
NASA
UNITED STATES

1
00:00:03,750 --> 00:00:02,149
go ahead

2
00:00:06,070 --> 00:00:03,760
good afternoon and welcome back to our

3
00:00:07,269 --> 00:00:06,080
astronaut initiative ideas synthesis

4
00:00:09,669 --> 00:00:07,279
workshop

5
00:00:11,749 --> 00:00:09,679
um our session this afternoon is on the

6
00:00:14,070 --> 00:00:11,759
crude mission systems

7
00:00:16,070 --> 00:00:14,080
and we really encourage those out there

8
00:00:17,590 --> 00:00:16,080
to participate you can send your inputs

9
00:00:19,990 --> 00:00:17,600
into twitter

10
00:00:21,990 --> 00:00:20,000
at the hashtag asteroid crew and then

11
00:00:23,670 --> 00:00:22,000
you can follow online as well

12
00:00:25,990 --> 00:00:23,680
at the asteroid initiative and then at

13
00:00:27,589 --> 00:00:26,000

www.nasa.gov

14
00:00:30,310 --> 00:00:27,599
asteroid workshop

15
00:00:31,349 --> 00:00:30,320
i really thank everybody for

16
00:00:33,190 --> 00:00:31,359
making

17
00:00:35,270 --> 00:00:33,200
the presentations available

18
00:00:37,910 --> 00:00:35,280
we had 22 total submittals and we'll

19
00:00:39,030 --> 00:00:37,920
talk about 13 of those today

20
00:00:40,549 --> 00:00:39,040
i'm going to talk a little bit about

21
00:00:42,470 --> 00:00:40,559
what we've been doing

22
00:00:44,869 --> 00:00:42,480
on the nasa side relative to the crude

23
00:00:48,229 --> 00:00:44,879
mission segment before we get started

24
00:00:50,069 --> 00:00:48,239
so uh we've had a team off working

25
00:00:52,389 --> 00:00:50,079
the mission concept for the

26
00:00:54,310 --> 00:00:52,399
redirect crew segment

27
00:00:56,069 --> 00:00:54,320
for about 10 months and that has been a

28
00:00:58,069 --> 00:00:56,079
multi-center team

29
00:01:00,229 --> 00:00:58,079
with participation from the johnson

30
00:01:02,630 --> 00:01:00,239
space center the goddard space flight

31
00:01:04,310 --> 00:01:02,640
center the glenn research center of

32
00:01:06,070 --> 00:01:04,320
kennedy space center

33
00:01:08,149 --> 00:01:06,080
the marshall space flight center and the

34
00:01:10,149 --> 00:01:08,159
langley research center and we've been

35
00:01:11,750 --> 00:01:10,159
focusing on putting together the concept

36
00:01:13,030 --> 00:01:11,760
we're very excited today though to hear

37
00:01:14,950 --> 00:01:13,040
your ideas

38
00:01:17,109 --> 00:01:14,960

i think you've seen the overall mission

39
00:01:18,390 --> 00:01:17,119
concept where we would send orion out to

40
00:01:20,630 --> 00:01:18,400
the asteroid

41
00:01:23,030 --> 00:01:20,640
and we would render with the robotic

42
00:01:24,710 --> 00:01:23,040
asteroid redirect vehicle spacecraft we

43
00:01:26,390 --> 00:01:24,720
would perform two

44
00:01:28,630 --> 00:01:26,400
spacewalks of approximately four hours

45
00:01:30,230 --> 00:01:28,640
in duration with two crew members

46
00:01:32,230 --> 00:01:30,240
we would get the samples as shown in the

47
00:01:33,429 --> 00:01:32,240
lower right hand slide

48
00:01:34,710 --> 00:01:33,439
with the astronauts performing the

49
00:01:36,069 --> 00:01:34,720
spacewalks and then return those in

50
00:01:37,350 --> 00:01:36,079
orion

51
00:01:39,429 --> 00:01:37,360
one of the things we've found as we've

52
00:01:40,710 --> 00:01:39,439
worked through this this mission is

53
00:01:42,230 --> 00:01:40,720
orion is

54
00:01:43,270 --> 00:01:42,240
kind of the perfect vehicle for this

55
00:01:45,990 --> 00:01:43,280
flight

56
00:01:47,590 --> 00:01:46,000
we've uh we've strived to make this a

57
00:01:49,830 --> 00:01:47,600
very affordable mission

58
00:01:52,069 --> 00:01:49,840
and so our approach has been to to

59
00:01:54,710 --> 00:01:52,079
utilize a lot of hardware in existence

60
00:01:56,389 --> 00:01:54,720
which we'll talk a little bit about and

61
00:01:58,389 --> 00:01:56,399
to try to minimize changes to orion

62
00:02:00,870 --> 00:01:58,399
orion is an ongoing program that's under

63
00:02:03,670 --> 00:02:00,880

development but what we found is orion

64
00:02:05,830 --> 00:02:03,680
is very capable even though it wasn't

65
00:02:06,709 --> 00:02:05,840
intended to do spacewalks as its primary

66
00:02:08,389 --> 00:02:06,719
mission

67
00:02:10,150 --> 00:02:08,399
we can actually do spacewalks using

68
00:02:12,309 --> 00:02:10,160
orion as the airlock

69
00:02:13,990 --> 00:02:12,319
we also are trying to minimize changes

70
00:02:15,350 --> 00:02:14,000
to the space launch system which is

71
00:02:18,150 --> 00:02:15,360
under development

72
00:02:19,750 --> 00:02:18,160
and uh it's a perfect vehicle a perfect

73
00:02:21,430 --> 00:02:19,760
rocket to provide

74
00:02:23,430 --> 00:02:21,440
the launch platform for ryan to go to

75
00:02:24,869 --> 00:02:23,440
this distant retrograde orbit meet up

76
00:02:27,110 --> 00:02:24,879
with the asteroid and then execute the

77
00:02:29,270 --> 00:02:27,120
space walks so we've spent a lot of time

78
00:02:30,390 --> 00:02:29,280
as we have developed the mission

79
00:02:33,110 --> 00:02:30,400
uh

80
00:02:35,990 --> 00:02:33,120
striving to be very affordable and using

81
00:02:38,630 --> 00:02:36,000
a very low cost approach and i'll talk a

82
00:02:40,150 --> 00:02:38,640
little bit about that

83
00:02:42,390 --> 00:02:40,160
of course here's the eva scenario you

84
00:02:45,830 --> 00:02:42,400
can see this graphic that shows

85
00:02:48,150 --> 00:02:45,840
uh two astronauts uh working from

86
00:02:51,350 --> 00:02:48,160
one working from a boom platform

87
00:02:53,589 --> 00:02:51,360
to uh to open up the the bag then closes

88
00:02:55,110 --> 00:02:53,599

the asteroid and perform the space walks

89
00:02:57,670 --> 00:02:55,120
and i show this graphic because a lot of

90
00:02:59,830 --> 00:02:57,680
the discussion today will will focus on

91
00:03:02,229 --> 00:02:59,840
on the space walks on the tools on

92
00:03:04,229 --> 00:03:02,239
anchoring techniques on potential

93
00:03:06,149 --> 00:03:04,239
robotic ways that we could execute the

94
00:03:09,990 --> 00:03:06,159
spacewalk and so a lot of the session

95
00:03:15,509 --> 00:03:13,030
here we uh we show some of our concepts

96
00:03:17,350 --> 00:03:15,519
and this shows affordability in terms of

97
00:03:20,149 --> 00:03:17,360
some of the things that we've developed

98
00:03:22,309 --> 00:03:20,159
to execute the space walks

99
00:03:25,509 --> 00:03:22,319
we have four kits that would go into

100
00:03:27,350 --> 00:03:25,519
orion to help augment the capability the

101
00:03:29,910 --> 00:03:27,360
first on the left-hand side of the chart

102
00:03:32,149 --> 00:03:29,920
is the eva servicing and recharge kits

103
00:03:33,670 --> 00:03:32,159
which are the suit itself is to derive

104
00:03:36,470 --> 00:03:33,680
from the shuttle

105
00:03:38,550 --> 00:03:36,480
modified aces but we would use

106
00:03:40,070 --> 00:03:38,560
servicing techniques that we use on

107
00:03:41,430 --> 00:03:40,080
space station today we leverage those

108
00:03:43,110 --> 00:03:41,440
capabilities

109
00:03:44,390 --> 00:03:43,120
to uh to service the suits in between

110
00:03:46,309 --> 00:03:44,400
evas

111
00:03:47,990 --> 00:03:46,319
on the next column you can see some of

112
00:03:49,750 --> 00:03:48,000
the tools that we might use and these

113
00:03:51,589 --> 00:03:49,760

leverage heritage from both shuttle and

114
00:03:52,550 --> 00:03:51,599
space station

115
00:03:54,070 --> 00:03:52,560
and then

116
00:03:55,030 --> 00:03:54,080
our communication plan would leverage a

117
00:03:57,190 --> 00:03:55,040
lot of the

118
00:03:58,710 --> 00:03:57,200
advanced exploration system suit work

119
00:04:00,149 --> 00:03:58,720
that we're doing today

120
00:04:02,149 --> 00:04:00,159
in addition to when we bring the

121
00:04:03,030 --> 00:04:02,159
vehicles together the dock system worked

122
00:04:04,630 --> 00:04:03,040
it's

123
00:04:06,070 --> 00:04:04,640
being developed for the space station

124
00:04:08,149 --> 00:04:06,080
for a commercial crew

125
00:04:10,710 --> 00:04:08,159
and then even in terms of repressing

126
00:04:12,309 --> 00:04:10,720
orion after we depressed the cabin and

127
00:04:14,869 --> 00:04:12,319
executed an eva when we repressed the

128
00:04:16,789 --> 00:04:14,879
cabin we would use a very simple

129
00:04:18,629 --> 00:04:16,799
pressurized container

130
00:04:21,030 --> 00:04:18,639
developed from the shuttle or the space

131
00:04:23,510 --> 00:04:21,040
station nitrogen oxygen recharge a

132
00:04:24,629 --> 00:04:23,520
similar concept to repress the cabin

133
00:04:26,710 --> 00:04:24,639
with air so

134
00:04:29,110 --> 00:04:26,720
we're putting together these very simple

135
00:04:30,710 --> 00:04:29,120
techniques to to do an early mission

136
00:04:31,590 --> 00:04:30,720
with orion

137
00:04:32,950 --> 00:04:31,600
and then

138
00:04:34,469 --> 00:04:32,960

the first part of our session today is

139
00:04:36,629 --> 00:04:34,479
going to focus on

140
00:04:38,469 --> 00:04:36,639
how we feed forward it's very important

141
00:04:40,390 --> 00:04:38,479
as we put this mission together

142
00:04:42,870 --> 00:04:40,400
in an affordable fashion that it leads

143
00:04:44,469 --> 00:04:42,880
to future exploration missions and

144
00:04:47,430 --> 00:04:44,479
we see this mission

145
00:04:49,270 --> 00:04:47,440
in three different dimensions one is

146
00:04:51,510 --> 00:04:49,280
uh maybe in the near term we're going to

147
00:04:53,189 --> 00:04:51,520
continue to work in cis lunar space

148
00:04:55,270 --> 00:04:53,199
with extended duration missions in cis

149
00:04:57,749 --> 00:04:55,280
lunar space you see on the left-hand

150
00:04:59,670 --> 00:04:57,759
side a kind of a notional exploration

151
00:05:01,990 --> 00:04:59,680
augmentation module that we would

152
00:05:03,670 --> 00:05:02,000
fly up after the first mission and could

153
00:05:05,590 --> 00:05:03,680
do extended duration

154
00:05:07,749 --> 00:05:05,600
spacewalks stay at the asteroid a little

155
00:05:09,590 --> 00:05:07,759
longer or do other science

156
00:05:11,670 --> 00:05:09,600
in system or space

157
00:05:12,550 --> 00:05:11,680
the middle graphic shows a potential

158
00:05:14,390 --> 00:05:12,560
path

159
00:05:16,870 --> 00:05:14,400
to uh to spiral down to low little orbit

160
00:05:18,230 --> 00:05:16,880
and do operations in the lunar vicinity

161
00:05:20,390 --> 00:05:18,240
and then of course our ultimate

162
00:05:22,950 --> 00:05:20,400
destination is mars putting together

163
00:05:26,070 --> 00:05:22,960

a combined spacecraft to go

164
00:05:28,629 --> 00:05:26,080
traverse to mars in the 20 30 time frame

165
00:05:31,270 --> 00:05:28,639
so uh with that i think we'll take our

166
00:05:34,950 --> 00:05:31,280
first presenter we'll follow

167
00:05:34,960 --> 00:05:39,830
is it shown here on the charts whoops

168
00:05:46,230 --> 00:05:41,270
somehow we're having a little graphic

169
00:05:50,830 --> 00:05:48,550
so again you can follow along online at

170
00:05:54,629 --> 00:05:50,840
the nasa.gov ashford workshop in the

171
00:05:57,749 --> 00:05:54,639
hashtag and we'll get into our series of

172
00:05:59,749 --> 00:05:57,759
discussions we had 22 rfi outputs again

173
00:06:01,749 --> 00:05:59,759
and we we have 13 today

174
00:06:03,749 --> 00:06:01,759
those were selected for the merits for

175
00:06:05,990 --> 00:06:03,759
this mission extensibility to future

176
00:06:07,189 --> 00:06:06,000
missions which will be the first topic

177
00:06:09,029 --> 00:06:07,199
that we'll cover and then design

178
00:06:11,350 --> 00:06:09,039
maturity

179
00:06:13,350 --> 00:06:11,360
and then our first presenter is from

180
00:06:14,870 --> 00:06:13,360
from the boeing corporation

181
00:06:16,230 --> 00:06:14,880
mike rafferty and he's going to talk a

182
00:06:18,309 --> 00:06:16,240
little bit about an exploration

183
00:06:20,469 --> 00:06:18,319
augmentation module

184
00:06:30,230 --> 00:06:20,479
and how we would use that to augment the

185
00:06:35,510 --> 00:06:32,469
well thank you steve and thanks to the

186
00:06:37,189 --> 00:06:35,520
lpi and to nasa for inviting us to speak

187
00:06:38,469 --> 00:06:37,199
we really appreciate the opportunity to

188
00:06:40,150 --> 00:06:38,479

talk

189
00:06:41,749 --> 00:06:40,160
i'm actually presenting matt duggins

190
00:06:43,909 --> 00:06:41,759
charts matt wasn't able to make it today

191
00:06:45,270 --> 00:06:43,919
so i'm kind of a stand in for matt so

192
00:06:47,510 --> 00:06:45,280
hopefully you'll be

193
00:06:49,110 --> 00:06:47,520
patient with me on questions and details

194
00:06:51,670 --> 00:06:49,120
a little bit

195
00:06:55,029 --> 00:06:51,680
uh what i'm going to talk about today is

196
00:06:57,270 --> 00:06:55,039
an idea for an asteroid exploration

197
00:06:59,189 --> 00:06:57,280
module so this is really directly

198
00:07:02,230 --> 00:06:59,199
addressing extensibility

199
00:07:04,070 --> 00:07:02,240
and the basic idea is

200
00:07:05,830 --> 00:07:04,080
the asteroid mission is really the first

201
00:07:08,230 --> 00:07:05,840
step of many steps that we're going to

202
00:07:09,589 --> 00:07:08,240
take in exploration with mars really

203
00:07:10,870 --> 00:07:09,599
being the ultimate destination that

204
00:07:12,870 --> 00:07:10,880
we're after

205
00:07:14,710 --> 00:07:12,880
the asteroid mission

206
00:07:16,710 --> 00:07:14,720
we want to configure in such a way that

207
00:07:19,749 --> 00:07:16,720
we'll be able to feed forward into the

208
00:07:21,430 --> 00:07:19,759
mars mission as best as possible so

209
00:07:23,189 --> 00:07:21,440
that's really what the whole idea behind

210
00:07:25,589 --> 00:07:23,199
extensibility is about

211
00:07:27,029 --> 00:07:25,599
and so the the idea behind the asteroid

212
00:07:29,110 --> 00:07:27,039
exploration module is that this is

213
00:07:31,749 --> 00:07:29,120

something that will really enhance

214
00:07:33,990 --> 00:07:31,759
the extensibility to

215
00:07:35,749 --> 00:07:34,000
subsequent missions to mars

216
00:07:37,430 --> 00:07:35,759
and other destinations

217
00:07:39,189 --> 00:07:37,440
but it also has direct benefits to the

218
00:07:41,110 --> 00:07:39,199
asteroid mission as well

219
00:07:43,270 --> 00:07:41,120
so i'm going to get into mostly the

220
00:07:44,629 --> 00:07:43,280
benefits to the asteroid mission

221
00:07:46,710 --> 00:07:44,639
maybe if there's time we'll talk a

222
00:07:48,390 --> 00:07:46,720
little bit about more extensibility

223
00:07:51,189 --> 00:07:48,400
benefits as well i'm going to go over

224
00:07:52,469 --> 00:07:51,199
three different concepts

225
00:07:54,390 --> 00:07:52,479
and i'm going to just give you a

226
00:07:56,150 --> 00:07:54,400
highlight of what they are on the next

227
00:07:58,950 --> 00:07:56,160
few pages

228
00:08:02,309 --> 00:07:58,960
but before i do that why focus on this

229
00:08:04,230 --> 00:08:02,319
kind of thing so the basic idea behind

230
00:08:06,070 --> 00:08:04,240
this kind of extensibility is to try to

231
00:08:08,469 --> 00:08:06,080
improve for the asteroid missions try to

232
00:08:09,909 --> 00:08:08,479
improve the safety of the mission

233
00:08:12,230 --> 00:08:09,919
as we all know this is a very

234
00:08:14,790 --> 00:08:12,240
challenging mission it's going to have

235
00:08:16,469 --> 00:08:14,800
very tight timelines on its performance

236
00:08:18,390 --> 00:08:16,479
and execution

237
00:08:20,550 --> 00:08:18,400
the the performance of the vehicles

238
00:08:22,950 --> 00:08:20,560

themselves are very close to what we

239
00:08:26,309 --> 00:08:22,960
need to execute the mission so anything

240
00:08:28,469 --> 00:08:26,319
that we can do to improve those margins

241
00:08:30,150 --> 00:08:28,479
both in terms of time and system

242
00:08:31,909 --> 00:08:30,160
capability are going to improve the

243
00:08:33,110 --> 00:08:31,919
safety for the crew

244
00:08:35,430 --> 00:08:33,120
the second thing they're going to do is

245
00:08:37,269 --> 00:08:35,440
they're going to improve the

246
00:08:39,509 --> 00:08:37,279
probability of mission success the

247
00:08:41,029 --> 00:08:39,519
chance that we're going to be successful

248
00:08:42,630 --> 00:08:41,039
in accomplishing all the objectives of

249
00:08:44,710 --> 00:08:42,640
the mission as well and a lot of that is

250
00:08:49,829 --> 00:08:44,720
done through the addition of

251
00:08:53,430 --> 00:08:49,839
capabilities like airlock capability or

252
00:08:55,509 --> 00:08:53,440
additional supplies additional gas fuel

253
00:08:57,670 --> 00:08:55,519
the ability to maneuver

254
00:09:00,550 --> 00:08:57,680
food and water and and things for the

255
00:09:02,790 --> 00:09:00,560
crew to allow them to stay longer

256
00:09:03,509 --> 00:09:02,800
all these things are very important

257
00:09:04,550 --> 00:09:03,519
for

258
00:09:13,030 --> 00:09:04,560
the

259
00:09:14,310 --> 00:09:13,040
missions is really directly relevant as

260
00:09:15,670 --> 00:09:14,320
well

261
00:09:16,870 --> 00:09:15,680
so what i'm going to do next is just

262
00:09:17,990 --> 00:09:16,880
kind of walk you through each of these

263
00:09:20,230 --> 00:09:18,000

three different options that we've

264
00:09:22,070 --> 00:09:20,240
looked at at boeing

265
00:09:23,190 --> 00:09:22,080
the first one is really an international

266
00:09:24,790 --> 00:09:23,200
option this is something that we've

267
00:09:28,310 --> 00:09:24,800
looked at together with a company called

268
00:09:30,150 --> 00:09:28,320
the nergia in russia and uh they are

269
00:09:31,670 --> 00:09:30,160
experts on spacecraft they were one of

270
00:09:33,430 --> 00:09:31,680
our partners on the international space

271
00:09:35,030 --> 00:09:33,440
station so they have a lot of experience

272
00:09:37,990 --> 00:09:35,040
we have a lot of experience working with

273
00:09:40,470 --> 00:09:38,000
them and this concept that we're showing

274
00:09:42,070 --> 00:09:40,480
here is really a derivative of a new

275
00:09:44,310 --> 00:09:42,080
module that they're working on for space

276
00:09:45,509 --> 00:09:44,320
station called the science power module

277
00:09:48,710 --> 00:09:45,519
spm

278
00:09:50,949 --> 00:09:48,720
so the idea here is to build a version

279
00:09:52,150 --> 00:09:50,959
so we would test the spm first on the

280
00:09:53,670 --> 00:09:52,160
iss

281
00:09:55,350 --> 00:09:53,680
and then we would build a version the

282
00:09:57,110 --> 00:09:55,360
russians would build a version of the

283
00:09:59,030 --> 00:09:57,120
spm that would be geared towards the

284
00:10:01,509 --> 00:09:59,040
asteroid mission and would be used for

285
00:10:03,430 --> 00:10:01,519
that mission specifically

286
00:10:04,389 --> 00:10:03,440
so there's a there's a timing sequence

287
00:10:05,750 --> 00:10:04,399
there

288
00:10:08,069 --> 00:10:05,760

and it would depend on whether the

289
00:10:10,389 --> 00:10:08,079
timing worked out for when

290
00:10:12,949 --> 00:10:10,399
the asteroid mission would be executed

291
00:10:14,389 --> 00:10:12,959
in the relationship with the iss mission

292
00:10:15,509 --> 00:10:14,399
that they already have planned and on

293
00:10:17,590 --> 00:10:15,519
the books

294
00:10:18,790 --> 00:10:17,600
but the basic idea is build another copy

295
00:10:20,870 --> 00:10:18,800
of what they're doing there a few

296
00:10:23,350 --> 00:10:20,880
modifications

297
00:10:24,949 --> 00:10:23,360
to enhance its use on the asteroid

298
00:10:26,470 --> 00:10:24,959
mission

299
00:10:28,949 --> 00:10:26,480
but this would be something that would

300
00:10:30,389 --> 00:10:28,959
require that we have a negotiation in

301
00:10:31,670 --> 00:10:30,399
agreement with the russians that they

302
00:10:33,350 --> 00:10:31,680
would do this

303
00:10:34,949 --> 00:10:33,360
but it would bring international

304
00:10:36,230 --> 00:10:34,959
participation into the program very

305
00:10:38,150 --> 00:10:36,240
important

306
00:10:39,910 --> 00:10:38,160
okay our second option is really based

307
00:10:41,750 --> 00:10:39,920
on equipment that we have this residual

308
00:10:43,509 --> 00:10:41,760
from the space shuttle program so this

309
00:10:46,389 --> 00:10:43,519
is u.s equipment

310
00:10:48,550 --> 00:10:46,399
there's an orbiter airlock that was part

311
00:10:50,069 --> 00:10:48,560
of the shuttle program actually there

312
00:10:52,710 --> 00:10:50,079
were two of them

313
00:10:56,310 --> 00:10:52,720

and we have these uh storage residual

314
00:10:59,990 --> 00:10:56,320
assets at nasa in kennedy space center

315
00:11:01,829 --> 00:11:00,000
and so if you look at the part um

316
00:11:03,030 --> 00:11:01,839
i'm going to test out the little

317
00:11:05,190 --> 00:11:03,040
pointer here

318
00:11:07,030 --> 00:11:05,200
that way that is bright isn't it so this

319
00:11:09,750 --> 00:11:07,040
being the capture spacecraft here and

320
00:11:11,750 --> 00:11:09,760
you can see the asteroid captured here

321
00:11:13,350 --> 00:11:11,760
this is actually the orbiter airlock

322
00:11:15,030 --> 00:11:13,360
here and what we've done is we've

323
00:11:17,350 --> 00:11:15,040
augmented the orbiter airlock with some

324
00:11:20,870 --> 00:11:17,360
additional systems to allow it to be

325
00:11:23,670 --> 00:11:20,880
able to exist in cis lunar space and be

326
00:11:27,670 --> 00:11:25,990
be on its own okay and then it would

327
00:11:29,509 --> 00:11:27,680
have a docking interface that would then

328
00:11:32,069 --> 00:11:29,519
dock to the spacecraft and would dock to

329
00:11:33,590 --> 00:11:32,079
the orion it would allow this to be used

330
00:11:35,190 --> 00:11:33,600
for an airlock

331
00:11:36,870 --> 00:11:35,200
and wood

332
00:11:39,990 --> 00:11:36,880
would be additional capability that we

333
00:11:42,470 --> 00:11:40,000
could store supplies and and relieve the

334
00:11:46,310 --> 00:11:42,480
requirement on the on the orion to have

335
00:11:47,430 --> 00:11:46,320
to do that that uh eva

336
00:11:49,590 --> 00:11:47,440
okay

337
00:11:50,629 --> 00:11:49,600
this the third option that we looked at

338
00:11:52,629 --> 00:11:50,639

also

339
00:11:54,629 --> 00:11:52,639
looks at um

340
00:11:57,430 --> 00:11:54,639
residual acids that we have and there's

341
00:11:59,590 --> 00:11:57,440
actually two variants of this one one is

342
00:12:01,590 --> 00:11:59,600
we use a residual

343
00:12:03,350 --> 00:12:01,600
node asset that we have from the iss

344
00:12:04,389 --> 00:12:03,360
program

345
00:12:06,150 --> 00:12:04,399
another

346
00:12:08,389 --> 00:12:06,160
way to do that would be to have the

347
00:12:10,310 --> 00:12:08,399
italians who built the nodes for the iss

348
00:12:12,790 --> 00:12:10,320
program build a new or lighter one and

349
00:12:14,629 --> 00:12:12,800
the real the trade there is the the one

350
00:12:15,990 --> 00:12:14,639
that we have is a little bit heavier

351
00:12:17,829 --> 00:12:16,000
they could build a newer one but it

352
00:12:20,870 --> 00:12:17,839
costs more money so it's a it's a

353
00:12:23,190 --> 00:12:20,880
capability versus cost kind of a trade

354
00:12:25,430 --> 00:12:23,200
and then we would augment that with a

355
00:12:27,269 --> 00:12:25,440
bus capability that would allow the it's

356
00:12:29,110 --> 00:12:27,279
essentially taking spacecraft systems

357
00:12:30,310 --> 00:12:29,120
and allowed that this node would be able

358
00:12:31,829 --> 00:12:30,320
to operate

359
00:12:35,110 --> 00:12:31,839
so the reason that you want to have

360
00:12:36,470 --> 00:12:35,120
nodes is because for future missions

361
00:12:39,269 --> 00:12:36,480
it's going to be very important to be

362
00:12:41,110 --> 00:12:39,279
able to dock multiple spacecraft to

363
00:12:43,350 --> 00:12:41,120

where where we have the asteroid or

364
00:12:46,949 --> 00:12:43,360
wherever we go to next in our next step

365
00:12:49,269 --> 00:12:47,750
so

366
00:12:50,790 --> 00:12:49,279
i went through the three concepts that

367
00:12:52,069 --> 00:12:50,800
we have at a really high level i know

368
00:12:53,910 --> 00:12:52,079
i'm probably getting a little bit

369
00:12:55,590 --> 00:12:53,920
shorter on time so

