20:33,320 --> 00:20:31,620

do things like you guys do

424

00:20:35,029 --> 00:20:33,330

it is it possible to learn robotics by

425

00:20:36,529 --> 00:20:35,039

self-study and tinkering with machines

426

00:20:40,070 --> 00:20:36,539

what books or resources would you

427

00:20:43,279 --> 00:20:40,080

suggest yes I would say I would say so

428

00:20:47,480 --> 00:20:43,289

robotics is it's very broad field so you

429

00:20:49,430 --> 00:20:47,490

can contribute to a robotics project you

430

00:20:52,250 --> 00:20:49,440

know with any kind of background almost

431

00:20:54,799 --> 00:20:52,260

you know product designers you know

432

00:20:55,909 --> 00:20:54,809

programmers electrical engineers

433

00:20:59,240 --> 00:20:55,919

mechanical engineers

434

00:21:01,970 --> 00:20:59,250

so really it's whatever you love to do

435

00:21:04,340 --> 00:21:01,980

you know what would you prefer to to do

436

00:21:07,460 --> 00:21:04,350

and then you know you can contribute

437

00:21:09,169 --> 00:21:07,470

then to yeah a robotics team that's

438

00:21:11,180 --> 00:21:09,179

awesome that's good news do a lot of

439

00:21:13,130 --> 00:21:11,190

different things yeah and I think a

440

00:21:14,210 --> 00:21:13,140

great thing today which didn't exist a

441

00:21:16,430 --> 00:21:14,220

few years ago is there are a lot of

442

00:21:18,470 --> 00:21:16,440

online classes you can take in robotics

443

00:21:19,490 --> 00:21:18,480

and so I think learning by yourself is

444

00:21:21,140 --> 00:21:19,500

totally possible

445

00:21:23,630 --> 00:21:21,150

there are even open-source robotics

446

00:21:24,740 --> 00:21:23,640

projects that you can contribute to and

447

00:21:27,140 --> 00:21:24,750

so I think the important thing is just

448

00:21:28,909 --> 00:21:27,150

to get involved and not worry about

449

00:21:35,599 --> 00:21:28,919

whether or not this is in a university

450

00:21:46,409 --> 00:21:44,039

and get started yeah mr tritscher prime

451
00:21:48,690 --> 00:21:46,419
qwerty r back I saw the floating square

452
00:21:50,549 --> 00:21:48,700
a robot assistant Esther B or maybe it

453
00:21:52,469 --> 00:21:50,559
was the other one I forget the name the

454
00:22:04,109 --> 00:21:52,479
assistant robots testing on the

455
00:22:06,899 --> 00:22:04,119
International and of course we had the

456
00:22:09,060 --> 00:22:06,909
speech TV net says on the ISS do they

457
00:22:10,680 --> 00:22:09,070
have something they can talk to or ask

458
00:22:17,570 --> 00:22:10,690
questions like a lecture at Google home

459
00:22:22,169 --> 00:22:20,279
good question Godzilla's asks can we

460
00:22:24,389 --> 00:22:22,179
expect robots to take over the role of

461
00:22:26,969 --> 00:22:24,399
astronauts on spacewalks and conduct

462
00:22:28,950 --> 00:22:26,979
things such as maintenance well I think

463
00:22:31,830 --> 00:22:28,960

you know machen is one of those things

464

00:22:33,839 --> 00:22:31,840

that we really want to see robots you

465

00:22:36,869 --> 00:22:33,849

know take on an increasing role because

466

00:22:39,450 --> 00:22:36,879

so much of the time of astronauts today

467

00:22:41,249 --> 00:22:39,460

is spent doing preventive and corrective

468

00:22:44,039 --> 00:22:41,259

maintenance onboard the space station

469

00:22:45,930 --> 00:22:44,049

and so we'd love to have robots be able

470

00:22:47,580 --> 00:22:45,940

to take spacewalks but you know right

471

00:22:49,200 --> 00:22:47,590

now we have these large arms that are

472

00:22:50,669 --> 00:22:49,210

actually used to do some amount of

473

00:22:55,919 --> 00:22:50,679

maintenance external to the space

474

00:23:01,769 --> 00:22:55,929

station without astronauts do you have

475

00:23:03,599 --> 00:23:01,779

another one you wanna see here there's a

476

00:23:17,639 --> 00:23:03,609

question about robotics competitions

477

00:23:18,889 --> 00:23:17,649

yeah MIT developed the exactly and it's

478

00:23:21,779 --> 00:23:18,899

a middle school and a high school

479

00:23:24,029 --> 00:23:21,789

sophomore competition so awesome the

480

00:23:26,909 --> 00:23:24,039

preliminaries are done in simulation you

481

00:23:29,369 --> 00:23:26,919

you program the spheres to perform

482

00:23:30,779 --> 00:23:29,379

certain tasks that so the preliminary

483

00:23:32,669 --> 00:23:30,789

rounds are done in simulation and then

484

00:23:34,830 --> 00:23:32,679

the finalists get to fly their code

485

00:23:37,769 --> 00:23:34,840

along the spheres on the international

486

00:23:38,940 --> 00:23:37,779

space station for real excellent yeah

487

00:23:40,499 --> 00:23:38,950

I'm good all in high school middle and

488

00:23:43,739 --> 00:23:40,509

high school yeah yeah

489

00:23:45,850 --> 00:23:43,749

get started early yeah it was not

490

00:24:02,710 --> 00:23:45,860

sending code to the space station

491

00:24:04,990 --> 00:24:02,720

I don't want to say my age the question

492

00:24:07,750 --> 00:24:05,000

here for Cali cama

493

00:24:10,299 --> 00:24:07,760

do you see a point where robot robotics

494

00:24:14,680 --> 00:24:10,309

will be able to perform enough tasks

495

00:24:16,180 --> 00:24:14,690

where humans won't be needed on ISS you

496

00:24:18,010 --> 00:24:16,190

know I am often asked that question

497

00:24:20,080 --> 00:24:18,020

about you know you know the relative

498

00:24:23,169 --> 00:24:20,090

strengths and weaknesses of humans and

499

00:24:24,789 --> 00:24:23,179

robots and I I think that you know we

500

00:24:26,289 --> 00:24:24,799

will always have humans involved in

501
00:24:28,799 --> 00:24:26,299
space I mean partially it's because you

502
00:24:31,299 --> 00:24:28,809
know we as humans want to also explore

503
00:24:33,490 --> 00:24:31,309
but it's also the case too that you know

504
00:24:36,220 --> 00:24:33,500
we can't do everything by ourselves and

505
00:24:38,530 --> 00:24:36,230
just like any you know team you know is

506
00:24:40,000 --> 00:24:38,540
more than one person involved and I

507
00:24:41,620 --> 00:24:40,010
think that'd be more than you know one

508
00:24:43,570 --> 00:24:41,630
human and one robot and more than just

509
00:24:46,110 --> 00:24:43,580
robots really I think the future is

510
00:24:49,060 --> 00:24:46,120
humans and robots together yeah yeah

511
00:24:52,480 --> 00:24:49,070
cool how about one more question from

512
00:24:55,510 --> 00:24:52,490
the chat okay move on which I have now

513
00:24:57,880 --> 00:24:55,520

lost space TV net hello wants to know

514

00:25:00,850 --> 00:24:57,890

what animal shape is the best for robots

515

00:25:04,330 --> 00:25:00,860

in zero gravity is there an animal in

516

00:25:08,340 --> 00:25:04,340

sprin nature inspiration shapes that

517

00:25:13,120 --> 00:25:11,470

for guys you know we like at least for

518

00:25:15,070 --> 00:25:13,130

flying robots to have some sort of

519

00:25:18,610 --> 00:25:15,080

symmetry to them because they can fly in

520

00:25:20,500 --> 00:25:18,620

any direction in space sometimes I think

521

00:25:23,830 --> 00:25:20,510

robot design draws inspiration from

522

00:25:25,659 --> 00:25:23,840

animals in biology has obviously evolved

523

00:25:27,070 --> 00:25:25,669

all kinds of different shapes different

524

00:25:28,990 --> 00:25:27,080

forms and we'd like to try to take

525

00:25:30,340 --> 00:25:29,000

advantage of that but we also sometimes

526

00:25:32,919 --> 00:25:30,350

draw inspiration you know as we said

527

00:25:34,810 --> 00:25:32,929

from like science fiction you know the

528

00:25:36,490 --> 00:25:34,820

idea that people come up with in

529

00:25:42,549 --> 00:25:36,500

Hollywood for robots I mean sometimes

530

00:25:43,870 --> 00:25:42,559

okay which makes the shape also it

531

00:25:45,940 --> 00:25:43,880

depends on what functionality you're

532

00:25:48,250 --> 00:25:45,950

looking for so you build it so that it's

533

00:25:51,280 --> 00:25:48,260

most efficient at the job interview want

534

00:25:53,430 --> 00:25:51,290

to accomplish so that's what drives that

535

00:25:55,500 --> 00:25:53,440

drives the show all right

536

00:25:57,900 --> 00:25:55,510

it makes sense well speaking of science

537

00:25:59,760 --> 00:25:57,910

fiction okay my question for us we see

538

00:26:01,440 --> 00:25:59,770

robots all over in movies and TV shows

539

00:26:03,990 --> 00:26:01,450

comics everything what are your

540

00:26:07,020 --> 00:26:04,000

favorites oh that's easy I mean for me

541

00:26:10,140 --> 00:26:07,030

you know my favorite robot is k9 which

542

00:26:13,470 --> 00:26:10,150

comes from Doctor Who k9 was the doctors

543

00:26:15,750 --> 00:26:13,480

robot dog and had basically you know a

544

00:26:19,170 --> 00:26:15,760

supercomputer built in inside and a

545

00:26:21,710 --> 00:26:19,180

little laser that's knows but yeah k9 no

546

00:26:27,480 --> 00:26:21,720

question have you built a dog robot yet

547

00:26:38,640 --> 00:26:27,490

I have to say that one of my previous

548

00:26:41,510 --> 00:26:38,650

robots in our group I don't really play

549

00:26:49,310 --> 00:26:41,520

favorites I don't really have a favorite

550

00:26:53,460 --> 00:26:52,830

all right well speaking of your

551

00:26:55,440 --> 00:26:53,470

favorites

552

00:26:57,890 --> 00:26:55,450

well now let's come to that in just a

553

00:26:59,970 --> 00:26:57,900

moment okay so we wanted to talk about

554

00:27:02,490 --> 00:26:59,980

characteristic yeah like what kind of

555

00:27:05,610 --> 00:27:02,500

qualities do you look for in a robot

556

00:27:07,380 --> 00:27:05,620

yeah right you know we look for we look

557

00:27:08,820 --> 00:27:07,390

for robots that can really help out

558

00:27:11,310 --> 00:27:08,830

especially we're talking about humans

559

00:27:13,980 --> 00:27:11,320

and robots in space yeah to really work

560

00:27:16,650 --> 00:27:13,990

well together and I think just like here

561

00:27:18,840 --> 00:27:16,660

on earth there's no single definition of

562

00:27:20,580 --> 00:27:18,850

what a team is the same is true in space

563

00:27:22,950 --> 00:27:20,590

I mean fact we could have robots that

564

00:27:25,680 --> 00:27:22,960

work say before humans or robots that

565

00:27:27,960 --> 00:27:25,690

work after humans or maybe even in

566

00:27:30,000 --> 00:27:27,970

parallel or in support so the idea is

567

00:27:32,820 --> 00:27:30,010

that you could have a team and all kinds

568

00:27:35,010 --> 00:27:32,830

of you know different settings and so

569

00:27:37,290 --> 00:27:35,020

sometimes we build robots to do things

570

00:27:38,730 --> 00:27:37,300

that might take a long period of time

571

00:27:39,360 --> 00:27:38,740

you have them work either before or

572

00:27:41,070 --> 00:27:39,370

after

573

00:27:44,220 --> 00:27:41,080

other times we want robots that can

574

00:27:46,890 --> 00:27:44,230

interact more sort of like human speed

575

00:27:50,610 --> 00:27:46,900

pacing so just like we're talking we'd

576

00:27:53,070 --> 00:27:50,620

like robots they can react to us - do

577

00:27:55,590 --> 00:27:53,080

you remember the other day - yes his

578

00:27:55,590 --> 00:27:55,600

comparison

579

00:27:55,600 --> 00:27:58,890

[Music]

