



1  
00:00:07,670 --> 00:00:04,710  
good afternoon and welcome back again to

2  
00:00:09,990 --> 00:00:07,680  
the sts-133 pre-flight briefings we're

3  
00:00:11,430 --> 00:00:10,000  
here now to focus on one of the items

4  
00:00:12,950 --> 00:00:11,440  
being brought up by discovery to the

5  
00:00:15,430 --> 00:00:12,960  
international space station inside the

6  
00:00:17,430 --> 00:00:15,440  
permanent multi-purpose module robonaut

7  
00:00:19,510 --> 00:00:17,440  
2 soon to be the first

8  
00:00:21,670 --> 00:00:19,520  
dexterous humanoid robot to

9  
00:00:24,950 --> 00:00:21,680  
visit space here to tell us about it we

10  
00:00:26,630 --> 00:00:24,960  
have rob ambrose the acting chief of the

11  
00:00:27,910 --> 00:00:26,640  
automation simulation and robotics

12  
00:00:29,990 --> 00:00:27,920  
division here in the engineering

13  
00:00:31,669 --> 00:00:30,000

department at johnson space center we'll

14

00:00:33,750 --> 00:00:31,679

start with an overview and then take

15

00:00:35,110 --> 00:00:33,760

questions from the audience rob

16

00:00:37,110 --> 00:00:35,120

thank you brad

17

00:00:39,750 --> 00:00:37,120

i'm here talking to you today about a

18

00:00:42,549 --> 00:00:39,760

project that we've been working on for

19

00:00:45,110 --> 00:00:42,559

about 15 years so it's really the

20

00:00:47,750 --> 00:00:45,120

culmination of many people's effort

21

00:00:50,069 --> 00:00:47,760

a terrific group of engineers

22

00:00:53,270 --> 00:00:50,079

that we call the robonauts we might

23

00:00:54,389 --> 00:00:53,280

think of a robot like robonaut as the

24

00:00:56,470 --> 00:00:54,399

machine

25

00:00:59,430 --> 00:00:56,480

but we really think of the people behind

26

00:01:01,670 --> 00:00:59,440

the robots as the real robonauts

27

00:01:03,430 --> 00:01:01,680

in the room today we've got

28

00:01:04,229 --> 00:01:03,440

one of the the latest units that we've

29

00:01:06,710 --> 00:01:04,239

built

30

00:01:10,149 --> 00:01:06,720

it's robonaut 2a

31

00:01:12,390 --> 00:01:10,159

the the first in the robonaut 2 series

32

00:01:13,910 --> 00:01:12,400

if you can take a look at it if we can

33

00:01:15,910 --> 00:01:13,920

cut over to

34

00:01:16,870 --> 00:01:15,920

show you the

35

00:01:19,190 --> 00:01:16,880

robot

36

00:01:20,789 --> 00:01:19,200

it's in the tuck and ready for launch

37

00:01:23,190 --> 00:01:20,799

position

38

00:01:25,429 --> 00:01:23,200

r2b is the one that's currently packed

39

00:01:28,070 --> 00:01:25,439

and ready for launch

40

00:01:30,230 --> 00:01:28,080

in the same posture

41

00:01:32,550 --> 00:01:30,240

preparing to go visit the

42

00:01:36,310 --> 00:01:32,560

international space station

43

00:01:39,749 --> 00:01:37,749

i'm going to show you today some of the

44

00:01:41,429 --> 00:01:39,759

history that got us to this point and

45

00:01:43,910 --> 00:01:41,439

talk to you about some of the the

46

00:01:45,429 --> 00:01:43,920

challenges that the team met and the

47

00:01:47,990 --> 00:01:45,439

future

48

00:01:51,030 --> 00:01:48,000

for what the robonaut system will

49

00:01:55,030 --> 00:01:52,469

in addition to all the engineers that

50

00:01:58,709 --> 00:01:55,040

are behind the robonaut team

51

00:02:00,870 --> 00:01:58,719

robotics is a growing field it's a

52

00:02:01,990 --> 00:02:00,880

potential future market for our country

53

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

in the world

54

00:02:05,350 --> 00:02:03,680

and there are a number of communities

55

00:02:06,469 --> 00:02:05,360

out there that are also looking to this

56

00:02:08,710 --> 00:02:06,479

launch

57

00:02:10,790 --> 00:02:08,720

as validation of the

58

00:02:12,710 --> 00:02:10,800

decades of research that have made

59

00:02:15,190 --> 00:02:12,720

things like robonaut possible

60

00:02:17,990 --> 00:02:15,200

so in a sense while it might be just a

61

00:02:22,550 --> 00:02:18,000

single step for this robot it's really a

62

00:02:27,190 --> 00:02:25,510

the challenge that we accepted when we

63

00:02:29,350 --> 00:02:27,200

started the robonaut project was to

64

00:02:30,630 --> 00:02:29,360

build something capable

65

00:02:33,910 --> 00:02:30,640

of doing

66

00:02:35,509 --> 00:02:33,920

dexterous human-like work

67

00:02:37,430 --> 00:02:35,519

and here at the johnson space center

68

00:02:38,790 --> 00:02:37,440

where we're very focused on human

69

00:02:39,589 --> 00:02:38,800

missions

70

00:02:41,509 --> 00:02:39,599

the

71

00:02:45,190 --> 00:02:41,519

idea was that that robot would be doing

72

00:02:47,509 --> 00:02:45,200

that work side by side with astronauts

73

00:02:49,190 --> 00:02:47,519

so from the very beginning the idea was

74

00:02:52,229 --> 00:02:49,200

that the robot had to be

75

00:02:55,430 --> 00:02:52,239

capable enough strong enough to do work

76  
00:02:58,470 --> 00:02:55,440  
but at the same time be safe and trusted

77  
00:03:01,589 --> 00:02:58,480  
to do that work right next to humans

78  
00:03:03,190 --> 00:03:01,599  
if you move to the second slide

79  
00:03:05,190 --> 00:03:03,200  
you'll see the

80  
00:03:06,390 --> 00:03:05,200  
history

81  
00:03:08,229 --> 00:03:06,400  
of

82  
00:03:10,710 --> 00:03:08,239  
well there's our vision our

83  
00:03:12,470 --> 00:03:10,720  
history for the robonaut one project

84  
00:03:14,869 --> 00:03:12,480  
going back to the first integrated

85  
00:03:16,869 --> 00:03:14,879  
products in 1998

86  
00:03:19,589 --> 00:03:16,879  
a whole series of

87  
00:03:20,630 --> 00:03:19,599  
developments building the robonaut 1a

88  
00:03:22,630 --> 00:03:20,640

system

89

00:03:23,990 --> 00:03:22,640

it started out as just a couple

90

00:03:25,670 --> 00:03:24,000

subsystems

91

00:03:27,589 --> 00:03:25,680

an arm and a hand

92

00:03:29,270 --> 00:03:27,599

by 99 we'd put the arm and the hand

93

00:03:31,430 --> 00:03:29,280

together with a head

94

00:03:33,830 --> 00:03:31,440

and for the first time we experienced

95

00:03:36,309 --> 00:03:33,840

dexterous telepresence where we could

96

00:03:38,710 --> 00:03:36,319

really just kind of step into this robot

97

00:03:41,030 --> 00:03:38,720

and reach out and interact with objects

98

00:03:42,710 --> 00:03:41,040

in a particular eva tools

99

00:03:44,630 --> 00:03:42,720

and at that point we realized we really

100

00:03:47,430 --> 00:03:44,640

had something special that this

101  
00:03:50,470 --> 00:03:47,440  
capability was possible

102  
00:03:52,949 --> 00:03:50,480  
and that it was within our grasp

103  
00:03:55,750 --> 00:03:52,959  
the robonaut 1a system evolved over a

104  
00:03:58,789 --> 00:03:55,760  
couple years we added a second limb

105  
00:04:01,030 --> 00:03:58,799  
we went upright with a torso

106  
00:04:03,509 --> 00:04:01,040  
and formed what we think of as an upper

107  
00:04:06,070 --> 00:04:03,519  
body for a robonaut system

108  
00:04:08,550 --> 00:04:06,080  
then we commissioned the robonaut 1b

109  
00:04:09,670 --> 00:04:08,560  
unit where 1a had a lot of electronics

110  
00:04:12,149 --> 00:04:09,680  
in a rack

111  
00:04:14,550 --> 00:04:12,159  
off to the side 1b's electronics were

112  
00:04:16,469 --> 00:04:14,560  
all integrated in its torso and that

113  
00:04:17,749 --> 00:04:16,479

opened up a whole new series of

114

00:04:19,909 --> 00:04:17,759

opportunities

115

00:04:22,310 --> 00:04:19,919

for making the robot portable able to

116

00:04:24,070 --> 00:04:22,320

move around not just requiring the work

117

00:04:27,270 --> 00:04:24,080

we brought to it but that it could go to

118

00:04:29,030 --> 00:04:27,280

the work and do the work where it sat

119

00:04:31,590 --> 00:04:29,040

we tried a number of lower bodies

120

00:04:34,150 --> 00:04:31,600

there's a picture there

121

00:04:35,590 --> 00:04:34,160

of a robonaut 1b with a leg which would

122

00:04:37,350 --> 00:04:35,600

be appropriate for climbing on the

123

00:04:38,950 --> 00:04:37,360

outside of the space station

124

00:04:39,990 --> 00:04:38,960

or for the ins on the inside for that

125

00:04:42,390 --> 00:04:40,000

matter

126  
00:04:44,629 --> 00:04:42,400  
plugging into work inner sight fixtures

127  
00:04:46,070 --> 00:04:44,639  
we also tried it on a segway and then

128  
00:04:47,430 --> 00:04:46,080  
there's a photo there of a four wheel

129  
00:04:48,950 --> 00:04:47,440  
base we built

130  
00:04:51,030 --> 00:04:48,960  
called centaur

131  
00:04:52,469 --> 00:04:51,040  
which we named based on the fact that it

132  
00:04:53,430 --> 00:04:52,479  
kind of looked like the mythological

133  
00:04:55,670 --> 00:04:53,440  
creature

134  
00:04:57,830 --> 00:04:55,680  
four wheels not four legs but with the

135  
00:05:00,070 --> 00:04:57,840  
upper body of a human

136  
00:05:02,150 --> 00:05:00,080  
we took that out to the field and

137  
00:05:05,749 --> 00:05:02,160  
tested it working with natural objects

138  
00:05:07,590 --> 00:05:05,759

like rocks and geological samples

139

00:05:10,390 --> 00:05:07,600

we learned a lot of things about the the

140

00:05:12,950 --> 00:05:10,400

upper body the dexterity the component

141

00:05:14,870 --> 00:05:12,960

technologies system level

142

00:05:17,670 --> 00:05:14,880

redundancy and

143

00:05:19,670 --> 00:05:17,680

made major steps forward in the software

144

00:05:21,909 --> 00:05:19,680

we were partnered with darpa the defense

145

00:05:23,909 --> 00:05:21,919

advanced research projects agency

146

00:05:27,270 --> 00:05:23,919

and teamed with a number of tremendous

147

00:05:28,469 --> 00:05:27,280

research partners across the country usc

148

00:05:30,950 --> 00:05:28,479

mit

149

00:05:33,270 --> 00:05:30,960

university of massachusetts vanderbilt

150

00:05:35,350 --> 00:05:33,280

rice and other universities were all

151  
00:05:37,029 --> 00:05:35,360  
brought in and have contributed in many

152  
00:05:39,590 --> 00:05:37,039  
ways to the

153  
00:05:41,189 --> 00:05:39,600  
robonaut software

154  
00:05:42,950 --> 00:05:41,199  
but at the end of this series we had a

155  
00:05:46,150 --> 00:05:42,960  
number of new ideas and you could only

156  
00:05:48,710 --> 00:05:46,160  
incrementally upgrade a robot so much

157  
00:05:50,310 --> 00:05:48,720  
we had some ideas for what robonaut 2

158  
00:05:52,070 --> 00:05:50,320  
would be

159  
00:05:53,830 --> 00:05:52,080  
and we went looking for some external

160  
00:05:57,110 --> 00:05:53,840  
funding if you could go to the next

161  
00:06:00,309 --> 00:05:59,270  
we found a terrific partner in general

162  
00:06:02,390 --> 00:06:00,319  
motors

163  
00:06:06,070 --> 00:06:02,400

they shared our vision for

164

00:06:08,710 --> 00:06:06,080

a robot that could do work real work and

165

00:06:10,710 --> 00:06:08,720

do it safely next to people

166

00:06:12,790 --> 00:06:10,720

kind of at the core of that idea is that