370
00:12:56,629 --> 00:12:55,600
what this chart tries to do is really

371
00:12:58,069 --> 00:12:56,639
just go through what are all the

372
00:12:59,750 --> 00:12:58,079
capabilities

373
00:13:01,910 --> 00:12:59,760
that we're looking for

374
00:13:04,790 --> 00:13:01,920
from the mission and

375
00:13:06,790 --> 00:13:04,800
it shows that you can meet most of what

376
00:13:09,030 --> 00:13:06,800
you need with just the orion and you

377
00:13:10,550 --> 00:13:09,040
pick up some really significant ones if

378
00:13:12,310 --> 00:13:10,560
you add

379
00:13:14,230 --> 00:13:12,320
an exploration module so this is really

380
00:13:15,350 --> 00:13:14,240
talking to benefits to the asteroid

381
00:13:16,870 --> 00:13:15,360
mission

382
00:13:19,110 --> 00:13:16,880
but of course one of the primary

383
00:13:21,670 --> 00:13:19,120
benefits is to what comes after the

384
00:13:22,629 --> 00:13:21,680
asteroid mission

385
00:13:24,150 --> 00:13:22,639
and so

386
00:13:26,870 --> 00:13:24,160
in summary

387
00:13:29,110 --> 00:13:26,880
improving safety for the crew

388
00:13:31,670 --> 00:13:29,120

improving success for the mission for

389
00:13:34,310 --> 00:13:31,680
the asteroid mission and then

390
00:13:37,750 --> 00:13:34,320
being able to support uh future missions

391
00:13:41,350 --> 00:13:40,069
so how'd i do on time we've got time for

392
00:13:47,110 --> 00:13:41,360
questions excellent yes we have some

393
00:13:51,670 --> 00:13:49,350
so we uh we do have time for a few

394
00:13:53,509 --> 00:13:51,680
questions if we have any questions uh

395
00:13:54,389 --> 00:13:53,519
virtual questions or questions here in

396
00:13:56,310 --> 00:13:54,399
the room

397
00:13:58,230 --> 00:13:56,320
uh you could address those to mike or

398
00:14:00,790 --> 00:13:58,240
myself or mark mcdonald

399
00:14:04,389 --> 00:14:00,800
who has served as our concept analysis

400
00:14:08,629 --> 00:14:06,389
well i had one question for you mike

401
00:14:10,710 --> 00:14:08,639
so did you uh consider the delivery of

402
00:14:12,949 --> 00:14:10,720
these elements to the dro and if so what

403
00:14:14,949 --> 00:14:12,959
launch vehicle did you assume yes what

404
00:14:17,670 --> 00:14:14,959
we looked at mark is that

405
00:14:19,590 --> 00:14:17,680
these are fairly large elements so sls

406
00:14:20,710 --> 00:14:19,600
would be the logical way to deliver

407
00:14:22,949 --> 00:14:20,720
these

408
00:14:24,470 --> 00:14:22,959
it would be possible maybe to look at

409
00:14:26,470 --> 00:14:24,480
delivery to low earth orbit and then

410
00:14:28,710 --> 00:14:26,480
using some kind of a tug to move but

411
00:14:30,470 --> 00:14:28,720
that's actually probably more expensive

412
00:14:33,509 --> 00:14:30,480
and would take longer

413
00:14:37,990 --> 00:14:33,519

than just a direct injection with sls

414
00:14:42,150 --> 00:14:40,550
any other questions

415
00:14:44,230 --> 00:14:42,160
and for those of you online we hope that

416
00:14:45,670 --> 00:14:44,240
you can submit your questions as well to

417
00:14:47,269 --> 00:14:45,680
our moderator and they will forward

418
00:14:57,269 --> 00:14:47,279
those to us so please participate where

419
00:15:02,069 --> 00:14:59,750
is there a concept of operations for

420
00:15:03,670 --> 00:15:02,079
automatic rendezvous and docking prior

421
00:15:05,750 --> 00:15:03,680
to the orion

422
00:15:07,750 --> 00:15:05,760
actually arriving

423
00:15:09,750 --> 00:15:07,760
the asteroid space sure

424
00:15:11,110 --> 00:15:09,760
yeah michelle i think um that many of

425
00:15:12,389 --> 00:15:11,120
the systems that are going to be needed

426
00:15:14,470 --> 00:15:12,399
for the spacecraft

427
00:15:16,710 --> 00:15:14,480
to rendezvous with the asteroid are the

428
00:15:19,110 --> 00:15:16,720
same kinds of systems that you would

429
00:15:21,110 --> 00:15:19,120
want um to be able to rendezvous between

430
00:15:22,790 --> 00:15:21,120
two spacecraft in fact if you think

431
00:15:24,230 --> 00:15:22,800
about it rendezvous between two

432
00:15:26,069 --> 00:15:24,240
spacecraft is actually a little bit

433
00:15:27,990 --> 00:15:26,079
easier than it is what we're trying to

434
00:15:30,870 --> 00:15:28,000
do with the asteroid mission because the

435
00:15:32,550 --> 00:15:30,880
asteroid mission is a tougher target

436
00:15:34,470 --> 00:15:32,560
whereas two spacecraft we actually

437
00:15:37,110 --> 00:15:34,480
control them both with the asteroid

438
00:15:39,110 --> 00:15:37,120

mission we only control one of them

439
00:15:40,870 --> 00:15:39,120
so we would use the same systems so even

440
00:15:43,030 --> 00:15:40,880
though they're residual hardware you

441
00:15:45,910 --> 00:15:43,040
could outfit with

442
00:15:47,910 --> 00:15:45,920
distance yes yeah we would we would

443
00:15:49,670 --> 00:15:47,920
retrofit there would need to be modif

444
00:15:51,430 --> 00:15:49,680
modifications made to this residual

445
00:15:53,110 --> 00:15:51,440
hardware in any case so yes we'd

446
00:15:55,430 --> 00:15:53,120
retrofit it

447
00:15:57,430 --> 00:15:55,440
so mike i have a question so um it looks

448
00:15:58,949 --> 00:15:57,440
like from your concept you could execute

449
00:15:59,670 --> 00:15:58,959
this in a number of different ways you

450
00:16:02,949 --> 00:15:59,680
could

451
00:16:04,550 --> 00:16:02,959
the reference redirect mission that

452
00:16:05,590 --> 00:16:04,560
we've talked about flying the crew up

453
00:16:08,389 --> 00:16:05,600
first

454
00:16:09,509 --> 00:16:08,399
and then you can fly perhaps this

455
00:16:11,110 --> 00:16:09,519
airlock

456
00:16:13,269 --> 00:16:11,120
tunnel adapter up as a second is that

457
00:16:14,470 --> 00:16:13,279
kind of what yeah i think so steve i

458
00:16:16,150 --> 00:16:14,480
think there are different options for

459
00:16:18,389 --> 00:16:16,160
how the mission could be done you could

460
00:16:20,470 --> 00:16:18,399
separate the launches of these elements

461
00:16:22,389 --> 00:16:20,480
you could even look at launching one of

462
00:16:24,629 --> 00:16:22,399
these elements together with the

463
00:16:26,470 --> 00:16:24,639

asteroid redirect spacecraft if you used

464
00:16:27,749 --> 00:16:26,480
sls because it's large enough to be able

465
00:16:29,269 --> 00:16:27,759
to launch both

466
00:16:31,350 --> 00:16:29,279
probably so

467
00:16:32,710 --> 00:16:31,360
and your your plan would be mike to use

468
00:16:34,790 --> 00:16:32,720
the international docking system

469
00:16:36,470 --> 00:16:34,800
standard just yes sure yeah that's

470
00:16:40,310 --> 00:16:36,480
already in development

471
00:16:44,389 --> 00:16:40,320
for iss and for uh for orion so we would

472
00:16:44,399 --> 00:16:48,230
any other questions before we

473
00:16:55,189 --> 00:16:50,710
okay thanks thanks mike appreciate it

474
00:17:00,389 --> 00:16:57,910
so our uh our next uh presentation is

475
00:17:01,749 --> 00:17:00,399
from douglas ross from lockheed barn

476
00:17:05,029 --> 00:17:01,759
corporation

477
00:17:07,429 --> 00:17:05,039
and doug's presentation uh is going to

478
00:17:09,350 --> 00:17:07,439
talk about an orion mission kit

479
00:17:11,750 --> 00:17:09,360
that consists of a

480
00:17:13,429 --> 00:17:11,760
concept called a pantry module that

481
00:17:16,230 --> 00:17:13,439
and a robotic arm

482
00:17:19,029 --> 00:17:16,240
that they would add to uh to augment the

483
00:17:20,949 --> 00:17:19,039
initial mission concept doug thank you

484
00:17:22,789 --> 00:17:20,959
good afternoon and i appreciate the

485
00:17:24,549 --> 00:17:22,799
opportunity to talk with you

486
00:17:25,829 --> 00:17:24,559
i'm from lockheed martin and we've

487
00:17:28,549 --> 00:17:25,839
looked at a few

488
00:17:30,310 --> 00:17:28,559

options that could either help this

489
00:17:32,549 --> 00:17:30,320
mission or again

490
00:17:38,230 --> 00:17:32,559
help prove out technologies and

491
00:17:42,390 --> 00:17:39,990
as an introduction

492
00:17:45,270 --> 00:17:42,400
both the asteroid retrieval vehicle and

493
00:17:47,350 --> 00:17:45,280
orion will need accommodation for

494
00:17:49,110 --> 00:17:47,360
the human interaction

495
00:17:50,950 --> 00:17:49,120
that will occur

496
00:17:53,029 --> 00:17:50,960
at the asteroid

497
00:17:56,390 --> 00:17:53,039
and so that will need to be factored

498
00:17:59,029 --> 00:17:56,400
into both of those designs of course

499
00:18:00,470 --> 00:17:59,039
the orion mission kit could include a

500
00:18:03,270 --> 00:18:00,480
pantry module

501
00:18:05,350 --> 00:18:03,280
or a robotic arm system or both to help

502
00:18:08,789 --> 00:18:05,360
the exploration

503
00:18:09,750 --> 00:18:08,799
and support mission flexibility

504
00:18:11,830 --> 00:18:09,760
and

505
00:18:13,990 --> 00:18:11,840
finally i'll talk a little bit about the

506
00:18:17,190 --> 00:18:14,000
human friendly features that will likely

507
00:18:19,029 --> 00:18:17,200
need to be incorporated into the arv

508
00:18:21,190 --> 00:18:19,039
in upfront

509
00:18:23,430 --> 00:18:21,200
design and hardware flexibility that

510
00:18:28,150 --> 00:18:23,440
will make that a

511
00:18:32,310 --> 00:18:30,710
first the orion mission kit increased

512
00:18:35,029 --> 00:18:32,320
stowage

513
00:18:36,390 --> 00:18:35,039

we've looked at a few options

514
00:18:38,630 --> 00:18:36,400
that

515
00:18:41,029 --> 00:18:38,640
could allow additional stowage on the

516
00:18:45,350 --> 00:18:41,039
front end of orion and i'll show you one

517
00:18:47,029 --> 00:18:45,360
of those that has been looked at

518
00:18:49,830 --> 00:18:47,039
the redirect mission will require

519
00:18:50,710 --> 00:18:49,840
attachment between orion and arv prior

520
00:18:53,270 --> 00:18:50,720
to

521
00:18:56,310 --> 00:18:53,280
extra vehicular activity

522
00:18:58,549 --> 00:18:56,320
current baseline is the the nds will not

523
00:19:01,669 --> 00:18:58,559
need a pressurized tunnel

524
00:19:03,590 --> 00:19:01,679
the mission may require extra stowage

525
00:19:05,430 --> 00:19:03,600
for the spacewalks

526
00:19:06,710 --> 00:19:05,440
and there are several considerations on

527
00:19:09,750 --> 00:19:06,720
how to do that

528
00:19:11,990 --> 00:19:09,760
the orion launch mass is very important

529
00:19:14,390 --> 00:19:12,000
entry system mass needs to be

530
00:19:17,110 --> 00:19:14,400
within the acceptable range

531
00:19:19,190 --> 00:19:17,120
tool volume pressurized sewage volume

532
00:19:21,270 --> 00:19:19,200
docking requirements sampling plan and

533
00:19:23,029 --> 00:19:21,280
probably several others

534
00:19:24,789 --> 00:19:23,039
lockheed martin has investigated several

535
00:19:27,270 --> 00:19:24,799
variations

536
00:19:30,310 --> 00:19:27,280
both pressurized and unpressurized

537
00:19:32,870 --> 00:19:30,320
one method of accommodation would be

538
00:19:35,270 --> 00:19:32,880

an external stowage module

539
00:19:37,590 --> 00:19:35,280
which would give up to two and a half

540
00:19:39,029 --> 00:19:37,600
cubic meters of space

541
00:19:41,350 --> 00:19:39,039
again could be pressurized or

542
00:19:43,190 --> 00:19:41,360
unpressurized

543
00:19:46,470 --> 00:19:43,200
this would be jettisoned prior to

544
00:19:50,470 --> 00:19:48,630
and

545
00:19:52,710 --> 00:19:50,480
it would attach to the top of the crew

546
00:19:55,590 --> 00:19:52,720
module below the trust and i'll show

547
00:19:59,430 --> 00:19:55,600
that in in the next page here

548
00:20:06,789 --> 00:19:59,440
uses the existing attachment interface

549
00:20:11,990 --> 00:20:09,510
this is what we envisioned

550
00:20:13,750 --> 00:20:12,000
uh it sits right underneath the launch

551
00:20:16,310 --> 00:20:13,760
abort system truss

552
00:20:18,950 --> 00:20:16,320
and during launch it it's attached to

553
00:20:21,190 --> 00:20:18,960
both orion and the truss so that the

554
00:20:26,149 --> 00:20:21,200
abort system could pull it off in the

555
00:20:31,190 --> 00:20:28,549
and i did want to point out that this is

556
00:20:33,990 --> 00:20:31,200
one concept it just shows that the space

557
00:20:38,630 --> 00:20:34,000
is available and there are several

558
00:20:42,230 --> 00:20:40,470
a few features

559
00:20:45,750 --> 00:20:42,240
it would provide

560
00:20:48,070 --> 00:20:45,760
forward mounted storage which would be

561
00:20:52,149 --> 00:20:48,080
very useful and and appropriately placed

562
00:20:55,510 --> 00:20:52,159
for the eva activities

563
00:20:59,750 --> 00:20:55,520

could be pressurized up to 23 cargo

564
00:21:05,110 --> 00:21:02,149
and like i said it would be closer to

565
00:21:09,270 --> 00:21:05,120
the asteroid and if it's unpressurized

566
00:21:10,470 --> 00:21:09,280
it makes it easier to get at those tools

567
00:21:12,789 --> 00:21:10,480
when

568
00:21:15,430 --> 00:21:12,799
if it were used with the orion hatch it

569
00:21:16,390 --> 00:21:15,440
could be open to either the crew cabin

570
00:21:17,669 --> 00:21:16,400
or

571
00:21:19,430 --> 00:21:17,679
as a

572
00:21:26,070 --> 00:21:19,440
or the space so it could be a small

573
00:21:30,630 --> 00:21:27,909
before i leave that

574
00:21:32,630 --> 00:21:30,640
last topic i do want to mention

575
00:21:35,270 --> 00:21:32,640
that the docking

576
00:21:37,590 --> 00:21:35,280
systems could be such that the active

577
00:21:39,669 --> 00:21:37,600
side were on the front of the

578
00:21:42,630 --> 00:21:39,679
of the module

579
00:21:43,510 --> 00:21:42,640
and a passive interface on the aft end

580
00:21:47,430 --> 00:21:43,520
so

581
00:21:49,590 --> 00:21:47,440
after the asteroid activity this module

582
00:21:50,710 --> 00:21:49,600
could be left there at the asteroid for

583
00:21:54,470 --> 00:21:50,720
future

584
00:21:57,510 --> 00:21:54,480
available

585
00:21:59,510 --> 00:21:57,520
the next chart here another potential

586
00:22:01,590 --> 00:21:59,520
for the the orion mission kit is a

587
00:22:03,830 --> 00:22:01,600
robotic manipulator

588
00:22:05,029 --> 00:22:03,840

uh lockheed martin and mcdonald

589
00:22:06,870 --> 00:22:05,039
associates

590
00:22:09,590 --> 00:22:06,880
have collaborated on a few studies in

591
00:22:10,830 --> 00:22:09,600
the past and looked at various

592
00:22:13,510 --> 00:22:10,840
arm

593
00:22:15,990 --> 00:22:13,520
combinations and

594
00:22:17,430 --> 00:22:16,000
there are some possibilities that could

595
00:22:19,430 --> 00:22:17,440
be used here

596
00:22:22,149 --> 00:22:19,440
and they could be mounted either on the

597
00:22:24,549 --> 00:22:22,159
the orion service module or the arv

598
00:22:26,549 --> 00:22:24,559
depending on on what

599
00:22:28,470 --> 00:22:26,559
made the most sense and and gave the

600
00:22:31,830 --> 00:22:28,480
most flexibility and and

601
00:22:34,630 --> 00:22:31,840
essentially had the most mass available

602
00:22:36,549 --> 00:22:34,640
there are some restrictions

603
00:22:38,390 --> 00:22:36,559
of course it could not be mounted to

604
00:22:40,789 --> 00:22:38,400
orion directly

605
00:22:42,549 --> 00:22:40,799
and would have to consider

606
00:22:44,149 --> 00:22:42,559
structural mounting aspects make sure

607
00:22:46,310 --> 00:22:44,159
that it was

608
00:22:47,909 --> 00:22:46,320
it was appropriate for launch loads

609
00:22:53,270 --> 00:22:47,919
and you'll hear more about this in an

610
00:22:57,029 --> 00:22:56,230
for human-friendly arv design

611
00:23:01,110 --> 00:22:57,039
the

612
00:23:03,430 --> 00:23:01,120
asteroid will require handholds

613
00:23:05,830 --> 00:23:03,440

platforms docking grapple points

614
00:23:10,230 --> 00:23:05,840
for the astronauts and we saw some of

615
00:23:11,669 --> 00:23:10,240
that yesterday in in steve stitch's nbl

616
00:23:13,270 --> 00:23:11,679
charts

617
00:23:15,350 --> 00:23:13,280
he showed some of those some of those

618
00:23:17,590 --> 00:23:15,360
ideas in work

619
00:23:19,190 --> 00:23:17,600
design flexibility and simplicity those

620
00:23:21,190 --> 00:23:19,200
will be key

621
00:23:23,909 --> 00:23:21,200
adapt to changing human interaction

622
00:23:27,909 --> 00:23:23,919
requirements both before launch and

623
00:23:31,909 --> 00:23:30,310
if simplicity and flexibility are

624
00:23:32,870 --> 00:23:31,919
designed in upfront

625
00:23:33,750 --> 00:23:32,880
it will

626
00:23:36,870 --> 00:23:33,760
allow

627
00:23:41,269 --> 00:23:36,880
the adaptation of the of the activity

628
00:23:43,990 --> 00:23:41,279
the evas potentially less scripted work

629
00:23:45,830 --> 00:23:44,000
and things can be adjusted

630
00:23:47,990 --> 00:23:45,840
when preempted by new

631
00:23:49,909 --> 00:23:48,000
new priorities

632
00:23:52,070 --> 00:23:49,919
lockheed martin has been fortunate to

633
00:23:55,430 --> 00:23:52,080
work with nasa on several human-rated

634
00:23:58,310 --> 00:23:55,440
mission planning and in crew operations

635
00:23:59,430 --> 00:23:58,320
including hst service missions

636
00:24:01,830 --> 00:23:59,440
eva

637
00:24:05,029 --> 00:24:01,840
operations and tool development for

638
00:24:07,669 --> 00:24:05,039

shuttle and iss operations missions

639
00:24:08,789 --> 00:24:07,679
as well as the orion development

640
00:24:11,190 --> 00:24:08,799
and

641
00:24:12,549 --> 00:24:11,200
refinement of the tool mock-ups

642
00:24:14,950 --> 00:24:12,559
early

643
00:24:19,990 --> 00:24:14,960
will be crucial and i was glad to see

644
00:24:25,350 --> 00:24:22,710
designing for safety and flexibility

645
00:24:28,630 --> 00:24:25,360
of course these will be

646
00:24:31,269 --> 00:24:28,640
crucial for for this mission and arv

647
00:24:33,269 --> 00:24:31,279
will need to be designed so that it's

648
00:24:36,230 --> 00:24:33,279
it's friendly and safe for the

649
00:24:40,789 --> 00:24:38,070
this will of course involve more

650
00:24:42,549 --> 00:24:40,799
rigorous review and procedures

651
00:24:44,230 --> 00:24:42,559
and additional testing

652
00:24:45,990 --> 00:24:44,240
so all of that will need to be factored

653
00:24:51,029 --> 00:24:46,000
in

654
00:24:53,430 --> 00:24:51,039
are shown there

655
00:24:54,310 --> 00:24:53,440
there are key documents out i'm sure

656
00:24:59,750 --> 00:24:54,320
that

657
00:25:01,510 --> 00:24:59,760
all those and those are available

658
00:25:03,750 --> 00:25:01,520
there are many lessons learned on

659
00:25:05,269 --> 00:25:03,760
designing for efficiency human safety

660
00:25:06,950 --> 00:25:05,279
advanced planning operational

661
00:25:09,990 --> 00:25:06,960
flexibility that should be

662
00:25:15,750 --> 00:25:12,789
i believe that a flexible approach

663
00:25:17,110 --> 00:25:15,760

for mass savings will will actually help

664
00:25:19,669 --> 00:25:17,120
this mission

665
00:25:22,310 --> 00:25:19,679
allow for different attach points

666
00:25:23,269 --> 00:25:22,320
different configuration options

667
00:25:25,669 --> 00:25:23,279
and

668
00:25:30,310 --> 00:25:25,679
as things change

669
00:25:34,310 --> 00:25:31,750
in summary

670
00:25:37,029 --> 00:25:34,320
lockheed martin's drawn on many lessons

671
00:25:39,830 --> 00:25:37,039
learned working with nasa

672
00:25:42,789 --> 00:25:39,840
on crude space missions and designing

673
00:25:45,269 --> 00:25:42,799
spacecraft and tools for astronauts

674
00:25:50,149 --> 00:25:45,279
there are several options which can

675
00:25:54,310 --> 00:25:52,470
an adaptable design and mission planning

676
00:25:57,590 --> 00:25:54,320
flexibility i think will be extremely

677
00:25:59,190 --> 00:25:57,600
important for arm as the development

678
00:26:02,390 --> 00:25:59,200
goes forward

679
00:26:05,990 --> 00:26:04,470
will enable several things including

680
00:26:06,710 --> 00:26:06,000
late adjustments

681
00:26:09,909 --> 00:26:06,720
to

682
00:26:12,070 --> 00:26:09,919
nominal and contingency eva plans it

683
00:26:13,269 --> 00:26:12,080
will increase human safety

684
00:26:15,990 --> 00:26:13,279
and allow

685
00:26:19,269 --> 00:26:16,000
potentially greater achievements with

686
00:26:25,269 --> 00:26:20,870
and that's all i have are there any

687
00:26:28,710 --> 00:26:27,029
i have one question well i think we have

688
00:26:32,149 --> 00:26:28,720

a question in the room mark sorry

689
00:26:36,070 --> 00:26:34,070
hi good afternoon just a quick question

690
00:26:38,549 --> 00:26:36,080
on the pantry module

691
00:26:39,909 --> 00:26:38,559
did you say that

692
00:26:43,029 --> 00:26:39,919
that could be either pressurized or

693
00:26:44,789 --> 00:26:43,039
non-pressurized if you leave it behind

694
00:26:47,590 --> 00:26:44,799
it could be

695
00:26:49,510 --> 00:26:47,600
there are options for both and you'd

696
00:26:51,029 --> 00:26:49,520
want to consider

697
00:26:53,430 --> 00:26:51,039
the long-term

698
00:26:54,630 --> 00:26:53,440
plan what you're going to do with it

699
00:26:55,909 --> 00:26:54,640
i would say if you're going to leave it

700
00:26:57,350 --> 00:26:55,919
behind it would probably be

701
00:26:59,430 --> 00:26:57,360
unpressurized

702
00:27:01,029 --> 00:26:59,440
okay so it could be both okay so you'd

703
00:27:04,230 --> 00:27:01,039
have a so you'd have to have some type

704
00:27:07,029 --> 00:27:04,240
of repressurization kit or would you

705
00:27:08,390 --> 00:27:07,039
rely on the orion

706
00:27:11,269 --> 00:27:08,400
yeah i think

707
00:27:15,110 --> 00:27:11,279
options exist for both okay yeah okay

708
00:27:15,120 --> 00:27:19,110
any other questions

709
00:27:22,549 --> 00:27:21,269
but did you have a in your concepts

710
00:27:24,549 --> 00:27:22,559
design did you come up with a mass

711
00:27:26,710 --> 00:27:24,559
estimate for the pantry module and and

712
00:27:28,710 --> 00:27:26,720
if so the estimate the performance of

713
00:27:31,190 --> 00:27:28,720

being able to have orion deliver it does

714
00:27:33,510 --> 00:27:31,200
that work out well i think that would be

715
00:27:35,350 --> 00:27:33,520
a challenge that's a good question the

716
00:27:38,789 --> 00:27:35,360
mass estimate for this particular

717
00:27:41,669 --> 00:27:38,799
concept was in the 300 kilogram range

718
00:27:43,909 --> 00:27:41,679
but i don't believe that accounted for

719
00:27:45,430 --> 00:27:43,919
the docking systems which of course you

720
00:27:46,549 --> 00:27:45,440
would need to add in

721
00:27:48,389 --> 00:27:46,559
and

722
00:27:50,470 --> 00:27:48,399
you wouldn't necessarily need all that

723
00:27:52,310 --> 00:27:50,480
capability that was factored in so it

724
00:27:56,549 --> 00:27:52,320
could could be lighter

725
00:28:03,510 --> 00:27:59,510
about questions uh from online joe yeah

726
00:28:07,590 --> 00:28:05,350
so in your presentation you stated that

727
00:28:09,909 --> 00:28:07,600
the mission does not need a pressurized

728
00:28:10,710 --> 00:28:09,919
tunnel why is that the case

729
00:28:13,110 --> 00:28:10,720
well

730
00:28:16,710 --> 00:28:13,120
it's because the crew does not need to

731
00:28:19,029 --> 00:28:16,720
transfer between orion and the arv

732
00:28:21,909 --> 00:28:19,039
there's nothing for them to go to

733
00:28:23,990 --> 00:28:21,919
it could be pressurized for

734
00:28:25,269 --> 00:28:24,000
easier crew access

735
00:28:29,430 --> 00:28:25,279
internally

736
00:28:33,110 --> 00:28:31,110
let's see doug did you have a did you

737
00:28:35,430 --> 00:28:33,120
have an estimate of how much stowage

738
00:28:37,590 --> 00:28:35,440

capacity in terms of tools and things

739
00:28:40,310 --> 00:28:37,600
like that i mean you had maybe 20

740
00:28:41,590 --> 00:28:40,320
somewhat ctb's but right

741
00:28:43,269 --> 00:28:41,600
did you

742
00:28:45,350 --> 00:28:43,279
scope how many

743
00:28:48,630 --> 00:28:45,360
kilograms of tools

744
00:28:52,470 --> 00:28:48,640
i'm not sure that would probably be more

745
00:28:53,909 --> 00:28:52,480
a driver for the total orion launch mass

746
00:28:56,870 --> 00:28:53,919
would determine that

747
00:29:00,870 --> 00:28:58,149
so we have one more question from the

748
00:29:02,789 --> 00:29:00,880
room speaking of that um i think i saw

749
00:29:04,230 --> 00:29:02,799
the mda presentation you're referring to

750
00:29:05,350 --> 00:29:04,240