580

00:28:03,700 --> 00:28:01,660

and Marie and I we spend all of our time

581

00:28:05,920 --> 00:28:03,710

here at work you know thinking about him

582

00:28:09,090 --> 00:28:05,930

trying to build robots and you know

583

00:28:11,740 --> 00:28:09,100

sometimes I admit it's it's frustrating

584

00:28:15,870 --> 00:28:11,750

it's it's not unlike you know trying to

585

00:28:18,520 --> 00:28:15,880

raise kids to be you know good

586

00:28:21,910 --> 00:28:18,530

autonomous team members and to work with

587

00:28:23,350 --> 00:28:21,920

you and you know sometimes I'm not sure

588

00:28:24,610 --> 00:28:23,360

if it's more or less challenging than

589

00:28:28,990 --> 00:28:24,620

trying to build robots to do the same

590

00:28:41,820 --> 00:28:29,000

thing my kids have grown up to be you

591

00:28:41,830 --> 00:28:51,930

[Laughter]

592

00:29:27,040 --> 00:29:05,860

vacuum cleaner to get well should we

593

00:29:29,650 --> 00:29:27,050

talk about what's the name in general

594

00:29:32,170 --> 00:29:29,660

these robots are called Astro B or hasta

595

00:29:35,920 --> 00:29:32,180

B's but they each have their own name

596

00:29:38,320 --> 00:29:35,930

and the color so this stunt double model

597

00:29:40,600 --> 00:29:38,330

you see is you turn it so you can see

598

00:29:44,170 --> 00:29:40,610

the color better is orange

599

00:29:46,870 --> 00:29:44,180

and it's called killer Olivia d'ervy but

600

00:29:49,260 --> 00:29:46,880

we also have three of these on space

601
00:29:52,780 --> 00:29:49,270
station currently and they are named

602
00:29:59,260 --> 00:29:52,790
bumble which is blue honey which is

603
00:30:00,940 --> 00:29:59,270
yellow and Queen which is green we

604
00:30:04,330 --> 00:30:00,950
always know which one it is of course on

605
00:30:06,250 --> 00:30:04,340
the color yeah so yeah this is Myra my

606
00:30:08,450 --> 00:30:06,260
favorite robot we just finished building

607
00:30:12,290 --> 00:30:08,460
these and watching them

608
00:30:13,670 --> 00:30:12,300
I'm very exciting yeah it's Maria's

609
00:30:21,170 --> 00:30:13,680
favorite robot cuz the past four years

610
00:30:23,000 --> 00:30:21,180
of my life exactly Farah no ask how long

611
00:30:24,950 --> 00:30:23,010
it takes to build something well as to

612
00:30:27,890 --> 00:30:24,960
be well it's been now almost five years

613
00:30:30,230 --> 00:30:27,900

since we started but but I mean fish

614

00:30:32,210 --> 00:30:30,240

building them and launching them within

615

00:30:33,740 --> 00:30:32,220

those five years so so they're and

616

00:30:36,470 --> 00:30:33,750

they're now starting to operate with it

617

00:30:39,670 --> 00:30:36,480

yeah so about like a little over four

618

00:30:41,840 --> 00:30:39,680

years to build the actual flight units

619

00:30:44,030 --> 00:30:41,850

and so I can I can tell you a little bit

620

00:30:45,440 --> 00:30:44,040

about how these work the number one

621

00:30:48,380 --> 00:30:45,450

question I get when talking about

622

00:30:51,560 --> 00:30:48,390

Ospreys was how do they move in day

623

00:30:53,690 --> 00:30:51,570

right so first of all after me only

624

00:30:57,370 --> 00:30:53,700

works inside the space station because

625

00:31:01,040 --> 00:30:57,380

it needs air it's fan base propulsion

626
00:31:05,060 --> 00:31:01,050
there are two fans on board the sort of

627
00:31:05,690 --> 00:31:05,070
circular yeah I can see it better there

628
00:31:07,730 --> 00:31:05,700
we go

629
00:31:16,970 --> 00:31:07,740
the the circular opening that you see on

630
00:31:18,740 --> 00:31:16,980
the side maybe like a speaker that's a

631
00:31:21,860 --> 00:31:18,750
there's an impeller fan in there so that

632
00:31:24,350 --> 00:31:21,870
pulls air in and lightly pressurizes the

633
00:31:26,450 --> 00:31:24,360
propulsion module and then those grills

634
00:31:28,190 --> 00:31:26,460
that you see there's there's two on

635
00:31:37,760 --> 00:31:28,200
every side so there's twelve total

636
00:31:40,430 --> 00:31:37,770
that's right open and close releasing

637
00:31:43,190 --> 00:31:40,440
some of that pressurized air and that's

638
00:31:45,290 --> 00:31:43,200

how it pushes itself around Space

639

00:31:47,750 --> 00:31:45,300

Station all right so yeah it's it's very

640

00:31:51,530 --> 00:31:47,760

light pressure it's only about point one

641

00:31:53,120 --> 00:31:51,540

psi over the ambient station pressure so

642

00:31:57,710 --> 00:31:53,130

very safe it's not gonna you know

643

00:31:59,420 --> 00:31:57,720

anything yes in fact we've seen it when

644

00:32:06,140 --> 00:31:59,430

its operating on orbit we'll see like

645

00:32:09,590 --> 00:32:06,150

here definitely see the air is moving

646

00:32:12,020 --> 00:32:09,600

yeah it's not gonna like push them out

647

00:32:14,510 --> 00:32:12,030

away you're an asset for this to push

648

00:32:16,220 --> 00:32:14,520

out yeah yeah cool all right now and

649

00:32:19,340 --> 00:32:16,230

then of course the other question we

650

00:32:20,340 --> 00:32:19,350

always get is how does it how does it

651
00:32:22,080 --> 00:32:20,350
know where it is

652
00:32:27,509 --> 00:32:22,090
you know how does it move and navigate

653
00:32:29,159 --> 00:32:27,519
and not crash into the walls it's sort

654
00:32:33,180 --> 00:32:29,169
of central white section that you see

655
00:32:36,409 --> 00:32:33,190
right there is the the heart and soul of

656
00:32:39,480 --> 00:32:36,419
it it's the core module inside our three

657
00:32:42,600 --> 00:32:39,490
cell phone class computers so pretty

658
00:32:50,669 --> 00:32:42,610
much the same as your cell phone and it

659
00:32:53,129 --> 00:32:50,679
uses a camera but the main camera the

660
00:32:56,850 --> 00:32:53,139
navigation camera on this end right

661
00:32:59,399 --> 00:32:56,860
there it uses that camera to look at

662
00:33:01,799 --> 00:32:59,409
features inside the space station okay

663
00:33:04,139 --> 00:33:01,809

so it has a map that it keeps on board

664

00:33:05,940 --> 00:33:04,149

of features it knows where those you

665

00:33:07,889 --> 00:33:05,950

know features should be in the station

666

00:33:09,659 --> 00:33:07,899

and then as its flying around it

667

00:33:12,680 --> 00:33:09,669

compares what it currently sees to that

668

00:33:15,210 --> 00:33:12,690

map to you know figure out where it is

669

00:33:17,249 --> 00:33:15,220

just like you know humans recognize

670

00:33:19,169 --> 00:33:17,259

landmarks to understand where we are

671

00:33:22,590 --> 00:33:19,179

this does that but in a much more

672

00:33:24,480 --> 00:33:22,600

precise manner and you know I think the

673

00:33:26,070 --> 00:33:24,490

other thing that Maria was kind of you

674

00:33:28,320 --> 00:33:26,080

know pointed out is that we've added a

675

00:33:30,419 --> 00:33:28,330

whole bunch of cameras on here that's

676
00:33:32,490 --> 00:33:30,429
really enable it to fly around and know

677
00:33:33,930 --> 00:33:32,500
where it is some of these are optimized

678
00:33:35,879 --> 00:33:33,940
for really sort of like the closed-end

679
00:33:38,820 --> 00:33:35,889
docking that you might want to do with a

680
00:33:40,590 --> 00:33:38,830
robot we need a lot of accuracy and

681
00:33:42,389 --> 00:33:40,600
others therefore just sort of like free

682
00:33:44,730 --> 00:33:42,399
flight when you're really just trying to

683
00:33:46,470 --> 00:33:44,740
worry about hey am I going to you know

684
00:33:48,930 --> 00:33:46,480
be in the center of a module or near a

685
00:33:50,129 --> 00:33:48,940
wall and that kind of thing yeah and

686
00:33:53,279 --> 00:33:50,139
then the last thing I like to point out

687
00:33:55,740 --> 00:33:53,289
on this model and part of the main

688
00:33:57,960 --> 00:33:55,750

purpose of this robot is to carry

689

00:34:00,419 --> 00:33:57,970

payloads we are actually going to be

690

00:34:03,389 --> 00:34:00,429

replacing the spheres that we saw

691

00:34:06,600 --> 00:34:03,399

earlier of to carry around other

692

00:34:08,790 --> 00:34:06,610

experiments okay and so there's a lot of

693

00:34:12,840 --> 00:34:08,800

open space you can sort of see me and

694

00:34:19,300 --> 00:34:16,930

allows other technologies to plug into

695

00:34:20,740 --> 00:34:19,310

this robot and we will fly you around

696

00:34:21,670 --> 00:34:20,750

where you ever you want to go in Space

697

00:34:23,920 --> 00:34:21,680

Station

698

00:34:26,680 --> 00:34:23,930

take your experiments your equipment

699

00:34:30,730 --> 00:34:26,690

yeah we'll take you around Space Station

700

00:34:32,890 --> 00:34:30,740

how cool is that if people out there

701
00:34:35,590 --> 00:34:32,900
have an idea for I got a great you know

702
00:34:37,480 --> 00:34:35,600
mechanism or a sensor or something else

703
00:34:42,340 --> 00:34:37,490
that could be built for s Trippi and you

704
00:34:44,320 --> 00:34:42,350
can go to wboc.com / Astro be a STR OBE

705
00:34:46,810 --> 00:34:44,330
and you'll find all kinds of information

706
00:34:49,720 --> 00:34:46,820
about the Astro B guest science program

707
00:34:51,730 --> 00:34:49,730