167

00:06:15,270 --> 00:06:12,800

we're not replacing people it doesn't

168

00:06:17,270 --> 00:06:15,280

make any sense to build a robot that can

169

00:06:19,189 --> 00:06:17,280

safely work around people

170

00:06:20,870 --> 00:06:19,199

if they're going to be no people it's

171

00:06:22,230 --> 00:06:20,880

really predicated on the idea that there

172

00:06:24,469 --> 00:06:22,240

will be people

173

00:06:27,189 --> 00:06:24,479

working with the robot

174

00:06:30,070 --> 00:06:27,199

they like that idea they saw that as a

175

00:06:31,909 --> 00:06:30,080

part of their future of combining humans

176  
00:06:33,670 --> 00:06:31,919  
and robots working together

177  
00:06:36,230 --> 00:06:33,680  
and they agreed to partner with us on

178  
00:06:38,390 --> 00:06:36,240  
the development of the robonaut 2 series

179  
00:06:40,309 --> 00:06:38,400  
to date we've built two units

180  
00:06:42,790 --> 00:06:40,319  
r2a is the one here in the room with us

181  
00:06:46,710 --> 00:06:42,800  
today and r2b is the one that is packed

182  
00:06:48,230 --> 00:06:46,720  
and ready for launch on sts-133

183  
00:06:50,710 --> 00:06:48,240  
we went through a similar build up where

184  
00:06:53,189 --> 00:06:50,720  
we built the robonaut 2 limb first

185  
00:06:54,950 --> 00:06:53,199  
the right arm on r2a

186  
00:06:57,350 --> 00:06:54,960  
and then

187  
00:07:01,110 --> 00:06:57,360  
we built the second limb in the torso

188  
00:07:03,350 --> 00:07:01,120

and then moved on to the second unit r2b

189

00:07:06,550 --> 00:07:03,360

when we were given the challenge to take

190

00:07:08,390 --> 00:07:06,560

a robonaut 2 to station we selected r2b

191

00:07:09,430 --> 00:07:08,400

as the more recent one

192

00:07:13,110 --> 00:07:09,440

and

193

00:07:14,150 --> 00:07:13,120

initiated a whole series of

194

00:07:17,350 --> 00:07:14,160

tests

195

00:07:20,790 --> 00:07:17,360

and then redesigned to qualify the r2b

196

00:07:24,710 --> 00:07:23,110

at the bottom of that slide is a photo

197

00:07:26,790 --> 00:07:24,720

of r2

198

00:07:29,430 --> 00:07:26,800

one of the r2 units in a test chamber

199

00:07:31,110 --> 00:07:29,440

out at the white sands test facility

200

00:07:32,629 --> 00:07:31,120

this was just one of the many tests that

201  
00:07:35,830 --> 00:07:32,639  
the robonaut system had to go through

202  
00:07:37,749 --> 00:07:35,840  
and pass before being allowed

203  
00:07:39,749 --> 00:07:37,759  
and be certified for use on space

204  
00:07:41,029 --> 00:07:39,759  
station in that particular test the

205  
00:07:43,189 --> 00:07:41,039  
robot was put

206  
00:07:45,510 --> 00:07:43,199  
literally in an oven and baked at 120

207  
00:07:47,110 --> 00:07:45,520  
degrees for about four or five days

208  
00:07:50,230 --> 00:07:47,120  
and at the end of that

209  
00:07:53,990 --> 00:07:50,240  
the air was extracted from the chamber

210  
00:07:55,029 --> 00:07:54,000  
and sniffed by a computer nose

211  
00:07:57,510 --> 00:07:55,039  
that

212  
00:07:59,990 --> 00:07:57,520  
found very little off gassing

213  
00:08:01,589 --> 00:08:00,000

and the robot passed it's very important

214

00:08:04,150 --> 00:08:01,599

when you put something like a robonaut

215

00:08:05,830 --> 00:08:04,160

in an iv environment that you not off

216

00:08:06,950 --> 00:08:05,840

gas emit

217

00:08:08,790 --> 00:08:06,960

chemicals

218

00:08:10,150 --> 00:08:08,800

off of the system and pollute the

219

00:08:11,990 --> 00:08:10,160

environment

220

00:08:13,510 --> 00:08:12,000

it turns out the robonaut 2s are pretty

221

00:08:15,510 --> 00:08:13,520

clean

222

00:08:17,110 --> 00:08:15,520

the robonaut went through a whole series

223

00:08:19,510 --> 00:08:17,120

of additional tests

224

00:08:20,390 --> 00:08:19,520

and it's been a great last six months or

225

00:08:22,629 --> 00:08:20,400

so

226

00:08:27,270 --> 00:08:22,639

getting it certified

227

00:08:30,230 --> 00:08:29,110

let me tell you a little bit a bit about

228

00:08:31,029 --> 00:08:30,240

the arm

229

00:08:34,630 --> 00:08:31,039

i

230

00:08:37,029 --> 00:08:34,640

padded

231

00:08:38,709 --> 00:08:37,039

there are no sharps or hard points

232

00:08:40,389 --> 00:08:38,719

that could hurt a person

233

00:08:43,110 --> 00:08:40,399

but that's really just the beginning

234

00:08:44,870 --> 00:08:43,120

of making a robot safe

235

00:08:47,590 --> 00:08:44,880

at the core in the muscles of every

236

00:08:49,829 --> 00:08:47,600

joint are springs that make the system

237

00:08:52,150 --> 00:08:49,839

compliant so if you go push on it it

238

00:08:53,990 --> 00:08:52,160

feels soft so if the robot is mining its

239

00:08:54,790 --> 00:08:54,000

own business and just basically turned

240

00:08:57,030 --> 00:08:54,800

off

241

00:08:58,710 --> 00:08:57,040

and an astronaut were to bump into it it

242

00:09:00,550 --> 00:08:58,720

would give a little and it would not

243

00:09:03,190 --> 00:09:00,560

injure the astronaut

244

00:09:05,509 --> 00:09:03,200

that's using a series of springs that we

245

00:09:07,350 --> 00:09:05,519

developed with sensors capturing the

246

00:09:09,030 --> 00:09:07,360

deflection of the springs

247

00:09:11,910 --> 00:09:09,040

in a concept called series elastic

248

00:09:14,949 --> 00:09:13,190

we've also

249

00:09:16,150 --> 00:09:14,959

developed a way to coordinate those

250

00:09:17,509 --> 00:09:16,160

springs

251  
00:09:19,030 --> 00:09:17,519  
not just

252  
00:09:20,710 --> 00:09:19,040  
through an entire limb

253  
00:09:24,389 --> 00:09:20,720  
but with two limbs reaching out and

254  
00:09:26,230 --> 00:09:24,399  
grasping objects in common

255  
00:09:27,670 --> 00:09:26,240  
most robots can't do that safely because

256  
00:09:30,389 --> 00:09:27,680  
they're very stiff

257  
00:09:32,310 --> 00:09:30,399  
and a very slight position error

258  
00:09:34,150 --> 00:09:32,320  
would produce large forces and the two

259  
00:09:36,150 --> 00:09:34,160  
arms would damage themselves

260  
00:09:37,990 --> 00:09:36,160  
because the robots are fundamentally

261  
00:09:39,590 --> 00:09:38,000  
these robots are fundamentally soft we

262  
00:09:41,430 --> 00:09:39,600  
are able to program them to work

263  
00:09:46,070 --> 00:09:41,440

together with multiple arms in fact work

264

00:09:49,750 --> 00:09:48,790

so superficially it's soft padded and

265

00:09:52,310 --> 00:09:49,760

safe

266

00:09:54,630 --> 00:09:52,320

mechanically it is

267

00:09:57,829 --> 00:09:54,640

soft as well with springs but deeper

268

00:10:00,550 --> 00:09:57,839

than that it has three levels of sensing

269

00:10:03,910 --> 00:10:00,560

sensors electrical sensors and software

270

00:10:06,150 --> 00:10:03,920

that can in each of the three levels

271

00:10:08,150 --> 00:10:06,160

identify forces that are

272

00:10:12,310 --> 00:10:08,160

being felt by the robot

273

00:10:13,990 --> 00:10:12,320

decide if those forces are safe or not

274

00:10:16,310 --> 00:10:14,000

and stop the robot

275

00:10:18,710 --> 00:10:16,320

that three levels of safety

276

00:10:20,470 --> 00:10:18,720

was essential in

277

00:10:22,069 --> 00:10:20,480

convincing our payload safety review

278

00:10:25,030 --> 00:10:22,079

panel that this robot would be safe to

279

00:10:26,710 --> 00:10:25,040

work adjacent to astronauts inside the

280

00:10:28,069 --> 00:10:26,720

space station

281

00:10:30,230 --> 00:10:28,079

each of those three levels has a

282

00:10:32,550 --> 00:10:30,240

separate sensor pack separate cable

283

00:10:35,190 --> 00:10:32,560

harness going back to a separate process

284

00:10:37,350 --> 00:10:35,200

running monitoring those forces and if

285

00:10:38,949 --> 00:10:37,360

there's ever a problem the robot can

286

00:10:41,509 --> 00:10:38,959

either just stop

287

00:10:43,670 --> 00:10:41,519

and and wait for the problem to go away

288

00:10:45,750 --> 00:10:43,680

or completely turn itself off it's

289

00:10:48,230 --> 00:10:45,760

programmable so we can have different

290

00:10:51,750 --> 00:10:48,240

levels or thresholds at which it will

291

00:10:53,910 --> 00:10:51,760

either pause or completely turn off

292

00:10:56,069 --> 00:10:53,920

that is at the core of every motion that

293

00:10:57,509 --> 00:10:56,079

the robonaut system makes and it gives

294

00:10:59,670 --> 00:10:57,519

us confidence that the robot will be

295

00:11:02,389 --> 00:10:59,680

safe working around us

296

00:11:04,550 --> 00:11:02,399

i'm going to now play uh two videos or a

297

00:11:06,790 --> 00:11:04,560

combination of two clips

298

00:11:09,829 --> 00:11:06,800

uh go to the first video sequence

299

00:11:11,269 --> 00:11:09,839

that shows this paradox

300

00:11:12,389 --> 00:11:11,279

we want to have a robot that's both

301  
00:11:16,870 --> 00:11:12,399  
strong

302  
00:11:19,829 --> 00:11:16,880  
and at the same time safe

303  
00:11:21,910 --> 00:11:19,839  
uh safe enough to do it right next to us

304  
00:11:24,310 --> 00:11:21,920  
so the first part of this shows it

305  
00:11:25,269 --> 00:11:24,320  
handling a dumbbell that's a 20 pound

306  
00:11:26,790 --> 00:11:25,279  
dumbbell

307  
00:11:28,710 --> 00:11:26,800  
you can relate to what that would feel

308  
00:11:29,910 --> 00:11:28,720  
like if you were to reach out and pick

309  
00:11:32,470 --> 00:11:29,920  
it up

310  
00:11:34,230 --> 00:11:32,480  
unlike people which tend to cheat

311  
00:11:36,389 --> 00:11:34,240  
this robot will really do what the

312  
00:11:39,990 --> 00:11:36,399  
physical trainers tell you to do which

313  
00:11:42,389 --> 00:11:40,000

is to do the bicep curls nice and slow

314

00:11:44,310 --> 00:11:42,399

so as the robot's doing it because of

315

00:11:46,790 --> 00:11:44,320

your empathy and the monkey c monkey

316

00:11:49,030 --> 00:11:46,800

doability of the human you can almost

317

00:11:50,949 --> 00:11:49,040

feel what that robot is feeling

318

00:11:53,030 --> 00:11:50,959

you know what that would feel like

319

00:11:54,870 --> 00:11:53,040

curling that weight

320

00:11:56,389 --> 00:11:54,880

and that's because that's the way humans

321

00:11:57,910 --> 00:11:56,399

work we look at other humans and we can

322

00:11:59,910 --> 00:11:57,920

kind of

323

00:12:01,509 --> 00:11:59,920

know what it would feel like if we were

324

00:12:03,509 --> 00:12:01,519

them

325

00:12:04,710 --> 00:12:03,519

that applies to this robot it is so

326

00:12:06,710 --> 00:12:04,720

human-like

327

00:12:08,230 --> 00:12:06,720

you have a good idea of what the forces

328

00:12:10,230 --> 00:12:08,240

are that are involved

329

00:12:15,430 --> 00:12:10,240

you can kind of feel the burn right as

330

00:12:19,670 --> 00:12:17,269

humans have greater peak strength and

331

00:12:21,509 --> 00:12:19,680

peak speed than a robonaut 2.