this morning

751
00:29:07,190 --> 00:29:05,360
it was

752
00:29:07,990 --> 00:29:07,200
very interesting or is it on the agenda

753
00:29:14,789 --> 00:29:08,000
there

754
00:29:17,750 --> 00:29:14,799
so one this morning that had a robotic

755
00:29:21,110 --> 00:29:17,760
manipulation robotic arm okay it may be

756
00:29:23,269 --> 00:29:21,120
similar and can you speak to stowage

757
00:29:27,269 --> 00:29:23,279
with regard to that

758
00:29:30,710 --> 00:29:27,279
stowage of an arm yeah well

759
00:29:32,870 --> 00:29:30,720
i think it would probably be best

760
00:29:34,870 --> 00:29:32,880
left or held until

761
00:29:38,389 --> 00:29:34,880
the mda presentation but

762
00:29:40,950 --> 00:29:38,399
um if the stowage were on the outside of

763
00:29:43,430 --> 00:29:40,960

the the

764
00:29:45,430 --> 00:29:43,440
orion crew module it would be

765
00:29:46,470 --> 00:29:45,440
probably along the length externally

766
00:29:53,350 --> 00:29:46,480
stowed

767
00:29:59,029 --> 00:29:53,360
in this space as well although it would

768
00:30:03,190 --> 00:30:00,549
see doug i have one more question you

769
00:30:05,430 --> 00:30:03,200
know we've worked pretty hard

770
00:30:07,510 --> 00:30:05,440
with our mission concept to try to

771
00:30:09,110 --> 00:30:07,520
not impact the orion design the

772
00:30:10,149 --> 00:30:09,120
structure

773
00:30:14,070 --> 00:30:10,159
and

774
00:30:17,590 --> 00:30:14,080
have you guys done

775
00:30:20,149 --> 00:30:17,600
a look at is this a big impact

776
00:30:23,190 --> 00:30:20,159
to the structure in terms of

777
00:30:25,510 --> 00:30:23,200
launch loads or any other kind of

778
00:30:27,190 --> 00:30:25,520
mission scenarios in terms of

779
00:30:29,269 --> 00:30:27,200
executing the mission

780
00:30:31,350 --> 00:30:29,279
as far as a pantry module yes to my

781
00:30:33,350 --> 00:30:31,360
knowledge adding a pantry module like

782
00:30:36,470 --> 00:30:33,360
this would not

783
00:30:39,269 --> 00:30:36,480
affect the orion design and that's one

784
00:30:40,470 --> 00:30:39,279
of the the benefits of it the space is

785
00:30:43,350 --> 00:30:40,480
available

786
00:30:44,789 --> 00:30:43,360
and could be used with with minimal to

787
00:30:47,669 --> 00:30:44,799
no impact

788
00:30:51,350 --> 00:30:47,679

okay thank you right

789
00:30:53,029 --> 00:30:51,360
any other questions for doug

790
00:30:58,389 --> 00:30:53,039
thank you very much doug thank you thank

791
00:31:02,470 --> 00:31:00,630
see our next presentation is that

792
00:31:05,110 --> 00:31:02,480
jonathan robel

793
00:31:11,350 --> 00:31:05,120
i believe he's an online presenter uh

794
00:31:11,360 --> 00:31:16,230
we'll try one more time jonathan

795
00:31:21,190 --> 00:31:18,710
how about uh let's we'll move along and

796
00:31:23,430 --> 00:31:21,200
we'll uh we'll pick that back up

797
00:31:26,870 --> 00:31:23,440
a little later in our program

798
00:31:28,710 --> 00:31:26,880
how about uh aaron parness from the john

799
00:31:30,789 --> 00:31:28,720
jeff propulsion lab erin

800
00:31:33,029 --> 00:31:30,799
let's move to that presentation and hey

801
00:31:34,389 --> 00:31:33,039
can you guys hear me oh okay are you

802
00:31:37,990 --> 00:31:34,399
there

803
00:31:40,149 --> 00:31:38,000
yeah sorry sorry about that aaron uh

804
00:31:41,590 --> 00:31:40,159
let's go go ahead jonathan

805
00:31:43,830 --> 00:31:41,600
in your presentation you have two

806
00:31:45,350 --> 00:31:43,840
presentations actually the first

807
00:31:47,350 --> 00:31:45,360
we'll discuss anchoring sample

808
00:31:49,190 --> 00:31:47,360
acquisition and

809
00:31:50,870 --> 00:31:49,200
in-situ resource utilization approaches

810
00:31:52,630 --> 00:31:50,880
for asteroids

811
00:31:54,070 --> 00:31:52,640
and then that's the first presentation

812
00:31:56,389 --> 00:31:54,080
so if you're ready we have the

813
00:31:58,549 --> 00:31:56,399

presentation called up

814
00:32:00,789 --> 00:31:58,559
brilliant thanks

815
00:32:01,909 --> 00:32:00,799
um

816
00:32:04,310 --> 00:32:01,919
sorry i'm just getting a little bit of

817
00:32:05,909 --> 00:32:04,320
feedback here

818
00:32:18,070 --> 00:32:05,919
okay

819
00:32:20,230 --> 00:32:18,080
yeah it is a pleasure uh to be

820
00:32:22,710 --> 00:32:20,240
presenting at the asteroid initiative

821
00:32:25,110 --> 00:32:22,720
idea synthesis workshop as you said i'm

822
00:32:27,590 --> 00:32:25,120
dr jonathan robel a senior research

823
00:32:29,430 --> 00:32:27,600
scientist at honeybee robotics

824
00:32:31,669 --> 00:32:29,440
and our flight systems group located in

825
00:32:33,669 --> 00:32:31,679
longmont colorado

826
00:32:36,149 --> 00:32:33,679
today i'll be presenting as you said on

827
00:32:39,909 --> 00:32:36,159
honeybee robotics technologies for crew

828
00:32:40,630 --> 00:32:39,919
systems for asteroid exploration

829
00:32:42,389 --> 00:32:40,640
and

830
00:32:43,669 --> 00:32:42,399
as i'm presenting remotely again please

831
00:32:45,269 --> 00:32:43,679
let me know if the audio is coming

832
00:32:46,789 --> 00:32:45,279
through clearly

833
00:32:49,029 --> 00:32:46,799
as the schedule has me down for two

834
00:32:51,029 --> 00:32:49,039
sequential talks on cruise systems i'll

835
00:32:52,389 --> 00:32:51,039
be rolling that into one that covers

836
00:32:58,789 --> 00:32:52,399
both anchoring

837
00:33:01,669 --> 00:32:59,830
no

838
00:33:03,269 --> 00:33:01,679

all right

839
00:33:05,509 --> 00:33:03,279
so before i begin i'd like to provide a

840
00:33:08,950 --> 00:33:05,519
bit of background on honeybee robotics

841
00:33:11,029 --> 00:33:08,960
founded in 1983 by steve gorvin and

842
00:33:13,430 --> 00:33:11,039
chris chapman honeybee robotics

843
00:33:15,509 --> 00:33:13,440
spacecraft mechanisms corporation is a

844
00:33:17,669 --> 00:33:15,519
privately owned small business committed

845
00:33:19,830 --> 00:33:17,679
to developing high reliability

846
00:33:21,990 --> 00:33:19,840
mechanical and electromechanical systems

847
00:33:22,789 --> 00:33:22,000
for the us government as well as long

848
00:33:24,870 --> 00:33:22,799
run

849
00:33:27,269 --> 00:33:24,880
sorry as well as our for the private

850
00:33:29,669 --> 00:33:27,279
aerospace and space texas

851
00:33:31,669 --> 00:33:29,679
we have offices in pasadena california

852
00:33:36,950 --> 00:33:31,679
longmont colorado

853
00:33:36,960 --> 00:33:40,950
wow bad feedback

854
00:33:44,549 --> 00:33:42,389
we are celebrating 30 years of

855
00:33:48,470 --> 00:33:44,559
developing space systems and this has

856
00:33:50,310 --> 00:33:48,480
included a number of nasa missions 2003

857
00:33:53,350 --> 00:33:50,320
mars exploration rover where we worked

858
00:33:56,470 --> 00:33:53,360
on the rock abrasion tool 2007 mars

859
00:33:58,310 --> 00:33:56,480
phoenix lander working on the tega

860
00:33:59,190 --> 00:33:58,320
dust cover and icy soil acquisition

861
00:34:02,149 --> 00:33:59,200
device

862
00:34:03,990 --> 00:34:02,159
2011 mars science laboratory a robotic

863
00:34:05,430 --> 00:34:04,000

sample manipulation system as well as

864
00:34:07,509 --> 00:34:05,440
the dust removal

865
00:34:09,750 --> 00:34:07,519
tool and defector

866
00:34:11,750 --> 00:34:09,760
we currently have six gadgets on mars

867
00:34:14,470 --> 00:34:11,760
and have successfully completed over 300

868
00:34:16,069 --> 00:34:14,480
excavations on the martian surface

869
00:34:18,550 --> 00:34:16,079
we believe this work is helping pave the

870
00:34:21,030 --> 00:34:18,560
way for human exploration of mars and we

871
00:34:23,990 --> 00:34:21,040
hope to support both robotic and human

872
00:34:31,990 --> 00:34:24,000
exploration of asteroids

873
00:34:35,990 --> 00:34:33,750
at this workshop honeybee is presenting

874
00:34:38,389 --> 00:34:36,000
a number of topic areas uh including

875
00:34:40,310 --> 00:34:38,399
topic two asteroid redirection systems

876
00:34:43,190 --> 00:34:40,320
topic three asteroid deflection

877
00:34:45,270 --> 00:34:43,200
demonstration topic four asteroid

878
00:34:47,109 --> 00:34:45,280
uh capture systems and topic five

879
00:34:51,030 --> 00:34:47,119
pre-systems for asteroid exploration and

880
00:34:53,829 --> 00:34:52,470
partnerships

881
00:34:56,950 --> 00:34:53,839
so

882
00:34:59,510 --> 00:34:56,960
technologies in these other topic areas

883
00:35:02,150 --> 00:34:59,520
but focus on topic five for this session

884
00:35:03,670 --> 00:35:02,160
crew systems for asteroid exploration

885
00:35:05,589 --> 00:35:03,680
many of these technologies can see dual

886
00:35:06,950 --> 00:35:05,599
purpose which is why i'm going this

887
00:35:08,550 --> 00:35:06,960
route

888
00:35:10,150 --> 00:35:08,560

the way we see our technologies they

889
00:35:11,750 --> 00:35:10,160
enable us to interact with the asteroid

890
00:35:14,390 --> 00:35:11,760
in different ways from helping us to

891
00:35:16,069 --> 00:35:14,400
better see it if you will to touching it

892
00:35:26,150 --> 00:35:16,079
and anchoring with it

893
00:35:30,310 --> 00:35:27,829
oops sorry

894
00:35:32,710 --> 00:35:30,320
flying through this thing

895
00:35:35,589 --> 00:35:32,720
the controls

896
00:35:37,670 --> 00:35:35,599
so in regards to seeing

897
00:35:39,109 --> 00:35:37,680
the asteroid

898
00:35:41,349 --> 00:35:39,119
we have developed laser induced

899
00:35:43,750 --> 00:35:41,359
breakdown spectroscopy instrumentation

900
00:35:44,390 --> 00:35:43,760
as well as 3d lidar well the focus of

901
00:35:47,109 --> 00:35:44,400
this

902
00:35:49,109 --> 00:35:47,119
of the application for these was proc

903
00:35:51,109 --> 00:35:49,119
out proxops and

904
00:35:53,270 --> 00:35:51,119
acquisition of composition information

905
00:35:55,030 --> 00:35:53,280
prior to engaging the asteroid

906
00:35:56,470 --> 00:35:55,040
we believe that a portable lid system

907
00:35:58,630 --> 00:35:56,480
can be very useful

908
00:36:00,790 --> 00:35:58,640
tool as a handheld or crew deployed

909
00:36:02,630 --> 00:36:00,800
system

910
00:36:05,349 --> 00:36:02,640
when exploring the surface

911
00:36:07,990 --> 00:36:05,359
libs works by using a laser to vaporize

912
00:36:10,630 --> 00:36:08,000
and ionize surface material and when the

913
00:36:12,230 --> 00:36:10,640

plasma puff that you create cools and

914
00:36:13,990 --> 00:36:12,240
recombines it will emit a spectrum

915
00:36:15,750 --> 00:36:14,000
reflecting its composition

916
00:36:17,670 --> 00:36:15,760
this allows identification of surface

917
00:36:20,230 --> 00:36:17,680
materials without collecting them in

918
00:36:21,990 --> 00:36:20,240
this way astronauts can identify

919
00:36:24,829 --> 00:36:22,000
and selectively collect materials from

920
00:36:31,510 --> 00:36:29,430
surface uh we also been working um

921
00:36:33,910 --> 00:36:31,520
on technologies for impacting uh the

922
00:36:36,230 --> 00:36:33,920
asteroid well not a crew system directly

923
00:36:37,990 --> 00:36:36,240
impact our technology would be useful

924
00:36:39,910 --> 00:36:38,000
uh prior to engaging with the asteroid

925
00:36:41,430 --> 00:36:39,920
for determining its composition

926
00:36:43,829 --> 00:36:41,440
furthermore it may provide a fresh

927
00:36:51,190 --> 00:36:43,839
crater for crews to explore and expose

928
00:36:51,200 --> 00:36:58,069
and in regards to touching the asteroid

929
00:37:03,510 --> 00:36:59,670
we

930
00:37:05,349 --> 00:37:03,520
originally designed for a touch and go

931
00:37:07,349 --> 00:37:05,359
surface sampler

932
00:37:08,790 --> 00:37:07,359
with a drill and sample collection unit

933
00:37:11,270 --> 00:37:08,800
would be lowered by tethers of the

934
00:37:13,030 --> 00:37:11,280
asteroid surface these can also serve as

935
00:37:15,190 --> 00:37:13,040
crew operated tools

936
00:37:17,750 --> 00:37:15,200
much work will have to go to tailoring

937
00:37:19,270 --> 00:37:17,760
the sample collection instruments

938
00:37:20,630 --> 00:37:19,280

to the expected surface type and

939
00:37:22,390 --> 00:37:20,640
composition

940
00:37:24,310 --> 00:37:22,400
or alternatively the crew will be could

941
00:37:26,150 --> 00:37:24,320
be outfitted with a quiver of tools to

942
00:37:28,390 --> 00:37:26,160
cover a wide array of sample collection

943
00:37:31,109 --> 00:37:28,400
environments so pairing that quiver of

944
00:37:33,670 --> 00:37:31,119
tools with a libs instrument or other

945
00:37:36,310 --> 00:37:33,680
rock identification system can help

946
00:37:40,950 --> 00:37:36,320
astronauts select the correct tool for

947
00:37:45,030 --> 00:37:43,430
honeybee has also done work

948
00:37:47,190 --> 00:37:45,040
for harpoon sampling and another

949
00:37:49,270 --> 00:37:47,200
technology it's another technology

950
00:37:51,270 --> 00:37:49,280
worked on for robotic sample acquisition

951
00:37:53,750 --> 00:37:51,280
the arp probe

952
00:37:55,349 --> 00:37:53,760
which would bring a sample back to an

953
00:37:57,270 --> 00:37:55,359
orbiting spacecraft providing

954
00:38:00,230 --> 00:37:57,280
composition information before the

955
00:38:02,150 --> 00:38:00,240
parent craft engages the asteroid

956
00:38:05,670 --> 00:38:02,160
this harpoon and drilling technology

957
00:38:09,589 --> 00:38:05,680
leads us to one of honeybees strengths

958
00:38:13,829 --> 00:38:11,349
honeybee robotics has a long history

959
00:38:14,870 --> 00:38:13,839
with robotic drilling and sample

960
00:38:16,150 --> 00:38:14,880
collection

961
00:38:18,230 --> 00:38:16,160
a number of our technologies are

962
00:38:20,310 --> 00:38:18,240
suitable to the crew systems aspect of

963
00:38:23,270 --> 00:38:20,320

the asteroid initiative these include

964
00:38:24,310 --> 00:38:23,280
the pneumatic approaches to sample

965
00:38:26,150 --> 00:38:24,320
collection

966
00:38:27,510 --> 00:38:26,160
which is a robust method for sample

967
00:38:28,630 --> 00:38:27,520
collection

968
00:38:30,150 --> 00:38:28,640
and

969
00:38:32,710 --> 00:38:30,160
as well as mobile institute water

970
00:38:34,630 --> 00:38:32,720
extractor system which will allow the

971
00:38:36,310 --> 00:38:34,640
selective collection of water focusing

972
00:38:38,310 --> 00:38:36,320
on drills

973
00:38:41,030 --> 00:38:38,320
numerous robotic and handheld drills

974
00:38:42,790 --> 00:38:41,040
support the many tasks astronauts

975
00:38:44,710 --> 00:38:42,800
will need to do

976
00:38:46,310 --> 00:38:44,720
on the surface drilling is often the

977
00:38:48,230 --> 00:38:46,320
method of choice for penetrating hard

978
00:38:50,630 --> 00:38:48,240
rocks and in a vast majority of

979
00:38:51,910 --> 00:38:50,640
applications drilling employs turning of

980
00:38:53,910 --> 00:38:51,920
a hardened bit

981
00:38:55,829 --> 00:38:53,920
forced into the rock abrading small

982
00:38:58,230 --> 00:38:55,839
particles once the drill bit becomes

983
00:39:00,069 --> 00:38:58,240
dull however the rate at which the drill

984
00:39:01,829 --> 00:39:00,079
bit penetrates the rock drops

985
00:39:03,589 --> 00:39:01,839
dramatically unless an ever increasing

986
00:39:05,430 --> 00:39:03,599
downward force

987
00:39:07,670 --> 00:39:05,440
in the case of vertical drilling

988
00:39:09,349 --> 00:39:07,680

is applied and that's creating higher

989
00:39:11,589 --> 00:39:09,359
and higher frictional heat the amount of

990
00:39:13,349 --> 00:39:11,599
this downward force is referred to as

991
00:39:15,430 --> 00:39:13,359
weight on bit

992
00:39:17,910 --> 00:39:15,440
and in a low gravity environment weight

993
00:39:19,190 --> 00:39:17,920
on bit can be severely limited

994
00:39:21,829 --> 00:39:19,200
and must be provided by either

995
00:39:24,230 --> 00:39:21,839
spacecraft thrusters or an anchored base

996
00:39:25,910 --> 00:39:24,240
for the drill to push or rather pull

997
00:39:28,310 --> 00:39:25,920
against

998
00:39:30,069 --> 00:39:28,320
rotary percussive drilling action can be

999
00:39:32,790 --> 00:39:30,079
employed to circumvent the need for

1000
00:39:33,589 --> 00:39:32,800
prohibitively high weight on bit

1001
00:39:35,670 --> 00:39:33,599
and

1002
00:39:37,990 --> 00:39:35,680
progressive or hammer systems while they

1003
00:39:40,230 --> 00:39:38,000
consume more power reduce the required

1004
00:39:42,950 --> 00:39:40,240
weight on bit by an order of magnitude

1005
00:39:44,310 --> 00:39:42,960
especially in hard rocks honeybee has

1006
00:39:45,750 --> 00:39:44,320
extensive experience with both

1007
00:39:47,430 --> 00:39:45,760
approaches

1008
00:39:49,670 --> 00:39:47,440
now the feasibility of drilling into

1009
00:39:51,829 --> 00:39:49,680
small bodies with low weight on bit

1010
00:39:53,589 --> 00:39:51,839
has been tested using relevant analog

1011
00:39:55,990 --> 00:39:53,599
rocks as stand-ins for the likely

1012
00:39:57,430 --> 00:39:56,000
asteroid surface materials

1013
00:39:59,030 --> 00:39:57,440

such testing demonstrates the

1014
00:40:01,109 --> 00:39:59,040
feasibility of drilling into a small

1015
00:40:02,230 --> 00:40:01,119
body with low weight on bit but it's

1016
00:40:04,950 --> 00:40:02,240
dependent on the strength of the

1017
00:40:07,030 --> 00:40:04,960
materials comprised in the small body

1018
00:40:09,270 --> 00:40:07,040
drilling in low strength materials such

1019
00:40:11,030 --> 00:40:09,280
as plaster or limestone is feasible

1020
00:40:13,510 --> 00:40:11,040
using a commercial valve commercially

1021
00:40:15,829 --> 00:40:13,520
available drill with a 1.6 millimeter

1022
00:40:17,829 --> 00:40:15,839
diameter bit with as little as 5

1023
00:40:19,030 --> 00:40:17,839
newton's weight on bit plaster and

1024
00:40:21,349 --> 00:40:19,040
limestone

1025
00:40:23,670 --> 00:40:21,359
have an unconfined compressive strength

1026
00:40:25,030 --> 00:40:23,680
of 8 megapascals and 40 megapascals

1027
00:40:27,030 --> 00:40:25,040
respectively which would be

1028
00:40:28,150 --> 00:40:27,040
representative of materials of a c-type

1029
00:40:31,510 --> 00:40:28,160
asteroid

1030
00:40:32,470 --> 00:40:31,520
however higher strength materials

1031
00:40:34,710 --> 00:40:32,480
such as those that would be

1032
00:40:36,150 --> 00:40:34,720
representative of an s-type asteroid

1033
00:40:40,470 --> 00:40:36,160
cannot be drilled under those same

1034
00:40:42,630 --> 00:40:40,480
conditions for instance 120 megapascal

1035
00:40:45,030 --> 00:40:42,640
basalt is representative of the upper

1036
00:40:46,790 --> 00:40:45,040
range of an s-type asteroid

1037
00:40:48,390 --> 00:40:46,800
and cannot be penetrated with low weight

1038
00:40:50,630 --> 00:40:48,400

on bit this is not to say that it's

1039
00:40:52,069 --> 00:40:50,640
infeasible to drill an s-type asteroid

1040
00:40:53,589 --> 00:40:52,079
but it does indicate that the drilling

1041
00:40:54,790 --> 00:40:53,599
system must be designed with the target

1042
00:40:55,829 --> 00:40:54,800
material

1043
00:40:57,750 --> 00:40:55,839
in mind

1044
00:41:04,069 --> 00:40:57,760
have sufficient anchoring and should be

1045
00:41:07,750 --> 00:41:05,990
we've also done work what we call

1046
00:41:10,150 --> 00:41:07,760
inhaling it

1047
00:41:13,349 --> 00:41:10,160
many terrestrial applications

1048
00:41:14,790 --> 00:41:13,359
use vacuum cleaners for picking up dirt

1049
00:41:16,150 --> 00:41:14,800
and collecting

1050
00:41:18,150 --> 00:41:16,160
material

1051
00:41:19,589 --> 00:41:18,160
the principle here lies in creating a

1052
00:41:21,589 --> 00:41:19,599
lower pressure at the back end of a

1053
00:41:23,349 --> 00:41:21,599
pickup hose and at the front and thereby

1054
00:41:25,589 --> 00:41:23,359
forcing the outside air to flow in and

1055
00:41:27,190 --> 00:41:25,599
lost particles along the way

1056
00:41:29,270 --> 00:41:27,200
now such a system will not work in the

1057
00:41:31,670 --> 00:41:29,280
vacuum space however one can create a

1058
00:41:33,510 --> 00:41:31,680
differential pressure by injecting gas

1059
00:41:35,829 --> 00:41:33,520
into the regolith and then guiding those

1060
00:41:38,390 --> 00:41:35,839
gas as it escapes from the regulate

1061
00:41:40,150 --> 00:41:38,400
into appropriate pickup tubes

1062
00:41:41,670 --> 00:41:40,160
as shown left we rely on injecting

1063
00:41:43,589 --> 00:41:41,680

pressurized gas into the top two

1064
00:41:45,430 --> 00:41:43,599
centimeters of regolith and then capture

1065
00:41:47,910 --> 00:41:45,440
the regolith propelled upwards by the

1066
00:41:50,710 --> 00:41:47,920
escaping gas into a transfer tube

1067
00:41:52,790 --> 00:41:50,720
pneumatic approach can be ideally

1068
00:41:54,630 --> 00:41:52,800
suited for obtaining both small and

1069
00:41:55,910 --> 00:41:54,640
small small samples for scientific

1070
00:41:58,230 --> 00:41:55,920
analysis

1071
00:42:00,150 --> 00:41:58,240
as well as bulk samples for mining or

1072
00:42:02,309 --> 00:42:00,160
processing of resources

1073
00:42:04,630 --> 00:42:02,319
and the working gas could be supplied by

1074
00:42:07,109 --> 00:42:04,640
electrolyzing water into hydrogen oxygen

1075
00:42:08,390 --> 00:42:07,119
so not incurring the mass burden for

1076
00:42:10,150 --> 00:42:08,400
launch

1077
00:42:12,790 --> 00:42:10,160
for bulk regulate

1078
00:42:15,109 --> 00:42:12,800
mining a potential approach might be

1079
00:42:16,950 --> 00:42:15,119
to use a system that has been

1080
00:42:17,910 --> 00:42:16,960
initially developed for lunar regolith

1081
00:42:20,069 --> 00:42:17,920
mining

1082
00:42:22,309 --> 00:42:20,079
the pneumatic regolith miner is a

1083
00:42:23,990 --> 00:42:22,319
similar to a conventional vacuum cleaner

1084
00:42:25,750 --> 00:42:24,000
however instead of creating suction at

1085
00:42:28,230 --> 00:42:25,760
the nozzle mouth a compressed gas is

1086
00:42:30,390 --> 00:42:28,240
injected again and moves the captured

1087
00:42:32,230 --> 00:42:30,400
soil in the nozzle up the tube

1088
00:42:33,430 --> 00:42:32,240

through the cyclone separator into a

1089
00:42:36,069 --> 00:42:33,440
soil bin

1090
00:42:38,150 --> 00:42:36,079
shown right is a pneumatic excavator

1091
00:42:40,950 --> 00:42:38,160
integrated into the nasa ames research

1092
00:42:42,790 --> 00:42:40,960
center k10 mini platform

1093
00:42:44,870 --> 00:42:42,800
a system has been successfully tested in

1094
00:42:48,230 --> 00:42:44,880
a three meter long bed filled with a

1095
00:42:49,990 --> 00:42:48,240
grc-1 soil simulant within a 3.5 meter

1096
00:42:52,710 --> 00:42:50,000
vacuum chamber

1097
00:42:53,750 --> 00:42:52,720
we think that this could be a very

1098
00:42:55,270 --> 00:42:53,760
useful

1099
00:42:57,349 --> 00:42:55,280
tool in the

1100
00:42:58,870 --> 00:42:57,359
cruise quiver as they

1101
00:43:02,470 --> 00:42:58,880
touch down on the surface and try to

1102
00:43:06,550 --> 00:43:05,030
honeybees also done work

1103
00:43:09,670 --> 00:43:06,560
snare

1104
00:43:10,790 --> 00:43:09,680
items

1105
00:43:12,630 --> 00:43:10,800
this has been

1106
00:43:14,950 --> 00:43:12,640
mostly focused in grappling with

1107
00:43:18,550 --> 00:43:14,960
spacecraft in orbit

1108
00:43:21,510 --> 00:43:20,390
or

1109
00:43:22,630 --> 00:43:21,520
satellite

1110
00:43:25,109 --> 00:43:22,640
deorbit

1111
00:43:27,270 --> 00:43:25,119
and our lasso technology can be used to

1112
00:43:30,150 --> 00:43:27,280
either anchor to protrusions on the

1113
00:43:31,990 --> 00:43:30,160

surface that are near part that are

1114
00:43:34,630 --> 00:43:32,000
maybe part of a much larger boulder or

1115
00:43:36,309 --> 00:43:34,640
the bulk of the asteroid

1116
00:43:37,430 --> 00:43:36,319
much like slinging a horn when rock

1117
00:43:39,109 --> 00:43:37,440
climbing

1118
00:43:40,950 --> 00:43:39,119
and in this case the technology can be

1119
00:43:42,150 --> 00:43:40,960
used for either crew or spacecraft

1120
00:43:43,990 --> 00:43:42,160
anchoring

1121
00:43:44,870 --> 00:43:44,000
basically what you have is a lasso as

1122
00:43:47,750 --> 00:43:44,880
the name

1123
00:43:49,990 --> 00:43:47,760
implies that cinches down

1124
00:43:51,750 --> 00:43:50,000
on a protrusion protruding rocker in

1125
00:43:53,430 --> 00:43:51,760