and that tells people about you know the

708
00:34:53,950 --> 00:34:51,740
physical size of the payload bay is you

709
00:34:56,440 --> 00:34:53,960
know how you can really develop software

710
00:34:57,580 --> 00:34:56,450
for this actually some of some of our

711
00:35:00,430 --> 00:34:57,590
interesting experiments are just gonna

712
00:35:02,560 --> 00:35:00,440
be just purely software people right and

713
00:35:04,600 --> 00:35:02,570

we upload into one or more of the

714

00:35:12,460 --> 00:35:04,610

processors onboard do you want some of

715

00:35:15,160 --> 00:35:12,470

our payload oh sure is this it's a it's

716

00:35:16,630 --> 00:35:15,170

actually a robot arm you can see the

717

00:35:35,550 --> 00:35:16,640

gripper here and we can open the gripper

718

00:35:39,610 --> 00:35:38,050

this is a payload for Astra be just like

719

00:35:41,470 --> 00:35:39,620

any other and it can plug in on the

720

00:35:43,720 --> 00:35:41,480

Henderson murió just show you where it

721

00:35:46,060 --> 00:35:43,730

would go like right in here in the top

722

00:35:49,090 --> 00:35:46,070

payload Bay we just slot it in here all

723

00:35:52,000 --> 00:35:49,100

right right these couple of levers here

724

00:35:53,290 --> 00:35:52,010

that the astronauts can can switch to

725

00:35:56,560 --> 00:35:53,300

lock it into place

726

00:35:58,900 --> 00:35:56,570

mm-hmm and so it ends oh how it should

727

00:36:01,060 --> 00:35:58,910

be used approaching arm oh so it has it

728

00:36:02,320 --> 00:36:01,070

has this gripper on the front here and

729

00:36:05,800 --> 00:36:02,330

you know I can actually open this up

730

00:36:09,340 --> 00:36:05,810

here this is designed to really you know

731

00:36:10,990 --> 00:36:09,350

reach in and grab something grab the

732

00:36:13,630 --> 00:36:11,000

bottle of water here

733

00:36:15,310 --> 00:36:13,640

okay but inside the space station there

734

00:36:17,050 --> 00:36:15,320

are all these handrails that are all

735

00:36:18,640 --> 00:36:17,060

over inside the space station and the

736

00:36:21,190 --> 00:36:18,650

astronauts actually reach out they grab

737

00:36:24,100 --> 00:36:21,200

on to them to hold on hold themselves in

738

00:36:26,140 --> 00:36:24,110

position or to push themselves on on to

739

00:36:28,780 --> 00:36:26,150

the next area and we can take advantage

740

00:36:31,030 --> 00:36:28,790

of all the handrails there for Astra be

741

00:36:33,310 --> 00:36:31,040

to grab onto and that's why we refer to

742

00:36:35,200 --> 00:36:33,320

this actually as the perching arm you

743

00:36:37,360 --> 00:36:35,210

know it's it's meant to perch on to

744

00:36:39,070 --> 00:36:37,370

things inside a station right when after

745

00:36:41,470 --> 00:36:39,080

we grabs hold of the handrail we can

746

00:36:43,980 --> 00:36:41,480

turn the propulsion modules off and save

747

00:36:49,150 --> 00:36:46,690

and because there's a camera we have a

748

00:36:51,100 --> 00:36:49,160

high-def camera on the front end and

749

00:36:54,040 --> 00:36:51,110

that the perching arm here would be off

750

00:36:56,820 --> 00:36:54,050

the back end right we can use this then

751

00:37:00,160 --> 00:36:56,830

as a pan tilt unit to point the camera

752

00:37:02,020 --> 00:37:00,170

okay so you can still move the can't

753

00:37:03,640 --> 00:37:02,030

even though the robot is kind of grabbed

754

00:37:05,980 --> 00:37:03,650

on to something and not flying around

755

00:37:08,680 --> 00:37:05,990

you can still point the camera and the

756

00:37:13,180 --> 00:37:08,690

camera we can still be working yeah I

757

00:37:15,040 --> 00:37:13,190

have a question here from M DM PhD what

758

00:37:16,480 --> 00:37:15,050

serious mission aspects can be worked by

759

00:37:20,170 --> 00:37:16,490

robots such as pester beam

760

00:37:22,510 --> 00:37:20,180

oh all kinds of things you know this in

761

00:37:24,670 --> 00:37:22,520

addition to being a research platform

762

00:37:27,130 --> 00:37:24,680

you know that's a gonna follow on two

763

00:37:29,260 --> 00:37:27,140

spheres is also for us meant to be

764

00:37:30,670 --> 00:37:29,270

something we can test out various things

765

00:37:33,340 --> 00:37:30,680

that we would like future robots to do

766

00:37:36,460 --> 00:37:33,350

inside of you know spacecraft or maybe

767

00:37:38,530 --> 00:37:36,470

even future habitats on planets so for

768

00:37:41,170 --> 00:37:38,540

example this robot is going to carry a

769

00:37:43,930 --> 00:37:41,180

different payload built by our friends

770

00:37:47,860 --> 00:37:43,940

down at NASA Johnson in Texas that's an

771

00:37:49,810 --> 00:37:47,870

RFID scanner so basically we can go

772

00:37:52,120 --> 00:37:49,820

around and use the free flying robot to

773

00:37:54,040 --> 00:37:52,130

take inventory of things that we have

774

00:37:58,150 --> 00:37:54,050

tagged with you know little little tags

775

00:38:01,120 --> 00:37:58,160

just like in your credit cards and

776

00:38:03,730 --> 00:38:01,130

grocery stores just to do inventory so

777

00:38:05,680 --> 00:38:03,740

inventory is a great task for robots

778

00:38:08,230 --> 00:38:05,690

another is just monitoring the

779

00:38:10,150 --> 00:38:08,240

environment just trying to assess you

780

00:38:12,220 --> 00:38:10,160

know like light levels or sound levels

781

00:38:13,870 --> 00:38:12,230

or air quality and so we can put

782

00:38:16,210 --> 00:38:13,880

different sensors onto Astra P and do

783

00:38:18,460 --> 00:38:16,220

that you know all kinds of interesting

784

00:38:20,380 --> 00:38:18,470

things that you can use a robot for

785

00:38:22,420 --> 00:38:20,390

really you know help take care of the

786

00:38:23,950 --> 00:38:22,430

environment inside your spacecraft and

787

00:38:24,370 --> 00:38:23,960

kind of freeing up the time for the

788

00:38:25,450 --> 00:38:24,380

Astra

789

00:38:27,430 --> 00:38:25,460

that's right because they spent a lot of

790

00:38:29,650 --> 00:38:27,440

time doing tasks like the inventory and

791

00:38:32,319 --> 00:38:29,660

the monitoring and if you have a robot

792

00:38:33,910 --> 00:38:32,329

doing that it you know freezin about to

793

00:38:38,950 --> 00:38:33,920

do other things right yes that kind of

794

00:38:40,930 --> 00:38:38,960

the I think today maybe we'll talk about

795

00:38:43,299 --> 00:38:40,940

this more and later on in the the show

796

00:38:45,069 --> 00:38:43,309

here but you know today on the space

797

00:38:46,509 --> 00:38:45,079

station it's a place where we have you

798

00:38:48,910 --> 00:38:46,519

know astronauts all the time it's been

799

00:38:50,559 --> 00:38:48,920

continuously man for a long time now but

800

00:38:52,150 --> 00:38:50,569

the astronauts actually spend a lot of

801
00:38:54,039 --> 00:38:52,160
their time doing maintenance a lot of

802
00:38:56,470 --> 00:38:54,049
routine maintenance some of it is just

803
00:38:57,910 --> 00:38:56,480
you know preventive you know it's time

804
00:38:58,299 --> 00:38:57,920
to actually you know change an air

805
00:38:59,799 --> 00:38:58,309
filter

806
00:39:01,960 --> 00:38:59,809
some of it is corrective because

807
00:39:03,880 --> 00:39:01,970
something broke and we'd like to try to

808
00:39:05,470 --> 00:39:03,890
use robots to help take care of those

809
00:39:09,809 --> 00:39:05,480
tasks so that you know the astronauts

810
00:39:22,539 --> 00:39:12,819
have a couple of comments about Astor V

811
00:39:26,710 --> 00:39:22,549
that's one weird-looking r2d2 kind of

812
00:39:28,390 --> 00:39:26,720
like a companion cube yes it's been

813
00:39:33,400 --> 00:39:28,400

pointed out to us that the resemblance

814

00:39:36,999 --> 00:39:33,410

in the past all right we have a question

815

00:39:43,749 --> 00:39:37,009

here this is how do you charge or

816

00:39:46,960 --> 00:39:43,759

recharge the attributes the astra B

817

00:39:50,829 --> 00:39:46,970

actually has a docking station on on

818

00:39:52,930 --> 00:39:50,839

space station that lets us the robot can

819

00:39:55,960 --> 00:39:52,940

actually autonomously plug itself in so

820

00:39:57,970 --> 00:39:55,970

it's kind of your Roomba in space you

821

00:40:01,450 --> 00:39:57,980

can go out and fly these sorties where

822

00:40:03,400 --> 00:40:01,460

it takes measurements and does guess

823

00:40:05,740 --> 00:40:03,410

science and then when it starts the

824

00:40:08,410 --> 00:40:05,750

power starts to run low it has a docking

825

00:40:10,569 --> 00:40:08,420

port on the back which we see here and

826

00:40:13,690 --> 00:40:10,579

it can actually back itself into its its

827

00:40:15,609 --> 00:40:13,700

docking station and recharge and we also

828

00:40:18,339 --> 00:40:15,619

give it an Ethernet connection to the

829

00:40:20,259 --> 00:40:18,349

space station local area network when we

830

00:40:23,079 --> 00:40:20,269

do that so we get a little bit a higher

831

00:40:26,820 --> 00:40:23,089

bandwidth on vacation oh yeah okay so

832

00:40:29,810 --> 00:40:26,830

you could download a neat detail exactly

833

00:40:37,070 --> 00:40:29,820

[Laughter]