332

00:12:22,870 --> 00:12:21,519

now you for a robot to be your assistant

333

00:12:24,550 --> 00:12:22,880

you really don't want it to move too

334

00:12:26,949 --> 00:12:24,560

fast

335

00:12:29,269 --> 00:12:26,959

but a robonaut has more endurance than a

336

00:12:31,750 --> 00:12:29,279

human while it might not have the same

337

00:12:33,990 --> 00:12:31,760

peak strength or peak velocity

338

00:12:35,590 --> 00:12:34,000

it can do things much longer and that's

339

00:12:37,509 --> 00:12:35,600

what you would really want in an

340

00:12:38,470 --> 00:12:37,519

assistant if you ask the robot to hold

341

00:12:39,670 --> 00:12:38,480

something

342

00:12:42,230 --> 00:12:39,680

and then you were going to work on it

343

00:12:44,150 --> 00:12:42,240

for a while the robot would not complain

344

00:12:47,190 --> 00:12:44,160

if you asked it to hold it for 30

345

00:12:47,990 --> 00:12:47,200

minutes in the same position

346

00:12:52,710 --> 00:12:48,000

that

347

00:12:57,350 --> 00:12:54,470

and unlike some people it will put

348

00:12:59,829 --> 00:12:57,360

things back when it's done

349

00:13:01,030 --> 00:12:59,839

another very useful thing in having an

350

00:13:02,870 --> 00:13:01,040

assistant

351

00:13:05,110 --> 00:13:02,880

when you're done with an object

352

00:13:07,430 --> 00:13:05,120

it can put it back for you

353

00:13:09,350 --> 00:13:07,440

so it's strong uh you will not see most

354

00:13:10,870 --> 00:13:09,360

of the humanoids out there handling

355

00:13:12,389 --> 00:13:10,880

20-pound dumbbells

356

00:13:13,590 --> 00:13:12,399

most of them don't even really have

357

00:13:15,430 --> 00:13:13,600

fingers

358

00:13:18,310 --> 00:13:15,440

they do a lot of dancing and you know

359

00:13:20,550 --> 00:13:18,320

we're we're fine with that

360

00:13:22,629 --> 00:13:20,560

we could probably program robonaut to do

361

00:13:24,710 --> 00:13:22,639

dancing but we're pretty sure

362

00:13:27,430 --> 00:13:24,720

no matter what dance move we would give

363

00:13:29,829 --> 00:13:27,440

it it would always do the robot

364

00:13:31,269 --> 00:13:29,839

for us it's more about doing work and

365

00:13:32,629 --> 00:13:31,279

that's why we really focused on the

366

00:13:34,870 --> 00:13:32,639

upper body

367

00:13:37,670 --> 00:13:34,880

so here it's doing a sequence uh it's

368

00:13:39,750 --> 00:13:37,680

running through some open space motion

369

00:13:41,509 --> 00:13:39,760

and now uh dr ron diffler is going to

370

00:13:43,509 --> 00:13:41,519

step into its workspace

371

00:13:46,230 --> 00:13:43,519

we call this the hitron demo

372

00:13:47,910 --> 00:13:46,240

and you see the robot stopped it paused

373

00:13:49,990 --> 00:13:47,920

it detected that ron had gotten in the

374

00:13:53,110 --> 00:13:50,000

way and then when he let it go

375

00:13:55,430 --> 00:13:53,120

it continued on with its sequence

376

00:13:57,750 --> 00:13:55,440

while it's pausing it's applying a very

377

00:13:59,189 --> 00:13:57,760

light force it's trying to catch up

378

00:14:01,189 --> 00:13:59,199

and when it does it goes back to the

379

00:14:03,750 --> 00:14:01,199

motions that it's programmed to do so

380

00:14:05,990 --> 00:14:03,760

this is running at the core of the robot

381

00:14:07,350 --> 00:14:06,000

every single time it moves if a person

382

00:14:08,949 --> 00:14:07,360

steps in the way

383

00:14:09,990 --> 00:14:08,959

and interferes with it

384

00:14:11,430 --> 00:14:10,000

nothing

385

00:14:13,350 --> 00:14:11,440

dangerous is going to happen the robot

386

00:14:15,030 --> 00:14:13,360

will just pause and if you hit it really

387

00:14:17,350 --> 00:14:15,040

hard it'll stop completely and turn

388

00:14:18,790 --> 00:14:17,360

itself off so we have those two levels

389

00:14:20,389 --> 00:14:18,800  
of safety

390

00:14:22,710 --> 00:14:20,399  
they're always running whenever a

391

00:14:25,030 --> 00:14:22,720  
robonaut is in motion

392

00:14:27,430 --> 00:14:25,040  
working with our astronauts

393

00:14:31,590 --> 00:14:27,440  
so move on to the next slide please i'll

394

00:14:36,069 --> 00:14:34,629  
within each finger we've got tendons and

395

00:14:39,110 --> 00:14:36,079  
we have force

396

00:14:41,030 --> 00:14:39,120  
control where we're able to sense

397

00:14:42,389 --> 00:14:41,040  
tendon forces and map that to finger

398

00:14:43,750 --> 00:14:42,399  
finger forces

399

00:14:45,670 --> 00:14:43,760  
we also have

400

00:14:48,150 --> 00:14:45,680  
load cells on every phalange every

401  
00:14:50,629 --> 00:14:48,160  
finger bone so we can measure fingertip

402  
00:14:52,470 --> 00:14:50,639  
contact forces we can also resolve the

403  
00:14:54,790 --> 00:14:52,480  
direction of those contacts

404  
00:14:55,829 --> 00:14:54,800  
so we can understand and let the robot

405  
00:14:58,150 --> 00:14:55,839  
understand

406  
00:15:00,150 --> 00:14:58,160  
that it's made contact with an object

407  
00:15:01,990 --> 00:15:00,160  
and even use those fingers

408  
00:15:03,590 --> 00:15:02,000  
kind of like sensors to map out the

409  
00:15:04,949 --> 00:15:03,600  
shape of an object

410  
00:15:06,550 --> 00:15:04,959  
you'll see how that's important in a

411  
00:15:09,829 --> 00:15:06,560  
minute

412  
00:15:10,949 --> 00:15:09,839  
we've mapped those tendons and tip force

413  
00:15:14,150 --> 00:15:10,959

sensors

414

00:15:15,750 --> 00:15:14,160

into whole finger control modes that

415

00:15:18,389 --> 00:15:15,760

allow the robot to be given different

416

00:15:20,470 --> 00:15:18,399

things like a soft grasp or a hard grasp

417

00:15:22,710 --> 00:15:20,480

power grasp lots of different

418

00:15:26,069 --> 00:15:22,720

shapes of grasps the humans just really

419

00:15:28,230 --> 00:15:26,079

take for for granted

420

00:15:29,590 --> 00:15:28,240

this hand is a mechanical marvel it's a

421

00:15:32,389 --> 00:15:29,600

mechatronic marvel because it's

422

00:15:34,150 --> 00:15:32,399

integrated with electronics as well

423

00:15:36,150 --> 00:15:34,160

it has some things that humans just take

424

00:15:38,710 --> 00:15:36,160

for granted but that you don't see in a

425

00:15:41,030 --> 00:15:38,720

lot of robot hands it actually has palms

426  
00:15:42,870 --> 00:15:41,040  
most robot hands only have grippers to

427  
00:15:44,629 --> 00:15:42,880  
grab things between fingers they don't

428  
00:15:45,509 --> 00:15:44,639  
envelop objects and bring them into a

429  
00:15:46,949 --> 00:15:45,519  
palm

430  
00:15:49,269 --> 00:15:46,959  
the second thing that this robot has

431  
00:15:51,910 --> 00:15:49,279  
that's unusual is a soft covering we

432  
00:15:53,910 --> 00:15:51,920  
take that for granted as humans we have

433  
00:15:55,430 --> 00:15:53,920  
skin and sometimes we put other layers

434  
00:15:57,030 --> 00:15:55,440  
on called gloves

435  
00:15:58,949 --> 00:15:57,040  
if you look at most robot hands they're

436  
00:16:00,790 --> 00:15:58,959  
hard steel fingers

437  
00:16:01,829 --> 00:16:00,800  
you would not ever want them to grab an

438  
00:16:03,509 --> 00:16:01,839

object

439

00:16:05,590 --> 00:16:03,519

and then have an astronaut grab that

440

00:16:07,749 --> 00:16:05,600

object later if it was an object that

441

00:16:09,749 --> 00:16:07,759

was made out of aluminum or steel

442

00:16:12,069 --> 00:16:09,759

those hard fingers might leave a burr or

443

00:16:13,910 --> 00:16:12,079

a nick on that object that could later

444

00:16:15,670 --> 00:16:13,920

cut the astronaut's glove

445

00:16:17,269 --> 00:16:15,680

what we want is to have a robot that

446

00:16:19,509 --> 00:16:17,279

does not cause nicks and burrs in the

447

00:16:21,189 --> 00:16:19,519

environment and will be safe to handle

448

00:16:22,710 --> 00:16:21,199

the same objects that we'll ask

449

00:16:24,389 --> 00:16:22,720

astronauts to handle

450

00:16:25,509 --> 00:16:24,399

the skin is also really important for

451  
00:16:27,350 --> 00:16:25,519  
friction

452  
00:16:28,150 --> 00:16:27,360  
we can put different kinds of materials

453  
00:16:31,990 --> 00:16:28,160  
in

454  
00:16:33,990 --> 00:16:32,000  
palm

455  
00:16:35,829 --> 00:16:34,000  
polymer surfaces fingers different

456  
00:16:38,310 --> 00:16:35,839  
levels of different coefficients of

457  
00:16:39,590 --> 00:16:38,320  
friction to allow to grasp objects more

458  
00:16:41,829 --> 00:16:39,600  
completely

459  
00:16:43,110 --> 00:16:41,839  
and also a little cushioning

460  
00:16:44,870 --> 00:16:43,120  
gives some give

461  
00:16:47,910 --> 00:16:44,880  
and allows the robot to have both a very

462  
00:16:49,509 --> 00:16:47,920  
delicate fine force resolution yet still

463  
00:16:52,470 --> 00:16:49,519

be tough enough to really get a white

464

00:16:54,629 --> 00:16:52,480

knuckle grasp on an object

465

00:16:57,350 --> 00:16:54,639

i'm going to show you a couple

466

00:16:58,790 --> 00:16:57,360

video clips here that demonstrate how we

467

00:17:01,590 --> 00:16:58,800

take advantage of that

468

00:17:04,150 --> 00:17:01,600

so please play the next video please

469

00:17:07,110 --> 00:17:04,160

so this shows the robot hand kind of

470

00:17:09,110 --> 00:17:07,120

groping an object it's a flexible

471

00:17:11,750 --> 00:17:09,120

material that's got a bump in it the

472

00:17:14,390 --> 00:17:11,760

robot is basically scanning the object

473

00:17:16,390 --> 00:17:14,400

using its sensors to map out the 3d

474

00:17:17,829 --> 00:17:16,400

shape of that object

475

00:17:19,669 --> 00:17:17,839

you wouldn't need to do this every time

476

00:17:21,909 --> 00:17:19,679

but once it's learned

477

00:17:23,990 --> 00:17:21,919

the feel of the object it could apply

478

00:17:25,429 --> 00:17:24,000

that so it grabs the object it

479

00:17:28,390 --> 00:17:25,439

immediately knows where it is and that

480

00:17:29,909 --> 00:17:28,400

can now put its thumb in that divot

481

00:17:32,390 --> 00:17:29,919

by having first

482

00:17:34,310 --> 00:17:32,400

familiarized itself with the object

483

00:17:36,710 --> 00:17:34,320

it's able to now do that automatically

484

00:17:39,029 --> 00:17:36,720

when it just first makes contact to

485