this case in the series of images that

1126
00:43:54,790 --> 00:43:53,440
would be the

1127
00:43:56,390 --> 00:43:54,800
thruster

1128
00:43:59,829 --> 00:43:56,400
cone the bell

1129
00:44:04,710 --> 00:44:01,910
now as i mentioned earlier it's

1130
00:44:07,349 --> 00:44:04,720
important to be able to

1131
00:44:09,270 --> 00:44:07,359
produce downward forces weight on bit

1132
00:44:11,109 --> 00:44:09,280
and other

1133
00:44:12,630 --> 00:44:11,119
downward forces and honeybee robotics is

1134
00:44:14,470 --> 00:44:12,640
a number of technologies to support the

1135
00:44:16,470 --> 00:44:14,480
ability of astronauts

1136
00:44:18,550 --> 00:44:16,480
to explore the surface of a captured

1137
00:44:20,630 --> 00:44:18,560
asteroid prospect for resources and

1138
00:44:22,790 --> 00:44:20,640

samples and this micro and gravity

1139
00:44:25,670 --> 00:44:22,800
microgravity environment anchoring their

1140
00:44:26,710 --> 00:44:25,680
astronauts and equipment is crucial

1141
00:44:28,710 --> 00:44:26,720
and

1142
00:44:30,630 --> 00:44:28,720
honeybee has a long history of anchoring

1143
00:44:33,270 --> 00:44:30,640
and has developed a number of approaches

1144
00:44:35,190 --> 00:44:33,280
including hard rock drilling

1145
00:44:37,190 --> 00:44:35,200
and hammering for setting anchors and

1146
00:44:39,430 --> 00:44:37,200
we've done preliminary feasibility tests

1147
00:44:42,069 --> 00:44:39,440
yielding interesting results

1148
00:44:44,470 --> 00:44:42,079
testing was performed with a 3.8

1149
00:44:46,790 --> 00:44:44,480
millimeter nail and traditional hammer

1150
00:44:49,670 --> 00:44:46,800
as well as an off-the-shelf nail gun on

1151
00:44:50,710 --> 00:44:49,680
eight megapascal plaster 40 megapascal

1152
00:44:53,430 --> 00:44:50,720
limestone

1153
00:44:55,670 --> 00:44:53,440
as well as 120 megapascal basalt so

1154
00:44:57,589 --> 00:44:55,680
capturing the cns type

1155
00:44:59,990 --> 00:44:57,599
asteroids

1156
00:45:01,510 --> 00:45:00,000
the nail did not penetrate the base salt

1157
00:45:03,270 --> 00:45:01,520
or limestone but managed to penetrate

1158
00:45:05,430 --> 00:45:03,280
plaster which we would expect and the

1159
00:45:06,870 --> 00:45:05,440
nail gun however on the other hand

1160
00:45:09,109 --> 00:45:06,880
was powerful enough to drive a short

1161
00:45:10,630 --> 00:45:09,119
nail into all three rock types now this

1162
00:45:12,950 --> 00:45:10,640
type of research is made possible by

1163
00:45:15,270 --> 00:45:12,960

honeybees test facilities in pasadena

1164
00:45:17,750 --> 00:45:15,280
where a large library of rock samples

1165
00:45:19,270 --> 00:45:17,760
allows testing of drills and anchoring

1166
00:45:21,349 --> 00:45:19,280
schemes

1167
00:45:23,109 --> 00:45:21,359
in a variety of configurations and with

1168
00:45:24,950 --> 00:45:23,119
a lot of instrumentation

1169
00:45:27,190 --> 00:45:24,960
now honeybee has also worked on fluid

1170
00:45:29,510 --> 00:45:27,200
anchors that allows anchoring to

1171
00:45:31,589 --> 00:45:29,520
featured surfaces with the benefit that

1172
00:45:32,950 --> 00:45:31,599
the anchor deployment does not exert any

1173
00:45:35,030 --> 00:45:32,960
force

1174
00:45:38,150 --> 00:45:35,040
that would be required it would require

1175
00:45:40,950 --> 00:45:38,160
a reaction by the spacecraft

1176
00:45:43,030 --> 00:45:40,960
or the crew in the fluid anchor approach

1177
00:45:45,670 --> 00:45:43,040
a wetting fluid such as foam cement

1178
00:45:47,910 --> 00:45:45,680
epoxy is injected onto a surface or into

1179
00:45:49,670 --> 00:45:47,920
the soil by a hollow spike beneath the

1180
00:45:51,430 --> 00:45:49,680
foot pad

1181
00:45:53,030 --> 00:45:51,440
and if applied to the surface the goal

1182
00:45:54,950 --> 00:45:53,040
of the fluid anchor is to inject an

1183
00:45:57,109 --> 00:45:54,960
adhesive cushion between the rock

1184
00:45:58,710 --> 00:45:57,119
surface and the spacecraft footbed or

1185
00:46:01,270 --> 00:45:58,720
crew anchor pad

1186
00:46:02,230 --> 00:46:01,280
and in turn provide an anchor uh once it

1187
00:46:03,990 --> 00:46:02,240
sets

1188
00:46:05,750 --> 00:46:04,000

if injected into the ground the fluid

1189
00:46:07,990 --> 00:46:05,760
would go deeper into the loose gravel or

1190
00:46:11,030 --> 00:46:08,000
soil allowing the anchor to

1191
00:46:13,270 --> 00:46:11,040
gauge a large larger volume of asteroid

1192
00:46:15,349 --> 00:46:13,280
material forming a composite footing

1193
00:46:17,190 --> 00:46:15,359
glue mixed with soil or gravel

1194
00:46:19,750 --> 00:46:17,200
the self-opposing multi-mode anchor

1195
00:46:21,270 --> 00:46:19,760
which is shown on this slide

1196
00:46:22,710 --> 00:46:21,280
allows payloads and equipment to be

1197
00:46:25,910 --> 00:46:22,720
securely anchored to the surface with

1198
00:46:30,550 --> 00:46:25,920
minimal applied force mostly using the

1199
00:46:33,829 --> 00:46:32,390
so we've presented a number of

1200
00:46:35,910 --> 00:46:33,839
technologies that we think will be

1201
00:46:36,950 --> 00:46:35,920
enabling for our cruise systems to

1202
00:46:38,630 --> 00:46:36,960
explore

1203
00:46:41,109 --> 00:46:38,640
the asteroid and

1204
00:46:42,390 --> 00:46:41,119
interact with it and as well a large

1205
00:46:43,910 --> 00:46:42,400
goal of asteroid initiative is to

1206
00:46:45,270 --> 00:46:43,920
capture and return an asteroid to the

1207
00:46:46,790 --> 00:46:45,280
earth facility

1208
00:46:49,589 --> 00:46:46,800
with their extensive background in

1209
00:46:51,270 --> 00:46:49,599
spacecraft mechanism and mechatronics

1210
00:46:53,990 --> 00:46:51,280
honeybee robotics is also excited to

1211
00:46:55,510 --> 00:46:54,000
support the direct capture phase

1212
00:46:57,030 --> 00:46:55,520
with that i'd like to conclude my talk

1213
00:46:59,510 --> 00:46:57,040

and open it for questions unless they're

1214
00:47:00,790 --> 00:46:59,520
being held to the end of the session and

1215
00:47:02,150 --> 00:47:00,800
i also encourage you to visit our

1216
00:47:04,309 --> 00:47:02,160
website listed at the bottom of this

1217
00:47:06,550 --> 00:47:04,319
page to further explore

1218
00:47:09,990 --> 00:47:06,560
any of our technologies and to contact

1219
00:47:11,190 --> 00:47:10,000
us thank you

1220
00:47:14,470 --> 00:47:11,200
there any questions in the room or

1221
00:47:18,470 --> 00:47:16,550
it's very hard to see with the light so

1222
00:47:19,750 --> 00:47:18,480
i did have one question for you

1223
00:47:21,829 --> 00:47:19,760
on your

1224
00:47:24,870 --> 00:47:21,839
pneumatic drill where you use the the

1225
00:47:25,990 --> 00:47:24,880
vacuum technology to to capture the the

1226
00:47:27,670 --> 00:47:26,000
dust

1227
00:47:30,309 --> 00:47:27,680
how much does a tool like that weigh and

1228
00:47:31,910 --> 00:47:30,319
how big is it

1229
00:47:33,670 --> 00:47:31,920
i knew i'd get a question that was going

1230
00:47:34,790 --> 00:47:33,680
to be a mess

1231
00:47:36,470 --> 00:47:34,800
and

1232
00:47:38,870 --> 00:47:36,480
the thought i had on that is it's really

1233
00:47:41,109 --> 00:47:38,880
going to depend on the application

1234
00:47:43,349 --> 00:47:41,119
like i said

1235
00:47:46,230 --> 00:47:43,359
what you're going to be drilling into

1236
00:47:48,150 --> 00:47:46,240
how you're going to be anchoring in

1237
00:47:50,230 --> 00:47:48,160
and then of course what you drill into

1238
00:47:51,430 --> 00:47:50,240

determines what material it is you're

1239
00:47:54,069 --> 00:47:51,440
collecting

1240
00:47:56,390 --> 00:47:54,079
so i unfortunately i'd say probably the

1241
00:47:59,030 --> 00:47:56,400
best answer to that is a parametric

1242
00:47:59,910 --> 00:47:59,040
study but

1243
00:48:05,349 --> 00:47:59,920
if you

1244
00:48:07,829 --> 00:48:05,359
scenario

1245
00:48:10,069 --> 00:48:07,839
i'll let you off the hook thank you much

1246
00:48:12,710 --> 00:48:10,079
you're welcome let's see joe do we have

1247
00:48:14,630 --> 00:48:12,720
any uh any questions virtual questions

1248
00:48:16,230 --> 00:48:14,640
on this present

1249
00:48:18,870 --> 00:48:16,240
well let's see i i have a question

1250
00:48:22,390 --> 00:48:18,880
jonathan i'm i'm intrigued by uh

1251
00:48:23,270 --> 00:48:22,400
by yourself opposing multi-mode anchor

1252
00:48:25,109 --> 00:48:23,280
and

1253
00:48:27,670 --> 00:48:25,119
you know there's a lot of debate

1254
00:48:30,390 --> 00:48:27,680
as to the consistency of an asteroid

1255
00:48:31,910 --> 00:48:30,400
uh ranging from a solid

1256
00:48:33,270 --> 00:48:31,920
rock material

1257
00:48:35,109 --> 00:48:33,280
to um

1258
00:48:37,670 --> 00:48:35,119
what's kind of called as a rubble pile

1259
00:48:40,950 --> 00:48:37,680
or almost a sand pile

1260
00:48:42,309 --> 00:48:40,960
or some theories are some asteroids may

1261
00:48:45,030 --> 00:48:42,319
be almost like a

1262
00:48:47,270 --> 00:48:45,040
dried mud like consistency

1263
00:48:49,190 --> 00:48:47,280

how do you envision the anchoring system

1264
00:48:53,109 --> 00:48:49,200
working in a variety of

1265
00:48:57,270 --> 00:48:55,589
well i think it depends how the the

1266
00:48:59,109 --> 00:48:57,280
mission evolves

1267
00:49:00,710 --> 00:48:59,119
and what asteroids targeted my

1268
00:49:02,309 --> 00:49:00,720
understanding

1269
00:49:03,589 --> 00:49:02,319
is that as you move towards the larger

1270
00:49:06,710 --> 00:49:03,599
asteroids

1271
00:49:09,030 --> 00:49:06,720
uh with the lower spin rates

1272
00:49:12,470 --> 00:49:09,040
the chances are you're counting

1273
00:49:14,390 --> 00:49:12,480
encountering a rubble pile um

1274
00:49:17,589 --> 00:49:14,400
there's the smaller ones and faster spin

1275
00:49:20,870 --> 00:49:17,599
rates should likely fly apart

1276
00:49:22,390 --> 00:49:20,880
so i think as the i think is the uh

1277
00:49:24,630 --> 00:49:22,400
the mission evolves

1278
00:49:27,990 --> 00:49:24,640
you would hopefully have some ability to

1279
00:49:29,589 --> 00:49:28,000
tailor the um

1280
00:49:31,670 --> 00:49:29,599
teller the anchoring approach to what

1281
00:49:33,510 --> 00:49:31,680
you expect to find or

1282
00:49:36,710 --> 00:49:33,520
as i've mentioned earlier for the crew

1283
00:49:40,309 --> 00:49:38,870
you kind of bring with you a quiver of

1284
00:49:43,270 --> 00:49:40,319
tools so

1285
00:49:44,870 --> 00:49:43,280
maybe if this opposing anchor

1286
00:49:47,990 --> 00:49:44,880
comes into

1287
00:49:50,150 --> 00:49:48,000
contact with a very

1288
00:49:52,790 --> 00:49:50,160

well consolidated or let's say solid

1289
00:49:55,270 --> 00:49:52,800
surface that's really not amenable to

1290
00:49:57,829 --> 00:49:55,280
just kind of sticking a shovel into it

1291
00:49:59,670 --> 00:49:57,839
and slowly you know a pick into it and

1292
00:50:01,990 --> 00:49:59,680
slowly anchoring in

1293
00:50:04,230 --> 00:50:02,000
maybe you can use a foaming anchor you

1294
00:50:06,870 --> 00:50:04,240
know a liquid anchor

1295
00:50:09,030 --> 00:50:06,880
in conjunction

1296
00:50:10,630 --> 00:50:09,040
so the idea would be to create something

1297
00:50:13,109 --> 00:50:10,640
that overlaps enough where you don't

1298
00:50:17,670 --> 00:50:13,119
have any holes in your

1299
00:50:23,270 --> 00:50:19,510
okay thanks uh thanks jonathan and i

1300
00:50:26,150 --> 00:50:23,280
think we do have uh one online question

1301
00:50:28,710 --> 00:50:26,160
when wendy or joe

1302
00:50:34,630 --> 00:50:31,990
yes um so the question is

1303
00:50:36,710 --> 00:50:34,640
since most asteroid capture systems have

1304
00:50:38,069 --> 00:50:36,720
a centralized hub

1305
00:50:40,710 --> 00:50:38,079
have you given any thought to how you

1306
00:50:42,150 --> 00:50:40,720
might sample the rock from that point

1307
00:50:46,790 --> 00:50:42,160
and then make that accessible to the

1308
00:50:51,109 --> 00:50:48,710
i think that that could

1309
00:50:52,390 --> 00:50:51,119
leverage some of the i guess marsupial

1310
00:50:55,270 --> 00:50:52,400
designs

1311
00:50:58,230 --> 00:50:55,280
where we um

1312
00:50:59,190 --> 00:50:58,240
had done work with this smaller craft

1313
00:51:02,069 --> 00:50:59,200

that would

1314
00:51:04,309 --> 00:51:02,079
fly ahead to uh

1315
00:51:06,710 --> 00:51:04,319
the asteroid surface to give composition

1316
00:51:09,670 --> 00:51:06,720
information ahead of the

1317
00:51:12,470 --> 00:51:09,680
bulk interaction and so

1318
00:51:14,790 --> 00:51:12,480
i think you could probably adapt those

1319
00:51:20,790 --> 00:51:16,630
ferrying

1320
00:51:24,790 --> 00:51:22,630
okay okay thanks jonathan

1321
00:51:31,190 --> 00:51:24,800
any other questions okay you're welcome

1322
00:51:35,510 --> 00:51:33,910
so our next presentation is from aaron

1323
00:51:38,069 --> 00:51:35,520
harness

1324
00:51:41,030 --> 00:51:38,079
from the jet propulsion lab

1325
00:51:43,670 --> 00:51:41,040
and aaron's presentation will discuss

1326
00:51:46,710 --> 00:51:43,680
self-anchoring microgravity

1327
00:51:49,030 --> 00:51:46,720
thrill for use to sample the asteroid

1328
00:51:51,349 --> 00:51:49,040
erin

1329
00:51:53,190 --> 00:51:51,359
yeah thank you very much uh i actually

1330
00:51:54,470 --> 00:51:53,200
also have back-to-back uh brief

1331
00:51:57,670 --> 00:51:54,480
presentations

1332
00:52:00,230 --> 00:51:57,680
uh the first one is more on a short-term

1333
00:52:03,670 --> 00:52:00,240
uh development project it's a tool that

1334
00:52:05,190 --> 00:52:03,680
might be used uh eva uh during the crude

1335
00:52:06,870 --> 00:52:05,200
portion of the mission

1336
00:52:08,950 --> 00:52:06,880
you can see a prototype of that tool

1337
00:52:12,069 --> 00:52:08,960
here it's a coring drill

1338
00:52:13,349 --> 00:52:12,079

and it uses an anchor to uh latch onto

1339
00:52:14,950 --> 00:52:13,359
the rock to

1340
00:52:16,710 --> 00:52:14,960
address the the problems we were just

1341
00:52:19,030 --> 00:52:16,720
hearing about in the prior presentation

1342
00:52:20,870 --> 00:52:19,040
of of that weight on bit

1343
00:52:22,390 --> 00:52:20,880
since it's very difficult to test in

1344
00:52:24,390 --> 00:52:22,400
zero gravity here on the surface of the

1345
00:52:26,950 --> 00:52:24,400
earth we test it in these different

1346
00:52:29,270 --> 00:52:26,960
configurations to try and cancel out the

1347
00:52:31,030 --> 00:52:29,280
effects of gravity so it's supporting

1348
00:52:33,430 --> 00:52:31,040
itself upside down there drilling into

1349
00:52:35,349 --> 00:52:33,440
the ceiling on the vertical wall where

1350
00:52:38,069 --> 00:52:35,359
we lift the rock up off the floor and

1351
00:52:40,069 --> 00:52:38,079
then drill into it

1352
00:52:42,470 --> 00:52:40,079
so to elaborate on the problem this is

1353
00:52:43,910 --> 00:52:42,480
itecawa that you see so there are big

1354
00:52:45,190 --> 00:52:43,920
rocks there that you might want to

1355
00:52:47,030 --> 00:52:45,200
sample from

1356
00:52:49,349 --> 00:52:47,040
but if you're using a typical drill like

1357
00:52:51,270 --> 00:52:49,359
the one on the curiosity rover you need

1358
00:52:53,990 --> 00:52:51,280
50 to 100 newtons

1359
00:52:56,230 --> 00:52:54,000
of force into that rock

1360
00:52:57,750 --> 00:52:56,240
and on a surface like irakawa where

1361
00:52:59,430 --> 00:52:57,760
there's so little gravity that means you

1362
00:53:01,750 --> 00:52:59,440
would have to land over a million

1363
00:53:03,750 --> 00:53:01,760

kilograms to react that force just with

1364
00:53:04,870 --> 00:53:03,760
gravity so we've got to come up with

1365
00:53:06,390 --> 00:53:04,880
another way

1366
00:53:08,069 --> 00:53:06,400
the problem gets worse if you've got an

1367
00:53:09,990 --> 00:53:08,079
astronaut who's pulling the trigger on

1368
00:53:12,150 --> 00:53:10,000
the drill you really don't want him to

1369
00:53:14,309 --> 00:53:12,160
start spinning around the drill bit

1370
00:53:16,470 --> 00:53:14,319
which is just as likely in zero gravity

1371
00:53:17,670 --> 00:53:16,480
as as the drill is to spin in the

1372
00:53:19,430 --> 00:53:17,680
borehole

1373
00:53:21,589 --> 00:53:19,440
so our approach is similar we're gonna

1374
00:53:24,230 --> 00:53:21,599
we're gonna anchor to the surface that

1375
00:53:26,630 --> 00:53:24,240
we want to sample from uh this is a free

1376
00:53:28,710 --> 00:53:26,640
body diagram of our gripper

1377
00:53:30,710 --> 00:53:28,720
it shows some some claws that are

1378
00:53:32,950 --> 00:53:30,720
grappling the surface of that rock and

1379
00:53:35,829 --> 00:53:32,960
that's what uh

1380
00:53:38,309 --> 00:53:35,839
redirects the forces and torques of the

1381
00:53:39,510 --> 00:53:38,319
sample back into the surface so you can

1382
00:53:41,109 --> 00:53:39,520
literally

1383
00:53:43,270 --> 00:53:41,119
push the button on this drill and tell

1384
00:53:46,069 --> 00:53:43,280
it to go and it's hands free all the

1385
00:53:47,990 --> 00:53:46,079
forces are closed loop in that in that

1386
00:53:50,309 --> 00:53:48,000
rock

1387
00:53:53,030 --> 00:53:50,319
so the way we do our anchoring uh is

1388
00:53:54,790 --> 00:53:53,040

using technology called micro spines was

1389
00:53:56,630 --> 00:53:54,800
originally developed for wall climbing

1390
00:53:59,589 --> 00:53:56,640
robots and we've been working to adapt

1391
00:54:01,750 --> 00:53:59,599
it for microgravity it's a sharp hook as

1392
00:54:03,829 --> 00:54:01,760
you can see in the lower left picture

1393
00:54:05,910 --> 00:54:03,839
that's embedded inside some kind of

1394
00:54:08,829 --> 00:54:05,920
frame with a compliant mechanism behind

1395
00:54:11,430 --> 00:54:08,839
it so it's basically a lot of claws on

1396
00:54:12,790 --> 00:54:11,440
springs and we use these in big arrays

1397
00:54:15,349 --> 00:54:12,800
so the gripper i'm going to show you in

1398
00:54:18,790 --> 00:54:15,359
a minute has 250 of these

1399
00:54:20,549 --> 00:54:18,800
distributed in a circle around the drill

1400
00:54:22,549 --> 00:54:20,559
our path to flight design which is shown

1401
00:54:24,710 --> 00:54:22,559
on the right there doesn't use any

1402
00:54:27,030 --> 00:54:24,720
rubber materials it's an all metal

1403
00:54:29,190 --> 00:54:27,040
design so it uses extension springs

1404
00:54:30,630 --> 00:54:29,200
instead of these flexures

1405
00:54:33,750 --> 00:54:30,640
in order to grip the surface and there

1406
00:54:36,150 --> 00:54:33,760
it is holding 30 pounds uh in a vertical

1407
00:54:38,470 --> 00:54:36,160
orientation on that's basalt vesicular

1408
00:54:41,030 --> 00:54:38,480
basalt

1409
00:54:44,230 --> 00:54:41,040
so you can see hopefully uh online as

1410
00:54:46,710 --> 00:54:44,240
well this movie of of one of these toes

1411
00:54:47,910 --> 00:54:46,720
gripping they're opportunistic so you

1412
00:54:50,230 --> 00:54:47,920
don't have to predict where the

1413
00:54:53,349 --> 00:54:50,240

roughness is on the surface you just put

1414
00:54:55,190 --> 00:54:53,359
them all down and and tell it to squeeze

1415
00:54:57,430 --> 00:54:55,200
and as they drag along the surface you

1416
00:54:59,829 --> 00:54:57,440
get a few of them to catch so in that

1417
00:55:02,710 --> 00:54:59,839
way it's also probabilistic in that you

1418
00:55:04,789 --> 00:55:02,720
don't need every single hook to catch in

1419
00:55:08,870 --> 00:55:04,799
fact with about 10 percent of the toes

1420
00:55:10,789 --> 00:55:08,880
engaging we can support 100 newtons

1421
00:55:12,710 --> 00:55:10,799
and most of the rocks i think all the

1422
00:55:13,910 --> 00:55:12,720
rocks we anticipate seeing are going to

1423
00:55:15,670 --> 00:55:13,920
be rough

1424
00:55:18,150 --> 00:55:15,680
the smooth rocks we see on earth are

1425
00:55:21,030 --> 00:55:18,160
usually processed by liquid water

1426
00:55:22,630 --> 00:55:21,040
either in a river or through glacial uh

1427
00:55:25,349 --> 00:55:22,640
sort of movements if we found very

1428
00:55:28,230 --> 00:55:25,359
smooth rocks that would be a remarkable

1429
00:55:31,349 --> 00:55:28,240
thing in and of itself

1430
00:55:33,030 --> 00:55:31,359
so here's a video um let's see

1431
00:55:39,990 --> 00:55:33,040
oh

1432
00:55:44,950 --> 00:55:42,710
there we go here it's going

1433
00:55:46,630 --> 00:55:44,960
so this is a video again the drill is

1434
00:55:47,589 --> 00:55:46,640
supporting its own weight so it's got

1435
00:55:49,589 --> 00:55:47,599
about

1436
00:55:52,069 --> 00:55:49,599
i think it's 3 kilograms in this

1437
00:55:54,710 --> 00:55:52,079
configuration plus the weight on bit

1438
00:55:57,589 --> 00:55:54,720

which in this case is 50 70 newtons or

1439
00:55:59,990 --> 00:55:57,599
so that is a basalt that's a vesicular

1440
00:56:02,470 --> 00:56:00,000
basalt that we're drilling into

1441
00:56:05,030 --> 00:56:02,480
it's a rotary percussive drill we

1442
00:56:07,109 --> 00:56:05,040
actually just took a bosch hammer drill

1443
00:56:09,030 --> 00:56:07,119
and hacked it apart and put our own

1444
00:56:11,109 --> 00:56:09,040
motor controllers on there

1445
00:56:12,390 --> 00:56:11,119
as a proof of concept

1446
00:56:15,030 --> 00:56:12,400
the depth at which you're going to be

1447
00:56:16,390 --> 00:56:15,040
able to drill and the the the width of

1448
00:56:18,069 --> 00:56:16,400
your borehole is going to be just

1449
00:56:19,430 --> 00:56:18,079
dependent on the power

1450
00:56:22,630 --> 00:56:19,440
and the length of travel that you want

1451
00:56:24,150 --> 00:56:22,640
to put into the mechanism

1452
00:56:26,150 --> 00:56:24,160
and you can see this is sped up about

1453
00:56:29,750 --> 00:56:26,160
eight times but we progress at about one

1454
00:56:32,950 --> 00:56:29,760
inch per minute in this type of basalt

1455
00:56:34,950 --> 00:56:32,960
using a typical carbide bit

1456
00:56:36,150 --> 00:56:34,960
so it's a coring bit so

1457
00:56:38,549 --> 00:56:36,160
that's the whole point you get to

1458
00:56:40,710 --> 00:56:38,559
collect a sample you can see one of the

1459
00:56:42,230 --> 00:56:40,720
instances of our sample i'm sorry i

1460
00:56:43,990 --> 00:56:42,240
should have a scale bar on there that's

1461
00:56:59,349 --> 00:56:44,000
a

1462
00:57:01,510 --> 00:56:59,359
puts in

1463
00:57:04,309 --> 00:57:01,520

these clips on their way up the the wall

1464
00:57:05,990 --> 00:57:04,319
in yosemite an astronaut might do that

1465
00:57:08,230 --> 00:57:06,000
onto the surface so that he or she could

1466
00:57:10,870 --> 00:57:08,240
later come back and and clip into that

1467
00:57:13,750 --> 00:57:10,880
boulder as a secure point

1468
00:57:16,390 --> 00:57:13,760
so to cap off the status of this so far

1469
00:57:18,630 --> 00:57:16,400
it's a self-contained unit um it's

1470
00:57:20,710 --> 00:57:18,640
robotic so you we have a set it and

1471
00:57:22,549 --> 00:57:20,720
forget it mentality that the astronaut

1472
00:57:25,190 --> 00:57:22,559
would would place the drill and then

1473
00:57:27,670 --> 00:57:25,200
wait five minutes or do some other task

1474
00:57:30,069 --> 00:57:27,680
and and come back and collect the sample

1475
00:57:32,630 --> 00:57:30,079
and we've designed it to be operable

1476
00:57:34,150 --> 00:57:32,640
with a big glove so this is one of our

1477
00:57:37,109 --> 00:57:34,160
interns who helped a lot with this

1478
00:57:39,589 --> 00:57:37,119
program and he's got four sets of gloves

1479
00:57:41,750 --> 00:57:39,599
on um so the path forward we're looking

1480
00:57:44,309 --> 00:57:41,760
to to start to collaborate with the crew

1481
00:57:47,670 --> 00:57:44,319
systems office uh specifically uh and

1482
00:57:49,670 --> 00:57:47,680
anyone else that that's interested um

1483
00:57:51,510 --> 00:57:49,680
to to take this to the next level we we

1484
00:57:55,109 --> 00:57:51,520
think it's kind of a proof of concept

1485
00:57:56,950 --> 00:57:55,119
now uh and and we need to up the trl

1486
00:57:57,990 --> 00:57:56,960
so i'll take any questions you have on

1487
00:57:59,430 --> 00:57:58,000
on this

1488
00:58:03,750 --> 00:57:59,440

uh tool

1489
00:58:03,760 --> 00:58:07,750
any questions in the rumor online

1490