834

00:40:44,490 --> 00:40:42,950

Astra B's first autonomous undock we see

835

00:40:46,350 --> 00:40:44,500

astronaut daavid

836

00:40:52,280 --> 00:40:46,360

they're giving us the play-by-play

837

00:40:57,030 --> 00:40:54,870

this motion and then here we see it

838

00:40:59,790 --> 00:40:57,040

docking this is our first autonomous

839

00:41:01,980 --> 00:40:59,800

docking motion so it just backed itself

840

00:41:03,480 --> 00:41:01,990

up into the dock we'll see a little like

841

00:41:06,570 --> 00:41:03,490

come on telling us that there we go

842

00:41:11,400 --> 00:41:06,580

we've got a good connection this was big

843

00:41:20,940 --> 00:41:11,410

celebration for us and and crew was very

844

00:41:26,100 --> 00:41:20,950

excited - yeah what if the astronauts

845

00:41:27,990 --> 00:41:26,110

say about working with aster be really

846

00:41:30,000 --> 00:41:28,000

positive comments from them I mean for

847

00:41:33,690 --> 00:41:30,010

them really it's it's a new teammate in

848

00:41:36,270 --> 00:41:33,700

space and you know I recall the first

849

00:41:38,070 --> 00:41:36,280

time you know that a3 was at least the

850

00:41:41,120 --> 00:41:38,080

first Astra be what was unboxed it was

851
00:41:44,160 --> 00:41:41,130
kind of like you know Christmas in space

852
00:41:44,580 --> 00:41:44,170
I got a new teammate I got a new

853
00:41:46,530 --> 00:41:44,590
roommate

854
00:42:02,940 --> 00:41:46,540
all you want and I can teach you how to

855
00:42:04,560 --> 00:42:02,950
actually you know be a good roommate so

856
00:42:05,790 --> 00:42:04,570
we certainly have that we well we were

857
00:42:07,920 --> 00:42:05,800
first building it was very much a

858
00:42:09,870 --> 00:42:07,930
concern that we would be good teammates

859
00:42:12,330 --> 00:42:09,880
that we would be for instance too loud

860
00:42:16,890 --> 00:42:12,340
you know we wanted to stay quiet and we

861
00:42:18,990 --> 00:42:16,900
don't to be annoying it's gonna make a

862
00:42:21,000 --> 00:42:19,000
constant noise so we want to you know

863
00:42:23,610 --> 00:42:21,010

minimize that and so far the feedback

864

00:42:25,470 --> 00:42:23,620

we've gotten from from astronauts is

865

00:42:27,390 --> 00:42:25,480

that it's it's very reasonable it's not

866

00:42:34,579 --> 00:42:27,400

too loud and it's they actually kind of

867

00:42:40,140 --> 00:42:37,009

fun things to say the other day about

868

00:42:42,719 --> 00:42:40,150

the astronauts are guiding it around I

869

00:42:44,609 --> 00:42:42,729

think so yes

870

00:42:47,189 --> 00:42:44,619

one of the first activities we had to do

871

00:42:50,789 --> 00:42:47,199

is build the map of the inside of the

872

00:42:52,559 --> 00:42:50,799

space station you need to know what it

873

00:42:56,160 --> 00:42:52,569

really looks like you know from the

874

00:42:59,400 --> 00:42:56,170

robots point of view so astronauts ovide

875

00:43:00,929 --> 00:42:59,410

was actually flying us manually flying

876

00:43:03,749 --> 00:43:00,939

us around so that we could collect

877

00:43:04,709 --> 00:43:03,759

imagery data while he was moving us

878

00:43:07,549 --> 00:43:04,719

around because we don't know where we

879

00:43:10,199 --> 00:43:07,559

are yet so we can't fly ourselves so we

880

00:43:11,459 --> 00:43:10,209

moved us back and forth and he it was

881

00:43:18,179 --> 00:43:11,469

great he said it was like teaching a

882

00:43:19,949 --> 00:43:18,189

child I must say it was really

883

00:43:22,259 --> 00:43:19,959

interesting and like exciting watching

884

00:43:24,599 --> 00:43:22,269

you guys you know do these you know

885

00:43:26,039 --> 00:43:24,609

tests in the lab here and just the

886

00:43:28,079 --> 00:43:26,049

excitement I mean the astronauts are

887

00:43:30,689 --> 00:43:28,089

excited and then the team's excited here

888

00:43:38,249 --> 00:43:30,699

it's really really cool experience I was

889

00:43:40,469 --> 00:43:38,259

in the back you know working through the

890

00:43:42,299 --> 00:43:40,479

design and development of Astro B and

891

00:43:44,459 --> 00:43:42,309

certainly I think for the team you know

892

00:43:46,229 --> 00:43:44,469

seeing it in space was just hugely you

893

00:43:47,969 --> 00:43:46,239

know really rewarding it was really

894

00:43:50,069 --> 00:43:47,979

great to see that you know you actually

895

00:43:52,289 --> 00:43:50,079

happen I can give you some breaking news

896

00:43:55,949 --> 00:43:52,299

that just yesterday morning very early

897

00:43:57,900 --> 00:43:55,959

in the morning we we have a test with

898

00:44:00,599 --> 00:43:57,910

Astro be with with bumble the blue or

899

00:44:02,969 --> 00:44:00,609

the blue robot flying it around it flew

900

00:44:04,199 --> 00:44:02,979

itself it autonomously operated it ran a

901
00:44:05,849 --> 00:44:04,209
whole bunch of plans

902
00:44:09,410 --> 00:44:05,859
you know undocked itself flew around

903
00:44:12,269 --> 00:44:09,420
came back to dock it went really great

904
00:44:21,929 --> 00:44:12,279
to see that independence it really is

905
00:44:23,669 --> 00:44:21,939
like a kid we don't want to wait you

906
00:44:29,370 --> 00:44:23,679
know 20 years for it to grow and get a

907
00:44:36,420 --> 00:44:33,560
[Laughter]