00:17:40,789 --> 00:17:39,039

immediately know where it is and slide

486

00:17:42,150 --> 00:17:40,799

its thumb into position

487

00:17:46,150 --> 00:17:42,160

as far as we know this is the first

488

00:17:53,590 --> 00:17:47,590

okay um

489

00:17:57,909 --> 00:17:55,830

oh

490

00:17:59,590 --> 00:17:57,919

okay well that's fine we can play this

491

00:18:02,549 --> 00:17:59,600

video so no we're now going to talk

492

00:18:04,710 --> 00:18:02,559

about the future for the robonaut system

493

00:18:07,110 --> 00:18:04,720

this is the very recent past

494

00:18:09,270 --> 00:18:07,120

the robonaut 2b system was processed at

495

00:18:12,470 --> 00:18:09,280

the kennedy space center

496

00:18:15,510 --> 00:18:12,480

being prepared to be packed in the mplm

497

00:18:17,750 --> 00:18:15,520

so this is a time lapse video showing

498

00:18:19,669 --> 00:18:17,760

the technicians both robonaut engineers

499

00:18:20,870 --> 00:18:19,679

and the kennedy

500

00:18:22,950 --> 00:18:20,880

workforce

501  
00:18:24,150 --> 00:18:22,960  
integrating the robot in its packing

502  
00:18:25,830 --> 00:18:24,160  
container

503  
00:18:30,150 --> 00:18:25,840  
that's then loaded inside yet another

504  
00:18:34,390 --> 00:18:32,230  
you can imagine after 15 years working

505  
00:18:35,190 --> 00:18:34,400  
on the project how excited the engineers

506  
00:18:36,870 --> 00:18:35,200  
were

507  
00:18:39,270 --> 00:18:36,880  
to participate in getting to load up

508  
00:18:43,029 --> 00:18:39,280  
this robot and prepare it for a ride

509  
00:18:53,669 --> 00:18:45,430  
it's in that same tucked position like

510  
00:18:58,150 --> 00:18:56,390  
station team built a terrific

511  
00:19:01,029 --> 00:18:58,160  
protective cage

512  
00:19:03,270 --> 00:19:01,039  
that packs the robot in foam

513  
00:19:05,190 --> 00:19:03,280

and then that box itself

514

00:19:09,430 --> 00:19:05,200

as you'll see is encapsulated in another

515

00:19:09,440 --> 00:19:16,470

and we didn't skimp on the screws

516

00:19:20,310 --> 00:19:17,590

now there's actually a couple other

517

00:19:21,590 --> 00:19:20,320

robots involved here that one's a crane

518

00:19:22,710 --> 00:19:21,600

people don't normally think of it as a

519

00:19:25,270 --> 00:19:22,720

robot

520

00:19:27,270 --> 00:19:25,280

but the next one you'll see

521

00:19:29,029 --> 00:19:27,280

most people would probably

522

00:19:30,470 --> 00:19:29,039

call it a robot

523

00:19:32,630 --> 00:19:30,480

it's a very large machine that's going

524

00:19:42,310 --> 00:19:32,640

to reach out and grab this

525

00:19:46,470 --> 00:19:44,710

so there the robonaut box is being

526

00:19:54,630 --> 00:19:46,480

encapsulated in yet another layer of

527

00:19:58,630 --> 00:19:56,789

and now this enormous robot arm is going

528

00:20:05,350 --> 00:19:58,640

to pick up the little robot

529

00:20:08,070 --> 00:20:06,630

okay

530

00:20:08,789 --> 00:20:08,080

so you can imagine trying to reach into

531

00:20:51,750 --> 00:20:08,799

a

532

00:20:53,510 --> 00:20:51,760

obviously we're very excited to get our

533

00:20:54,870 --> 00:20:53,520

2b sent to station

534

00:20:57,029 --> 00:20:54,880

we've been working on some other lower

535

00:20:59,270 --> 00:20:57,039

bodies that are of interest for

536

00:21:01,909 --> 00:20:59,280

future applications we'd like to add

537

00:21:03,350 --> 00:21:01,919

legs to the r2b system so they could

538

00:21:04,950 --> 00:21:03,360

climb around on the inside of the space

539

00:21:07,190 --> 00:21:04,960

station

540

00:21:09,270 --> 00:21:07,200

again we don't want to just have to

541

00:21:10,710 --> 00:21:09,280

bring work to it we would like once

542

00:21:13,029 --> 00:21:10,720

we've

543

00:21:14,789 --> 00:21:13,039

shown the robot's ability to do work to

544

00:21:16,710 --> 00:21:14,799

free it up to climb around on the inside

545

00:21:18,470 --> 00:21:16,720

of the station and go to where the

546

00:21:20,310 --> 00:21:18,480

action is

547

00:21:22,870 --> 00:21:20,320

solving problems with the crew

548

00:21:24,870 --> 00:21:22,880

we've identified a number of tasks that

549

00:21:26,710 --> 00:21:24,880

we think are appropriate for the robot

550

00:21:29,430 --> 00:21:26,720

it's being shipped with a task board

551  
00:21:32,390 --> 00:21:29,440  
that's basically a test apparatus that

552  
00:21:34,710 --> 00:21:32,400  
has a lot of different interfaces on it

553  
00:21:35,909 --> 00:21:34,720  
it has switches and latches and valves

554  
00:21:40,789 --> 00:21:35,919  
and

555  
00:21:42,710 --> 00:21:40,799  
interfaces that the

556  
00:21:43,750 --> 00:21:42,720  
the astronauts use on a daily basis in

557  
00:21:44,870 --> 00:21:43,760  
space

558  
00:21:46,470 --> 00:21:44,880  
we're going to practice using the

559  
00:21:48,630 --> 00:21:46,480  
robonaut 2 system on each of those

560  
00:21:49,830 --> 00:21:48,640  
interfaces we have a similar system here

561  
00:21:51,750 --> 00:21:49,840  
on the ground

562  
00:21:53,909 --> 00:21:51,760  
and we will of course try everything

563  
00:21:56,070 --> 00:21:53,919

first on a ground robot

564

00:21:58,630 --> 00:21:56,080

but the questions remain as to how the

565

00:22:00,789 --> 00:21:58,640

robot will work in zero gravity

566

00:22:02,070 --> 00:22:00,799

will all those interfaces work the same

567

00:22:03,029 --> 00:22:02,080

when there's no gravity load on the

568

00:22:05,510 --> 00:22:03,039

robot

569

00:22:07,990 --> 00:22:05,520

and we'll compare the gravity results

570

00:22:11,270 --> 00:22:08,000

with the zero gravity results from the

571

00:22:15,430 --> 00:22:13,350

we're also looking at some

572

00:22:17,830 --> 00:22:15,440

surface applications

573

00:22:20,470 --> 00:22:17,840

we've got a new wheeled base

574

00:22:22,070 --> 00:22:20,480

that we've developed called centaur 2 an

575

00:22:23,669 --> 00:22:22,080

upgrade to the

576

00:22:26,149 --> 00:22:23,679

the ride we built for the robonaut 1

577

00:22:28,950 --> 00:22:26,159

series the centaur 2 was recently taken

578

00:22:31,029 --> 00:22:28,960

out to desert rats one of our

579

00:22:33,190 --> 00:22:31,039

analog field test programs

580

00:22:34,390 --> 00:22:33,200

where i was given a shakeout cruise and

581

00:22:36,149 --> 00:22:34,400

that base

582

00:22:37,909 --> 00:22:36,159

shown there in the center

583

00:22:39,909 --> 00:22:37,919

really proved its metal it's going to be

584

00:22:41,510 --> 00:22:39,919

a fantastic little rover for the

585

00:22:42,230 --> 00:22:41,520

robonaut to ride on

586

00:22:44,470 --> 00:22:42,240

and

587

00:22:45,750 --> 00:22:44,480

might be the precursor robot of the

588

00:22:47,990 --> 00:22:45,760

future

589

00:22:49,510 --> 00:22:48,000

able to go out ahead of astronauts and

590

00:22:50,390 --> 00:22:49,520

explore worlds before the humans get

591

00:22:53,990 --> 00:22:50,400

there

592

00:22:56,390 --> 00:22:54,000

and or maybe be left behind as a

593

00:22:57,750 --> 00:22:56,400

caretaker we're also looking at legs and

594

00:22:59,190 --> 00:22:57,760

other wheeled bases that might be

595

00:23:00,470 --> 00:22:59,200

appropriate

596

00:23:02,149 --> 00:23:00,480

and throughout the history of the

597

00:23:03,350 --> 00:23:02,159

robonaut team

598

00:23:05,190 --> 00:23:03,360

considering

599

00:23:08,070 --> 00:23:05,200

lots of different lower body options has

600

00:23:10,310 --> 00:23:08,080

been our philosophy it's allowed us to

601  
00:23:12,549 --> 00:23:10,320  
adapt the system to different kind of

602  
00:23:14,870 --> 00:23:12,559  
worlds different gravity levels and find

603  
00:23:16,470 --> 00:23:14,880  
the right mobility for the application

604  
00:23:18,470 --> 00:23:16,480  
but at the same time allow us to stay

605  
00:23:20,630 --> 00:23:18,480  
focused on the upper body the part of

606  
00:23:22,070 --> 00:23:20,640  
the robonaut that really does the work

607  
00:23:23,830 --> 00:23:22,080  
that's what the robonaut program is all

608  
00:23:26,630 --> 00:23:23,840  
about

609  
00:23:28,390 --> 00:23:26,640  
we have one last video it's kind of a

610  
00:23:30,710 --> 00:23:28,400  
vision of the future

611  
00:23:34,230 --> 00:23:30,720  
we would like to take the robonaut 2

612  
00:23:35,909 --> 00:23:34,240  
system outside once we

613  
00:23:36,950 --> 00:23:35,919

add legs to the system so that it can

614

00:23:38,789 --> 00:23:36,960

climb

615

00:23:41,190 --> 00:23:38,799

we would like to go outside with the

616

00:23:42,149 --> 00:23:41,200

robonaut and help the crew with eva

617

00:23:43,830 --> 00:23:42,159

tasks

618

00:23:45,830 --> 00:23:43,840

just like it'll be helping with iva

619

00:23:52,149 --> 00:23:45,840

tasks in this coming year if we could

620

00:23:57,269 --> 00:23:54,549

so pretty amazing rock climbing right

621

00:23:59,029 --> 00:23:57,279

zero g rock climbing but you'd still

622

00:24:01,350 --> 00:23:59,039

like to have a leg or some kind of

623

00:24:05,190 --> 00:24:01,360

stabilizing appendage

624

00:24:06,950 --> 00:24:05,200

to free the hands to do work

625

00:24:07,990 --> 00:24:06,960

because we've certified it for indoor

626  
00:24:09,430 --> 00:24:08,000  
work

627  
00:24:11,430 --> 00:24:09,440  
with toxicity and flammability

628  
00:24:13,029 --> 00:24:11,440  
certifications we've really built an

629  
00:24:14,630 --> 00:24:13,039  
indoor outdoor robot

630  
00:24:18,470 --> 00:24:14,640  
so it might just go in and out through

631  
00:24:20,470 --> 00:24:18,480  
the airlock like the astronauts do

632  
00:24:22,789 --> 00:24:20,480  
but unlike the astronauts it could be

633  
00:24:24,710 --> 00:24:22,799  
left out indefinitely

634  
00:24:26,149 --> 00:24:24,720  
and available for emergencies like

635  
00:24:29,029 --> 00:24:26,159  
patching leaks

636  
00:24:31,110 --> 00:24:29,039  
or other emergencies that

637  
00:24:33,269 --> 00:24:31,120  
have to be dealt with immediately

638  
00:24:35,510 --> 00:24:33,279

while waiting for astronauts to go eva

639

00:24:36,710 --> 00:24:35,520

and come out to help

640

00:24:38,789 --> 00:24:36,720

so that's been the vision for the

641

00:24:40,310 --> 00:24:38,799

robonaut system working safely with