00:58:13,750 --> 00:58:11,829
i i do have one question uh yeah

1491
00:58:15,270 --> 00:58:13,760
back on the drill concept

1492
00:58:17,589 --> 00:58:15,280
uh how much

1493
00:58:20,150 --> 00:58:17,599
torque is required in the motor

1494
00:58:22,630 --> 00:58:20,160
to actually perform that operation

1495
00:58:25,990 --> 00:58:22,640
yeah so you know it's something we

1496
00:58:27,670 --> 00:58:26,000
should have measured um it's it's a 22

1497
00:58:29,829 --> 00:58:27,680
volt battery and

1498
00:58:32,630 --> 00:58:29,839
well

1499
00:58:35,030 --> 00:58:32,640
i'm not exactly sure but uh i think we

1500
00:58:36,549 --> 00:58:35,040
can get those numbers for you

1501
00:58:38,309 --> 00:58:36,559
of course that's also going to depend on

1502
00:58:39,990 --> 00:58:38,319
the speed at which you want to drill and

1503
00:58:41,670 --> 00:58:40,000
and the loads that you're applying and

1504
00:58:44,870 --> 00:58:41,680
like the weight on bit yeah i was kind

1505
00:58:46,549 --> 00:58:44,880
of curious was it kind of of the same

1506
00:58:47,670 --> 00:58:46,559
variety that you might use on an

1507
00:58:49,829 --> 00:58:47,680
astronaut's

1508
00:58:51,430 --> 00:58:49,839
pistol rule yeah i think it i think it

1509
00:58:53,430 --> 00:58:51,440
would be very similar to that all of

1510
00:58:55,270 --> 00:58:53,440
those usually have four or five stage

1511
00:58:57,190 --> 00:58:55,280
little planetary gearbox in there and

1512
00:58:58,870 --> 00:58:57,200
the motor is substantial so it's it's a

1513
00:59:00,549 --> 00:58:58,880

fair bit of torque because you could

1514
00:59:02,390 --> 00:59:00,559
maybe see a concept where you could take

1515
00:59:04,230 --> 00:59:02,400
a device like this

1516
00:59:05,510 --> 00:59:04,240
and maybe use one of these pistol grip

1517
00:59:07,030 --> 00:59:05,520
tools and

1518
00:59:09,670 --> 00:59:07,040
yeah that would certainly be a mass

1519
00:59:12,549 --> 00:59:09,680
savings as well i think that you could

1520
00:59:14,710 --> 00:59:12,559
the gripper itself only weighs uh 1.2

1521
00:59:17,589 --> 00:59:14,720
kilograms right now most of the weight

1522
00:59:19,430 --> 00:59:17,599
is in that drill apparatus so that would

1523
00:59:21,270 --> 00:59:19,440
be where the savings would be okay thank

1524
00:59:22,789 --> 00:59:21,280
you i believe you just answered my

1525
00:59:25,430 --> 00:59:22,799
question which is your current prototype

1526
00:59:28,069 --> 00:59:25,440
is battery powered uh yes it is

1527
00:59:30,829 --> 00:59:28,079
but lithium polymer batteries so not

1528
00:59:32,710 --> 00:59:30,839
it's not path to flight yeah

1529
00:59:34,470 --> 00:59:32,720
yeah see i think there's a question here

1530
00:59:37,030 --> 00:59:34,480
in the front

1531
00:59:39,030 --> 00:59:37,040
yeah oh yeah thanks um you've shown a

1532
00:59:40,549 --> 00:59:39,040
drill application but on the screen of

1533
00:59:42,390 --> 00:59:40,559
course there's another application one

1534
00:59:44,309 --> 00:59:42,400
can imagine all kinds of

1535
00:59:46,950 --> 00:59:44,319
applications for this can you talk a

1536
00:59:49,990 --> 00:59:46,960
little bit about the letting go part two

1537
00:59:52,150 --> 00:59:50,000
so sure uh yeah so the the little

1538
00:59:53,670 --> 00:59:52,160

climbing robot there uh

1539
00:59:55,510 --> 00:59:53,680
photoshopped on the bottom that's what

1540
00:59:57,670 --> 00:59:55,520
i'm gonna talk about next

1541
00:59:59,829 --> 00:59:57,680
it is a gripper that's meant to grip and

1542
01:00:00,950 --> 00:59:59,839
release many times we've tested that in

1543
01:00:03,109 --> 01:00:00,960
the lab

1544
01:00:04,150 --> 01:00:03,119
out to several hundred cycles

1545
01:00:05,750 --> 01:00:04,160
um

1546
01:00:07,670 --> 01:00:05,760
because you have so many of these toes

1547
01:00:08,710 --> 01:00:07,680
if you lose a few of them if a few of

1548
01:00:10,950 --> 01:00:08,720
them break

1549
01:00:13,190 --> 01:00:10,960
it's no big deal you're you're counting

1550
01:00:17,109 --> 01:00:13,200
on this probability anyways so

1551
01:00:20,069 --> 01:00:17,119
um we have a an act an actuator to to

1552
01:00:22,710 --> 01:00:20,079
release those claws from the surface

1553
01:00:24,870 --> 01:00:22,720
so uh i will talk about that in the next

1554
01:00:26,470 --> 01:00:24,880
one how that happens but it's an active

1555
01:00:28,309 --> 01:00:26,480
release and and

1556
01:00:30,710 --> 01:00:28,319
we make sure that actuators power fully

1557
01:00:35,990 --> 01:00:30,720
enough to actually break the the claws

1558
01:00:41,270 --> 01:00:37,990
any other questions

1559
01:00:43,589 --> 01:00:41,280
let's go on your second pixel great

1560
01:00:47,109 --> 01:00:43,599
uh let's see is somebody else gonna swap

1561
01:00:51,589 --> 01:00:49,349
so this is a mobile robot with micro

1562
01:00:53,990 --> 01:00:51,599
spline anchors

1563
01:00:54,870 --> 01:00:54,000

yeah so this is addressing sort of some

1564
01:00:59,030 --> 01:00:54,880
of the

1565
01:01:00,390 --> 01:00:59,040
initiative uh looking a little bit more

1566
01:01:02,069 --> 01:01:00,400
long-term

1567
01:01:04,630 --> 01:01:02,079
this would be a limbed robot that could

1568
01:01:06,870 --> 01:01:04,640
provide a permanent presence exploring

1569
01:01:09,030 --> 01:01:06,880
the surface of of an asteroid

1570
01:01:12,309 --> 01:01:09,040
demonstrating um

1571
01:01:14,390 --> 01:01:12,319
uh orbit uh alteration techniques

1572
01:01:16,710 --> 01:01:14,400
collecting samples or preparing that

1573
01:01:17,990 --> 01:01:16,720
asteroid for for crew

1574
01:01:19,349 --> 01:01:18,000
interaction

1575
01:01:21,829 --> 01:01:19,359
um

1576
01:01:23,910 --> 01:01:21,839
this was actually the the initial part

1577
01:01:27,829 --> 01:01:23,920
of the work this is a movie so let me

1578
01:01:30,630 --> 01:01:28,950
um

1579
01:01:31,670 --> 01:01:30,640
so this is a rock climbing robot we

1580
01:01:33,670 --> 01:01:31,680
developed

1581
01:01:34,630 --> 01:01:33,680
uh we think it's the first rock climbing

1582
01:01:36,470 --> 01:01:34,640
robot

1583
01:01:39,670 --> 01:01:36,480
that's been built for for natural rock

1584
01:01:41,190 --> 01:01:39,680
here it is climbing upside down

1585
01:01:43,030 --> 01:01:41,200
this is some of the early work on these

1586
01:01:46,069 --> 01:01:43,040
hand actuated grippers so there's

1587
01:01:48,630 --> 01:01:46,079
there's two actuation uh methods that

1588
01:01:52,470 --> 01:01:48,640

are controlling over 750 of these

1589
01:01:55,670 --> 01:01:52,480
independent claws well three per toe

1590
01:01:57,190 --> 01:01:55,680
and so the first actuator

1591
01:01:59,510 --> 01:01:57,200
is shown here

1592
01:02:01,510 --> 01:01:59,520
pulling those claws off the surface and

1593
01:02:03,430 --> 01:02:01,520
so that's how we would release

1594
01:02:04,710 --> 01:02:03,440
the second actuator actually squeezes

1595
01:02:06,150 --> 01:02:04,720
those claws

1596
01:02:07,190 --> 01:02:06,160
inwards as you're seeing in the video

1597
01:02:08,710 --> 01:02:07,200
right there

1598
01:02:10,870 --> 01:02:08,720
and that's what loads them all up that's

1599
01:02:13,349 --> 01:02:10,880
what allows them to opportunistically

1600
01:02:14,789 --> 01:02:13,359
find those rough spots to grip

1601
01:02:17,029 --> 01:02:14,799
so you might be able to see some of

1602
01:02:18,789 --> 01:02:17,039
those stretching out now rocks typically

1603
01:02:21,349 --> 01:02:18,799
have a fractal roughness so you need to

1604
01:02:23,510 --> 01:02:21,359
conform at multiple length scales so the

1605
01:02:25,910 --> 01:02:23,520
individual hooks are doing sort of

1606
01:02:27,510 --> 01:02:25,920
millimeter scale stuff we have 16 of

1607
01:02:29,349 --> 01:02:27,520
those in a carriage and then of course

1608
01:02:32,069 --> 01:02:29,359
the limb of the robot itself has some

1609
01:02:34,150 --> 01:02:32,079
ability to conform to the surface

1610
01:02:36,309 --> 01:02:34,160
these are omni-directional anchors so we

1611
01:02:37,910 --> 01:02:36,319
can tug on them uh directly away from

1612
01:02:41,510 --> 01:02:37,920
the surface or directly along the

1613
01:02:43,750 --> 01:02:41,520

surface everything uh in between

1614
01:02:46,309 --> 01:02:43,760
and uh you can see the robot's got

1615
01:02:49,109 --> 01:02:46,319
stereo cameras on the front there we're

1616
01:02:51,029 --> 01:02:49,119
also building in some force sensing into

1617
01:02:52,710 --> 01:02:51,039
the grippers so that we know whether or

1618
01:02:54,789 --> 01:02:52,720
not we have a good grip

1619
01:02:56,549 --> 01:02:54,799
we're also trying to learn how that grip

1620
01:02:58,230 --> 01:02:56,559
is distributed because there are some

1621
01:03:00,470 --> 01:02:58,240
techniques you could use if you if you

1622
01:03:02,470 --> 01:03:00,480
say only have the top of your gripper

1623
01:03:04,309 --> 01:03:02,480
engaged in the bottom of another gripper

1624
01:03:06,150 --> 01:03:04,319
you can use the body of that robot to do

1625
01:03:08,710 --> 01:03:06,160
a squeeze you see rock climbers putting

1626
01:03:11,270 --> 01:03:08,720
themselves into all kinds of crazy uh

1627
01:03:13,109 --> 01:03:11,280
configurations to take advantage of the

1628
01:03:15,510 --> 01:03:13,119
the grips that that are available to

1629
01:03:18,069 --> 01:03:15,520
them uh we'd like to get this robot to a

1630
01:03:20,390 --> 01:03:18,079
point where it's able to do that as well

1631
01:03:22,710 --> 01:03:20,400
now this robot was originally built

1632
01:03:25,029 --> 01:03:22,720
about uh 10 years ago

1633
01:03:26,950 --> 01:03:25,039
uh brett kennedy was the original

1634
01:03:29,029 --> 01:03:26,960
builder i got to jpl a few years ago

1635
01:03:30,710 --> 01:03:29,039
nobody was using it and so we we sort of

1636
01:03:31,510 --> 01:03:30,720
hacked it apart and added the grippers

1637
01:03:35,270 --> 01:03:31,520
on

1638
01:03:37,349 --> 01:03:35,280

degrees of freedom three active joints

1639
01:03:39,910 --> 01:03:37,359
per limb so that's not enough to do

1640
01:03:42,549 --> 01:03:39,920
really complex topographies right now

1641
01:03:44,470 --> 01:03:42,559
we're currently in the process of um

1642
01:03:46,309 --> 01:03:44,480
upgrading those limbs to six active

1643
01:03:48,230 --> 01:03:46,319
degrees of freedom so that we can do

1644
01:03:50,789 --> 01:03:48,240
things like plane changes and curving

1645
01:03:54,069 --> 01:03:50,799
surfaces i actually was out crawling

1646
01:03:55,910 --> 01:03:54,079
around in a in a cave in the desert um

1647
01:03:57,349 --> 01:03:55,920
a couple of weeks ago and and we had a

1648
01:03:59,430 --> 01:03:57,359
gripper and we were hanging the gripper

1649
01:04:01,270 --> 01:03:59,440
on the ceiling of the cave so my dream

1650
01:04:03,109 --> 01:04:01,280
to become a famous youtube star is to

1651
01:04:06,950 --> 01:04:03,119
get the robot to go around in circles

1652
01:04:08,069 --> 01:04:06,960
inside the inside the lava tube there

1653
01:04:09,750 --> 01:04:08,079
you can see a little bit more of the

1654
01:04:11,430 --> 01:04:09,760
drill here and the in the operation but

1655
01:04:14,150 --> 01:04:11,440
i'm gonna i think i'm gonna skip ahead

1656
01:04:16,150 --> 01:04:14,160
in the interest of time

1657
01:04:17,910 --> 01:04:16,160
so as i mentioned we we do have a path

1658
01:04:20,069 --> 01:04:17,920
to flight this isn't always going to be

1659
01:04:21,190 --> 01:04:20,079
a rapid prototype and rubber band kind

1660
01:04:23,109 --> 01:04:21,200
of system

1661
01:04:25,349 --> 01:04:23,119
this is the diagram of that path to

1662
01:04:26,549 --> 01:04:25,359
flight prototype that we built it's got

1663
01:04:28,309 --> 01:04:26,559

the extension springs those are

1664
01:04:30,390 --> 01:04:28,319
protected inside a housing so that

1665
01:04:32,710 --> 01:04:30,400
debris and dust and things don't get in

1666
01:04:34,950 --> 01:04:32,720
there and clog up the works but again it

1667
01:04:38,069 --> 01:04:34,960
is it is a probabilistic system so if

1668
01:04:41,589 --> 01:04:38,079
you lose one or two it's no big deal you

1669
01:04:42,950 --> 01:04:41,599
have a power in numbers so here's that

1670
01:04:44,870 --> 01:04:42,960
testing in all the different

1671
01:04:45,990 --> 01:04:44,880
orientations about 30 pounds in each

1672
01:04:48,069 --> 01:04:46,000
direction

1673
01:04:50,549 --> 01:04:48,079
we've tested on other kinds of samples

1674
01:04:52,309 --> 01:04:50,559
we use the mars drilling suite of rocks

1675
01:04:53,910 --> 01:04:52,319
and we get more than 60 newtons on all

1676
01:04:55,510 --> 01:04:53,920
of those we've also tested on some

1677
01:04:57,510 --> 01:04:55,520
granular surfaces

1678
01:04:59,829 --> 01:04:57,520
the idea would be to to really anchor to

1679
01:05:02,470 --> 01:04:59,839
the boulders put in permanent anchor

1680
01:05:04,069 --> 01:05:02,480
points and then kind of tiptoe across

1681
01:05:05,829 --> 01:05:04,079
the loose stuff and get to another

1682
01:05:06,789 --> 01:05:05,839
boulder and if you look at itakawa and

1683
01:05:08,549 --> 01:05:06,799
the other

1684
01:05:10,470 --> 01:05:08,559
asteroids that looks like a feasible

1685
01:05:12,710 --> 01:05:10,480
concept of operations

1686
01:05:14,390 --> 01:05:12,720
so the overall benefits we think this

1687
01:05:15,990 --> 01:05:14,400
technology can enable

1688
01:05:17,670 --> 01:05:16,000

alternative capture techniques if you're

1689
01:05:19,029 --> 01:05:17,680
going to grab a boulder off the surface

1690
01:05:20,789 --> 01:05:19,039
for instance

1691
01:05:23,029 --> 01:05:20,799
this could help

1692
01:05:25,510 --> 01:05:23,039
it could enable new kinds of deflection

1693
01:05:28,870 --> 01:05:25,520
capabilities you can position reflectors

1694
01:05:30,870 --> 01:05:28,880
or explosives or uh thrusters um at

1695
01:05:32,309 --> 01:05:30,880
strategic locations instead of just

1696
01:05:34,069 --> 01:05:32,319
where they fall down

1697
01:05:37,109 --> 01:05:34,079
uh you can get a lot of science return

1698
01:05:39,109 --> 01:05:37,119
by you know traversing large areas but

1699
01:05:40,549 --> 01:05:39,119
positioning your your instruments very

1700
01:05:43,349 --> 01:05:40,559
precisely and acquiring these core

1701
01:05:45,270 --> 01:05:43,359
samples and really my my favorite

1702
01:05:46,710 --> 01:05:45,280
version of this is as a precursor to a

1703
01:05:48,549 --> 01:05:46,720
crude mission

1704
01:05:50,470 --> 01:05:48,559
where the robot is sort of scouting out

1705
01:05:52,710 --> 01:05:50,480
locations of interest but also setting

1706
01:05:54,870 --> 01:05:52,720
up a network of cables that you've

1707
01:05:56,150 --> 01:05:54,880
tested so you know that they're secure

1708
01:05:57,910 --> 01:05:56,160
so that when the astronauts get there

1709
01:05:59,430 --> 01:05:57,920
they don't have to worry about

1710
01:06:02,230 --> 01:05:59,440
the safety problems they can worry about

1711
01:06:04,309 --> 01:06:02,240
the exploration problems

1712
01:06:12,309 --> 01:06:04,319
so again thanks for your time i'm happy

1713
01:06:16,870 --> 01:06:14,549

i'm just curious what the face the

1714
01:06:18,870 --> 01:06:16,880
initial face pressure for that gripper

1715
01:06:20,630 --> 01:06:18,880
would be against the surface

1716
01:06:24,470 --> 01:06:20,640
yeah it's a good question it actually

1717
01:06:26,150 --> 01:06:24,480
doesn't require any preload

1718
01:06:28,710 --> 01:06:26,160
those

1719
01:06:30,069 --> 01:06:28,720
carriages of claws are spring-loaded so

1720
01:06:41,109 --> 01:06:30,079
the

1721
01:06:43,510 --> 01:06:41,119
doesn't require any significant force

1722
01:06:45,750 --> 01:06:43,520
and it doesn't tend to push itself away

1723
01:06:47,589 --> 01:06:45,760
it comes down and scrapes along because

1724
01:06:50,950 --> 01:06:47,599
of the kinematics of those

1725
01:06:55,190 --> 01:06:50,960
carriages so it tends to self-grip

1726
01:07:01,990 --> 01:06:56,549
any other questions in the room or

1727
01:07:05,589 --> 01:07:04,069
not so much a question but as a comment

1728
01:07:07,349 --> 01:07:05,599
but everyone seems to really enjoy the

1729
01:07:08,870 --> 01:07:07,359
videos i think your robot's pretty thank

1730
01:07:10,470 --> 01:07:08,880
you thank you

1731
01:07:12,150 --> 01:07:10,480
yeah you can go to youtube and see it

1732
01:07:14,390 --> 01:07:12,160
and you get the the most interesting

1733
01:07:16,710 --> 01:07:14,400
comments there sometimes

1734
01:07:19,349 --> 01:07:16,720
well i hope we help your youtube career

1735
01:07:21,190 --> 01:07:19,359
ah thank you thank you thank you and i

1736
01:07:22,630 --> 01:07:21,200
think one thing this will you know a lot

1737
01:07:24,470 --> 01:07:22,640
of promise maybe on the drill for the

1738
01:07:26,390 --> 01:07:24,480

asteroid yeah mission something that

1739
01:07:28,150 --> 01:07:26,400
intrigues us i think as we think about

1740
01:07:29,510 --> 01:07:28,160
it and then personally maybe i can

1741
01:07:31,270 --> 01:07:29,520
become a rock climber app with your

1742
01:07:37,510 --> 01:07:31,280
devices so thank you very much yeah

1743
01:07:43,430 --> 01:07:41,029
so let's see our next presentation uh is

1744
01:07:44,870 --> 01:07:43,440
paul fulford from

1745
01:07:46,470 --> 01:07:44,880
mda

1746
01:07:48,870 --> 01:07:46,480
he's going to talk about robotic

1747
01:07:50,950 --> 01:07:48,880
manipulators eva tools

1748
01:07:53,029 --> 01:07:50,960
and collaboration between humans and

1749
01:07:56,470 --> 01:07:53,039
robotics

1750
01:08:02,470 --> 01:07:58,710
the first slide is just an introduction

1751
01:08:05,589 --> 01:08:02,480
to mda in our past

1752
01:08:06,630 --> 01:08:05,599
and maybe just an overarching theme that

1753
01:08:09,270 --> 01:08:06,640
the

1754
01:08:12,069 --> 01:08:09,280
acquisition or or capture of an asteroid

1755
01:08:13,349 --> 01:08:12,079
is not dissimilar at all to capturing a

1756
01:08:16,070 --> 01:08:13,359
spacecraft

1757
01:08:18,070 --> 01:08:16,080
uh be it cooperative or uncooperative

1758
01:08:20,709 --> 01:08:18,080
as early as 1981

1759
01:08:22,070 --> 01:08:20,719
the first canadarm or srms flew on board

1760
01:08:24,550 --> 01:08:22,080
the shuttle

1761
01:08:26,870 --> 01:08:24,560
and did a whole series of different uh

1762
01:08:28,950 --> 01:08:26,880
complex operations in in terms of

1763
01:08:31,269 --> 01:08:28,960

capturing very large both cooperative

1764
01:08:34,070 --> 01:08:31,279
and uncooperative spacecraft

1765
01:08:35,590 --> 01:08:34,080
as well as manipulating uh eva

1766
01:08:38,229 --> 01:08:35,600
crew

1767
01:08:41,030 --> 01:08:38,239
on the leftmost side you can see

1768
01:08:42,950 --> 01:08:41,040
servicing the hubble space telescope

1769
01:08:45,990 --> 01:08:42,960
and then through the years and into the

1770
01:08:48,630 --> 01:08:46,000
2000s we extended different capabilities

1771
01:08:50,390 --> 01:08:48,640
for the canadarm or the

1772
01:08:53,110 --> 01:08:50,400
shuttle manipulator for its return to

1773
01:08:56,309 --> 01:08:53,120
flight we added appendages to do

1774
01:08:58,149 --> 01:08:56,319
a survey of the underside which would be

1775
01:08:59,349 --> 01:08:58,159
quite similar to to that of an asteroid

1776
01:09:02,470 --> 01:08:59,359
mission

1777
01:09:04,309 --> 01:09:02,480
we've provided sensors for the xss-11

1778
01:09:05,990 --> 01:09:04,319
satellite rendezvous mission and

1779
01:09:09,510 --> 01:09:06,000
provided the robots for the orbital

1780
01:09:12,390 --> 01:09:10,390
through

1781
01:09:14,470 --> 01:09:12,400
this last decade and in fact in in the

1782
01:09:16,470 --> 01:09:14,480
last few years the canadian space

1783
01:09:17,910 --> 01:09:16,480
agency's funded

1784
01:09:21,430 --> 01:09:17,920
significant development on the next

1785
01:09:23,189 --> 01:09:21,440
generation canadarm so we have

1786
01:09:24,630 --> 01:09:23,199
different products that that i'll show

1787
01:09:27,269 --> 01:09:24,640
in a few minutes

1788
01:09:30,870 --> 01:09:27,279

and of recent we've been doing a number

1789
01:09:33,110 --> 01:09:30,880
of studies in part with lockheed martin

1790
01:09:36,630 --> 01:09:33,120
trying to figure out how we can

1791
01:09:38,149 --> 01:09:36,640
adapt our robots for

1792
01:09:42,070 --> 01:09:38,159
the physical characteristics of the

1793
01:09:45,510 --> 01:09:43,349
so

1794
01:09:47,189 --> 01:09:45,520
along the theme of

1795
01:09:49,189 --> 01:09:47,199
this is really no different than than

1796
01:09:50,550 --> 01:09:49,199
addressing any other type of

1797
01:09:52,550 --> 01:09:50,560
space vehicle

1798
01:09:55,110 --> 01:09:52,560
that this slide just breaks down the

1799
01:09:57,590 --> 01:09:55,120
concept of operations from you need to

1800
01:09:59,750 --> 01:09:57,600
meet you need to prepare the ev

1801
01:10:01,350 --> 01:09:59,760
a crew for egress

1802
01:10:04,070 --> 01:10:01,360
the crew need to translate be it on

1803
01:10:05,270 --> 01:10:04,080
their own or with robots

1804
01:10:07,110 --> 01:10:05,280
to secure

1805
01:10:09,270 --> 01:10:07,120
the work site

1806
01:10:10,390 --> 01:10:09,280
then to conduct different

1807
01:10:16,229 --> 01:10:10,400
tasks

1808
01:10:21,430 --> 01:10:19,270
in terms of capability in canada and at

1809
01:10:23,990 --> 01:10:21,440
mda there are many high

1810
01:10:26,229 --> 01:10:24,000
trl systems

1811
01:10:29,110 --> 01:10:26,239
that include

1812
01:10:31,110 --> 01:10:29,120
the the functions to capture and birth

1813
01:10:35,270 --> 01:10:31,120

either an orion

1814
01:10:37,270 --> 01:10:35,280
to an arv or an arv to an orion

1815
01:10:38,870 --> 01:10:37,280
the functions of translating crew

1816
01:10:41,830 --> 01:10:38,880
positioning

1817
01:10:45,350 --> 01:10:41,840
and providing the the static stability

1818
01:10:47,510 --> 01:10:45,360
or support when working

1819
01:10:49,510 --> 01:10:47,520
to provide both astronaut and and tool

1820
01:10:51,270 --> 01:10:49,520
stabilization

1821
01:10:55,030 --> 01:10:51,280
uh to do uh

1822
01:10:58,149 --> 01:10:55,040
pre-site uh work and post site so the

1823
01:11:00,870 --> 01:10:58,159
idea of

1824
01:11:01,750 --> 01:11:00,880
doing preparatory or precursor or triage

1825
01:11:04,950 --> 01:11:01,760
work

1826
01:11:07,830 --> 01:11:04,960
with robotics and after eva to continue

1827
01:11:09,590 --> 01:11:07,840
on doing so perhaps to follow on aaron's

1828
01:11:11,830 --> 01:11:09,600
presentation

1829
01:11:13,350 --> 01:11:11,840
a robotic arm could continue to do say

1830
01:11:15,750 --> 01:11:13,360
deep drilling

1831
01:11:21,189 --> 01:11:15,760
after the eva

1832
01:11:26,950 --> 01:11:23,830
this slide i'd like to say the

1833
01:11:28,550 --> 01:11:26,960
today's off nominal will be tomorrow's

1834
01:11:31,030 --> 01:11:28,560
nominal and

1835
01:11:33,350 --> 01:11:31,040
what i mean by that is

1836
01:11:35,030 --> 01:11:33,360
a lot of the operations to date on the

1837
01:11:37,030 --> 01:11:35,040
shuttle and on the space station are

1838
01:11:39,750 --> 01:11:37,040

heavily scripted

1839
01:11:41,910 --> 01:11:39,760
extremely rehearsed well prepared

1840
01:11:43,830 --> 01:11:41,920
all of the what-if scenarios have been

1841
01:11:45,510 --> 01:11:43,840
rehearsed the neutral buoyancy lab tests

1842
01:11:47,750 --> 01:11:45,520
the validation of all of these

1843
01:11:49,910 --> 01:11:47,760
operations as we get further and further

1844
01:11:51,270 --> 01:11:49,920
away from home

1845
01:11:52,870 --> 01:11:51,280
i think it's really important to

1846
01:11:55,270 --> 01:11:52,880
understand that we need to

1847
01:11:56,229 --> 01:11:55,280
abstract those operations up up one

1848
01:11:59,189 --> 01:11:56,239
level

1849
01:12:02,070 --> 01:11:59,199
higher and be prepared for anything and

1850
01:12:03,669 --> 01:12:02,080
having lots of margin gives you

1851
01:12:05,430 --> 01:12:03,679
lots of room to be prepared but we don't

1852
01:12:08,229 --> 01:12:05,440
actually have the luxury of that given

1853
01:12:09,990 --> 01:12:08,239
the size of the spacecraft but what

1854