908
00:44:38,160 --> 00:44:36,430
all right so we've been talking about

909
00:44:40,470 --> 00:44:38,170
how these robots are helping astronauts

910
00:44:41,910 --> 00:44:40,480
today right so what about looking a

911
00:44:44,460 --> 00:44:41,920
little bit ahead because right now NASA

912
00:44:46,620 --> 00:44:44,470
is busy working to get humans to the

913
00:44:49,410 --> 00:44:46,630

moon in 2024 that's the Emmis burgers

914

00:44:51,510 --> 00:44:49,420

right could you maybe summarize for

915

00:44:53,580 --> 00:44:51,520

people what Artemis is all about and

916

00:44:55,860 --> 00:44:53,590

then yeah so I mean Artemis is certainly

917

00:44:58,320 --> 00:44:55,870

a first step of you know extending human

918

00:45:00,720 --> 00:44:58,330

presence beyond just you know Earth and

919

00:45:02,340 --> 00:45:00,730

Earth orbit you know our goal here is of

920

00:45:04,740 --> 00:45:02,350

course to get people back to the moon

921

00:45:05,760 --> 00:45:04,750

you know by 2024 and to do that we're

922

00:45:08,970 --> 00:45:05,770

building a number of different systems

923

00:45:10,440 --> 00:45:08,980

you know new spacecraft new Landers and

924

00:45:12,750 --> 00:45:10,450

this really interesting thing called the

925

00:45:15,420 --> 00:45:12,760

Gateway yeah you know it's meant to be

926

00:45:17,430 --> 00:45:15,430

an orbiting sort of mini space station

927

00:45:19,890 --> 00:45:17,440

around the moon and it's a place that

928

00:45:21,030 --> 00:45:19,900

we're building not just because we want

929

00:45:22,890 --> 00:45:21,040

something to orbit the moon but it's

930

00:45:25,020 --> 00:45:22,900

really a jumping-off point yeah I'm to

931

00:45:26,790 --> 00:45:25,030

go beyond the moon and also to be a

932

00:45:29,400 --> 00:45:26,800

place where you can you know carry out

933

00:45:31,380 --> 00:45:29,410

experiments beyond Earth orbit in a

934

00:45:34,710 --> 00:45:31,390

place where you can you use that to go

935

00:45:36,000 --> 00:45:34,720

to and from the lunar surface but unlike

936

00:45:37,530 --> 00:45:36,010

the space station it's meant to be a

937

00:45:38,970 --> 00:45:37,540

place where you know we'll only

938

00:45:41,310 --> 00:45:38,980

occasionally be there at least at first

939

00:45:43,170 --> 00:45:41,320

okay and so if you're only there for say

940

00:45:45,090 --> 00:45:43,180

you know a few weeks of the year what

941

00:45:46,470 --> 00:45:45,100

happens rest the time well it's like

942

00:45:48,090 --> 00:45:46,480

having a vacation home you still need to

943

00:45:50,820 --> 00:45:48,100

take care of that maintainer you need to

944

00:45:52,050 --> 00:45:50,830

do caretaking and this in my opinion I

945

00:45:55,500 --> 00:45:52,060

think the very best way of doing that is

946

00:46:08,970 --> 00:45:55,510

to make use of robots you know maybe

947

00:46:10,470 --> 00:46:08,980

they'll be a little lonely because the

948

00:46:12,540 --> 00:46:10,480

Gateway it might be fun for people to

949

00:46:14,670 --> 00:46:12,550

see that and I think you just answered

950

00:46:16,230 --> 00:46:14,680

Pluto Oh nines question could you

951
00:46:20,550 --> 00:46:16,240
explain how the role of robotics could

952
00:46:24,850 --> 00:46:22,750
robots being inside and outside a

953
00:46:28,090 --> 00:46:24,860
station so and I think the same thing is

954
00:46:30,070 --> 00:46:28,100
true about the Gateway certainly we

955
00:46:31,450 --> 00:46:30,080
expect there to be an external robot arm

956
00:46:34,540 --> 00:46:31,460
you can see that right there in the

957
00:46:36,070 --> 00:46:34,550
animation and I think at some point in

958
00:46:38,490 --> 00:46:36,080
the future hopefully not too distant

959
00:46:40,540 --> 00:46:38,500
future we'll see robots inside

960
00:46:43,480 --> 00:46:40,550
performing some of these these

961
00:46:45,610 --> 00:46:43,490
caretaking right now tasks and I think

962
00:46:48,130 --> 00:46:45,620
beyond that to of course you know here

963
00:46:49,810 --> 00:46:48,140

you know at NASA we have spent quite a

964

00:46:52,150 --> 00:46:49,820

bit of time you know researching

965

00:46:54,930 --> 00:46:52,160

studying you know how humans the robots

966

00:46:57,610 --> 00:46:54,940

can work together on planetary surfaces

967

00:46:59,440 --> 00:46:57,620

as we get you know people back to the

968

00:47:01,600 --> 00:46:59,450

moon I fully expect there to be be

969

00:47:03,220 --> 00:47:01,610

robots there as well and there are the

970

00:47:05,980 --> 00:47:03,230

idea is that you could have humans and

971

00:47:07,720 --> 00:47:05,990

robots doing things on the surface maybe

972

00:47:09,130 --> 00:47:07,730

the robots are doing scouting maybe

973

00:47:11,710 --> 00:47:09,140

they're setting up you know

974

00:47:18,490 --> 00:47:11,720

infrastructure like communication arrays

975

00:47:20,650 --> 00:47:18,500

solar panels and they're you know really

976

00:47:22,360 --> 00:47:20,660

I think the honestly the sky's the limit

977

00:47:25,090 --> 00:47:22,370

about the things you can think about or

978

00:47:27,760 --> 00:47:25,100

ways for humans and robots the team as

979

00:47:29,200 --> 00:47:27,770

we carry out future exploration mmm I

980

00:47:30,790 --> 00:47:29,210

think we have a question here from and

981

00:47:35,860 --> 00:47:30,800

you know to what you're speaking about

982

00:47:39,190 --> 00:47:35,870

airplane men 1997 will we have robots in

983

00:47:41,290 --> 00:47:39,200

deep space on other planets that will

984

00:47:42,640 --> 00:47:41,300

help humans you know explore those

985

00:47:44,830 --> 00:47:42,650

planets that we've never you know

986

00:47:47,080 --> 00:47:44,840

support before yeah absolutely I mean we

987

00:47:48,490 --> 00:47:47,090

have robots today on Mars but at some

988

00:47:51,340 --> 00:47:48,500

point in time we'll have humans there as

989

00:47:53,110 --> 00:47:51,350

well you know and I think at least right

990

00:47:55,240 --> 00:47:53,120

now the current focus on the moon is a

991

00:47:57,550 --> 00:47:55,250

great opportunity of not just for NASA

992

00:48:00,160 --> 00:47:57,560

but for the you know the entire world to

993

00:48:01,810 --> 00:48:00,170

learn how to really live and work you

994

00:48:04,120 --> 00:48:01,820

know another planetary surface on the

995

00:48:05,320 --> 00:48:04,130

moon and then we use all the things that

996

00:48:07,420 --> 00:48:05,330

we learn everything that we've developed

997

00:48:10,240 --> 00:48:07,430

and tested and apply it to other places

998

00:48:12,070 --> 00:48:10,250

such as Mars kind of continue the

999

00:48:16,990 --> 00:48:12,080

teaming that you talked about earlier

1000

00:48:18,940 --> 00:48:17,000

great strength exactly you guys already

1001
00:48:21,400 --> 00:48:18,950
talked a little bit about the before in

1002
00:48:23,980 --> 00:48:21,410
parallel and after kind of idea

1003
00:48:25,630 --> 00:48:23,990
Terry sort of covered that with talking

1004
00:48:28,180 --> 00:48:25,640
about scouting and preparing

1005
00:48:30,130 --> 00:48:28,190
infrastructure sort of the after is you

1006
00:48:31,510 --> 00:48:30,140
can you know crew is only going to be

1007
00:48:33,100 --> 00:48:31,520
there for a certain amount of time you

1008
00:48:36,520 --> 00:48:33,110
know that the humans are probably then

1009
00:48:38,230 --> 00:48:36,530
after a few months or year maybe and

1010
00:48:40,960 --> 00:48:38,240
then you want that the robots will stay

1011
00:48:43,300 --> 00:48:40,970
behind so they can continue to do some

1012
00:48:44,950 --> 00:48:43,310
of the work that the astronauts started

1013
00:48:47,710 --> 00:48:44,960

yeah for instance we talked about those

1014

00:48:49,270 --> 00:48:47,720

tedious you know jobs yes taking lots of

1015

00:49:00,510 --> 00:48:49,280

measurements so they could go in there

1016

00:49:06,330 --> 00:49:04,770

go spend several years ago we had a

1017

00:49:08,760 --> 00:49:06,340

research project here at NASA Ames

1018

00:49:11,310 --> 00:49:08,770

called the robotic follow-up project and

1019

00:49:13,050 --> 00:49:11,320

Maria was actually the project manager

1020

00:49:15,060 --> 00:49:13,060

for that okay and that was really all

1021

00:49:17,820 --> 00:49:15,070

about exactly that you know we we sent

1022

00:49:20,940 --> 00:49:17,830

out some astronauts into the field and

1023

00:49:27,060 --> 00:49:20,950

they had handheld you know cameras and

1024

00:49:29,310 --> 00:49:27,070

instruments here on earth I guess we

1025

00:49:31,440 --> 00:49:29,320

call a planetary analog you know so a

1026

00:49:34,080 --> 00:49:31,450

location on Earth that has features

1027

00:49:35,460 --> 00:49:34,090

similar exactly to places in the care

1028

00:49:36,630 --> 00:49:35,470

about on the Moon or Mars in this

1029

00:49:36,960 --> 00:49:36,640

particular case was in the Canadian

1030

00:49:39,420 --> 00:49:36,970

Arctic

1031

00:49:41,640 --> 00:49:39,430

oh this wonderfully interesting place

1032

00:49:44,550 --> 00:49:41,650

called Devon Island and on there is a

1033

00:49:47,670 --> 00:49:44,560

large 20 kilometer you know 12 meter or

1034

00:49:51,270 --> 00:49:47,680

12 mile or so diameter impact structure

1035

00:49:54,630 --> 00:49:51,280

a big giant crater we had simulated

1036

00:49:57,630 --> 00:49:54,640

astronauts doing some mapping work there

1037

00:49:59,580 --> 00:49:57,640

some field geology work and then after

1038

00:50:10,200 --> 00:49:59,590

they were done you know they came back

1039

00:50:12,390 --> 00:50:10,210

home like for instance he's a

1040

00:50:14,040 --> 00:50:12,400

ground-penetrating radar and they'll

1041

00:50:16,260 --> 00:50:14,050

sweep over the ground you're just going

1042

00:50:20,910 --> 00:50:16,270

back and forth yeah usually mowing the

1043

00:50:23,760 --> 00:50:20,920

lawn taking thousands of measurements

1044

00:50:26,550 --> 00:50:23,770

that frankly would have been really

1045

00:50:30,690 --> 00:50:26,560

tedious really you know difficult I

1046

00:50:43,770 --> 00:50:30,700

think for humans yeah how did it do did

1047

00:50:50,700 --> 00:50:43,780

it do well its job well another robot

1048

00:50:53,099 --> 00:50:50,710

robots they run out of energy that's

1049

00:50:56,070 --> 00:50:53,109

true okay yeah so that was the after

1050

00:50:57,900 --> 00:50:56,080

example of this for during and after

1051
00:51:00,349 --> 00:50:57,910
humans are there which is kind of like

1052
00:51:03,000 --> 00:51:00,359
surgery he told me the other day yeah

1053
00:51:04,590 --> 00:51:03,010
it's like surgery to you know I mean you

1054
00:51:06,510 --> 00:51:04,600
know obviously the brain surgeons not

1055
00:51:08,849 --> 00:51:06,520
gonna do everything and and there's

1056
00:51:10,740 --> 00:51:08,859
someone who's doing preparation and they

1057
00:51:11,570 --> 00:51:10,750
get the patient ready in the operating

1058
00:51:13,670 --> 00:51:11,580
room and

1059
00:51:16,910 --> 00:51:13,680
ready and then the brain surgeon comes

1060
00:51:19,610 --> 00:51:16,920
in and then somebody cleans up

1061
00:51:22,070 --> 00:51:19,620
afterwards uh you know and I think you

1062
00:51:24,140 --> 00:51:22,080
know the idea that humans working with

1063
00:51:25,400 --> 00:51:24,150

robots in space you know it might they

1064

00:51:27,020 --> 00:51:25,410

might fall out see I'm kind of model you

1065

00:51:28,970 --> 00:51:27,030

have robots that are doing things ahead

1066

00:51:31,370 --> 00:51:28,980

of time and maybe takes a long time mhm

1067

00:51:33,530 --> 00:51:31,380