642

00:24:42,149 --> 00:24:40,320

humans

643

00:24:43,909 --> 00:24:42,159

for over 15 years

644

00:24:44,789 --> 00:24:43,919

it's a dream come true to get to launch

645

00:24:46,390 --> 00:24:44,799

one

646

00:24:47,350 --> 00:24:46,400

i can't tell you how we're how excited

647

00:24:49,830 --> 00:24:47,360

we are

648

00:24:51,510 --> 00:24:49,840

uh all the robonaut engineers have

649

00:24:54,149 --> 00:24:51,520

looked forward to this day

650

00:24:57,029 --> 00:24:54,159

for many years and i applaud them for

651  
00:24:58,310 --> 00:24:57,039  
their uh patience and persistence and

652  
00:25:00,710 --> 00:24:58,320  
all the hard work that's gone into

653  
00:25:02,789 --> 00:25:00,720  
making this possible

654  
00:25:04,549 --> 00:25:02,799  
at this point i think we're ready for

655  
00:25:06,230 --> 00:25:04,559  
questions okay we'll start here with

656  
00:25:07,909 --> 00:25:06,240  
questions here at the johnson space

657  
00:25:10,870 --> 00:25:07,919  
center then take questions at other

658  
00:25:15,269 --> 00:25:13,430  
hi robert perlman with collectspace.com

659  
00:25:17,590 --> 00:25:15,279  
with a couple of questions

660  
00:25:19,269 --> 00:25:17,600  
first given how packed up it is in

661  
00:25:21,029 --> 00:25:19,279  
multiple layers of foam and screws and

662  
00:25:22,789 --> 00:25:21,039  
such how long will it take the

663  
00:25:24,789 --> 00:25:22,799

astronauts to unpack

664

00:25:26,310 --> 00:25:24,799

we think a

665

00:25:27,190 --> 00:25:26,320

couple hours

666

00:25:28,870 --> 00:25:27,200

should

667

00:25:30,870 --> 00:25:28,880

unpack the system there'll be a lot of

668

00:25:32,070 --> 00:25:30,880

screws they have to keep track of

669

00:25:36,070 --> 00:25:32,080

but uh

670

00:25:37,110 --> 00:25:36,080

it's not that hard to un unpack it

671

00:25:39,750 --> 00:25:37,120

and um

672

00:25:42,870 --> 00:25:39,760

with the example that was given on

673

00:25:48,630 --> 00:25:42,880

the um the hit and dawn i guess um with

674

00:25:48,640 --> 00:25:52,070

the uh

675

00:25:56,149 --> 00:25:54,310

ron was on earth with gravity anchoring

676  
00:25:57,510 --> 00:25:56,159  
him to the ground if an astronaut was

677  
00:25:59,510 --> 00:25:57,520  
free-floating

678  
00:26:01,110 --> 00:25:59,520  
and that and an arm were to come in

679  
00:26:03,029 --> 00:26:01,120  
place does the small pressure that you

680  
00:26:05,350 --> 00:26:03,039  
mentioned does that have enough force to

681  
00:26:06,390 --> 00:26:05,360  
push the astronaut back so this is one

682  
00:26:08,950 --> 00:26:06,400  
of the things that we're going to be

683  
00:26:10,390 --> 00:26:08,960  
experimenting with on earth we've set

684  
00:26:12,070 --> 00:26:10,400  
the thresholds

685  
00:26:14,230 --> 00:26:12,080  
where it will pause

686  
00:26:16,549 --> 00:26:14,240  
at you know just a couple pounds and

687  
00:26:19,190 --> 00:26:16,559  
then thresholds for it completely safe

688  
00:26:21,110 --> 00:26:19,200

in itself a little deeper than that

689

00:26:22,390 --> 00:26:21,120

but those forces

690

00:26:24,390 --> 00:26:22,400

are

691

00:26:26,149 --> 00:26:24,400

kind of biased by all the gravity loads

692

00:26:29,350 --> 00:26:26,159

that the robot feels

693

00:26:30,870 --> 00:26:29,360

when we get into zero g all the gravity

694

00:26:33,269 --> 00:26:30,880

loads go away

695

00:26:35,350 --> 00:26:33,279

so if it feels a contact it feels loads

696

00:26:37,990 --> 00:26:35,360

it's really contact so we should be able

697

00:26:39,350 --> 00:26:38,000

to dial down those thresholds to an even

698

00:26:40,310 --> 00:26:39,360

finer level

699

00:26:42,710 --> 00:26:40,320

so

700

00:26:45,269 --> 00:26:42,720

we can't simulate that on earth you know

701  
00:26:47,510 --> 00:26:45,279  
we don't really have a zero g chamber

702  
00:26:49,110 --> 00:26:47,520  
so it's part of the reason we have to do

703  
00:26:51,430 --> 00:26:49,120  
this in space

704  
00:26:52,390 --> 00:26:51,440  
is to experimentally lower those

705  
00:26:54,630 --> 00:26:52,400  
thresholds

706  
00:26:57,269 --> 00:26:54,640  
and make it finer and finer to see how

707  
00:26:59,830 --> 00:26:57,279  
low we can go how light of a force could

708  
00:27:01,669 --> 00:26:59,840  
the robot detect and still pause

709  
00:27:02,950 --> 00:27:01,679  
that's part of one of our experimental

710  
00:27:04,390 --> 00:27:02,960  
objectives

711  
00:27:06,230 --> 00:27:04,400  
on earth we're

712  
00:27:07,669 --> 00:27:06,240  
on the order of like one or two pounds

713  
00:27:11,669 --> 00:27:07,679

to move it around

714

00:27:15,510 --> 00:27:14,549

uh mark caro for aviation mark

715

00:27:18,870 --> 00:27:15,520

hi

716

00:27:20,389 --> 00:27:18,880

um can you tell us what the plan is for

717

00:27:22,710 --> 00:27:20,399

unpacking

718

00:27:24,630 --> 00:27:22,720

robonaut in terms of time frame will it

719

00:27:27,350 --> 00:27:24,640

happen on this mission or

720

00:27:28,870 --> 00:27:27,360

or some weeks away and what do you sort

721

00:27:32,310 --> 00:27:28,880

of anticipate

722

00:27:34,549 --> 00:27:32,320

being the first series of activities

723

00:27:36,149 --> 00:27:34,559

that you would do as far as testing or

724

00:27:37,909 --> 00:27:36,159

operating or

725

00:27:39,269 --> 00:27:37,919

shaking down or however

726

00:27:40,630 --> 00:27:39,279

well the crew are busy you know we're

727

00:27:43,510 --> 00:27:40,640

scheduling when it will be unpacked

728

00:27:45,269 --> 00:27:43,520

it'll be long after the shuttle has left

729

00:27:46,230 --> 00:27:45,279

uh we're hoping for a good christmas

730

00:27:47,029 --> 00:27:46,240

present

731

00:27:48,789 --> 00:27:47,039

uh

732

00:27:51,190 --> 00:27:48,799

around christmas time maybe early

733

00:27:53,029 --> 00:27:51,200

january we have a whole series of tests

734

00:27:54,870 --> 00:27:53,039

that we would like to do

735

00:27:57,510 --> 00:27:54,880

the first is just a

736

00:27:58,470 --> 00:27:57,520

a power up test and watch the levels and

737

00:28:01,350 --> 00:27:58,480

make sure

738

00:28:03,669 --> 00:28:01,360

that everything came up

739

00:28:05,350 --> 00:28:03,679

as we expected and then a whole series

740

00:28:06,870 --> 00:28:05,360

of kind of incrementally

741

00:28:07,909 --> 00:28:06,880

turning on more and more parts of the

742

00:28:09,510 --> 00:28:07,919

robot

743

00:28:11,909 --> 00:28:09,520

and verifying that

744

00:28:12,710 --> 00:28:11,919

uh the robot is health healthy

745

00:28:15,269 --> 00:28:12,720

and

746

00:28:16,710 --> 00:28:15,279

that the the current levels are the same

747

00:28:18,389 --> 00:28:16,720

as they were measured at kennedy right

748

00:28:20,070 --> 00:28:18,399

before it was packed

749

00:28:21,510 --> 00:28:20,080

so a whole series of those kind of

750

00:28:24,310 --> 00:28:21,520

checkouts

751

00:28:26,710 --> 00:28:24,320

the robot is designed with a base

752

00:28:28,070 --> 00:28:26,720

stanchion pedestal so it could be set up

753

00:28:29,669 --> 00:28:28,080

pretty quickly

754

00:28:31,350 --> 00:28:29,679

and the astronauts can set it up or

755

00:28:34,789 --> 00:28:31,360

leave it up

756

00:28:39,990 --> 00:28:37,510

over the this year we've got a whole

757

00:28:41,669 --> 00:28:40,000

series of task board experiments once

758

00:28:43,830 --> 00:28:41,679

we've checked out the robot we'll kind

759

00:28:46,149 --> 00:28:43,840

of work our way across the task board

760

00:28:48,630 --> 00:28:46,159

from some of the simpler interfaces to

761

00:28:51,269 --> 00:28:48,640

the more progressively complicated ones

762

00:28:52,630 --> 00:28:51,279

finishing handling flexible fabrics

763

00:28:54,549 --> 00:28:52,640

something that robots really don't do

764

00:28:56,710 --> 00:28:54,559

well but that robonaut is really well

765

00:28:58,389 --> 00:28:56,720

designed to handle

766

00:28:59,830 --> 00:28:58,399

so we'll kind of progress our way across

767

00:29:01,430 --> 00:28:59,840

the task board

768

00:29:02,870 --> 00:29:01,440

then we've got a couple tasks that we've

769

00:29:05,110 --> 00:29:02,880

been thinking of

770

00:29:06,389 --> 00:29:05,120

that we would like to mock up on that

771

00:29:07,669 --> 00:29:06,399

task board

772

00:29:09,430 --> 00:29:07,679

and here we'll probably want to take

773

00:29:12,149 --> 00:29:09,440

advantage of equipment that's already on

774

00:29:13,830 --> 00:29:12,159

station and have the astronauts bring it

775

00:29:15,110 --> 00:29:13,840

to the task board

776  
00:29:17,909 --> 00:29:15,120  
uh two

777  
00:29:19,190 --> 00:29:17,919  
tasks that have been identified

778  
00:29:21,269 --> 00:29:19,200  
are both house

779  
00:29:23,269 --> 00:29:21,279  
housekeeping tasks

780  
00:29:26,389 --> 00:29:23,279  
for 20 years i've asked people if you

781  
00:29:28,470 --> 00:29:26,399  
had a robot what would you do with it

782  
00:29:30,230 --> 00:29:28,480  
and very consistently

783  
00:29:32,549 --> 00:29:30,240  
i've asked that question

784  
00:29:34,070 --> 00:29:32,559  
and if kids i get two answers

785  
00:29:35,669 --> 00:29:34,080  
they first say i would i would like it

786  
00:29:37,510 --> 00:29:35,679  
to do my homework

787  
00:29:39,269 --> 00:29:37,520  
and then the second answer is

788  
00:29:41,029 --> 00:29:39,279

and then clean their room

789

00:29:43,430 --> 00:29:41,039

when i ask adults

790

00:29:44,870 --> 00:29:43,440

they always say cleaning

791

00:29:46,710 --> 00:29:44,880

and then they usually mention either

792

00:29:48,310 --> 00:29:46,720

kitchen or bathroom

793

00:29:49,190 --> 00:29:48,320

very consistently i've asked that

794

00:29:50,789 --> 00:29:49,200

question

795

00:29:51,669 --> 00:29:50,799

if you had a robot what would you have

796

00:29:55,190 --> 00:29:51,679

it do

797

00:29:57,190 --> 00:29:55,200

for over 20 years and house cleaning is

798

00:29:59,590 --> 00:29:57,200

at the top of the list

799

00:30:01,190 --> 00:29:59,600

so there are two that we're looking at

800

00:30:03,669 --> 00:30:01,200

the astronauts have to wipe down the

801  
00:30:06,549 --> 00:30:03,679  
handrails inside the space station with

802  