01:12:12,310 --> 01:12:10,000
robotic systems can do

1855
01:12:14,070 --> 01:12:12,320
is they can provide flexibility

1856
01:12:16,070 --> 01:12:14,080
adaptability

1857
01:12:18,310 --> 01:12:16,080
why don't we try this why don't we try

1858
01:12:21,110 --> 01:12:18,320
that so so just to give you some ideas

1859
01:12:22,550 --> 01:12:21,120
from the past in the upper left corner

1860
01:12:23,990 --> 01:12:22,560
is a thermal blanket repair on the

1861
01:12:26,950 --> 01:12:24,000
shuttle

1862
01:12:29,030 --> 01:12:26,960
that was unplanned and the crew members

1863
01:12:31,189 --> 01:12:29,040

on a portable foot restraint on the end

1864
01:12:33,990 --> 01:12:31,199
of the robotic arm

1865
01:12:35,830 --> 01:12:34,000
the middle one is the

1866
01:12:37,430 --> 01:12:35,840
additional boom sensor that was on

1867
01:12:39,430 --> 01:12:37,440
critical path for shuttle return to

1868
01:12:40,470 --> 01:12:39,440
flight after the last disaster

1869
01:12:43,189 --> 01:12:40,480
and

1870
01:12:44,149 --> 01:12:43,199
was used until the retirement to inspect

1871
01:12:46,550 --> 01:12:44,159
the

1872
01:12:48,229 --> 01:12:46,560
heating tiles underneath

1873
01:12:49,990 --> 01:12:48,239
the one on the right

1874
01:12:52,630 --> 01:12:50,000
was affectionately called the fly

1875
01:12:55,350 --> 01:12:52,640
swatter which i think had to do with um

1876
01:12:58,470 --> 01:12:55,360
just adding an adapted tool to the end

1877
01:13:00,550 --> 01:12:58,480
effector the robot arm to support uh

1878
01:13:03,350 --> 01:13:00,560
deployment of communications

1879
01:13:05,110 --> 01:13:03,360
in the bottom left is the most recent

1880
01:13:06,950 --> 01:13:05,120
robotic refueling mission with goddard

1881
01:13:09,030 --> 01:13:06,960
space flight center

1882
01:13:11,189 --> 01:13:09,040
on the international space station where

1883
01:13:13,030 --> 01:13:11,199
the whole premise of that work is to

1884
01:13:15,590 --> 01:13:13,040
look at uncooperative

1885
01:13:16,830 --> 01:13:15,600
unstructured unplanned type operations

1886
01:13:19,669 --> 01:13:16,840
anything

1887
01:13:22,310 --> 01:13:19,679
from cutting wires to removing both

1888
01:13:24,709 --> 01:13:22,320

captive and non-captive bolts to cutting

1889
01:13:26,870 --> 01:13:24,719
thermal blankets

1890
01:13:29,110 --> 01:13:26,880
the the middle bottom is just to support

1891
01:13:31,189 --> 01:13:29,120
science and and sometimes certain

1892
01:13:33,270 --> 01:13:31,199
instruments things didn't go as planned

1893
01:13:35,030 --> 01:13:33,280
or the situation changed so so you could

1894
01:13:37,110 --> 01:13:35,040
use a robotic arm to

1895
01:13:39,750 --> 01:13:37,120
to orient or locate a different

1896
01:13:43,189 --> 01:13:39,760
spacecraft and then on the the bottom

1897
01:13:45,830 --> 01:13:43,199
right is to survey solar rays

1898
01:13:47,830 --> 01:13:45,840
it's in the crew where it's actually not

1899
01:13:49,110 --> 01:13:47,840
favorable or appropriate to send an eba

1900
01:13:52,070 --> 01:13:49,120
crew member

1901
01:13:52,080 --> 01:13:55,510
okay i'll just leave it there

1902
01:13:58,870 --> 01:13:57,830
so in terms of our latest and greatest

1903
01:14:01,669 --> 01:13:58,880
concepts

1904
01:14:03,750 --> 01:14:01,679
since 2008 we've been working with

1905
01:14:05,590 --> 01:14:03,760
lockheed martin funded by the canadian

1906
01:14:07,430 --> 01:14:05,600
space agency

1907
01:14:08,630 --> 01:14:07,440
and combining the technologies we

1908
01:14:10,149 --> 01:14:08,640
developed for the next generation

1909
01:14:11,510 --> 01:14:10,159
canadarm

1910
01:14:13,030 --> 01:14:11,520
trying to figure out

1911
01:14:16,550 --> 01:14:13,040
different ways to

1912
01:14:18,070 --> 01:14:16,560
adapt our systems for future missions

1913
01:14:19,750 --> 01:14:18,080

and what you can see

1914
01:14:22,709 --> 01:14:19,760
up in the top

1915
01:14:23,750 --> 01:14:22,719
is our next generation canadarm concept

1916
01:14:27,030 --> 01:14:23,760
that has

1917
01:14:28,870 --> 01:14:27,040
extendable passive booms so

1918
01:14:30,470 --> 01:14:28,880
by anchoring either end of the of the

1919
01:14:33,189 --> 01:14:30,480
robot

1920
01:14:35,350 --> 01:14:33,199
and commanding the joints

1921
01:14:38,149 --> 01:14:35,360
through that actuation you're

1922
01:14:40,390 --> 01:14:38,159
you're extending or retracting the booms

1923
01:14:41,830 --> 01:14:40,400
which better storage

1924
01:14:43,510 --> 01:14:41,840
now we're looking at lighter weight

1925
01:14:44,709 --> 01:14:43,520
systems

1926
01:14:46,310 --> 01:14:44,719
to answer

1927
01:14:48,070 --> 01:14:46,320
one of the questions earlier from one of

1928
01:14:49,990 --> 01:14:48,080
the earlier presentations

1929
01:14:52,630 --> 01:14:50,000
we're studying the orion vehicle

1930
01:14:54,310 --> 01:14:52,640
there there's three possible areas right

1931
01:14:57,430 --> 01:14:54,320
now to date

1932
01:14:58,950 --> 01:14:57,440
one is the pantry module one is called a

1933
01:15:01,750 --> 01:14:58,960
a sim bay

1934
01:15:02,870 --> 01:15:01,760
which is on the exterior of the service

1935
01:15:04,630 --> 01:15:02,880
module

1936
01:15:05,910 --> 01:15:04,640
and then there's a possibility for

1937
01:15:07,590 --> 01:15:05,920
additional room

1938
01:15:09,750 --> 01:15:07,600

inside the

1939
01:15:11,590 --> 01:15:09,760
the service module as well each have

1940
01:15:13,110 --> 01:15:11,600
have their own unique constraints we're

1941
01:15:14,709 --> 01:15:13,120
trying to study them all

1942
01:15:16,229 --> 01:15:14,719
and come up with a solution that could

1943
01:15:18,470 --> 01:15:16,239
potentially work in them all depending

1944
01:15:20,390 --> 01:15:18,480
on the scenario and so far it's looking

1945
01:15:21,350 --> 01:15:20,400
favorable in terms of

1946
01:15:23,030 --> 01:15:21,360
volume

1947
01:15:27,189 --> 01:15:23,040
we would still need to study mass and

1948
01:15:31,750 --> 01:15:28,470
in terms of

1949
01:15:35,590 --> 01:15:31,760
tools and aids

1950
01:15:38,630 --> 01:15:35,600
both the robots that canada have built

1951
01:15:41,030 --> 01:15:38,640
and the tools that canada have built

1952
01:15:42,070 --> 01:15:41,040
have accommodated a wide variety of

1953
01:15:44,229 --> 01:15:42,080
tools

1954
01:15:46,709 --> 01:15:44,239
developed not only in canada but but

1955
01:15:48,870 --> 01:15:46,719
around the world

1956
01:15:51,110 --> 01:15:48,880
the robotic refueling mission is one

1957
01:15:53,270 --> 01:15:51,120
example where there's tools developed at

1958
01:15:55,590 --> 01:15:53,280
goddard space flight center

1959
01:15:59,350 --> 01:15:55,600
that the robots can adapt to and the

1960
01:16:01,110 --> 01:15:59,360
whole idea of having a multi-purpose

1961
01:16:03,110 --> 01:16:01,120
robotic system that's flexible and

1962
01:16:05,430 --> 01:16:03,120
adaptable

1963
01:16:07,590 --> 01:16:05,440

modular reconfigurable all of those

1964
01:16:09,910 --> 01:16:07,600
attributes i think will lend themselves

1965
01:16:11,669 --> 01:16:09,920
quite well and we've done a lot of

1966
01:16:13,350 --> 01:16:11,679
different operations to date and we'll

1967
01:16:14,550 --> 01:16:13,360
continue to do so

1968
01:16:16,470 --> 01:16:14,560
some of the more novel ones with the

1969
01:16:18,550 --> 01:16:16,480
next generation canadarm

1970
01:16:20,390 --> 01:16:18,560
have also dealt with satellite refueling

1971
01:16:23,189 --> 01:16:20,400
and the transport

1972
01:16:25,830 --> 01:16:23,199
burning of fluids and stuff

1973
01:16:27,110 --> 01:16:25,840
this is my last slide

1974
01:16:28,630 --> 01:16:27,120
and

1975
01:16:30,470 --> 01:16:28,640
for those that weren't at the morning

1976
01:16:32,709 --> 01:16:30,480
session this could be considered a

1977
01:16:35,750 --> 01:16:32,719
little cheeky but

1978
01:16:38,390 --> 01:16:35,760
it's also showing mda's concept for

1979
01:16:39,590 --> 01:16:38,400
an alternate idea for capturing of an

1980
01:16:42,310 --> 01:16:39,600
asteroid

1981
01:16:45,430 --> 01:16:42,320
and this image is intended to represent

1982
01:16:47,990 --> 01:16:45,440
uh the cooperative efforts between

1983
01:16:49,910 --> 01:16:48,000
a robot and the eva crew you can

1984
01:16:51,750 --> 01:16:49,920
actually see that other structure where

1985
01:16:54,390 --> 01:16:51,760
crew can climb all over

1986
01:16:56,390 --> 01:16:54,400
those robotic limbs and you can have a

1987
01:16:59,110 --> 01:16:56,400
manipulator mounted to the orion vehicle

1988
01:17:00,470 --> 01:16:59,120

or to the arv and and provide tools

1989
01:17:02,630 --> 01:17:00,480
provide

1990
01:17:03,750 --> 01:17:02,640
stability platforms to do different

1991
01:17:05,510 --> 01:17:03,760
survey

1992
01:17:07,990 --> 01:17:05,520
camera views uh

1993
01:17:10,070 --> 01:17:08,000
whatever is required

1994
01:17:18,390 --> 01:17:10,080
and with that i'll i'll take any

1995
01:17:22,390 --> 01:17:20,550
traditionally the canada canada arm has

1996
01:17:24,229 --> 01:17:22,400
been operated by an iba crew member in

1997
01:17:25,590 --> 01:17:24,239
support of eva crew and what i haven't

1998
01:17:27,110 --> 01:17:25,600
seen here

1999
01:17:28,870 --> 01:17:27,120
under the premise that this mission

2000
01:17:31,830 --> 01:17:28,880
would have two crew members on board

2001
01:17:34,229 --> 01:17:31,840
who's operating the robot

2002
01:17:36,149 --> 01:17:34,239
and you know hearkening to the european

2003
01:17:37,910 --> 01:17:36,159
robotic arm which at one point in time

2004
01:17:40,390 --> 01:17:37,920
had an eva

2005
01:17:41,510 --> 01:17:40,400
uh operated capability on it is that

2006
01:17:44,470 --> 01:17:41,520
something that you would consider

2007
01:17:46,950 --> 01:17:44,480
hosting on on this mission as well

2008
01:17:48,870 --> 01:17:46,960
uh yeah yes so under consideration is

2009
01:17:49,990 --> 01:17:48,880
the whole cherry picker idea where there

2010
01:17:51,990 --> 01:17:50,000
would be a

2011
01:17:53,430 --> 01:17:52,000
control console as part of the portable

2012
01:17:55,270 --> 01:17:53,440
foot restraint

2013
01:17:56,550 --> 01:17:55,280

that's under consideration

2014
01:17:58,070 --> 01:17:56,560
um

2015
01:17:59,430 --> 01:17:58,080
and i'm not sure if everyone is aware

2016
01:18:01,669 --> 01:17:59,440
but the majority of the robotic

2017
01:18:04,550 --> 01:18:01,679
operations on the iss are now done on

2018
01:18:06,470 --> 01:18:04,560
the ground so there's also ground-based

2019
01:18:07,430 --> 01:18:06,480
operations where if anything they're

2020
01:18:09,990 --> 01:18:07,440
done

2021
01:18:11,590 --> 01:18:10,000
when the crew is asleep

2022
01:18:16,390 --> 01:18:11,600
to

2023
01:18:19,590 --> 01:18:16,400
on the station so

2024
01:18:21,270 --> 01:18:19,600
um given the locations here uh it would

2025
01:18:23,270 --> 01:18:21,280
be quite feasible especially using

2026
01:18:25,030 --> 01:18:23,280
different varying levels of autonomy you

2027
01:18:27,189 --> 01:18:25,040
can have direct tail operation you can

2028
01:18:29,270 --> 01:18:27,199
have scripts you can have scripts with

2029
01:18:31,189 --> 01:18:29,280
supervisory control

2030
01:18:32,950 --> 01:18:31,199
um all those different types of uh

2031
01:18:34,950 --> 01:18:32,960
autonomy i think would support that as

2032
01:18:36,870 --> 01:18:34,960
well so you could have it on the ground

2033
01:18:39,110 --> 01:18:36,880
if it made sense you could have it in

2034
01:18:40,470 --> 01:18:39,120
the orion vehicle you could also have a

2035
01:18:42,310 --> 01:18:40,480
cherry picker

2036
01:18:44,470 --> 01:18:42,320
type eva crew member commanding and

2037
01:18:45,910 --> 01:18:44,480
controlling

2038
01:18:48,070 --> 01:18:45,920

there might be some combination where

2039
01:18:49,510 --> 01:18:48,080
you use the ground to move it to some

2040
01:18:50,709 --> 01:18:49,520
position and then maybe the crew does

2041
01:18:51,990 --> 01:18:50,719
some fine

2042
01:18:54,550 --> 01:18:52,000
you know

2043
01:18:55,510 --> 01:18:54,560
inch left or inch ride or whatever other

2044
01:18:57,110 --> 01:18:55,520
questions

2045
01:19:00,470 --> 01:18:57,120
what do you think are the worst load

2046
01:19:04,070 --> 01:19:01,830
what what do you think are the worst

2047
01:19:05,910 --> 01:19:04,080
load cases when you're uh when you're

2048
01:19:07,350 --> 01:19:05,920
designing an arm like that for for this

2049
01:19:11,510 --> 01:19:07,360
mission

2050
01:19:13,669 --> 01:19:11,520
uh stopping a large mass

2051
01:19:15,669 --> 01:19:13,679
that would be the worst scenario either

2052
01:19:17,990 --> 01:19:15,679
either

2053
01:19:21,830 --> 01:19:18,000
stopping its rate or its linear or all

2054
01:19:25,750 --> 01:19:21,840
six degree of freedom translation

2055
01:19:27,510 --> 01:19:25,760
um that's that's tied to time so

2056
01:19:29,590 --> 01:19:27,520
what its rate is how quickly the arm can

2057
01:19:32,229 --> 01:19:29,600
move how quickly it can capture and then

2058
01:19:36,709 --> 01:19:32,239
decelerate it to a zero velocity those

2059
01:19:40,709 --> 01:19:38,870
any other questions i think there's one

2060
01:19:42,310 --> 01:19:40,719
in the back i'll just

2061
01:19:44,070 --> 01:19:42,320
help you with the answer also to say

2062
01:19:46,470 --> 01:19:44,080
that uh probably the highest load case

2063
01:19:48,310 --> 01:19:46,480

would be testing it on the ground

2064
01:19:50,229 --> 01:19:48,320
right that ends up usually lots of time

2065
01:19:51,990 --> 01:19:50,239
being the driver you end up flying a

2066
01:19:54,470 --> 01:19:52,000
heavier arm because you wanted a 1g

2067
01:19:55,830 --> 01:19:54,480
testable or not i know it's a classic

2068
01:19:58,390 --> 01:19:55,840
trade that

2069
01:20:01,510 --> 01:19:58,400
roboticists have to make

2070
01:20:03,669 --> 01:20:01,520
yeah and it's worth noting that

2071
01:20:05,030 --> 01:20:03,679
many of our manipulators can't support

2072
01:20:08,390 --> 01:20:05,040
their own

2073
01:20:14,470 --> 01:20:08,400
mass in 1g environment we have different

2074
01:20:14,480 --> 01:20:20,629
thank you very much sir thank you

2075
01:20:24,870 --> 01:20:22,870
so our next presentation uh this is a

2076
01:20:26,870 --> 01:20:24,880
virtual presentation uh

2077
01:20:28,550 --> 01:20:26,880
the presenter is dave aiken he's from

2078
01:20:30,229 --> 01:20:28,560
the university of maryland

2079
01:20:31,990 --> 01:20:30,239
and dave's going to talk about a

2080
01:20:34,229 --> 01:20:32,000
free-flying camera for asteroid

2081
01:20:35,270 --> 01:20:34,239
inspection tether systems to anchor the

2082
01:20:37,110 --> 01:20:35,280
crew and

2083
01:20:39,750 --> 01:20:37,120
space utility vehicle

2084
01:20:42,070 --> 01:20:39,760
um dave are you online

2085
01:20:44,950 --> 01:20:42,080
i am online however i don't see anything

2086
01:20:48,629 --> 01:20:44,960
on uh adobe connect except click here

2087
01:20:52,070 --> 01:20:50,310
do you have the slides yourself the

2088
01:20:53,430 --> 01:20:52,080

slides are up here in the room in

2089
01:20:55,350 --> 01:20:53,440
houston

2090
01:21:03,750 --> 01:20:55,360
okay let me just uh go

2091
01:21:08,229 --> 01:21:05,350
um

2092
01:21:10,870 --> 01:21:08,239
so what i'm going to talk about today

2093
01:21:13,030 --> 01:21:10,880
are you ready we are ready thanks

2094
01:21:14,950 --> 01:21:13,040
okay what i'm going to talk about today

2095
01:21:16,950 --> 01:21:14,960
are three different appropriate

2096
01:21:19,030 --> 01:21:16,960
technologies that we've been detesting

2097
01:21:20,629 --> 01:21:19,040
here in the space systems lab

2098
01:21:22,709 --> 01:21:20,639
at the university of maryland that i

2099
01:21:25,110 --> 01:21:22,719
think would have rare utility

2100
01:21:26,390 --> 01:21:25,120
in an asteroid mission

2101
01:21:35,270 --> 01:21:26,400
the

2102
01:21:38,390 --> 01:21:35,280
um

2103
01:21:43,430 --> 01:21:38,400
we actually developed this for

2104
01:21:47,910 --> 01:21:44,149
the

2105
01:21:52,470 --> 01:21:50,709
inspire program which is an outgrowth of

2106
01:21:54,310 --> 01:21:52,480
the spheres

2107
01:21:56,790 --> 01:21:54,320
and it was called exospheres and the

2108
01:21:59,990 --> 01:21:56,800
intent is to come up with

2109
01:22:01,590 --> 01:22:00,000
a small free flying vehicle

2110
01:22:04,070 --> 01:22:01,600
that is

2111
01:22:05,830 --> 01:22:04,080
capable of being certified to

2112
01:22:07,510 --> 01:22:05,840
operationally

2113
01:22:09,510 --> 01:22:07,520

and routinely

2114
01:22:11,910 --> 01:22:09,520
do sorties around the outside of

2115
01:22:13,750 --> 01:22:11,920
international space station

2116
01:22:15,430 --> 01:22:13,760
we actually have teamed up teamed up

2117
01:22:17,750 --> 01:22:15,440
with arizona state

2118
01:22:19,110 --> 01:22:17,760
and looked at the utility of a vehicle

2119
01:22:20,790 --> 01:22:19,120
of this class

2120
01:22:21,910 --> 01:22:20,800
at an asteroid

2121
01:22:23,510 --> 01:22:21,920
as

2122
01:22:25,510 --> 01:22:23,520
adjunct to a human

2123
01:22:27,830 --> 01:22:25,520
mission to do things like do

2124
01:22:29,350 --> 01:22:27,840
magnetometer surveys and

2125
01:22:30,750 --> 01:22:29,360
close inspection

2126
01:22:33,830 --> 01:22:30,760
mapping and

2127
01:22:37,270 --> 01:22:33,840
photomosaicing and issues like that

2128
01:22:40,709 --> 01:22:37,280
it's a 50 kilogram cold gas vehicle

2129
01:22:42,790 --> 01:22:40,719
using co2 as the propellant

2130
01:22:45,110 --> 01:22:42,800
we sized it for

2131
01:22:47,270 --> 01:22:45,120
an eight hour sortie at international

2132
01:22:48,149 --> 01:22:47,280
space station it has about 40 meters per

2133
01:22:51,110 --> 01:22:48,159
second

2134
01:22:53,830 --> 01:22:51,120
delta v capability total

2135
01:22:56,229 --> 01:22:53,840
we wanted it to be easily recon uh

2136
01:22:59,350 --> 01:22:56,239
figurable for particular missions

2137
01:23:00,310 --> 01:22:59,360
so the 50 kilogram vehicle is the poor

2138
01:23:02,070 --> 01:23:00,320

vehicle

2139
01:23:03,990 --> 01:23:02,080
and there are fittings on each end for

2140
01:23:04,830 --> 01:23:04,000
what we call amps which are advanced

2141
01:23:07,990 --> 01:23:04,840
mission

2142
01:23:09,990 --> 01:23:08,000
packages so you can dock into one on the

2143
01:23:12,070 --> 01:23:10,000
front and one on the back

2144
01:23:13,430 --> 01:23:12,080
we can also use that for additional

2145
01:23:16,070 --> 01:23:13,440
capability

2146
01:23:17,350 --> 01:23:16,080
in terms of more propellant and power

2147
01:23:21,030 --> 01:23:17,360
for longer

2148
01:23:24,229 --> 01:23:21,040
duration or longer distance missions

2149
01:23:26,390 --> 01:23:24,239
the configuration the top image shows is

2150
01:23:27,750 --> 01:23:26,400
our space station inspection

2151
01:23:28,870 --> 01:23:27,760
configuration

2152
01:23:31,990 --> 01:23:28,880
with

2153
01:23:33,750 --> 01:23:32,000
basically a suite of cameras

2154
01:23:36,070 --> 01:23:33,760
both for navigation and for close

2155
01:23:40,310 --> 01:23:36,080
inspection of the external structure of

2156
01:23:43,270 --> 01:23:40,320
station this would also be viable on uh

2157
01:23:44,870 --> 01:23:43,280
asteroidal uh photomosaicing and the

2158
01:23:46,229 --> 01:23:44,880
arizona state folks have come up with a

2159
01:23:48,950 --> 01:23:46,239
lot of other

2160
01:23:51,590 --> 01:23:48,960
instrumentation that could be put into

2161
01:23:55,350 --> 01:23:51,600
emission packages the system is capable

2162
01:23:58,629 --> 01:23:55,360
of being based externally refueling and

2163
01:24:00,950 --> 01:23:58,639

resupplying autonomously outside

2164
01:24:02,709 --> 01:24:00,960
we can also change out the mission

2165
01:24:04,390 --> 01:24:02,719
packages by itself

2166
01:24:05,510 --> 01:24:04,400
so you don't have to bring it in and

2167
01:24:07,350 --> 01:24:05,520
play with it

2168
01:24:09,350 --> 01:24:07,360
it's it basically is good for multiple

2169
01:24:12,709 --> 01:24:09,360
sorties

2170
01:24:14,950 --> 01:24:12,719
so we have a prototype not shown here

2171
01:24:17,189 --> 01:24:14,960
which is

2172
01:24:19,990 --> 01:24:17,199
running on our air bearing table and we

2173
01:24:21,430 --> 01:24:20,000
have a duplicate version called euclid

2174
01:24:24,950 --> 01:24:21,440
which works in our neutral buoyancy

2175
01:24:28,310 --> 01:24:24,960
facility and gives us the ability to do

2176
01:24:29,350 --> 01:24:28,320
fairly high fidelity extended navigation

2177
01:24:31,750 --> 01:24:29,360
and

2178
01:24:33,669 --> 01:24:31,760
mobility studies

2179
01:24:35,510 --> 01:24:33,679
so this would basically go with the crew

2180
01:24:37,189 --> 01:24:35,520
to the asteroid and give the ability to

2181
01:24:39,030 --> 01:24:37,199
do a lot of interaction

2182
01:24:42,070 --> 01:24:39,040
locally

2183
01:24:43,830 --> 01:24:42,080
we also think this is extendable to

2184
01:24:46,070 --> 01:24:43,840
sampling

2185
01:24:46,870 --> 01:24:46,080
under an air force program we developed

2186
01:24:55,030 --> 01:24:46,880
a

2187
01:24:58,070 --> 01:24:55,040
centimeters long seven degrees of

2188
01:24:59,910 --> 01:24:58,080

freedom and five kilograms total mass

2189
01:25:02,709 --> 01:24:59,920
and it's capable of simple sampling

2190
01:25:04,790 --> 01:25:02,719
instrument placement and uh

2191
01:25:07,910 --> 01:25:04,800
tasks such as that

2192
01:25:09,270 --> 01:25:07,920
um and so that i should say i'm on page

2193
01:25:10,709 --> 01:25:09,280
three now

2194
01:25:13,830 --> 01:25:10,719
if you didn't figure that out so that

2195
01:25:15,990 --> 01:25:13,840
would be a useful tool as well

2196
01:25:18,070 --> 01:25:16,000
on page four

2197
01:25:20,550 --> 01:25:18,080
we were interested in restraining

2198
01:25:21,830 --> 01:25:20,560
mobility at asteroidal gravitational

2199
01:25:24,070 --> 01:25:21,840
levels

2200
01:25:27,030 --> 01:25:24,080
so this is a concept of

2201
01:25:29,030 --> 01:25:27,040
a three-point restraint to fixed

2202
01:25:31,430 --> 01:25:29,040
locations uh

2203
01:25:33,189 --> 01:25:31,440
and being able to have programmable

2204
01:25:34,709 --> 01:25:33,199
tension in the cables

2205
01:25:37,430 --> 01:25:34,719
to be able to

2206
01:25:40,870 --> 01:25:37,440
adjust the downforce to whatever is

2207
01:25:42,470 --> 01:25:40,880
appropriate for the task you're doing

2208
01:25:44,709 --> 01:25:42,480
you can see patterns down here that

2209
01:25:46,390 --> 01:25:44,719
we've looked at for handoffs between

2210
01:25:48,629 --> 01:25:46,400
cables to be able to maintain a

2211
01:25:50,229 --> 01:25:48,639
three-point restraint

2212
01:25:52,470 --> 01:25:50,239
throughout

2213
01:25:54,629 --> 01:25:52,480

effectively if you have depending on the

2214
01:25:55,910 --> 01:25:54,639
size of the asteroid and the the length

2215
01:25:58,310 --> 01:25:55,920
of the cables

2216
01:26:00,470 --> 01:25:58,320
and the topology

2217
01:26:03,590 --> 01:26:00,480
you can cover the surface of an asteroid

2218
01:26:05,750 --> 01:26:03,600
with a sort of a restrained approach

2219
01:26:07,590 --> 01:26:05,760
page five

2220
01:26:08,870 --> 01:26:07,600
shows some underwater testing that we've

2221
01:26:11,669 --> 01:26:08,880
done

2222
01:26:13,270 --> 01:26:11,679
uh in our neutral buoyancy facility

2223
01:26:15,910 --> 01:26:13,280
so the test subject here is on a

2224
01:26:18,870 --> 01:26:15,920
treadmill we were actually interested

2225
01:26:20,070 --> 01:26:18,880
more or less as an ancillary research

2226
01:26:22,950 --> 01:26:20,080
topic

2227
01:26:23,830 --> 01:26:22,960
of how low can you go in gravitational

2228
01:26:25,030 --> 01:26:23,840
level

2229
01:26:28,870 --> 01:26:25,040
and still

2230
01:26:30,310 --> 01:26:28,880
um reasonably use a walking or

2231
01:26:33,030 --> 01:26:30,320
other

2232
01:26:35,030 --> 01:26:33,040
two-legged gait for mobility

2233
01:26:36,629 --> 01:26:35,040
so what we have are three cables to the

2234
01:26:38,310 --> 01:26:36,639
test subject

2235
01:26:41,270 --> 01:26:38,320
if you look carefully at the image you

2236