and then the humans arrive and do the

1068

00:51:35,960 --> 00:51:33,540

parts that require humans and you know

1069

00:51:37,820 --> 00:51:35,970

afterwards yeah the robots come back and

1070

00:51:50,210 --> 00:51:37,830

they say okay now that pesky humans are

1071

00:51:51,890 --> 00:51:50,220

gone ninety seven once know should there

1072

00:51:53,510 --> 00:51:51,900

be a robot that follows people around to

1073

00:51:56,780 --> 00:51:53,520

make sure areas are safe when we're on

1074

00:51:58,610 --> 00:51:56,790

Mars for example yeah there have been

1075

00:52:01,040 --> 00:51:58,620

other projects here at NASA that have

1076
00:52:02,810 --> 00:52:01,050
looked at the idea of robots doing

1077
00:52:05,060 --> 00:52:02,820
scouting we're asking where they're

1078
00:52:07,010 --> 00:52:05,070
really scouting you know not you know

1079
00:52:09,200 --> 00:52:07,020
years in advance but just ahead of

1080
00:52:11,990 --> 00:52:09,210
humans or maybe robots that are just

1081
00:52:14,240 --> 00:52:12,000
behind them carrying tools or supplies

1082
00:52:16,610 --> 00:52:14,250
yeah I think that kind of you know

1083
00:52:21,590 --> 00:52:16,620
real-time support is also really of

1084
00:52:22,760 --> 00:52:21,600
interest to yeah well three yeah we've

1085
00:52:25,490 --> 00:52:22,770
got lots of questions we're gonna

1086
00:52:28,250 --> 00:52:25,500
definitely save time for those uh some

1087
00:52:35,060 --> 00:52:28,260
comments like the life is yours calls

1088
00:52:36,950 --> 00:52:35,070

Esther be space Roomba we've had other

1089

00:52:38,660 --> 00:52:36,960

comments to that you know people have

1090

00:52:40,160 --> 00:52:38,670

said hey you know you the the spheres

1091

00:52:42,110 --> 00:52:40,170

robots that you guys been working with

1092

00:52:43,640 --> 00:52:42,120

obviously inspired by Star Wars and you

1093

00:52:46,160 --> 00:52:43,650

know some some people have said well you

1094

00:52:48,650 --> 00:52:46,170

know your new robot is a cube you know

1095

00:52:54,520 --> 00:52:48,660

so was that inspired by that other

1096

00:53:08,650 --> 00:53:07,220

what are its intentions just wanna make

1097

00:53:11,330 --> 00:53:08,660

that clear

1098

00:53:14,420 --> 00:53:11,340

we are questionable we have a question

1099

00:53:16,160 --> 00:53:14,430

here from coffee FX saying what are the

1100

00:53:17,690 --> 00:53:16,170

biggest challenges in building a robot

1101
00:53:19,070 --> 00:53:17,700
designed to operate in a space

1102
00:53:20,420 --> 00:53:19,080
environment yeah that's a great question

1103
00:53:23,390 --> 00:53:20,430
so actually one of our biggest

1104
00:53:26,060 --> 00:53:23,400
challenges in it comes from operating

1105
00:53:28,040 --> 00:53:26,070
near humans in safety right of course so

1106
00:53:31,730 --> 00:53:28,050
you know we could probably make a robot

1107
00:53:34,820 --> 00:53:31,740
that can fly real fast and but you know

1108
00:53:39,890 --> 00:53:34,830
there are windows so we don't want to

1109
00:53:42,260 --> 00:53:39,900
actually be actually it's been pretty

1110
00:53:46,360 --> 00:53:42,270
challenging coming up with a propulsion

1111
00:53:48,590 --> 00:53:46,370
system that's very nimble responsive

1112
00:53:50,960 --> 00:53:48,600
mooses are like a reasonable rate can

1113
00:53:54,500 --> 00:53:50,970

move a reasonable amount of mass and yet

1114

00:53:55,910 --> 00:53:54,510

is safe right so you know those

1115

00:53:59,090 --> 00:53:55,920

considerations are really making a

1116

00:54:01,910 --> 00:53:59,100

challenge and there I don't know their

1117

00:54:08,570 --> 00:54:01,920

hardware considerations like does it

1118

00:54:11,270 --> 00:54:08,580

have to be extra sturdy the space

1119

00:54:13,010 --> 00:54:11,280

station environment is actually a nice

1120

00:54:15,080 --> 00:54:13,020

gentle environment I mean there's

1121

00:54:16,430 --> 00:54:15,090

there's there's very little gravity and

1122

00:54:19,130 --> 00:54:16,440

it's really microgravity they're

1123

00:54:20,540 --> 00:54:19,140

essentially zero gravity and it's like

1124

00:54:25,700 --> 00:54:20,550

an office environment you know it's

1125

00:54:28,190 --> 00:54:25,710

shirt sleeved it's but the problem is

1126

00:54:30,770 --> 00:54:28,200

getting there because to get there you

1127

00:54:32,990 --> 00:54:30,780

have to get on a rocket a rocket shakes

1128

00:54:35,030 --> 00:54:33,000

you and shakes you and shakes you and so

1129

00:54:36,980 --> 00:54:35,040

some of what we did over the past couple

1130

00:54:39,530 --> 00:54:36,990

years was try to design an Astra be to

1131

00:54:41,750 --> 00:54:39,540

survive really the shock of being

1132

00:54:44,540 --> 00:54:41,760

blanched to the space station yeah yeah

1133

00:54:48,320 --> 00:54:44,550

we have to do vibration testing and it

1134

00:54:50,720 --> 00:54:48,330

still worked after we shook it there are

1135

00:54:52,700 --> 00:54:50,730

structural constraints electricity

1136

00:54:54,170 --> 00:54:52,710

electrical as well your sisters you have

1137

00:54:57,000 --> 00:54:54,180

to be make sure they aren't going to

1138

00:55:00,690 --> 00:54:57,010

shock any you know

1139

00:55:02,310 --> 00:55:00,700

yeah any other system on the space

1140

00:55:04,440 --> 00:55:02,320

station so you have two pretty nice with

1141

00:55:06,750 --> 00:55:04,450

all the other systems long space yeah so

1142

00:55:09,060 --> 00:55:06,760

you know you have to look at radiate

1143

00:55:10,890 --> 00:55:09,070

like do you are you radiating noise you

1144

00:55:13,830 --> 00:55:10,900

know are you gonna interfere with the

1145

00:55:16,320 --> 00:55:13,840

other systems on Space Station and of

1146

00:55:18,300 --> 00:55:16,330

course we control Astra from the ground

1147

00:55:20,520 --> 00:55:18,310

from Mission Control and so that means

1148

00:55:22,440 --> 00:55:20,530

we're sending you know data back and

1149

00:55:24,480 --> 00:55:22,450

forth yeah on the space station it's

1150

00:55:26,100 --> 00:55:24,490

being you know set across the the

1151
00:55:27,750 --> 00:55:26,110
wireless network the Wi-Fi network on

1152
00:55:41,610 --> 00:55:27,760
space station it's of course you don't

1153
00:55:44,730 --> 00:55:41,620
want to be a network hog are you

1154
00:55:46,380 --> 00:55:44,740
watching also I know I've talked to you

1155
00:55:48,240 --> 00:55:46,390
guys about this I'm you know taking what

1156
00:55:51,690 --> 00:55:48,250
you guys learn from spheres and applying

1157
00:55:54,920 --> 00:55:51,700
that to ash Toby in your design and

1158
00:55:57,570 --> 00:55:54,930
testing for you know yeah absolutely so

1159
00:55:59,370 --> 00:55:57,580
one of our considerations was we didn't

1160
00:56:01,920 --> 00:55:59,380
want to have astronauts have to put

1161
00:56:04,380 --> 00:56:01,930
these gas canisters into Astra me that's

1162
00:56:06,570 --> 00:56:04,390
that's a chore that we're adding to the

1163
00:56:08,670 --> 00:56:06,580

chores then you take care of the robot

1164

00:56:10,260 --> 00:56:08,680

so we made an all-electric system and

1165

00:56:11,820 --> 00:56:10,270

that can just plug itself in and is the

1166

00:56:14,670 --> 00:56:11,830

only consumable is electricity

1167

00:56:17,370 --> 00:56:14,680

you know battery power docking stations

1168

00:56:18,660 --> 00:56:17,380

they can go recharge itself yeah yeah I

1169

00:56:20,340 --> 00:56:18,670

guess the other thing to the but we

1170

00:56:23,340 --> 00:56:20,350

should have point out about spheres is

1171

00:56:25,200 --> 00:56:23,350

that in addition to this you know carbon

1172

00:56:27,420 --> 00:56:25,210

dioxide propulsion which is in a little

1173

00:56:29,460 --> 00:56:27,430

tank that you change out it requires a

1174

00:56:32,250 --> 00:56:29,470

basically these these eight pack of

1175

00:56:33,810 --> 00:56:32,260

double-a batteries yeah and of course

1176

00:56:35,730 --> 00:56:33,820

that what that means is that the spheres

1177

00:56:38,580 --> 00:56:35,740

couldn't really run for a pretty long

1178

00:56:39,950 --> 00:56:38,590

time maybe an hour or two and then you

1179

00:56:42,480 --> 00:56:39,960

know someone's have come over and

1180

00:56:45,360 --> 00:56:42,490

changed the tank and changed the

1181

00:56:47,730 --> 00:56:45,370

batteries and so a stir be of core part

1182

00:56:50,460 --> 00:56:47,740

of the design was let's get away from

1183

00:56:52,020 --> 00:56:50,470

all that let it just recharge itself and

1184

00:56:54,120 --> 00:56:52,030

then spheres also was not allowed to

1185

00:56:55,920 --> 00:56:54,130

operate by itself because the materials

1186

00:56:58,710 --> 00:56:55,930

are not are there's some flammable

1187

00:57:01,290 --> 00:56:58,720

materials so it had to have human

1188

00:57:02,100 --> 00:57:01,300

oversight at all times yeah in case it

1189

00:57:09,100 --> 00:57:02,110

bursts into flame

1190

00:57:14,120 --> 00:57:11,840

so all the materials on aster be are

1191

00:57:16,010 --> 00:57:14,130

either flame-retardant or they're

1192

00:57:18,830 --> 00:57:16,020

they're such a small amount that they

1193

00:57:21,620 --> 00:57:18,840

aren't a hazard or we cover them with a

1194

00:57:24,920 --> 00:57:21,630

flame-retardant material oh yeah that's

1195

00:57:27,350 --> 00:57:24,930

pretty cool yeah you were talking about

1196

00:57:29,780 --> 00:57:27,360

communicating with the robots so here's

1197

00:57:31,190 --> 00:57:29,790

maybe a bigger general question are

1198

00:57:33,230 --> 00:57:31,200

these robots designed to communicate

1199

00:57:38,000 --> 00:57:33,240

directly with the DSN and can you tell

1200

00:57:40,400 --> 00:57:38,010

us what the DSN the Deep Space Network

1201
00:57:43,130 --> 00:57:40,410
it's what NASA and and frankly I believe

1202
00:57:45,920 --> 00:57:43,140
all spacefaring countries used to

1203
00:57:50,180 --> 00:57:45,930
communicate to spacecraft robotics or

1204
00:57:52,610 --> 00:57:50,190
human in space you know I think as we

1205
00:57:54,080 --> 00:57:52,620
see robots going to other places along

1206
00:57:56,420 --> 00:57:54,090
with humans then there'll be you know

1207
00:57:59,330 --> 00:57:56,430
more and more use of the the DSN for

1208
00:58:01,280 --> 00:57:59,340
communications on the space station of

1209
00:58:04,040 --> 00:58:01,290
course we don't use the DSN because it's

1210
00:58:13,630 --> 00:58:04,050
in Earth orbit we instead use another

1211
00:58:19,370 --> 00:58:16,640
tracking and data relay satellite system

1212
00:58:21,770 --> 00:58:19,380
I think it's a set of communication

1213
00:58:24,350 --> 00:58:21,780

satellites in Earth orbit and it relays

1214

00:58:27,860 --> 00:58:24,360

the signals from the space station to

1215

00:58:29,360 --> 00:58:27,870

the ground to Mission Control and so we

1216

00:58:30,040 --> 00:58:29,370

use that to communicate to and from the

1217

00:58:35,120 --> 00:58:30,050

space station

1218

00:58:37,670 --> 00:58:35,130

all right perfecting yes there are

1219

00:58:39,350 --> 00:58:37,680

dropouts in comm between the space

1220

00:58:41,270 --> 00:58:39,360

station and the ground yeah

1221

00:58:43,460 --> 00:58:41,280

so we also design a sturdy to be able to

1222

00:58:45,680 --> 00:58:43,470

operate through those dropouts when it

1223

00:58:48,590 --> 00:58:45,690

can't oh okay to the ground yeah that's

1224

00:58:50,960 --> 00:58:48,600

what yeah the autonomous nature of can

1225

00:58:51,590 --> 00:58:50,970

carry on

1226

00:58:55,179 --> 00:58:51,600

[Music]

1227

00:58:56,829 --> 00:58:55,189

[Laughter]