00:30:09,029 --> 00:30:06,559  
some wet wipes once a week just to

803  
00:30:09,830 --> 00:30:09,039  
for hygiene reasons not to pass germs

804  
00:30:11,750 --> 00:30:09,840  
and

805  
00:30:13,750 --> 00:30:11,760  
develop biofilms

806  
00:30:15,830 --> 00:30:13,760  
what a great job for the robot where the

807  
00:30:18,710 --> 00:30:15,840  
astronauts might be able to do it in a

808  
00:30:21,510 --> 00:30:19,990  
wouldn't it be great if the robot was

809  
00:30:22,870 --> 00:30:21,520  
just always doing that working its way

810  
00:30:24,310 --> 00:30:22,880  
around the station always kind of

811  
00:30:26,630 --> 00:30:24,320  
cleaning

812  
00:30:28,870 --> 00:30:26,640  
another is vacuuming the air filters all

813  
00:30:30,870 --> 00:30:28,880

the electronics racks have these air

814

00:30:33,110 --> 00:30:30,880

filters so as they're bringing air

815

00:30:35,190 --> 00:30:33,120

through the racks to cool it the filters

816

00:30:37,510 --> 00:30:35,200

capture particulates and keep it from

817

00:30:39,110 --> 00:30:37,520

going inside the electronics the crew

818

00:30:41,190 --> 00:30:39,120

have to go around and pull out these air

819

00:30:43,269 --> 00:30:41,200

filters and then with a separate vacuum

820

00:30:44,389 --> 00:30:43,279

cleaner vacuum out each of those air

821

00:30:46,470 --> 00:30:44,399

filters

822

00:30:48,149 --> 00:30:46,480

another very tedious task

823

00:30:50,549 --> 00:30:48,159

i'd much rather give the crew their

824

00:30:52,470 --> 00:30:50,559

saturday mornings back if we could let

825

00:30:54,870 --> 00:30:52,480

the robot do those house cleaning

826

00:30:57,509 --> 00:30:54,880

housekeeping tasks

827

00:30:59,590 --> 00:30:57,519

what a great thing to give the crew back

828

00:31:01,190 --> 00:30:59,600

and i think it fits with

829

00:31:03,590 --> 00:31:01,200

terrestrial models for what robots

830

00:31:05,669 --> 00:31:03,600

should do helping people

831

00:31:07,750 --> 00:31:05,679

we're looking for more tasks though and

832

00:31:09,750 --> 00:31:07,760

it might be the the crew are our best

833

00:31:12,310 --> 00:31:09,760

source of ideas

834

00:31:13,750 --> 00:31:12,320

i'd like to say that the sts-133 crew

835

00:31:15,909 --> 00:31:13,760

has been terrific

836

00:31:17,590 --> 00:31:15,919

in embracing robonaut

837

00:31:19,029 --> 00:31:17,600

on this ride to station

838

00:31:20,630 --> 00:31:19,039

and we've been working with some of the

839

00:31:23,190 --> 00:31:20,640

astronauts that will be working with it

840

00:31:25,190 --> 00:31:23,200

on station

841

00:31:27,350 --> 00:31:25,200

they've got a great attitude thinking

842

00:31:29,269 --> 00:31:27,360

about what the robot could do

843

00:31:32,389 --> 00:31:29,279

embracing this new idea

844

00:31:34,710 --> 00:31:32,399

and being very creative about applying

845

00:31:36,230 --> 00:31:34,720

the technology to future missions

846

00:31:38,389 --> 00:31:36,240

i'm really looking to them to come up

847

00:31:40,389 --> 00:31:38,399

with the next tasks for what the robot

848

00:31:41,430 --> 00:31:40,399

could do they'll be living with it

849

00:31:43,509 --> 00:31:41,440

they'll have a lot of time with the

850

00:31:47,110 --> 00:31:43,519

robot and i'm really excited about what

851  
00:31:49,029 --> 00:31:47,120  
they will come up with as experimenters

852  
00:31:50,870 --> 00:31:49,039  
thanks could you just talk about turning

853  
00:31:52,789 --> 00:31:50,880  
it on do you turn it on once and leave

854  
00:31:54,389 --> 00:31:52,799  
it on forever or do you turn him on and

855  
00:31:55,750 --> 00:31:54,399  
if you do how long does it take and if

856  
00:31:57,190 --> 00:31:55,760  
you turn them off how long does that

857  
00:31:59,110 --> 00:31:57,200  
take

858  
00:32:01,350 --> 00:31:59,120  
they come up pretty quickly

859  
00:32:02,789 --> 00:32:01,360  
there's a console that looks remarkably

860  
00:32:05,269 --> 00:32:02,799  
like your laptop

861  
00:32:06,710 --> 00:32:05,279  
that is set up that is used to operate

862  
00:32:09,350 --> 00:32:06,720  
the robot

863  
00:32:10,630 --> 00:32:09,360

it comes up in just a matter of minutes

864

00:32:11,909 --> 00:32:10,640

and it goes down

865

00:32:13,269 --> 00:32:11,919

much quickly

866

00:32:15,430 --> 00:32:13,279

than that

867

00:32:16,470 --> 00:32:15,440

in an emergency it shuts off itself off

868

00:32:18,070 --> 00:32:16,480

instantly

869

00:32:20,070 --> 00:32:18,080

but normally it takes a couple minutes

870

00:32:21,590 --> 00:32:20,080

to turn it off and bring its power

871

00:32:24,710 --> 00:32:21,600

levels down

872

00:32:26,389 --> 00:32:24,720

we will likely bring it up and

873

00:32:28,070 --> 00:32:26,399

use it for a session and then turn it

874

00:32:29,430 --> 00:32:28,080

off

875

00:32:31,509 --> 00:32:29,440

one of the things that we've always done

876  
00:32:33,430 --> 00:32:31,519  
with our robots is we've had an

877  
00:32:35,669 --> 00:32:33,440  
emergency stop switch

878  
00:32:37,909 --> 00:32:35,679  
that we've used to

879  
00:32:39,590 --> 00:32:37,919  
just be safe

880  
00:32:41,029 --> 00:32:39,600  
because of the three levels of safety

881  
00:32:43,110 --> 00:32:41,039  
software we are not going to need to use

882  
00:32:44,950 --> 00:32:43,120  
that switch so we're not going to waste

883  
00:32:46,549 --> 00:32:44,960  
an astronaut having to float through

884  
00:32:47,830 --> 00:32:46,559  
with their thumb on a button

885  
00:32:49,509 --> 00:32:47,840  
the whole time

886  
00:32:52,950 --> 00:32:49,519  
we really trust the robot to do the

887  
00:32:55,350 --> 00:32:52,960  
right thing and to be safe

888  
00:32:57,350 --> 00:32:55,360

that said you know that the astronauts

889

00:32:59,669 --> 00:32:57,360

will be able to operate the robot or

890

00:33:02,389 --> 00:32:59,679

conduct experiments with the robot or

891

00:33:07,029 --> 00:33:02,399

just turn it on and let people

892

00:33:11,509 --> 00:33:09,029

eric berger with the houston chronicle

893

00:33:13,669 --> 00:33:11,519

um so in a year or two as you sort of

894

00:33:15,750 --> 00:33:13,679

get into the shake out the robot and get

895

00:33:20,950 --> 00:33:15,760

to the experimental phase what

896

00:33:25,669 --> 00:33:23,350

so we've kind of laid out an evolution

897

00:33:28,549 --> 00:33:25,679

where the robot will first

898

00:33:31,509 --> 00:33:28,559

demonstrate its ability to do

899

00:33:34,389 --> 00:33:31,519

tasks with its hands in zero g

900

00:33:37,110 --> 00:33:34,399

for us that will be mission success

901  
00:33:38,870 --> 00:33:37,120  
but for the robot to really be useful it

902  
00:33:39,750 --> 00:33:38,880  
will have to be mobile so they can go

903  
00:33:41,430 --> 00:33:39,760  
around

904  
00:33:43,590 --> 00:33:41,440  
and do work

905  
00:33:45,190 --> 00:33:43,600  
so from a technology standpoint

906  
00:33:47,190 --> 00:33:45,200  
demonstrating the ability to handle all

907  
00:33:50,630 --> 00:33:47,200  
these interfaces in xero g

908  
00:33:52,630 --> 00:33:50,640  
is really our our engineering objective

909  
00:33:54,950 --> 00:33:52,640  
from a practical standpoint

910  
00:33:57,110 --> 00:33:54,960  
having the robot really pay its own way

911  
00:33:58,710 --> 00:33:57,120  
it needs to be mobile so that it can

912  
00:34:01,430 --> 00:33:58,720  
climb around station

913  
00:34:03,669 --> 00:34:01,440

and do work wherever the work is found

914

00:34:06,870 --> 00:34:03,679

so the evolution is uh this year it'll

915

00:34:09,430 --> 00:34:06,880

be mounted fixed on its pedestal

916

00:34:11,270 --> 00:34:09,440

next year we're looking to

917

00:34:13,349 --> 00:34:11,280

send up legs so that it could be

918

00:34:15,750 --> 00:34:13,359

upgraded to go mobile

919

00:34:17,109 --> 00:34:15,760

and we would like the year after that to

920

00:34:19,589 --> 00:34:17,119

send up a

921

00:34:21,109 --> 00:34:19,599

torso upgrade computer upgrade in its

922

00:34:23,589 --> 00:34:21,119

chest

923

00:34:25,750 --> 00:34:23,599

to allow it to go eva

924

00:34:27,750 --> 00:34:25,760

allow it to go outside into the thermal

925

00:34:29,589 --> 00:34:27,760

vacuum environment of space

926

00:34:30,550 --> 00:34:29,599

so that's the the evolution

927

00:34:33,030 --> 00:34:30,560

from a

928

00:34:34,470 --> 00:34:33,040

engineering standpoint the zero-g

929

00:34:37,829 --> 00:34:34,480

manipulation

930

00:34:39,270 --> 00:34:37,839

is really our primary objective

931

00:34:41,270 --> 00:34:39,280

and just a quick follow-up could the

932

00:34:42,950 --> 00:34:41,280

legs and the torso i mean that's a

933

00:34:44,069 --> 00:34:42,960

pretty sizable thing go up on progress

934

00:34:46,230 --> 00:34:44,079

or how would you get that there are a

935

00:34:50,790 --> 00:34:46,240

lot of options we've explored they would

936

00:34:55,990 --> 00:34:53,109

smaller packages we've looked at

937

00:34:57,430 --> 00:34:56,000

progress htv atv and maybe future

938

00:34:59,910 --> 00:34:57,440

commercial

939

00:35:03,270 --> 00:34:59,920

options for launching robonaut parts

940

00:35:05,990 --> 00:35:03,280

upgrade parts in the future

941

00:35:07,190 --> 00:35:06,000

thank you hi uh greg dobbs with hdnet

942

00:35:09,030 --> 00:35:07,200

television

943

00:35:11,510 --> 00:35:09,040

two questions please number one the

944

00:35:12,870 --> 00:35:11,520

long-term task goal she talked about

945

00:35:13,829 --> 00:35:12,880

what it can do and those are really

946

00:35:16,390 --> 00:35:13,839

tests

947

00:35:19,109 --> 00:35:16,400

to utilize it in the station but

948

00:35:21,670 --> 00:35:19,119

deeper into space you said

949

00:35:24,310 --> 00:35:21,680

generally maybe it will enter worlds

950

00:35:26,390 --> 00:35:24,320

that are unexplored before man goes in

951  
00:35:28,069 --> 00:35:26,400  
can you be more elaborate about your

952  
00:35:30,790 --> 00:35:28,079  
long-term goals and long-term

953  
00:35:32,230 --> 00:35:30,800  
capabilities

954  
00:35:34,950 --> 00:35:32,240  
so for robots that are designed to work

955  
00:35:35,829 --> 00:35:34,960  
with humans they're really three phases

956  
00:35:38,069 --> 00:35:35,839  