01:26:43,510 --> 01:26:41,280
can see little round dots on his legs

2237
01:26:45,669 --> 01:26:43,520
and a green light that's showing through

2238
01:26:48,310 --> 01:26:45,679

about his belly button

2239
01:26:50,709 --> 01:26:48,320
that is a 12 camera equal assist motion

2240
01:26:53,590 --> 01:26:50,719
tracking system we have in the tank

2241
01:26:55,910 --> 01:26:53,600
so we can get sub-centimeter resolution

2242
01:26:58,149 --> 01:26:55,920
at 50 to 100 hertz on an effectively

2243
01:27:00,709 --> 01:26:58,159
unlimited number of targets

2244
01:27:01,910 --> 01:27:00,719
and that allows us to get very fine data

2245
01:27:04,390 --> 01:27:01,920
on uh

2246
01:27:06,870 --> 01:27:04,400
details of gate as a function of gravity

2247
01:27:09,350 --> 01:27:06,880
and which is basically the same as

2248
01:27:11,110 --> 01:27:09,360
uh the level of downforce you dial in on

2249
01:27:12,950 --> 01:27:11,120
the restraint system

2250
01:27:16,470 --> 01:27:12,960
uh

2251
01:27:19,030 --> 01:27:16,480
so with verify that this system works

2252
01:27:21,830 --> 01:27:19,040
and uh i think that it's uh

2253
01:27:23,350 --> 01:27:21,840
now actually we've talked about i i have

2254
01:27:24,790 --> 01:27:23,360
do a lot of collaborative stuff with the

2255
01:27:27,189 --> 01:27:24,800
folks in uh

2256
01:27:29,510 --> 01:27:27,199
the astronomy and space sciences uh

2257
01:27:31,110 --> 01:27:29,520
division here michael o'hearn from the

2258
01:27:33,030 --> 01:27:31,120
deep impact probe

2259
01:27:34,229 --> 01:27:33,040
and jessica sunshine and those folks and

2260
01:27:35,910 --> 01:27:34,239
they actually

2261
01:27:37,750 --> 01:27:35,920
are concerned that there's not going to

2262
01:27:40,550 --> 01:27:37,760
be a that most of these are going to be

2263
01:27:42,390 --> 01:27:40,560

loose aggregates rather than uh rocks

2264
01:27:44,229 --> 01:27:42,400
so that's an issue that's beyond my

2265
01:27:45,270 --> 01:27:44,239
opinion

2266
01:27:47,350 --> 01:27:45,280
uh

2267
01:27:49,430 --> 01:27:47,360
slide six

2268
01:27:53,030 --> 01:27:49,440
represents uh

2269
01:27:54,870 --> 01:27:53,040
uh an an instantiation of about 20 years

2270
01:27:57,510 --> 01:27:54,880
of research

2271
01:27:59,510 --> 01:27:57,520
on single person what we call space

2272
01:28:01,270 --> 01:27:59,520
utility vehicles

2273
01:28:03,590 --> 01:28:01,280
largely to prevent them from being

2274
01:28:05,430 --> 01:28:03,600
called man in a can which i think is

2275
01:28:08,870 --> 01:28:05,440
probably one of the reasons why no one's

2276
01:28:13,189 --> 01:28:11,350
one approach we've taken from after a

2277
01:28:16,229 --> 01:28:13,199
lot of

2278
01:28:18,390 --> 01:28:16,239
trades is to unlike say flexcraft which

2279
01:28:20,390 --> 01:28:18,400
is out of nasa marshall

2280
01:28:23,270 --> 01:28:20,400
to basically incorporate

2281
01:28:25,669 --> 01:28:23,280
hard suit ax5 type elements

2282
01:28:27,350 --> 01:28:25,679
that allow us to maintain both

2283
01:28:29,910 --> 01:28:27,360
particulate and

2284
01:28:31,669 --> 01:28:29,920
to a lesser extent radiation shielding

2285
01:28:35,910 --> 01:28:31,679
while providing

2286
01:28:38,950 --> 01:28:35,920
the occupant with eyes and hands on task

2287
01:28:40,310 --> 01:28:38,960
so it's actually a hybrid system between

2288
01:28:47,510 --> 01:28:40,320

the

2289
01:28:51,830 --> 01:28:49,270
so we've looked at this for a variety of

2290
01:28:53,189 --> 01:28:51,840
tasks again if you have shifting

2291
01:28:55,510 --> 01:28:53,199
particulate

2292
01:28:56,790 --> 01:28:55,520
structure to the asteroids you're

2293
01:28:58,790 --> 01:28:56,800
approaching

2294
01:29:01,990 --> 01:28:58,800
this would be far safer than going up to

2295
01:29:04,310 --> 01:29:02,000
it in a soft suit or hybrid suit

2296
01:29:06,550 --> 01:29:04,320
in terms of making sure that you don't

2297
01:29:10,070 --> 01:29:06,560
get trapped or you don't get uh

2298
01:29:11,510 --> 01:29:10,080
have problems with uh

2299
01:29:12,790 --> 01:29:11,520
impact

2300
01:29:16,070 --> 01:29:12,800
the

2301
01:29:17,910 --> 01:29:16,080
this

2302
01:29:19,830 --> 01:29:17,920
would make a great deal of sense as the

2303
01:29:21,270 --> 01:29:19,840
asteroid exploration module people have

2304
01:29:23,189 --> 01:29:21,280
been talking about

2305
01:29:25,110 --> 01:29:23,199
so the idea is rather than have it just

2306
01:29:27,669 --> 01:29:25,120
be a module that has an airlock it would

2307
01:29:30,390 --> 01:29:27,679
be one that would support an airlock or

2308
01:29:32,790 --> 01:29:30,400
be usable as an airlock would probably

2309
01:29:35,270 --> 01:29:32,800
have a pair of suit ports

2310
01:29:36,709 --> 01:29:35,280
so you don't have to lock out on nominal

2311
01:29:40,709 --> 01:29:36,719
operations

2312
01:29:43,510 --> 01:29:40,719
and provide a variety of robotic and uh

2313
01:29:45,990 --> 01:29:43,520

wall mounted uh suit manipu

2314
01:29:48,470 --> 01:29:46,000
arms for manipulation

2315
01:29:49,990 --> 01:29:48,480
uh so that you don't actually do an eva

2316
01:29:51,189 --> 01:29:50,000
unless it's something that particularly

2317
01:29:54,149 --> 01:29:51,199
needs

2318
01:30:01,270 --> 01:29:54,159
the mobility or extra

2319
01:30:04,950 --> 01:30:03,590
so in

2320
01:30:07,510 --> 01:30:04,960
that's pretty much what i was going to

2321
01:30:09,270 --> 01:30:07,520
say and slide seven

2322
01:30:11,189 --> 01:30:09,280
uh that you could launch it with the

2323
01:30:13,830 --> 01:30:11,199
retrieval mission it

2324
01:30:15,430 --> 01:30:13,840
could orion could dock to it and use it

2325
01:30:17,990 --> 01:30:15,440
as an air lock

2326
01:30:18,950 --> 01:30:18,000
also through the suit ports

2327
01:30:21,430 --> 01:30:18,960
you could

2328
01:30:23,750 --> 01:30:21,440
detach from orion and use it in

2329
01:30:25,189 --> 01:30:23,760
preflight mode with the coal gas

2330
01:30:28,390 --> 01:30:25,199
thruster system

2331
01:30:30,070 --> 01:30:28,400
or use it at like a small mmsev

2332
01:30:32,470 --> 01:30:30,080
with one person inside supporting the

2333
01:30:34,709 --> 01:30:32,480
person in a suit

2334
01:30:37,350 --> 01:30:34,719
and the nice thing about a vehicle like

2335
01:30:38,709 --> 01:30:37,360
this because of the dexter's robotics

2336
01:30:41,350 --> 01:30:38,719
after the

2337
01:30:43,990 --> 01:30:41,360
orion leaves you can use it in either

2338
01:30:46,550 --> 01:30:44,000

autonomous or tally operated mode uh to

2339
01:30:47,669 --> 01:30:46,560
continue the exploration um actually if

2340
01:30:49,189 --> 01:30:47,679
you get

2341
01:30:51,030 --> 01:30:49,199
10 tickets there before the crew does

2342
01:30:53,430 --> 01:30:51,040
you could tell they operated to start

2343
01:30:55,910 --> 01:30:53,440
the sample collection process and have a

2344
01:30:58,629 --> 01:30:55,920
case of samples ready when this uh crew

2345
01:31:01,990 --> 01:30:58,639
gets there so by my timer i'm about at a

2346
01:31:03,750 --> 01:31:02,000
time uh the last slide is just a way of

2347
01:31:06,149 --> 01:31:03,760
contacting me if anybody has any

2348
01:31:09,189 --> 01:31:06,159
interest or whatever and if i have time

2349
01:31:11,430 --> 01:31:09,199
i'd be happy to take questions

2350
01:31:12,709 --> 01:31:11,440
any questions in the room

2351
01:31:15,030 --> 01:31:12,719
yeah i think we have time for one

2352
01:31:17,750 --> 01:31:15,040
question yes

2353
01:31:20,470 --> 01:31:17,760
or maybe one question from online

2354
01:31:21,910 --> 01:31:20,480
well i have one question on your uh

2355
01:31:24,070 --> 01:31:21,920
portable camera system the first

2356
01:31:26,310 --> 01:31:24,080
technology you discussed does that

2357
01:31:28,629 --> 01:31:26,320
technology have the capability to be

2358
01:31:31,030 --> 01:31:28,639
refueled robotically

2359
01:31:31,990 --> 01:31:31,040
um so that it can be reused time after

2360
01:31:33,350 --> 01:31:32,000
time

2361
01:31:35,270 --> 01:31:33,360
or do you have to bring it inside to

2362
01:31:37,189 --> 01:31:35,280
re-service it with human interaction

2363
01:31:38,709 --> 01:31:37,199

yeah we have a

2364
01:31:40,950 --> 01:31:38,719
service

2365
01:31:43,189 --> 01:31:40,960
system designed

2366
01:31:45,189 --> 01:31:43,199
actually the the particular design we

2367
01:31:46,310 --> 01:31:45,199
have is for station but it's adaptable

2368
01:31:48,149 --> 01:31:46,320
to anything

2369
01:31:50,149 --> 01:31:48,159
so that

2370
01:31:51,990 --> 01:31:50,159
when you dock to it

2371
01:31:54,149 --> 01:31:52,000
fluid couples couplings are made

2372
01:31:56,629 --> 01:31:54,159
electrical couplings are made and you

2373
01:31:57,430 --> 01:31:56,639
can recharge the batteries and resupply

2374
01:31:58,950 --> 01:31:57,440
the

2375
01:32:00,390 --> 01:31:58,960
coal gas system

2376
01:32:03,350 --> 01:32:00,400
while you're docked

2377
01:32:05,350 --> 01:32:03,360
beautiful what so you said that the

2378
01:32:07,669 --> 01:32:05,360
excursion vehicle was 50 kilograms

2379
01:32:09,990 --> 01:32:07,679
what's the mass of the docking

2380
01:32:11,270 --> 01:32:10,000
system and resurfacing

2381
01:32:13,510 --> 01:32:11,280
um

2382
01:32:15,750 --> 01:32:13,520
right now it's probably about 200

2383
01:32:19,750 --> 01:32:15,760
kilograms but most of that

2384
01:32:21,990 --> 01:32:19,760
was a long uh was basically um

2385
01:32:24,870 --> 01:32:22,000
enough propellant to do something like

2386
01:32:27,189 --> 01:32:24,880
50 sorties on space station

2387
01:32:28,229 --> 01:32:27,199
uh so it's basically most of the mass is

2388
01:32:30,470 --> 01:32:28,239

in uh

2389
01:32:32,470 --> 01:32:30,480
co2 canisters

2390
01:32:35,030 --> 01:32:32,480
so if you had a smaller number of

2391
01:32:37,350 --> 01:32:35,040
sorties planned you could uh pare down

2392
01:32:39,430 --> 01:32:37,360
the docking station considerably right

2393
01:32:41,350 --> 01:32:39,440
the actual interface is about 20

2394
01:32:42,629 --> 01:32:41,360
kilograms

2395
01:32:45,350 --> 01:32:42,639
thank you

2396
01:32:47,189 --> 01:32:45,360
any other questions

2397
01:32:53,030 --> 01:32:47,199
thank you very much doctor thanks dave

2398
01:32:58,070 --> 01:32:55,590
so our next presentation is rob mueller

2399
01:32:59,990 --> 01:32:58,080
from the kennedy space center and rob's

2400
01:33:02,390 --> 01:33:00,000
uh presentation is entitled

2401
01:33:04,229 --> 01:33:02,400
electrodynamic dust shield

2402
01:33:07,430 --> 01:33:04,239
pneumatic regolith wraith and a

2403
01:33:08,950 --> 01:33:07,440
percussive evacuation shovel so

2404
01:33:11,189 --> 01:33:08,960
looking forward to hearing

2405
01:33:13,270 --> 01:33:11,199
great thank you good afternoon

2406
01:33:16,070 --> 01:33:13,280
i'd like to start by acknowledging uh my

2407
01:33:20,149 --> 01:33:16,080
co-investigators here dr carlos kaye and

2408
01:33:22,149 --> 01:33:20,159
dr jim montevani they're both in the

2409
01:33:23,750 --> 01:33:22,159
swamp works which is an innovation lab

2410
01:33:25,430 --> 01:33:23,760
that we have at kennedy space center

2411
01:33:26,870 --> 01:33:25,440
it's part of the surface systems office

2412
01:33:29,430 --> 01:33:26,880
it's dedicated to

2413
01:33:31,590 --> 01:33:29,440

lean development and

2414
01:33:34,229 --> 01:33:31,600
providing new technologies for human and

2415
01:33:35,669 --> 01:33:34,239
robotic space exploration

2416
01:33:40,870 --> 01:33:35,679
so

2417
01:33:43,430 --> 01:33:40,880
three technologies uh in our portfolio

2418
01:33:44,470 --> 01:33:43,440
of technology development because they

2419
01:33:46,629 --> 01:33:44,480
seem to be

2420
01:33:48,470 --> 01:33:46,639
rather relevant to the asteroid

2421
01:33:50,470 --> 01:33:48,480
initiative when the rfi came out we

2422
01:33:53,350 --> 01:33:50,480
looked at what we had going on we said

2423
01:33:55,270 --> 01:33:53,360
well these technologies seem like they

2424
01:33:57,990 --> 01:33:55,280
would be very useful

2425
01:33:59,910 --> 01:33:58,000
for a crew

2426
01:34:02,229 --> 01:33:59,920
asteroid mission

2427
01:34:05,189 --> 01:34:02,239
where the crew needs to to have some

2428
01:34:06,390 --> 01:34:05,199
help and possibly make the mission safer

2429
01:34:08,950 --> 01:34:06,400
because

2430
01:34:10,390 --> 01:34:08,960
we have never done this before and so we

2431
01:34:12,950 --> 01:34:10,400
need to make sure we don't get the

2432
01:34:15,030 --> 01:34:12,960
astronauts into situations with the the

2433
01:34:17,030 --> 01:34:15,040
regolith and and the rocks and the

2434
01:34:18,629 --> 01:34:17,040
abrasiveness

2435
01:34:19,830 --> 01:34:18,639
one of the biggest problems in apollo

2436
01:34:20,709 --> 01:34:19,840
was a dust

2437
01:34:22,709 --> 01:34:20,719
so

2438
01:34:25,669 --> 01:34:22,719

this is in in many of the talks this

2439
01:34:28,229 --> 01:34:25,679
morning you've heard that dust does

2440
01:34:30,950 --> 01:34:28,239
exist on asteroids and it's held down by

2441
01:34:33,910 --> 01:34:30,960
van der waals forces and the combined

2442
01:34:36,229 --> 01:34:33,920
forces of billions of small particles

2443
01:34:38,070 --> 01:34:36,239
is actually quite high so

2444
01:34:40,390 --> 01:34:38,080
the same forces electrostatic and van

2445
01:34:41,990 --> 01:34:40,400
der waals can stick to your eva suit and

2446
01:34:43,669 --> 01:34:42,000
cause problems

2447
01:34:49,350 --> 01:34:43,679
so

2448
01:34:51,830 --> 01:34:49,360
called the electrodynamic dust shield

2449
01:34:53,590 --> 01:34:51,840
and this is a series of electrodes

2450
01:34:55,750 --> 01:34:53,600
embedded in a material

2451
01:34:58,070 --> 01:34:55,760
and it could be used for visors optical

2452
01:34:59,750 --> 01:34:58,080
devices viewports transparent electrodes

2453
01:35:01,350 --> 01:34:59,760
on film plastic or glass so you can

2454
01:35:03,510 --> 01:35:01,360
imagine it could be used on the visor of

2455
01:35:05,669 --> 01:35:03,520
the eva suit could be used on camera

2456
01:35:08,229 --> 01:35:05,679
lenses it could be used on sensors

2457
01:35:09,990 --> 01:35:08,239
anything that could be spoofed by dust

2458
01:35:12,629 --> 01:35:10,000
or obscured

2459
01:35:14,550 --> 01:35:12,639
by dust or regoliths

2460
01:35:16,229 --> 01:35:14,560
in general would would be used this

2461
01:35:19,750 --> 01:35:16,239
technology would be useful

2462
01:35:21,910 --> 01:35:19,760
uh we've also been working to embed this

2463
01:35:23,669 --> 01:35:21,920

if you look at the the upper right here

2464
01:35:25,910 --> 01:35:23,679
let's see if this mouse works so

2465
01:35:27,910 --> 01:35:25,920
everybody online can see it

2466
01:35:29,990 --> 01:35:27,920
on the upper right this is actually the

2467
01:35:32,149 --> 01:35:30,000
electrodynamic dust shield

2468
01:35:34,950 --> 01:35:32,159
printed onto a fabric

2469
01:35:36,709 --> 01:35:34,960
and so not only does it work on a solid

2470
01:35:39,350 --> 01:35:36,719
piece of glass which is what you see

2471
01:35:41,350 --> 01:35:39,360
here in the on the top left and then in

2472
01:35:43,990 --> 01:35:41,360
the middle you see it's dirty and then

2473
01:35:46,229 --> 01:35:44,000
you flick the switch and it cleans it

2474
01:35:48,550 --> 01:35:46,239
that square is is cleaned

2475
01:35:49,270 --> 01:35:48,560
by the embedded electrodes you can also

2476
01:35:54,310 --> 01:35:49,280
put

2477
01:35:56,229 --> 01:35:54,320
flexible film and we've tested this if

2478
01:35:58,709 --> 01:35:56,239
you look in the bottom right here in a

2479
01:36:00,629 --> 01:35:58,719
reduced gravity flight so the trl

2480
01:36:03,030 --> 01:36:00,639
progression is significant and we're

2481
01:36:05,510 --> 01:36:03,040
almost ready to to go with this now in

2482
01:36:06,790 --> 01:36:05,520
fact it's going on missy x to station in

2483
01:36:09,109 --> 01:36:06,800
a couple years

2484
01:36:11,510 --> 01:36:09,119
next opportunity and at that point we

2485
01:36:13,669 --> 01:36:11,520
will say it's a trl

2486
01:36:15,990 --> 01:36:13,679
nine maybe eight or nine

2487
01:36:18,149 --> 01:36:16,000
uh so this is an exciting technology i

2488
01:36:19,830 --> 01:36:18,159

do have a video let's see if we get

2489
01:36:22,310 --> 01:36:19,840
lucky here

2490
01:36:24,950 --> 01:36:22,320
and we did so here's the video i hope

2491
01:36:27,669 --> 01:36:24,960
you can see it online and this is the

2492
01:36:29,270 --> 01:36:27,679
results of the reduced gravity test

2493
01:36:30,470 --> 01:36:29,280
flight what you see there's a vacuum

2494
01:36:32,870 --> 01:36:30,480
chamber

2495
01:36:35,109 --> 01:36:32,880
which was uh on loan from langley and

2496
01:36:36,629 --> 01:36:35,119
the crew is from kennedy and so with a

2497
01:36:38,470 --> 01:36:36,639
collaborative effort between the two

2498
01:36:40,550 --> 01:36:38,480
space centers we tested this and you can

2499
01:36:42,229 --> 01:36:40,560
see those electrodes starting to work

2500
01:36:44,390 --> 01:36:42,239
now they're not on all the time they

2501
01:36:46,070 --> 01:36:44,400
just pulse and every time they pulse

2502
01:36:48,709 --> 01:36:46,080
you'll see the dust moving so right now

2503
01:36:50,229 --> 01:36:48,719
you see that spiral pattern the spiral

2504
01:36:52,390 --> 01:36:50,239
is is the electrodes and then they

2505
01:36:54,470 --> 01:36:52,400
pulsed it again and now it's clean

2506
01:36:56,070 --> 01:36:54,480
so it's very efficient and if you look

2507
01:36:57,990 --> 01:36:56,080
at this in slow motion on the mic under

2508
01:37:00,149 --> 01:36:58,000
a microscope it's pretty cool because

2509
01:37:01,990 --> 01:37:00,159
it's like ripples in a pond if you throw

2510
01:37:03,830 --> 01:37:02,000
a rock into a pond and the ripples move

2511
01:37:05,750 --> 01:37:03,840
concentrically outwards that's exactly

2512
01:37:08,870 --> 01:37:05,760
what it does to dust and it just moves

2513
01:37:10,550 --> 01:37:08,880

the dust sideways off of your optics so

2514
01:37:12,390 --> 01:37:10,560
that's one exciting technology we'd like

2515
01:37:14,790 --> 01:37:12,400
to present today

2516
01:37:16,550 --> 01:37:14,800
the next technology we'd like to suggest

2517
01:37:18,870 --> 01:37:16,560
could be useful in a mission like this

2518
01:37:20,550 --> 01:37:18,880
is a pneumatic regolith rake now you've

2519
01:37:22,709 --> 01:37:20,560
already heard today about

2520
01:37:24,390 --> 01:37:22,719
doing things with pneumatics

2521
01:37:26,950 --> 01:37:24,400
this was a technology that we developed

2522
01:37:29,669 --> 01:37:26,960
in collaboration with honeybee robotics

2523
01:37:31,910 --> 01:37:29,679
uh in under an sbir contract and we've

2524
01:37:34,390 --> 01:37:31,920
since taken in our lab to the next level

2525
01:37:36,550 --> 01:37:34,400
for this kind of application and so what

2526
01:37:37,430 --> 01:37:36,560
this does is uh

2527
01:37:39,030 --> 01:37:37,440
people

2528
01:37:41,990 --> 01:37:39,040
always have a problem with pneumatics

2529
01:37:44,470 --> 01:37:42,000
and vacuum and rightfully so but what

2530
01:37:46,790 --> 01:37:44,480
the key to this technology is the gas

2531
01:37:48,470 --> 01:37:46,800
never actually goes out into the vacuum

2532
01:37:50,870 --> 01:37:48,480
and is lost the gas

2533
01:37:53,109 --> 01:37:50,880
makes a small jet and creates a hole

2534
01:37:54,790 --> 01:37:53,119
imagine taking your garden hose and

2535
01:37:57,189 --> 01:37:54,800
pointing it downward in your garden into

2536
01:37:59,430 --> 01:37:57,199
the mud and it goes straight down does a

2537
01:38:01,109 --> 01:37:59,440
u-turn comes right back into your face

2538
01:38:04,070 --> 01:38:01,119

and that's exactly what this technology

2539
01:38:05,910 --> 01:38:04,080
does it goes the gas goes straight down

2540
01:38:08,870 --> 01:38:05,920
and it digs a hole

2541
01:38:11,910 --> 01:38:08,880
pneumatically and it traps the little

2542
01:38:14,070 --> 01:38:11,920
granules of regolith in the gas flow and

2543
01:38:15,590 --> 01:38:14,080
then it brings it back up and you

2544
01:38:17,030 --> 01:38:15,600
capture it in a concentric tube so

2545
01:38:18,790 --> 01:38:17,040
there's an annulus inside the

2546
01:38:20,629 --> 01:38:18,800
cross-section of the tube and then you

2547
01:38:22,870 --> 01:38:20,639
capture that regulates pneumatically and

2548
01:38:25,030 --> 01:38:22,880
we've had very high efficiencies a

2549
01:38:26,629 --> 01:38:25,040
thousand to one and higher in in a

2550
01:38:28,470 --> 01:38:26,639
reduced gravity environment in a vacuum

2551
01:38:30,550 --> 01:38:28,480
so what we thought we'd do is if you

2552
01:38:34,790 --> 01:38:30,560
look at this picture here

2553
01:38:37,109 --> 01:38:34,800
it's a series of pneumatic tubes that

2554
01:38:39,910 --> 01:38:37,119
can actually capture each tube can

2555
01:38:41,590 --> 01:38:39,920
capture regolith and now if you take

2556
01:38:43,590 --> 01:38:41,600
lunar regulators as an analog the

2557
01:38:45,750 --> 01:38:43,600
particles are typically under 100

2558
01:38:48,070 --> 01:38:45,760
microns between 20 and 100 microns 80

2559
01:38:50,229 --> 01:38:48,080
percent are between 20 and 100 and 20

2560
01:38:51,830 --> 01:38:50,239
percent are under 20 micron the rest

2561
01:38:54,709 --> 01:38:51,840
only five percent of the rocks on the

2562
01:38:56,950 --> 01:38:54,719
moon are are actually bigger than 100

2563
01:38:58,629 --> 01:38:56,960

microns so that's the distribution of

2564
01:39:00,229 --> 01:38:58,639
the particles now i don't know if an

2565
01:39:03,270 --> 01:39:00,239
asteroid will be like that but let's

2566
01:39:04,470 --> 01:39:03,280
assume it is then most of the regular

2567
01:39:05,910 --> 01:39:04,480
sample that you want is actually a

2568
01:39:09,189 --> 01:39:05,920
granular material

2569
01:39:11,750 --> 01:39:09,199
the rest are rocks so we can kill two

2570
01:39:13,910 --> 01:39:11,760
birds with one stone by having a rake by

2571
01:39:15,990 --> 01:39:13,920
taking these tubes making a rake out of

2572
01:39:17,910 --> 01:39:16,000
them mounting them on a handle and then

2573
01:39:20,149 --> 01:39:17,920
the regolith will be captured by the

2574
01:39:21,189 --> 01:39:20,159
tubes and the rocks will be captured by

2575
01:39:23,510 --> 01:39:21,199
the rake

2576
01:39:25,430 --> 01:39:23,520
and the nice thing about this design is

2577
01:39:26,790 --> 01:39:25,440
you can put it on a handle and if you

2578
01:39:29,350 --> 01:39:26,800
look at that video of the asteroid

2579
01:39:31,590 --> 01:39:29,360
initiative with a crew going up the pole

2580
01:39:33,189 --> 01:39:31,600
and cutting open the bag you really

2581
01:39:35,510 --> 01:39:33,199
don't want to get too close to that

2582
01:39:36,870 --> 01:39:35,520
regolith until you know what's in it so

2583
01:39:39,030 --> 01:39:36,880
you could reach out with a rake and

2584
01:39:41,030 --> 01:39:39,040
capture a sample and that would be one

2585
01:39:42,950 --> 01:39:41,040
enhancement for your mission

2586
01:39:46,229 --> 01:39:42,960
another technology we have is a

2587
01:39:48,950 --> 01:39:46,239
percussive excavation shovel and so

2588
01:39:50,390 --> 01:39:48,960

percussion reduces reaction forces

2589
01:39:51,910 --> 01:39:50,400
biggest problem in outer space and

2590
01:39:55,030 --> 01:39:51,920
reduce gravity is you have no reaction

2591
01:39:56,950 --> 01:39:55,040
force so you try to dig and you don't

2592
01:39:59,030 --> 01:39:56,960
dig you don't penetrate if you had a

2593
01:40:00,470 --> 01:39:59,040
robot if you had a front end loader like

2594
01:40:01,750 --> 01:40:00,480
you have here on a construction site and

2595
01:40:02,950 --> 01:40:01,760
you put it on the moon and you push the

2596
01:40:05,109 --> 01:40:02,960
bucket of the front end loader into the

2597
01:40:06,470 --> 01:40:05,119
soil the machine would do a push-up it

2598
01:40:08,870 --> 01:40:06,480
would not penetrate the soil because

2599
01:40:11,270 --> 01:40:08,880
there's not enough reaction force from

2600
01:40:13,350 --> 01:40:11,280
the actual weight of the machine in that

2601
01:40:15,590 --> 01:40:13,360