1228

00:58:59,410 --> 00:58:56,839

we actually have some questions about

1229

00:59:01,029 --> 00:58:59,420

career paths into robotics and things

1230

00:59:03,219 --> 00:59:01,039

like that can you guys kind of share how

1231

00:59:04,870 --> 00:59:03,229

you got into robotics and you know

1232

00:59:06,699 --> 00:59:04,880

education we have people who are

1233

00:59:08,799 --> 00:59:06,709

interested in you know what kind of you

1234

00:59:10,269 --> 00:59:08,809

know programs were you in in school and

1235

00:59:11,529 --> 00:59:10,279

internships and things like that so

1236

00:59:14,259 --> 00:59:11,539

first off I might be a little bit biased

1237

00:59:19,929 --> 00:59:14,269

but you know I think everybody should be

1238

00:59:22,089 --> 00:59:19,939

a roboticist i I think partially is

1239

00:59:24,759 --> 00:59:22,099

because it is really fun working with

1240

00:59:27,160 --> 00:59:24,769

with robots yeah and I said earlier I

1241

00:59:29,019 --> 00:59:27,170

mean robotics and covers lots of

1242

00:59:31,419 --> 00:59:29,029

different kinds of domains lots of

1243

00:59:33,759 --> 00:59:31,429

different areas of study and so there's

1244

00:59:36,099 --> 00:59:33,769

not one single path that you can go down

1245

00:59:38,169 --> 00:59:36,109

or have to go down you can if you like

1246

00:59:39,609 --> 00:59:38,179

you know computers you can be a come to

1247

00:59:41,529 --> 00:59:39,619

this from computer science point of view

1248

00:59:42,579 --> 00:59:41,539

if you like mechanical design you know

1249

00:59:48,160 --> 00:59:42,589

mechanical engineering or Electrical

1250

00:59:49,839 --> 00:59:48,170

Engineering we need you all somebody

1251

00:59:55,599 --> 00:59:49,849

wanted to know if you can use

1252

00:59:58,089 --> 00:59:55,609

programmers yes do web developers health

1253

01:00:01,179 --> 00:59:58,099

and robotics oh yeah definitely

1254

01:00:02,709 --> 01:00:01,189

yeah because one of the key things we we

1255

01:00:04,509 --> 01:00:02,719

worry about us you know how do we

1256

01:00:06,009 --> 01:00:04,519

understand what the robot is doing and

1257

01:00:08,140 --> 01:00:06,019

how do we communicate to that how do we

1258

01:00:09,729 --> 01:00:08,150

command it and so in addition to

1259

01:00:11,650 --> 01:00:09,739

building the robot system itself we'll

1260

01:00:13,599 --> 01:00:11,660

build user interfaces you know all the

1261

01:00:15,819 --> 01:00:13,609

interfaces that run admission control

1262

01:00:17,439 --> 01:00:15,829

that talk to spacecraft well some of

1263

01:00:20,140 --> 01:00:17,449

those are custom interfaces some of them

1264

01:00:22,719 --> 01:00:20,150

just run on web browsers might be web

1265

01:00:25,299 --> 01:00:22,729

applications and so I think the answer

1266

01:00:26,919 --> 01:00:25,309

is definitely yes you know you can get

1267

01:00:28,809 --> 01:00:26,929

involved if you do web programming hey

1268

01:00:30,880 --> 01:00:28,819

you could do that for a robot too

1269

01:00:35,169 --> 01:00:30,890

absolutely yeah very good

1270

01:00:37,630 --> 01:00:35,179

good news GDS system yeah but software

1271

01:00:40,269 --> 01:00:37,640

design here we have actually a ground

1272

01:00:42,309 --> 01:00:40,279

data system that that we use for science

1273

01:00:44,380 --> 01:00:42,319

playing so mission science planning

1274

01:00:49,749 --> 01:00:44,390

oh yeah that's web-based cool all right

1275

01:00:52,539 --> 01:00:49,759

so a resounding yes a couple of people

1276

01:00:54,729 --> 01:00:52,549

have asked about the cost of space

1277

01:00:56,019 --> 01:00:54,739

robots and when do you consider that

1278

01:00:58,719 --> 01:00:56,029

that was the question do you consider

1279

01:01:00,400 --> 01:00:58,729

the cost before after and yes in terms

1280

01:01:02,199 --> 01:01:00,410

of like you know the robots themselves

1281

01:01:03,999 --> 01:01:02,209

these days at least for the ones inside

1282

01:01:06,080 --> 01:01:04,009

a space station which is just like being

1283

01:01:08,060 --> 01:01:06,090

in an office or a home

1284

01:01:10,040 --> 01:01:08,070

you know the-the-the components actually

1285

01:01:11,990 --> 01:01:10,050

are not the main cost the main cost has

1286

01:01:14,750 --> 01:01:12,000

to do with the the time spent developing

1287

01:01:17,420 --> 01:01:14,760

and building an engineer the engineering

1288

01:01:21,500 --> 01:01:17,430

time but you know astra B as Maria said

1289

01:01:23,840 --> 01:01:21,510

uses a set of basically smartphone class

1290

01:01:27,770 --> 01:01:23,850

processors and we use off-the-shelf

1291

01:01:30,410 --> 01:01:27,780

software as well Astra bade runs both

1292

01:01:32,960 --> 01:01:30,420

Android and Linux in terms of operating

1293

01:01:35,960 --> 01:01:32,970

system and and so it's not you know like

1294

01:01:38,780 --> 01:01:35,970

we've custom crafted our own unique you

1295

01:01:40,400 --> 01:01:38,790

know set of software some of the

1296

01:01:41,480 --> 01:01:40,410

hardware obviously is unique I mean

1297

01:01:49,400 --> 01:01:41,490

master B doesn't look like anything

1298

01:01:51,710 --> 01:01:49,410

you'd buy in a store machine parts open

1299

01:01:54,290 --> 01:01:51,720

it up allow the inside no I recognize

1300

01:01:58,520 --> 01:01:54,300

that I could buy that mm-hmm all right

1301

01:02:01,280 --> 01:01:58,530

cool I have one that I like I'm curious

1302

01:02:03,500 --> 01:02:01,290

about say the JP guy asks is it possible

1303

01:02:10,150 --> 01:02:03,510

to create self-sterilizing robots to

1304

01:02:13,010 --> 01:02:10,160

prevent contamination during exercise a

1305

01:02:15,380 --> 01:02:13,020

possible payload for aster be in the

1306

01:02:18,530 --> 01:02:15,390

near future we had some folks come in to

1307

01:02:21,020 --> 01:02:18,540

talk to us about its equipment for

1308

01:02:22,730 --> 01:02:21,030

sterilizing inside the space station

1309

01:02:26,660 --> 01:02:22,740

it's basically ultraviolet light I think

1310

01:02:29,120 --> 01:02:26,670

light UV some yeah yeah right

1311

01:02:31,610 --> 01:02:29,130

the it's basically like a panel of LEDs

1312

01:02:33,350 --> 01:02:31,620

that you just go and hold it up against

1313

01:02:53,480 --> 01:02:33,360

the our nearest surface and the light

1314

01:02:56,960 --> 01:02:53,490

will sterilize okay UV light to kill off

1315

01:03:02,870 --> 01:02:56,970

bacteria and that could work it could

1316

01:03:09,290 --> 01:03:02,880

work you have a comment here from wall

1317

01:03:11,900 --> 01:03:09,300

opposed very cool y'all here's a

1318

01:03:15,830 --> 01:03:11,910

question from rest are are there any

1319

01:03:18,560 --> 01:03:15,840

crawling robots robots that could easily

1320

01:03:20,300 --> 01:03:18,570

manipulate things rather than flying

1321

01:03:23,270 --> 01:03:20,310

because that uses you know a certain

1322

01:03:24,740 --> 01:03:23,280

kind of energy yeah yeah well I mean we

1323

01:03:26,300 --> 01:03:24,750

saw some of the other robots that NASA

1324

01:03:29,330 --> 01:03:26,310

has worked with in the past earlier on

1325

01:03:32,090 --> 01:03:29,340

the show um you know I certainly think

1326

01:03:33,859 --> 01:03:32,100

that all kinds of robots are needed and

1327

01:03:36,680 --> 01:03:33,869

of course you know robots light like

1328

01:03:37,790 --> 01:03:36,690

like Robonaut 2 we had a few years ago I

1329

01:03:40,849 --> 01:03:37,800

mean those were designed to be humanoid

1330

01:03:42,560 --> 01:03:40,859

Robonaut 2 actually at one point was

1331

01:03:45,500 --> 01:03:42,570

going to have a pair of these climbing

1332

01:03:46,520 --> 01:03:45,510

limbs so well the legs are kind of

1333

01:03:53,480 --> 01:03:46,530

backwards to the knees were kind of

1334

01:03:54,920 --> 01:03:53,490

backwards base to really like climb all

1335

01:03:57,410 --> 01:03:54,930

over in the inside of Space Station so

1336

01:03:59,390 --> 01:03:57,420

it would have two arms and two legs or

1337

01:04:01,010 --> 01:03:59,400

two limbs and then you could use all

1338

01:04:03,140 --> 01:04:01,020

four of those to climb around now

1339

01:04:04,849 --> 01:04:03,150

unfortunately we had some some problems

1340

01:04:07,099 --> 01:04:04,859

with the electrical system and we

1341

01:04:08,540 --> 01:04:07,109

brought Robonaut to back down but maybe

1342

01:04:11,840 --> 01:04:08,550

in the future you'll see systems like

1343

01:04:13,849 --> 01:04:11,850

Robonaut 2 that can climb yeah actually

1344

01:04:16,849 --> 01:04:13,859

for ground exploration yet there are

1345

01:04:23,690 --> 01:04:16,859

snake robots and you know that again

1346

01:04:25,190 --> 01:04:23,700

bio-inspired you know you know move

1347

01:04:27,859 --> 01:04:25,200

across the ground in different ways and

1348

01:04:29,930 --> 01:04:27,869

can be very efficient yeah and so

1349

01:04:32,420 --> 01:04:29,940

there's a lot of work developing these

1350

01:04:34,280 --> 01:04:32,430

sort of bio-inspired robots that's cool

1351

01:04:36,440 --> 01:04:34,290

it's kind of related to this one the

1352

01:04:38,780 --> 01:04:36,450

life is yours asks what a robot like the

1353

01:04:41,920 --> 01:04:38,790

Boston dynamic ones work on Mars and the

1354

01:04:45,859 --> 01:04:44,300

obviously Boston Dynamics has created

1355

01:04:47,150 --> 01:04:45,869

lots of really interesting videos

1356

01:04:50,690 --> 01:04:47,160

showing their robots doing everything

1357

01:04:52,310 --> 01:04:50,700

from gymnastics all kinds of things you

1358

01:04:54,770 --> 01:04:52,320

know with running and jumping and

1359

01:04:56,390 --> 01:04:54,780

hopping and you know quite honestly you

1360

01:04:58,520 --> 01:04:56,400

know NASA has interest in those things

1361

01:05:00,800 --> 01:04:58,530

those kinds of you know robot

1362

01:05:02,650 --> 01:05:00,810

capabilities because there are places

1363

01:05:05,359 --> 01:05:02,660

they're just not suited to wheels

1364

01:05:06,859 --> 01:05:05,369

they're places where maybe you can't fly

1365

01:05:08,480 --> 01:05:06,869

if there's no atmosphere

1366

01:05:10,730 --> 01:05:08,490

you know Astro B for example it does

1367

01:05:12,680 --> 01:05:10,740

require error and the Mars helicopter

1368

01:05:14,060 --> 01:05:12,690

requires error on Mars you can't really

1369

01:05:21,560 --> 01:05:14,070

have that kind of flying robot on the

1370

01:05:24,170 --> 01:05:21,570

moon robot doesn't require air to move

1371

01:05:26,240 --> 01:05:24,180

and it's probably designed to operate in

1372

01:05:28,099 --> 01:05:26,250

air for things like cooling so you

1373

01:05:30,299 --> 01:05:28,109

couldn't just transport that that

1374

01:05:33,519 --> 01:05:30,309

particular robot as

1375

01:05:35,680 --> 01:05:33,529

that's yeah so you do have to do some

1376

01:05:37,509 --> 01:05:35,690

redesign so that would be capable of

1377

01:05:39,819 --> 01:05:37,519

operating on those other in those other

1378

01:05:43,120 --> 01:05:39,829

environments but the method of

1379

01:05:45,400 --> 01:05:43,130

locomotion certainly yeah we would look

1380

01:05:50,890 --> 01:05:45,410

at walking and crawling robots and

1381

01:05:54,220 --> 01:05:50,900

jumping and hopping and we'll see a

1382

01:05:56,410 --> 01:05:54,230

couple people have asked again I think

1383

01:05:58,480 --> 01:05:56,420

it's about Esther B how did these robots

1384

01:06:00,609 --> 01:05:58,490

propel themselves in zero-gravity in a

1385

01:06:04,509 --> 01:06:00,619

spaceship so because you just review

1386

01:06:05,829 --> 01:06:04,519

quickly fan base system you know this

1387

01:06:08,200 --> 01:06:05,839

our particular robot there are other

1388

01:06:11,859 --> 01:06:08,210

ways of propelling yourself yeah inside

1389

01:06:14,289 --> 01:06:11,869

a space base station but after me in

1390

01:06:21,130 --> 01:06:14,299

particular its fan based it has impeller

1391

01:06:22,569 --> 01:06:21,140

I'm actually alright so actually right

1392

01:06:25,930 --> 01:06:22,579

there is might be good so I can actually

1393

01:06:32,490 --> 01:06:25,940

point things yeah so again the circular

1394

01:06:37,390 --> 01:06:35,289

can actually talk to the microphone so

1395

01:06:40,450 --> 01:06:37,400

the circular part here there's a fan

1396

01:06:42,730 --> 01:06:40,460

inside here and that brings the air into

1397

01:06:45,339 --> 01:06:42,740

this sort of it's sort of like a box

1398

01:06:49,240 --> 01:06:45,349

almost on the end of the robot this sort

1399