of

957  
00:35:41,829 --> 00:35:38,079  
exploration the first phase is where the

958  
00:35:44,630 --> 00:35:42,710  
then

959  
00:35:47,750 --> 00:35:44,640  
second phase is while the humans are at

960  
00:35:51,829 --> 00:35:50,069  
the robot's working with humans

961  
00:35:55,030 --> 00:35:51,839  
typically those phases of emission would

962  
00:35:57,510 --> 00:35:55,040  
be short maybe weeks or months

963  
00:35:59,589 --> 00:35:57,520

and then either in between human crews

964

00:36:01,990 --> 00:35:59,599

going back to the same site

965

00:36:05,349 --> 00:36:04,069

where the humans never returned to that

966

00:36:07,030 --> 00:36:05,359

site

967

00:36:09,510 --> 00:36:07,040

in either case the robot would be left

968

00:36:12,230 --> 00:36:09,520

behind as a caretaker

969

00:36:14,470 --> 00:36:12,240

to run longer term experiments

970

00:36:16,470 --> 00:36:14,480

maybe set up by the crew and then tended

971

00:36:18,230 --> 00:36:16,480

by the robot so those are really the

972

00:36:21,750 --> 00:36:18,240

three phases where a robot could help

973

00:36:23,829 --> 00:36:21,760

humans as precursors to human missions

974

00:36:26,870 --> 00:36:23,839

during the human phase of the mission

975

00:36:30,230 --> 00:36:26,880

and then following human phases

976  
00:36:32,230 --> 00:36:30,240  
as caretakers or experiment tenders

977  
00:36:34,550 --> 00:36:32,240  
this robot with

978  
00:36:36,950 --> 00:36:34,560  
different lower bodies is applicable to

979  
00:36:39,510 --> 00:36:36,960  
many destinations

980  
00:36:41,190 --> 00:36:39,520  
we're obviously starting with in space

981  
00:36:44,710 --> 00:36:41,200  
where it's going to be working in a zero

982  
00:36:46,870 --> 00:36:44,720  
g environment zero gravity environment

983  
00:36:48,950 --> 00:36:46,880  
we've been testing them to date in a 1g

984  
00:36:51,349 --> 00:36:48,960  
earth gravity environment

985  
00:36:52,710 --> 00:36:51,359  
so basically any planet with gravity up

986  
00:36:54,630 --> 00:36:52,720  
to earth's

987  
00:36:56,230 --> 00:36:54,640  
we think we can handle

988  
00:36:58,630 --> 00:36:56,240

so that would include

989

00:37:00,150 --> 00:36:58,640

mars and the moon and certainly any

990

00:37:02,470 --> 00:37:00,160

asteroid

991

00:37:04,630 --> 00:37:02,480

the robot is obviously strong enough to

992

00:37:06,790 --> 00:37:04,640

handle objects in one g

993

00:37:08,150 --> 00:37:06,800

and would be quite capable

994

00:37:10,390 --> 00:37:08,160

in 0g

995

00:37:13,589 --> 00:37:10,400

microgravity of an asteroid on the lunar

996

00:37:16,710 --> 00:37:13,599

surface or on the martian surface

997

00:37:18,630 --> 00:37:16,720

so those destinations are are ideal for

998

00:37:20,630 --> 00:37:18,640

this robot based on the way it's been

999

00:37:22,470 --> 00:37:20,640

designed in each case we would probably

1000

00:37:24,230 --> 00:37:22,480

want a different lower body

1001  
00:37:26,470 --> 00:37:24,240  
so again we're more focused on the upper

1002  
00:37:27,750 --> 00:37:26,480  
body the part that does work

1003  
00:37:29,910 --> 00:37:27,760  
and we're looking at different lower

1004  
00:37:33,670 --> 00:37:29,920  
body options that can be used to

1005  
00:37:35,589 --> 00:37:33,680  
customize it to the specific destination

1006  
00:37:37,030 --> 00:37:35,599  
and the question about power it's not

1007  
00:37:38,630 --> 00:37:37,040  
going to have scrambled eggs every

1008  
00:37:40,790 --> 00:37:38,640  
morning

1009  
00:37:43,990 --> 00:37:40,800  
what will power what will recharge it is

1010  
00:37:46,230 --> 00:37:44,000  
it exotic or is it fairly conventional

1011  
00:37:48,550 --> 00:37:46,240  
well at this point it's really simple it

1012  
00:37:50,150 --> 00:37:48,560  
has no stomach

1013  
00:37:52,390 --> 00:37:50,160

it's amazing what a human can do on one

1014

00:37:55,030 --> 00:37:52,400

hershey candy bar right it's a lot of

1015

00:37:57,670 --> 00:37:55,040

energy in that hershey candy bar

1016

00:37:59,030 --> 00:37:57,680

this robot has no battery or storage so

1017

00:38:02,310 --> 00:37:59,040

it's plugged in

1018

00:38:04,470 --> 00:38:02,320

its backpack is an adapter that adapts

1019

00:38:06,069 --> 00:38:04,480

from the station flavor of power

1020

00:38:08,470 --> 00:38:06,079

to all the different voltages and

1021

00:38:10,790 --> 00:38:08,480

currents that the robot needs inside

1022

00:38:12,950 --> 00:38:10,800

to go free climbing we need to swap the

1023

00:38:14,230 --> 00:38:12,960

backpack out with a new backpack that

1024

00:38:15,510 --> 00:38:14,240

would have a battery or some other

1025

00:38:18,470 --> 00:38:15,520

energy source

1026

00:38:20,069 --> 00:38:18,480

that could then go recharge itself

1027

00:38:21,990 --> 00:38:20,079

that would also be the ideal backpack

1028

00:38:23,430 --> 00:38:22,000

for going outside as well

1029

00:38:25,030 --> 00:38:23,440

where it would be able to work for some

1030

00:38:27,670 --> 00:38:25,040

period of time

1031

00:38:30,790 --> 00:38:27,680

unplugged and then get back in time

1032

00:38:32,870 --> 00:38:30,800

to plug itself in and recharge

1033

00:38:35,190 --> 00:38:32,880

if it's plugged into a rover

1034

00:38:36,950 --> 00:38:35,200

it may need no backpack at all if the

1035

00:38:37,750 --> 00:38:36,960

rover is designed to provide just the

1036

00:38:41,030 --> 00:38:37,760

right

1037

00:38:42,950 --> 00:38:41,040

flavor of power to the upper body

1038

00:38:44,390 --> 00:38:42,960

it may need no backpack

1039

00:38:48,790 --> 00:38:44,400

and be able to plug right into the

1040

00:38:51,829 --> 00:38:50,550

hi mark kirkman interspace news i

1041

00:38:52,950 --> 00:38:51,839

actually have a million questions but i

1042

00:38:56,550 --> 00:38:52,960

think brandy's only going to have a

1043

00:38:59,270 --> 00:38:56,560

couple um where on station will r2b

1044

00:39:00,470 --> 00:38:59,280

be located at in the u.s lab in the us

1045

00:39:02,470 --> 00:39:00,480

lab and

1046

00:39:04,390 --> 00:39:02,480

i assume you've tested in the vr lab the

1047

00:39:05,990 --> 00:39:04,400

ability does he have the ability to get

1048

00:39:07,190 --> 00:39:06,000

anywhere on the station using just the

1049

00:39:09,829 --> 00:39:07,200

two arms

1050

00:39:11,109 --> 00:39:09,839

um we're not planning to have it free

1051  
00:39:14,710 --> 00:39:11,119  
climb

1052  
00:39:17,030 --> 00:39:14,720  
uh with just two arms

1053  
00:39:22,150 --> 00:39:17,040  
our plan is to add legs

1054  
00:39:26,950 --> 00:39:24,630  
slow and deliberate manner

1055  
00:39:28,870 --> 00:39:26,960  
the pedestal that you see

1056  
00:39:30,550 --> 00:39:28,880  
over on the display there

1057  
00:39:32,710 --> 00:39:30,560  
is designed to go into the seat track on

1058  
00:39:34,150 --> 00:39:32,720  
the side walls of the space on the space

1059  
00:39:36,310 --> 00:39:34,160  
station lab

1060  
00:39:38,150 --> 00:39:36,320  
well we are thinking and we're open to

1061  
00:39:40,550 --> 00:39:38,160  
ideas but what we're thinking is that

1062  
00:39:42,870 --> 00:39:40,560  
we'll build feet modular feet on these

1063  
00:39:45,109 --> 00:39:42,880

legs that will be able to grip the

1064

00:39:46,710 --> 00:39:45,119

various interfaces that exist

1065

00:39:48,550 --> 00:39:46,720

on the inside of the station

1066

00:39:49,829 --> 00:39:48,560

so if you had two legs

1067

00:39:52,790 --> 00:39:49,839

one could be

1068

00:39:53,910 --> 00:39:52,800

locked in and the other could reach out

1069

00:39:55,109 --> 00:39:53,920

make

1070

00:39:56,790 --> 00:39:55,119

contact

1071

00:39:59,190 --> 00:39:56,800

rigidized and then let go of the other

1072

00:40:02,310 --> 00:39:59,200

one that would free the upper arms as

1073

00:40:04,790 --> 00:40:02,320

it's climbing to be carrying objects

1074

00:40:07,109 --> 00:40:04,800

carrying wet wipes or carrying tools

1075

00:40:09,270 --> 00:40:07,119

as it's climbing around the station

1076

00:40:10,470 --> 00:40:09,280

so it's kind of like rock climbing but

1077

00:40:13,109 --> 00:40:10,480

in rock climbing you're typically

1078

00:40:15,349 --> 00:40:13,119

hanging on your fingers with gravity and

1079

00:40:17,910 --> 00:40:15,359

you're not really making a firm

1080

00:40:19,829 --> 00:40:17,920

rigid interface to the rock you're just

1081

00:40:21,910 --> 00:40:19,839

kind of hanging

1082

00:40:23,190 --> 00:40:21,920

in zero g you have to make a more

1083

00:40:25,349 --> 00:40:23,200

complete

1084

00:40:26,870 --> 00:40:25,359

grasp of the object because there's no

1085

00:40:28,790 --> 00:40:26,880

gravity bias

1086

00:40:29,589 --> 00:40:28,800

so the feet will need to be able to lock

1087

00:40:31,589 --> 00:40:29,599

in

1088

00:40:35,190 --> 00:40:31,599

to those seat tracks to stabilize the

1089

00:40:36,550 --> 00:40:35,200

upper body as it climbs

1090

00:40:38,069 --> 00:40:36,560

and then i guess this will be my last

1091

00:40:39,670 --> 00:40:38,079

one um

1092

00:40:41,430 --> 00:40:39,680

can you elaborate a little bit on how

1093

00:40:43,910 --> 00:40:41,440

those sensors work i mean are they

1094

00:40:45,670 --> 00:40:43,920

specifically force feedback sensors in

1095

00:40:47,430 --> 00:40:45,680

the joints or do you have stuff within

1096

00:40:49,910 --> 00:40:47,440

the skin because it seems like and i

1097

00:40:52,390 --> 00:40:49,920

have jokingly say this you guys have put

1098

00:40:54,150 --> 00:40:52,400

a lot of emphasis on asimov's three laws

1099

00:40:56,710 --> 00:40:54,160

here trying to make sure that there's no

1100

00:40:58,710 --> 00:40:56,720

way that he can he can hurt an astronaut

1101  
00:41:00,069 --> 00:40:58,720  
or vice versa can you explain how those

1102  
00:41:04,069 --> 00:41:00,079  
sensors work with a little more detail

1103  
00:41:07,190 --> 00:41:05,510  
we have a lot of intellectual property

1104  
00:41:09,349 --> 00:41:07,200  
that is coming out on the robot we've

1105  
00:41:10,870 --> 00:41:09,359  
filed over 40 patents and so that will

1106  
00:41:12,470 --> 00:41:10,880  
be coming out and you'll be able to read

1107  
00:41:14,470 --> 00:41:12,480  