01:06:51,910 --> 01:06:49,250

of black section and then it goes it's

1400

01:06:55,630 --> 01:06:51,920

so it lightly pressurizes the box and

1401

01:06:57,009 --> 01:06:55,640

then these grilles right here it looks

1402

01:07:00,130 --> 01:06:57,019

like the vents in your cooler they look

1403

01:07:01,650 --> 01:07:00,140

like many events there's a nozzle behind

1404

01:07:07,390 --> 01:07:01,660

that right that the grille is to keep

1405

01:07:10,089 --> 01:07:07,400

astronaut fingers from going in but

1406

01:07:13,990 --> 01:07:10,099

behind there are these nozzles that have

1407

01:07:16,480 --> 01:07:14,000

flappers that open and close and so that

1408

01:07:17,920 --> 01:07:16,490

lets air out and you have that different

1409

01:07:19,029 --> 01:07:17,930

amounts of different amounts right you

1410

01:07:20,400 --> 01:07:19,039

open it a little bit yeah a little bit

1411

01:07:23,710 --> 01:07:20,410

of air you open it wide to get more air

1412

01:07:25,809 --> 01:07:23,720

and then so that the air moving out

1413

01:07:27,819 --> 01:07:25,819

pushes the robot in the opposite

1414

01:07:32,499 --> 01:07:27,829

direction this is the whole magic of

1415

01:07:35,799 --> 01:07:32,509

zero-g it's the you know equal and

1416

01:07:37,630 --> 01:07:35,809

opposite reaction that's how we we

1417

01:07:40,960 --> 01:07:37,640

propel ourselves around Space Station

1418

01:07:42,310 --> 01:07:40,970

awesome yeah Apollo mg asks is it gyro

1419

01:07:44,830 --> 01:07:42,320

stabilized

1420

01:07:47,980 --> 01:07:44,840

and what does it's partially quote

1421

01:07:49,660 --> 01:07:47,990

gyro-stabilized you know you have fans

1422

01:07:52,710 --> 01:07:49,670

here and there's actually a fan on both

1423

01:07:55,180 --> 01:07:52,720

sides so it's it's counter-rotating and

1424

01:07:57,430 --> 01:07:55,190

what's fascinating is that depending on

1425

01:08:00,400 --> 01:07:57,440

how fast we spin this you know we can

1426

01:08:02,500 --> 01:08:00,410

change how stable is in space so as we

1427

01:08:05,560 --> 01:08:02,510

do docking for example and we want to

1428

01:08:07,510 --> 01:08:05,570

move in very precisely and very you know

1429

01:08:09,040 --> 01:08:07,520

it was very smooth motion will basically

1430

01:08:11,560 --> 01:08:09,050

spin up the robot and you can actually

1431

01:08:14,200 --> 01:08:11,570

hear it get louder yeah and it becomes

1432

01:08:15,400 --> 01:08:14,210

more stable because it's using its fans

1433

01:08:16,960 --> 01:08:15,410

and how fast they're spinning to

1434

01:08:18,910 --> 01:08:16,970

stabilize it it also gives a little more

1435

01:08:20,620 --> 01:08:18,920

control authority because there's a

1436

01:08:22,270 --> 01:08:20,630

little more pressure a touchable

1437

01:08:30,700 --> 01:08:22,280

pressure so it can actually push itself

1438

01:08:33,790 --> 01:08:30,710

a little bit harder keeps coming in we

1439

01:08:35,530 --> 01:08:33,800

have one question from ill Inc are

1440

01:08:38,320 --> 01:08:35,540

robots good for tending the growing of

1441

01:08:43,840 --> 01:08:38,330

plants in space oh you know this is

1442

01:08:46,720 --> 01:08:43,850

actually a super timely question I went

1443

01:08:50,460 --> 01:08:46,730

to a NASA workshop on how robots could

1444

01:08:53,620 --> 01:08:50,470

be used to help grow crops in space and

1445

01:08:55,240 --> 01:08:53,630

it's fascinating you think about all the

1446

01:08:56,740 --> 01:08:55,250

challenges that you know would be

1447

01:09:00,340 --> 01:08:56,750

associated with doing that I mean

1448

01:09:02,140 --> 01:09:00,350

planting and monitoring and tending and

1449

01:09:04,599 --> 01:09:02,150

harvesting and then processing

1450

01:09:07,060 --> 01:09:04,609

afterwards yeah so I think it's a great

1451

01:09:10,329 --> 01:09:07,070

area for research and development not

1452

01:09:12,640 --> 01:09:10,339

ready today but if we want to send

1453

01:09:14,349 --> 01:09:12,650

humans especially the deep space can't

1454

01:09:15,329 --> 01:09:14,359

just package all the food right they're

1455

01:09:17,440 --> 01:09:15,339

not just gonna be eating you know

1456

01:09:20,110 --> 01:09:17,450

microwavable things okay they're gonna

1457

01:09:22,900 --> 01:09:20,120

need fresh food and it's really as

1458

01:09:25,120 --> 01:09:22,910

anybody who's grown anything knows it

1459

01:09:28,349 --> 01:09:25,130

takes a lot of effort so I think robots

1460

01:09:30,910 --> 01:09:28,359

definitely are needed for that mm-hmm

1461

01:09:37,630 --> 01:09:30,920

some are already being used on earth

1462

01:09:39,849 --> 01:09:37,640

yeah at end yeah there's this whole new

1463

01:09:41,920 --> 01:09:39,859

interesting you know category called

1464

01:09:45,190 --> 01:09:41,930

vertical farming you know what people

1465

01:09:47,290 --> 01:09:45,200

want to like grow really crops inside

1466

01:09:50,740 --> 01:09:47,300

their homes or their apartments and a

1467

01:09:51,910 --> 01:09:50,750

small space how can you grow vertically

1468

01:09:53,559 --> 01:09:51,920

you have all these different like

1469

01:09:57,010 --> 01:09:53,569

shelves and like

1470

01:09:59,140 --> 01:09:57,020

like hydroponics that go into you know

1471

01:10:00,669 --> 01:09:59,150

help plants grow but the problem is you

1472

01:10:02,109 --> 01:10:00,679

still take care of the system itself

1473

01:10:05,350 --> 01:10:02,119

you know things always get clogged

1474

01:10:08,709 --> 01:10:05,360

things need to get harvested so I think

1475

01:10:11,979 --> 01:10:08,719

we're gonna need robots for that here's

1476

01:10:14,379 --> 01:10:11,989

an interesting one phone things as to

1477

01:10:16,359 --> 01:10:14,389

what types of prehensile tasks do robots

1478

01:10:20,649 --> 01:10:16,369

performance space ie gripping and

1479

01:10:23,140 --> 01:10:20,659

grasping tasks is that as well so we've

1480

01:10:26,560 --> 01:10:23,150

talked about the perching are purging

1481

01:10:29,410 --> 01:10:26,570

arms yes lots of finger and and yes save

1482

01:10:31,569 --> 01:10:29,420

energy by doing that also we've been

1483

01:10:34,600 --> 01:10:31,579

looking at prehensile tasks that like a

1484

01:10:37,089 --> 01:10:34,610

rover out rinse in a wheeled robots can

1485

01:10:39,339 --> 01:10:37,099

do when it's on a planetary surface

1486

01:10:41,530 --> 01:10:39,349

mm-hmm for instance it can dig a trench

1487

01:10:43,180 --> 01:10:41,540

right if you you drive three of the

1488

01:10:44,919 --> 01:10:43,190

wheels and your fourth one you just kind

1489

01:10:46,089 --> 01:10:44,929

of you turn it sideways and spin it a

1490

01:10:49,540 --> 01:10:46,099

little bit differently you can actually

1491

01:10:51,430 --> 01:10:49,550

dig a trench so for instance say you

1492

01:10:54,790 --> 01:10:51,440

want to lay some cables you know that

1493

01:10:56,379 --> 01:10:54,800

you then bury around the habitat you

1494

01:10:59,200 --> 01:10:56,389

could use the robot to dig the trenches

1495

01:11:00,609 --> 01:10:59,210

to put the cables in okay that's kind of

1496

01:11:08,350 --> 01:11:00,619

a gripping task because it's holding

1497

01:11:10,569 --> 01:11:08,360

that's we Hansel so there's no but in

1498

01:11:12,669 --> 01:11:10,579

terms of grasping things you know we

1499

01:11:15,700 --> 01:11:12,679

said earlier that Astra P only has an

1500

01:11:18,430 --> 01:11:15,710

arm for perching but obviously other

1501
01:11:21,040 --> 01:11:18,440
systems like Robonaut 2 or even on the

1502
01:11:23,169 --> 01:11:21,050
Camino the canadarm2 with its dexter

1503
01:11:25,270 --> 01:11:23,179
system you know has the ability to

1504
01:11:26,740 --> 01:11:25,280
really reach out and and physically

1505
01:11:28,990 --> 01:11:26,750
interact with things you know maybe

1506
01:11:31,450 --> 01:11:29,000
you're gonna try to to unscrew something

1507
01:11:35,600 --> 01:11:31,460
or to swap out some module which needs

1508
01:11:41,830 --> 01:11:38,939
[Laughter]

1509
01:11:46,569 --> 01:11:41,840
actually developing a gecko inspired

1510
01:11:48,669 --> 01:11:46,579
gripper perching are for astra baby is

1511
01:11:51,069 --> 01:11:48,679
already actually on orbit it wants yeah

1512
01:11:54,180 --> 01:11:51,079
it just launched and so they're looking

1513
01:11:56,500 --> 01:11:54,190

at being able to perch on any surface

1514

01:11:58,810 --> 01:11:56,510

the universal gripper i mean you think

1515

01:12:05,140 --> 01:11:58,820

you know geckos they can you know adhere

1516

01:12:13,580 --> 01:12:07,040

not so thrilled about that when they're

1517

01:12:15,439 --> 01:12:13,590

in your home this new this new robot

1518

01:12:17,240 --> 01:12:15,449

hand basically is meant to be the

1519

01:12:20,330 --> 01:12:17,250

universal thing so it can stick to any

1520

01:12:21,560 --> 01:12:20,340

kind of surface any kind of shape and

1521

01:12:23,240 --> 01:12:21,570

that's one of the things that over the

1522

01:12:28,490 --> 01:12:23,250

next several months we're hoping to see

1523

01:12:31,299 --> 01:12:28,500

tested with a strobe hmm very cool cuz

1524

01:12:33,529 --> 01:12:31,309

we're gonna have to finish soon are ya

1525

01:12:35,660 --> 01:12:33,539

do you have a favorite question or

1526

01:12:38,540 --> 01:12:35,670

should I throw one out there uh you go

1527

01:12:40,299 --> 01:12:38,550

first okay pour us an under South so how

1528

01:12:43,010 --> 01:12:40,309

could you perform real-life tests

1529

01:12:44,959 --> 01:12:43,020

parabolic flights perhaps that's nearly

1530

01:12:47,180 --> 01:12:44,969

testing like with punch punch cards

1531

01:12:50,209 --> 01:12:47,190

cost-wise well how would you how do you

1532

01:12:52,459 --> 01:12:50,219

test these space robots on earth well so

1533

01:12:56,149 --> 01:12:52,469

Astra B we test it on a granite table

1534

01:12:58,640 --> 01:12:56,159

it's kind of an upside down air hockey

1535

01:13:00,260 --> 01:12:58,650

table huh where instead of the air

1536

01:13:02,720 --> 01:13:00,270

coming out of the table it comes out of

1537

01:13:10,580 --> 01:13:02,730

a puck and the robot sits on top of this

1538

01:13:13,459 --> 01:13:10,590

puck it's like a frictionless surface so

1539

01:13:14,899 --> 01:13:13,469

it can simulate what it's like to fire

1540

01:13:17,600 --> 01:13:14,909

unfortunately we can only do two

1541

01:13:19,069 --> 01:13:17,610

dimensions not three yeah yeah we don't

1542

01:13:27,120 --> 01:13:19,079

have enough thrust to actually lift up

1543

01:13:34,380 --> 01:13:32,250

faster as a job

1544

01:13:37,050 --> 01:13:34,390

we have these kind of gantry crane

1545

01:13:43,010 --> 01:13:37,060

systems that are used as gravity offset

1546

01:13:48,149 --> 01:13:46,439

I'm you know the effects of gravity's

1547

01:13:50,430 --> 01:13:48,159

you attach something you hang it from it

1548

01:13:51,600 --> 01:13:50,440

and then basically how you program the

1549

01:13:53,459 --> 01:13:51,610

crane to move around

1550

01:13:56,399 --> 01:13:53,469

you know simulates it being you know

1551

01:13:59,959 --> 01:13:56,409

basically in zero gravity you can't use

1552

01:14:03,410 --> 01:13:59,969

the propulsion system on it when you're

1553

01:14:08,490 --> 01:14:03,420

it commands the crane to move it as if

1554

01:14:10,470 --> 01:14:08,500

propulsion system work okay since since

1555

01:14:13,020 --> 01:14:10,480

the comment mentioned parabolic flights

1556

01:14:15,089 --> 01:14:13,030

and we did do some tests you know a few

1557

01:14:21,180 --> 01:14:15,099

years ago with spheres the smart spheres

1558

01:14:27,209 --> 01:14:21,190

you know and sort of this you know they

1559

01:14:30,330 --> 01:14:27,219

briefly mimic seconds at most periods

1560

01:14:31,919 --> 01:14:30,340

and so you know from a engineering you

1561

01:14:33,060 --> 01:14:31,929

know point of view it's really hard or

1562

01:14:34,890 --> 01:14:33,070

you say okay let's get ready to get

1563

01:14:44,609 --> 01:14:34,900

ready and then that comes in like what

1564

01:14:46,770 --> 01:14:44,619

we learn in fifteen seconds it's

1565

01:14:49,229 --> 01:14:46,780

probably the highest fidelity way we can

1566

01:14:55,800 --> 01:14:49,239

you know simulate you know here on earth

1567

01:14:58,020 --> 01:14:55,810

rate on earth you know thank you guys so

1568

01:15:00,479 --> 01:14:58,030

much for joining us today I think that's

1569

01:15:02,430 --> 01:15:00,489

about all the time we have today huge

1570

01:15:05,310 --> 01:15:02,440

thanks to everyone who joined us in the