about the patents that's the nature of a

1108  
00:41:17,030 --> 00:41:14,480  
patent without giving away any of that

1109  
00:41:18,309 --> 00:41:17,040  
information until the patents are filed

1110  
00:41:20,470 --> 00:41:18,319  
i can tell you that there are hundreds

1111  
00:41:23,109 --> 00:41:20,480  
of sensors in this robot and going back

1112  
00:41:24,630 --> 00:41:23,119  
even to the robonaut one there were 150

1113  
00:41:27,270 --> 00:41:24,640

sensors per limb

1114

00:41:29,270 --> 00:41:27,280

so these are very sensate robots with

1115

00:41:32,150 --> 00:41:29,280

the robonaut one we went through four

1116

00:41:34,390 --> 00:41:32,160

different gloves with all kinds of skin

1117

00:41:36,710 --> 00:41:34,400

embedded tactile sensors

1118

00:41:39,109 --> 00:41:36,720

evolving the glove

1119

00:41:40,950 --> 00:41:39,119

through four generations of gloves

1120

00:41:43,670 --> 00:41:40,960

we experimented with sensors under the

1121

00:41:44,550 --> 00:41:43,680

skin to detect people

1122

00:41:46,710 --> 00:41:44,560

and

1123

00:41:48,870 --> 00:41:46,720

in this design the sensors are more i

1124

00:41:49,829 --> 00:41:48,880

can only say more deep

1125

00:41:51,990 --> 00:41:49,839

that they're

1126  
00:41:54,309 --> 00:41:52,000  
in the core of the machine so we're able

1127  
00:41:55,670 --> 00:41:54,319  
to detect the loads

1128  
00:41:58,550 --> 00:41:55,680  
but yes

1129  
00:42:00,230 --> 00:41:58,560  
sensing is very important to the machine

1130  
00:42:02,390 --> 00:42:00,240  
hundreds of sensors

1131  
00:42:04,950 --> 00:42:02,400  
throughout the whole robot

1132  
00:42:06,950 --> 00:42:04,960  
the control loop rates are

1133  
00:42:09,829 --> 00:42:06,960  
thousands of times a second

1134  
00:42:10,630 --> 00:42:09,839  
monitoring those sensor signals

1135  
00:42:11,829 --> 00:42:10,640  
and

1136  
00:42:14,069 --> 00:42:11,839  
looking for

1137  
00:42:15,430 --> 00:42:14,079  
accidental contact to make the robot

1138  
00:42:17,430 --> 00:42:15,440

safe

1139

00:42:18,550 --> 00:42:17,440

our three levels aren't exactly azimov's

1140

00:42:20,630 --> 00:42:18,560

three laws

1141

00:42:23,670 --> 00:42:20,640

but we think that three-layer safe is

1142

00:42:26,870 --> 00:42:25,270

okay i think next we'll take some

1143

00:42:30,230 --> 00:42:26,880

questions from kennedy space center in

1144

00:42:34,550 --> 00:42:31,990

uh yes hello marcia dumb with the

1145

00:42:37,109 --> 00:42:34,560

associated press um first question i

1146

00:42:39,109 --> 00:42:37,119

have is cost um how much money has gone

1147

00:42:44,069 --> 00:42:39,119

into the robonaut program and how much

1148

00:42:45,990 --> 00:42:44,079

is this individual robot worth by itself

1149

00:42:47,510 --> 00:42:46,000

think that about um

1150

00:42:48,870 --> 00:42:47,520

two and a half million dollars is the

1151  
00:42:50,390 --> 00:42:48,880  
unit cost

1152  
00:42:52,309 --> 00:42:50,400  
i've never had the privilege of building

1153  
00:42:53,910 --> 00:42:52,319  
robots in large quantities like i'm not

1154  
00:42:56,390 --> 00:42:53,920  
an industrial engineer

1155  
00:42:58,870 --> 00:42:56,400  
so i couldn't give you

1156  
00:42:59,750 --> 00:42:58,880  
a better number than that

1157  
00:43:01,750 --> 00:42:59,760  
for the

1158  
00:43:03,589 --> 00:43:01,760  
case where we might make dozens or

1159  
00:43:06,309 --> 00:43:03,599  
hundreds of these robots

1160  
00:43:07,910 --> 00:43:06,319  
but i can tell you when i look at

1161  
00:43:11,589 --> 00:43:07,920  
a robonaut 2

1162  
00:43:13,910 --> 00:43:11,599  
and i look at my family car

1163  
00:43:16,390 --> 00:43:13,920

the robonaut has fewer parts

1164

00:43:18,390 --> 00:43:16,400

it has less material

1165

00:43:20,150 --> 00:43:18,400

and it seems that if you were to make

1166

00:43:21,349 --> 00:43:20,160

robonauts in the same quantities as you

1167

00:43:23,990 --> 00:43:21,359

make that car

1168

00:43:26,069 --> 00:43:24,000

that the robonaut should cost a lot less

1169

00:43:27,349 --> 00:43:26,079

now again i'm not an industrial engineer

1170

00:43:29,670 --> 00:43:27,359

so

1171

00:43:33,349 --> 00:43:29,680

don't take that estimate to the bank

1172

00:43:35,270 --> 00:43:33,359

um but in quantities of one or two

1173

00:43:40,150 --> 00:43:35,280

robonaut 2's cost

1174

00:43:44,550 --> 00:43:42,069

thank you and and another question i

1175

00:43:47,109 --> 00:43:44,560

have is is this the only robonaut that

1176

00:43:48,710 --> 00:43:47,119

will be flying to the space station

1177

00:43:51,270 --> 00:43:48,720

um

1178

00:43:54,950 --> 00:43:51,280

or will you plan to fly another entirety

1179

00:43:56,630 --> 00:43:54,960

to go outside and if this

1180

00:43:58,150 --> 00:43:56,640

robonaut is the only one or there are

1181

00:43:59,990 --> 00:43:58,160

more to follow will they all go down

1182

00:44:01,430 --> 00:44:00,000

with the station eventually or did would

1183

00:44:03,990 --> 00:44:01,440

you might hope to bring them back one

1184

00:44:07,670 --> 00:44:05,510

well so a couple questions there let me

1185

00:44:09,670 --> 00:44:07,680

answer the the first at this point we

1186

00:44:10,790 --> 00:44:09,680

only have plans for this one that we

1187

00:44:13,190 --> 00:44:10,800

will

1188

00:44:15,109 --> 00:44:13,200

look to fly upgrade components to the

1189

00:44:17,510 --> 00:44:15,119

station for example

1190

00:44:19,990 --> 00:44:17,520

giving it legs or a new backpack or a

1191

00:44:22,630 --> 00:44:20,000

new torso computer

1192

00:44:24,550 --> 00:44:22,640

we would love to fly more in the future

1193

00:44:26,230 --> 00:44:24,560

we're looking at all sorts of missions

1194

00:44:27,030 --> 00:44:26,240

beyond low earth orbit

1195

00:44:28,870 --> 00:44:27,040

where

1196

00:44:31,430 --> 00:44:28,880

the dexterous capability of a robonaut

1197

00:44:33,349 --> 00:44:31,440

system might come in quite handy

1198

00:44:34,950 --> 00:44:33,359

the second part of your question was

1199

00:44:36,630 --> 00:44:34,960

will it come home

1200

00:44:38,150 --> 00:44:36,640

at this point we have no plans for

1201

00:44:40,309 --> 00:44:38,160

robonaut 2b

1202

00:44:42,790 --> 00:44:40,319

to come back

1203

00:44:43,990 --> 00:44:42,800

i can't say what the future will hold it

1204

00:44:46,230 --> 00:44:44,000

may you know

1205

00:44:48,150 --> 00:44:46,240

ride the station

1206

00:44:49,670 --> 00:44:48,160

into the pacific

1207

00:44:50,950 --> 00:44:49,680

but we don't know where a station might

1208

00:44:51,750 --> 00:44:50,960

go someday

1209

00:44:52,950 --> 00:44:51,760

so

1210

00:44:54,950 --> 00:44:52,960

uh

1211

00:44:56,309 --> 00:44:54,960

that chapter in robonaut's life has not

1212

00:44:59,030 --> 00:44:56,319

been written yet

1213

00:45:00,950 --> 00:44:59,040

uh we might take the robot

1214

00:45:02,630 --> 00:45:00,960

maybe that same one beyond low earth

1215

00:45:03,910 --> 00:45:02,640

orbit in the future

1216

00:45:06,870 --> 00:45:03,920

it's got to earn its stripes first

1217

00:45:13,109 --> 00:45:09,589

um and and lastly um is there any real

1218

00:45:14,550 --> 00:45:13,119

time control needed of robonaut or is

1219

00:45:17,030 --> 00:45:14,560

this all program

1220

00:45:18,630 --> 00:45:17,040

programmable in other words uh if you

1221

00:45:21,190 --> 00:45:18,640

need the robot to

1222

00:45:23,430 --> 00:45:21,200

wash down the walls or the handrails

1223

00:45:25,589 --> 00:45:23,440

how do you get that in from how do you

1224

00:45:27,589 --> 00:45:25,599

get that command into the robot and how

1225

00:45:30,950 --> 00:45:27,599

much interaction from that point on is

1226  
00:45:32,390 --> 00:45:30,960  
there with any crew or ground member

1227  
00:45:34,230 --> 00:45:32,400  
so when we started working with general

1228  
00:45:35,750 --> 00:45:34,240  
motors we went away from the tel

1229  
00:45:37,109 --> 00:45:35,760  
operation model that we had for the

1230  
00:45:38,230 --> 00:45:37,119  
robonaut one

1231  
00:45:39,829 --> 00:45:38,240  
um for

1232  
00:45:41,109 --> 00:45:39,839  
gm it really didn't make sense to have a

1233  
00:45:43,190 --> 00:45:41,119  
person have to

1234  
00:45:44,309 --> 00:45:43,200  
tell operate the robot doing a task you

1235  
00:45:46,470 --> 00:45:44,319  
know that

1236  
00:45:47,910 --> 00:45:46,480  
wouldn't really buy you anything

1237  
00:45:49,829 --> 00:45:47,920  
so we wanted to build the machine able

1238  
00:45:51,829 --> 00:45:49,839

to do tasks on its own

1239

00:45:53,990 --> 00:45:51,839

so again working with general motors we

1240

00:45:55,589 --> 00:45:54,000

built a really nice interface software

1241

00:45:57,670 --> 00:45:55,599

interface to the robot that is

1242

00:45:59,589 --> 00:45:57,680

essentially script driven now the robot

1243

00:46:02,390 --> 00:45:59,599

itself is very sensate in it's sensing

1244

00:46:04,309 --> 00:46:02,400

forces it's reacting to forces it

1245

00:46:06,150 --> 00:46:04,319

reaches out and grabs objects and it

1246

00:46:09,270 --> 00:46:06,160

feels when it grabs them

1247

00:46:11,510 --> 00:46:09,280

but all of that is automatic

1248

00:46:13,670 --> 00:46:11,520

you start the script

1249

00:46:15,510 --> 00:46:13,680

it reaches till it feels the forces and

1250

00:46:21,270 --> 00:46:15,520

does what it needs to do on its own

1251

00:46:25,510 --> 00:46:22,710

okay i think that's actually about all

1252

00:46:27,349 --> 00:46:25,520

we have time for today we can find out

1253

00:46:29,750 --> 00:46:27,359

more about robonaut online at

1254

00:46:31,589 --> 00:46:29,760

[www.nasa.gov](http://www.nasa.gov)

1255

00:46:33,430 --> 00:46:31,599

robonaut there's a fact sheet there as

1256

00:46:35,190 --> 00:46:33,440

well as videos

1257

00:46:37,030 --> 00:46:35,200

and photos

1258

00:46:38,910 --> 00:46:37,040

coming up next on nasa tv we'll have a

1259

00:46:41,910 --> 00:46:38,920

quick look at some more b-roll for the

1260

00:46:43,510 --> 00:46:41,920

sts-133 mission and then at 2 pm we'll

1261

00:46:46,950 --> 00:46:43,520

wrap up today's pre-flight briefings

1262

00:46:48,630 --> 00:46:46,960

with the sts-133 crew news conference