reduced gravity environment so what we

2602
01:40:18,629 --> 01:40:15,600
found is that because it's a dry

2603
01:40:20,870 --> 01:40:18,639
granular material if you use percussion

2604
01:40:23,189 --> 01:40:20,880
the little particles are actually

2605
01:40:25,430 --> 01:40:23,199
for lack of a better word jiggled around

2606
01:40:27,189 --> 01:40:25,440
and it creates a bow wake and then by

2607
01:40:29,109 --> 01:40:27,199
creating this bow wick you reduce the

2608
01:40:29,990 --> 01:40:29,119
excavation forces now it's a trade-off

2609
01:40:31,189 --> 01:40:30,000
because

2610
01:40:33,270 --> 01:40:31,199
and the reason they don't do this here

2611
01:40:35,270 --> 01:40:33,280
on earth is because it takes more energy

2612
01:40:36,390 --> 01:40:35,280
so but you have energy in space you have

2613
01:40:38,149 --> 01:40:36,400

plenty of sunlight

2614
01:40:39,910 --> 01:40:38,159
but you don't have reaction force so

2615
01:40:41,910 --> 01:40:39,920
this is a trade-off a simple mechanical

2616
01:40:43,910 --> 01:40:41,920
trade-off by using more energy to use

2617
01:40:45,830 --> 01:40:43,920
percussion you can reduce the excavation

2618
01:40:49,030 --> 01:40:45,840
force and we found it's very

2619
01:40:52,070 --> 01:40:49,040
scale-dependent it's it's very

2620
01:40:54,310 --> 01:40:52,080
small implements have up to 90

2621
01:40:56,229 --> 01:40:54,320
force reduction reaction force reduction

2622
01:40:57,750 --> 01:40:56,239
the larger implements we've only been

2623
01:40:58,470 --> 01:40:57,760
getting 50 percent

2624
01:40:59,750 --> 01:40:58,480
so

2625
01:41:01,270 --> 01:40:59,760
it's it's very much

2626
01:41:02,629 --> 01:41:01,280
scale dependent we're still learning a

2627
01:41:05,189 --> 01:41:02,639
lot about that but we thought if we took

2628
01:41:07,510 --> 01:41:05,199
this mechanism and forgive the the

2629
01:41:10,629 --> 01:41:07,520
cartoon here but we just photoshopped

2630
01:41:12,709 --> 01:41:10,639
this onto a shovel and we think if we

2631
01:41:14,870 --> 01:41:12,719
could make a percussive shovel that

2632
01:41:18,629 --> 01:41:14,880
would be very useful to an astronaut on

2633
01:41:20,950 --> 01:41:18,639
orbit or actually at an asteroid

2634
01:41:22,390 --> 01:41:20,960
so in conclusion

2635
01:41:23,830 --> 01:41:22,400
we think that astronauts working with

2636
01:41:25,669 --> 01:41:23,840
asteroid regolith will need protection

2637
01:41:27,590 --> 01:41:25,679
from dust and dust mitigation for

2638
01:41:30,070 --> 01:41:27,600

payloads and instruments we think that

2639
01:41:32,709 --> 01:41:30,080
just as harrison schmidt said in apollo

2640
01:41:35,109 --> 01:41:32,719
he said dust and regolith are the number

2641
01:41:37,669 --> 01:41:35,119
one challenge of going back to planetary

2642
01:41:39,669 --> 01:41:37,679
surface and we think that's correct

2643
01:41:41,590 --> 01:41:39,679
and so with the electrodynamic dust

2644
01:41:43,030 --> 01:41:41,600
shields at trl6 now and it's it should

2645
01:41:45,030 --> 01:41:43,040
be available from mission infusion after

2646
01:41:47,030 --> 01:41:45,040
it's gone up on missy x

2647
01:41:48,790 --> 01:41:47,040
and then the pneumatic regolith rake is

2648
01:41:50,310 --> 01:41:48,800
is a lower trl that's just something

2649
01:41:51,830 --> 01:41:50,320
we've been done in the lab and when we

2650
01:41:54,070 --> 01:41:51,840
haven't pursued it much it's just

2651
01:41:57,350 --> 01:41:54,080
opportunistic and that's trl3 the

2652
01:42:00,310 --> 01:41:57,360
percussive excavation shovel is at trl4

2653
01:42:03,030 --> 01:42:00,320
and so i'd like to thank the space

2654
01:42:04,950 --> 01:42:03,040
technology mission directorate at nasa

2655
01:42:06,470 --> 01:42:04,960
the game changing division under the

2656
01:42:08,550 --> 01:42:06,480
human robotics systems project for

2657
01:42:10,470 --> 01:42:08,560
funding this work because

2658
01:42:13,750 --> 01:42:10,480
this is a technology push

2659
01:42:16,070 --> 01:42:13,760
and many times people have a trouble

2660
01:42:18,149 --> 01:42:16,080
with technology push because they can't

2661
01:42:19,910 --> 01:42:18,159
see how it will be applied but this is a

2662
01:42:22,709 --> 01:42:19,920
perfect example of something we

2663
01:42:25,590 --> 01:42:22,719

developed and now the application has

2664
01:42:27,430 --> 01:42:25,600
arrived and we're ready and so or we

2665
01:42:29,109 --> 01:42:27,440
could be ready if if we were asked to be

2666
01:42:31,189 --> 01:42:29,119
ready so this is a good example of

2667
01:42:33,669 --> 01:42:31,199
technology push meeting technology pull

2668
01:42:35,830 --> 01:42:33,679
in a mission and we think it's it's a

2669
01:42:38,149 --> 01:42:35,840
great model on how to operate inside

2670
01:42:39,750 --> 01:42:38,159
nasa so thanks for your attention

2671
01:42:49,030 --> 01:42:39,760
any questions

2672
01:42:52,870 --> 01:42:51,270
um yes like a question on the

2673
01:42:55,189 --> 01:42:52,880
electrodynamic

2674
01:42:58,229 --> 01:42:55,199
dust shield

2675
01:43:00,790 --> 01:42:58,239
now would that be incorporated

2676
01:43:03,350 --> 01:43:00,800
in the suit or like i guess i'm a little

2677
01:43:05,189 --> 01:43:03,360
confused on how that would

2678
01:43:07,669 --> 01:43:05,199
would that be incorporated in the suit

2679
01:43:09,510 --> 01:43:07,679
on the fabric right okay so on the

2680
01:43:11,270 --> 01:43:09,520
fabric we're looking at actually

2681
01:43:13,430 --> 01:43:11,280
printing it you know the

2682
01:43:16,390 --> 01:43:13,440
the eva suit is is actually several

2683
01:43:18,790 --> 01:43:16,400
suits right it's a layered approach and

2684
01:43:20,470 --> 01:43:18,800
so this would be the outer garment

2685
01:43:23,189 --> 01:43:20,480
and i was actually looking at it out in

2686
01:43:25,189 --> 01:43:23,199
the lobby earlier on it's an and i

2687
01:43:28,310 --> 01:43:25,199
quizzed the guy pretty good

2688
01:43:30,870 --> 01:43:28,320

and he said it's a teflon covered aramid

2689
01:43:34,709 --> 01:43:30,880
fiber and that's as far as i got with

2690
01:43:36,149 --> 01:43:34,719
that uh but so if it's a teflon covered

2691
01:43:38,550 --> 01:43:36,159
fabric that's what you see there is a

2692
01:43:40,390 --> 01:43:38,560
teflon covered fabric and we're trying

2693
01:43:43,109 --> 01:43:40,400
to it's very difficult because to get

2694
01:43:45,990 --> 01:43:43,119
these these electrode patterns to stick

2695
01:43:47,590 --> 01:43:46,000
to teflon is is almost impossible so

2696
01:43:49,430 --> 01:43:47,600
we've we've been experimenting with that

2697
01:43:51,189 --> 01:43:49,440
and we have managed to get it to work so

2698
01:43:53,350 --> 01:43:51,199
the vision is that you would print it

2699
01:43:56,070 --> 01:43:53,360
directly onto the fabric

2700
01:43:57,830 --> 01:43:56,080
and and then use it as the outer garment

2701
01:44:00,310 --> 01:43:57,840
that that's the vision now we're not

2702
01:44:03,430 --> 01:44:00,320
there yet and it's not proven yet but

2703
01:44:05,510 --> 01:44:03,440
that that is we've done little swatches

2704
01:44:07,350 --> 01:44:05,520
fabric swatches like this

2705
01:44:09,669 --> 01:44:07,360
so it looks like you could incorporate

2706
01:44:11,830 --> 01:44:09,679
this to different if not the hosts who

2707
01:44:12,629 --> 01:44:11,840
maybe different sections of it

2708
01:44:15,750 --> 01:44:12,639
and

2709
01:44:18,629 --> 01:44:15,760
the the mass or the required

2710
01:44:20,950 --> 01:44:18,639
weight of this would that be dramatic or

2711
01:44:22,390 --> 01:44:20,960
the mass is negligible negligible and

2712
01:44:24,390 --> 01:44:22,400
the power people always ask about power

2713
01:44:25,750 --> 01:44:24,400

when they see this next one yeah so i'll

2714
01:44:27,830 --> 01:44:25,760
preempt that

2715
01:44:29,270 --> 01:44:27,840
it's it's uh

2716
01:44:32,950 --> 01:44:29,280
let's see let me get this right it's

2717
01:44:35,750 --> 01:44:32,960
it's low current high voltage

2718
01:44:39,350 --> 01:44:35,760
so it's low power but it is high voltage

2719
01:44:47,350 --> 01:44:39,360
but low current typically that's pretty

2720
01:44:51,830 --> 01:44:49,350
on the same chart you show an

2721
01:44:54,070 --> 01:44:51,840
application for a viewport or optical

2722
01:44:57,590 --> 01:44:54,080
devices would that affect the

2723
01:45:00,550 --> 01:44:57,600
transmission of light through the

2724
01:45:02,870 --> 01:45:00,560
optical device yeah great question

2725
01:45:04,709 --> 01:45:02,880
this is um dr carlos kaye is the

2726
01:45:06,310 --> 01:45:04,719
principal investigator on this and and i

2727
01:45:08,149 --> 01:45:06,320
i myself have quizzed him on this and

2728
01:45:10,470 --> 01:45:08,159
said well don't you lose something

2729
01:45:12,950 --> 01:45:10,480
because if the the vision for this too

2730
01:45:14,310 --> 01:45:12,960
is you put it on on a solar power a

2731
01:45:17,510 --> 01:45:14,320
photovoltaic

2732
01:45:19,350 --> 01:45:17,520
farm in say in an arizona desert and

2733
01:45:21,750 --> 01:45:19,360
then it would self-clean itself actually

2734
01:45:23,830 --> 01:45:21,760
this technology was developed for mars

2735
01:45:26,470 --> 01:45:23,840
it never did fly on mars because of the

2736
01:45:28,149 --> 01:45:26,480
trl issues but it was originally

2737
01:45:30,149 --> 01:45:28,159
designed for the solar panels for mars

2738
01:45:32,149 --> 01:45:30,159

which which was a show stopper until the

2739
01:45:34,629 --> 01:45:32,159
dust devils came and cleaned them off

2740
01:45:40,870 --> 01:45:37,510
carlos tells me that it's 95

2741
01:45:43,109 --> 01:45:40,880
translucent so you lose 5 percent

2742
01:45:44,550 --> 01:45:43,119
for that blockage from each electrode

2743
01:45:45,669 --> 01:45:44,560
and he tells me

2744
01:45:47,510 --> 01:45:45,679
that's pretty good and we're also

2745
01:45:48,709 --> 01:45:47,520
talking to the camera manufacturers on

2746
01:45:50,550 --> 01:45:48,719
wouldn't they be interested in having

2747
01:45:51,910 --> 01:45:50,560
this what they do today is they have a

2748
01:45:53,910 --> 01:45:51,920
little cmos chip in there and they just

2749
01:45:55,270 --> 01:45:53,920
they vibrate it they have a pizza

2750
01:45:57,109 --> 01:45:55,280
electric vibrator and they just vibrate

2751
01:45:58,550 --> 01:45:57,119
and shake the dust off because it's

2752
01:46:04,310 --> 01:45:58,560
internal to the camera but this could be

2753
01:46:07,109 --> 01:46:05,750
so we're going to do one more question

2754
01:46:08,229 --> 01:46:07,119
and then we're going to move on so if we

2755
01:46:10,550 --> 01:46:08,239
could go ahead and do this one here in

2756
01:46:14,470 --> 01:46:12,870
wendy go ahead just this one in front

2757
01:46:16,790 --> 01:46:14,480
here yeah

2758
01:46:19,669 --> 01:46:16,800
for the percussive shovel is there a

2759
01:46:21,669 --> 01:46:19,679
relationship between the granular size

2760
01:46:23,430 --> 01:46:21,679
and the frequency

2761
01:46:25,109 --> 01:46:23,440
of the percussion

2762
01:46:27,750 --> 01:46:25,119
yeah so

2763
01:46:30,950 --> 01:46:27,760

percussion is tricky

2764
01:46:34,470 --> 01:46:30,960
and it it is very dependent on the

2765
01:46:35,910 --> 01:46:34,480
granular medium you're operating in

2766
01:46:37,910 --> 01:46:35,920
and

2767
01:46:40,390 --> 01:46:37,920
what's interesting is well first of all

2768
01:46:42,709 --> 01:46:40,400
it has to be a dry granular medium

2769
01:46:45,750 --> 01:46:42,719
so it cannot be

2770
01:46:46,709 --> 01:46:45,760
wet like a clay type of soil no it will

2771
01:46:48,550 --> 01:46:46,719
not work

2772
01:46:49,270 --> 01:46:48,560
because the particles stick stick with

2773
01:46:53,750 --> 01:46:49,280
the

2774
01:46:55,030 --> 01:46:53,760
but in a planetary environment

2775
01:46:56,870 --> 01:46:55,040
the regolith

2776
01:46:58,550 --> 01:46:56,880
is a good

2777
01:47:00,149 --> 01:46:58,560
candidate for percussive excavation

2778
01:47:01,990 --> 01:47:00,159
because of this particle size

2779
01:47:03,990 --> 01:47:02,000
distribution

2780
01:47:05,750 --> 01:47:04,000
if if you go on the premise that

2781
01:47:08,310 --> 01:47:05,760
regolith is crushed rock

2782
01:47:11,669 --> 01:47:08,320
from a high energy impact then that's

2783
01:47:14,709 --> 01:47:11,679
just basic physics and geology

2784
01:47:16,470 --> 01:47:14,719
and so turns out in most places

2785
01:47:19,830 --> 01:47:16,480
regolith is in that particle size

2786
01:47:22,070 --> 01:47:19,840
distribution of of 100 microns and below

2787
01:47:23,270 --> 01:47:22,080
so that's a pretty nice granular medium

2788
01:47:24,709 --> 01:47:23,280

and then what we've seen when we dig

2789
01:47:26,709 --> 01:47:24,719
with these percussive shovels there's

2790
01:47:28,550 --> 01:47:26,719
this thing called the brazil nut effect

2791
01:47:30,149 --> 01:47:28,560
the brazil nut effect is where when you

2792
01:47:32,470 --> 01:47:30,159
buy a

2793
01:47:34,470 --> 01:47:32,480
jar of nuts and you open it up the

2794
01:47:36,950 --> 01:47:34,480
brazil nuts are always at the top

2795
01:47:39,189 --> 01:47:36,960
the brazil nuts float to the top as they

2796
01:47:41,430 --> 01:47:39,199
get shaken in transportation

2797
01:47:43,510 --> 01:47:41,440
so when you do percussive excavation in

2798
01:47:46,149 --> 01:47:43,520
a regular simulant which we have a

2799
01:47:48,149 --> 01:47:46,159
basaltic regulation in our lab you see

2800
01:47:50,870 --> 01:47:48,159
the darker particles the bigger

2801
01:47:52,629 --> 01:47:50,880
particles float to the top

2802
01:47:54,470 --> 01:47:52,639
and and you see this brazil nut effect

2803
01:47:56,629 --> 01:47:54,480
so it's classic granular mechanics that

2804
01:47:58,629 --> 01:47:56,639
work and and so

2805
01:48:00,950 --> 01:47:58,639
i think your question is very good but

2806
01:48:03,350 --> 01:48:00,960
it does depend on what you're digging in

2807
01:48:05,350 --> 01:48:03,360
but turns out that planetary regolith is

2808
01:48:08,070 --> 01:48:05,360
a pretty good granular material for this

2809
01:48:14,070 --> 01:48:09,590
thank you very much rob

2810
01:48:19,350 --> 01:48:16,629
so our next presentation is from doyle

2811
01:48:20,950 --> 01:48:19,360
tiles from atk space systems

2812
01:48:24,149 --> 01:48:20,960
and the doyle's talk will be on

2813
01:48:25,830 --> 01:48:24,159

telescope telescoping booms for the

2814
01:48:28,390 --> 01:48:25,840
translation by the astronauts and eba

2815
01:48:29,669 --> 01:48:28,400
tools on the asteroid

2816
01:48:31,270 --> 01:48:29,679
well thank you very much for the

2817
01:48:33,830 --> 01:48:31,280
opportunity and i'd also also like to

2818
01:48:35,750 --> 01:48:33,840
thank jose guerrero who led our rfi

2819
01:48:40,070 --> 01:48:35,760
response as well as ken steele provided

2820
01:48:44,550 --> 01:48:42,550
atk space systems provides small

2821
01:48:46,229 --> 01:48:44,560
spacecraft as well as integrated thermal

2822
01:48:48,310 --> 01:48:46,239
systems

2823
01:48:50,229 --> 01:48:48,320
as well as other components and

2824
01:48:52,870 --> 01:48:50,239
engineering services to most the major

2825
01:48:56,390 --> 01:48:52,880
nasa centers including goddard jsc and

2826
01:49:01,270 --> 01:48:59,350
for the obligatory capabilities chart

2827
01:49:04,149 --> 01:49:01,280
we have 25 years of experience

2828
01:49:05,590 --> 01:49:04,159
supporting eva tools for hubble

2829
01:49:06,950 --> 01:49:05,600
servicing

2830
01:49:09,830 --> 01:49:06,960
from the deploy mission all the way

2831
01:49:12,950 --> 01:49:09,840
through the fifth servicing mission

2832
01:49:15,430 --> 01:49:12,960
a lot of these tools and tasks were not

2833
01:49:17,030 --> 01:49:15,440
designed to to be

2834
01:49:17,910 --> 01:49:17,040
eva serviceable

2835
01:49:20,550 --> 01:49:17,920
but we

2836
01:49:22,310 --> 01:49:20,560
designed special tools to be able to

2837
01:49:24,790 --> 01:49:22,320
allow their astronauts to perform very

2838
01:49:26,790 --> 01:49:24,800

complex tasks

2839
01:49:28,950 --> 01:49:26,800
and then we supported the space shuttle

2840
01:49:31,589 --> 01:49:28,960
program as well as international space

2841
01:49:33,109 --> 01:49:31,599
station for both tools and deployable

2842
01:49:35,669 --> 01:49:33,119
booms

2843
01:49:38,070 --> 01:49:35,679
and more recently we've supported uh evr

2844
01:49:40,390 --> 01:49:38,080
tools both for the robotic refueling

2845
01:49:42,709 --> 01:49:40,400
mission as well as for the darpa phoenix

2846
01:49:45,030 --> 01:49:42,719
mission and you see some examples here

2847
01:49:46,629 --> 01:49:45,040
for those tools that are either flying

2848
01:49:48,310 --> 01:49:46,639
in the case of robotic refueling mission

2849
01:49:49,750 --> 01:49:48,320
or being developed for the phoenix

2850
01:49:52,390 --> 01:49:49,760
mission

2851
01:49:55,669 --> 01:49:52,400
and lastly our pasadena office has spent

2852
01:49:57,990 --> 01:49:55,679
16 years supporting jpl and developing

2853
01:50:00,709 --> 01:49:58,000
sample acquisition and handling systems

2854
01:50:02,390 --> 01:50:00,719
we supported the mars science lab chemin

2855
01:50:04,470 --> 01:50:02,400
instrument development

2856
01:50:06,070 --> 01:50:04,480
as well as we've been doing planetary

2857
01:50:08,629 --> 01:50:06,080
drill technology

2858
01:50:10,950 --> 01:50:08,639
and we have specifically looked at deep

2859
01:50:12,550 --> 01:50:10,960
drilling we're actually able to drill

2860
01:50:14,629 --> 01:50:12,560
we've shown in the field to go down to

2861
01:50:17,589 --> 01:50:14,639
10 meters and we have a system that can

2862
01:50:19,830 --> 01:50:17,599
go to 20 meters operating on 60 watts of

2863
01:50:24,709 --> 01:50:19,840

power with a single bit all the way down

2864
01:50:28,629 --> 01:50:26,470
so we tried to put together all the

2865
01:50:30,470 --> 01:50:28,639
things that would be needed by the crew

2866
01:50:32,550 --> 01:50:30,480
obviously there needs to be translation

2867
01:50:34,390 --> 01:50:32,560
to get out to the asteroid

2868
01:50:36,629 --> 01:50:34,400
atk has developed a telescoping boom

2869
01:50:39,189 --> 01:50:36,639
which i'll talk about a little bit more

2870
01:50:41,510 --> 01:50:39,199
we've also supported the the trouble

2871
01:50:43,350 --> 01:50:41,520
servicing missions with translation aids

2872
01:50:45,270 --> 01:50:43,360
that fit to the carriers that allow

2873
01:50:46,790 --> 01:50:45,280
astronauts to be able to move out to the

2874
01:50:48,629 --> 01:50:46,800
hubble

2875
01:50:50,629 --> 01:50:48,639
and then you also need restraints and

2876
01:50:52,550 --> 01:50:50,639
we're saying to use the existing foot

2877
01:50:56,149 --> 01:50:52,560
restraints that are available

2878
01:50:58,390 --> 01:50:56,159
and then lastly you need to have a tool

2879
01:51:00,870 --> 01:50:58,400
uh the sample storage and a toolbox to

2880
01:51:02,310 --> 01:51:00,880
carry all those tools

2881
01:51:04,550 --> 01:51:02,320
so we've elaborated something that we

2882
01:51:07,990 --> 01:51:04,560
developed for proposal for a lunar

2883
01:51:11,430 --> 01:51:09,669
i'll give a little bit more detail about

2884
01:51:13,990 --> 01:51:11,440
the telescoping boom

2885
01:51:16,629 --> 01:51:14,000
this is a design that flew both on the

2886
01:51:19,189 --> 01:51:16,639
shuttle as well as supported the space

2887
01:51:22,470 --> 01:51:19,199
station and it's a

2888
01:51:23,669 --> 01:51:22,480

build building process

2889
01:51:25,830 --> 01:51:23,679
we can

2890
01:51:28,229 --> 01:51:25,840
hold many cycles on this thing it can

2891
01:51:29,990 --> 01:51:28,239
allow a lot of force to be able to

2892
01:51:32,310 --> 01:51:30,000
deploy and retract it

2893
01:51:34,470 --> 01:51:32,320
you can also limit that force

2894
01:51:36,870 --> 01:51:34,480
it can be made out of either metal or

2895
01:51:38,550 --> 01:51:36,880
composites

2896
01:51:41,189 --> 01:51:38,560
and it has a high torsion and bending

2897
01:51:42,709 --> 01:51:41,199
strength and the design is very scalable

2898
01:51:45,430 --> 01:51:42,719
to go anything from three inches

2899
01:51:47,430 --> 01:51:45,440
diameter all the way up to 30 inches

2900
01:51:49,430 --> 01:51:47,440
and it's already been proven to be eva

2901
01:51:55,830 --> 01:51:49,440
safe and you can add things to it

2902
01:51:59,750 --> 01:51:57,990
so for the toolbox what we tried to do

2903
01:52:02,790 --> 01:51:59,760
is think of all the tools that we might

2904
01:52:05,430 --> 01:52:02,800
need and try to cram them all in there

2905
01:52:07,109 --> 01:52:05,440
and what we're showing is basically

2906
01:52:09,030 --> 01:52:07,119
the toolbox that you can open on either

2907
01:52:10,149 --> 01:52:09,040
side and it has multiple shelves on each

2908
01:52:12,629 --> 01:52:10,159
side

2909
01:52:14,709 --> 01:52:12,639
so on the top sections you'll see that

2910
01:52:17,510 --> 01:52:14,719
we tried to fit all the basic tools that

2911
01:52:18,950 --> 01:52:17,520
would be used to actually remove rocks

2912
01:52:20,790 --> 01:52:18,960
and so forth

2913
01:52:22,390 --> 01:52:20,800

into those two sections and down down

2914
01:52:24,149 --> 01:52:22,400
the bottom we said all the sample

2915
01:52:28,790 --> 01:52:24,159
acquisition systems as well as the

2916
01:52:32,790 --> 01:52:30,629
so to get into a little bit more detail

2917
01:52:33,910 --> 01:52:32,800
about the tools that might be used uh

2918
01:52:35,189 --> 01:52:33,920
one of the things we're doing is

2919
01:52:37,430 --> 01:52:35,199
leveraging a lot of the tools we

2920
01:52:39,109 --> 01:52:37,440
developed for hubble servicing

2921
01:52:41,109 --> 01:52:39,119
and other missions

2922
01:52:43,109 --> 01:52:41,119
and on the the first one there the rock

2923
01:52:45,109 --> 01:52:43,119
capture clamp that was actually a

2924
01:52:46,629 --> 01:52:45,119
connector tool that was developed for

2925
01:52:48,790 --> 01:52:46,639
hubble servicing

2926
01:52:51,510 --> 01:52:48,800
what we're calling the rock crack pick

2927
01:52:53,430 --> 01:52:51,520
is actually for manipulating small

2928
01:52:55,270 --> 01:52:53,440
fasteners that we had to remove for

2929
01:52:57,510 --> 01:52:55,280
special tasks

2930
01:52:59,830 --> 01:52:57,520
and then your typical hammer and chisel

2931
01:53:02,550 --> 01:52:59,840
kind of tools that you might need

2932
01:53:05,589 --> 01:53:02,560
the rock lift jack tool is actually a

2933
01:53:07,589 --> 01:53:05,599
tool that was used for hubble in which

2934
01:53:09,910 --> 01:53:07,599
we might not have a handrail in the

2935
01:53:11,669 --> 01:53:09,920
right location we could actually attach

2936
01:53:13,750 --> 01:53:11,679
this handrail so we're saying we can use

2937
01:53:15,270 --> 01:53:13,760
that same technology to be able to grab

2938
01:53:18,950 --> 01:53:15,280

a rock that might be somewhat attached

2939
01:53:21,750 --> 01:53:19,830
and then

2940
01:53:24,870 --> 01:53:21,760
needing to do anchoring you can use you

2941
01:53:27,030 --> 01:53:24,880
know your typical rock climbing tools

2942
01:53:28,870 --> 01:53:27,040
or you can have specialized tools like

2943
01:53:31,350 --> 01:53:28,880
this anchor clap which is clamp which is

2944
01:53:33,350 --> 01:53:31,360
also leveraged from hubble servicing

2945
01:53:35,189 --> 01:53:33,360
to be able to go into a crack that might

2946
01:53:37,189 --> 01:53:35,199
exist in the asteroid and be able to

2947
01:53:39,830 --> 01:53:37,199
climb anchor in

2948
01:53:43,030 --> 01:53:39,840
as well as the gripper type the tool

2949
01:53:43,910 --> 01:53:43,040
that aaron was showing earlier

2950
01:53:45,669 --> 01:53:43,920
and then

2951
01:53:47,430 --> 01:53:45,679
the contact surface sampling if you had

2952
01:53:49,669 --> 01:53:47,440
some loose particles on the surface and

2953
01:53:51,910 --> 01:53:49,679
you wanted to collect those

2954
01:53:54,709 --> 01:53:51,920
this is using a tool that was actually

2955
01:53:57,030 --> 01:53:54,719
used for the lunar missions

2956
01:53:58,550 --> 01:53:57,040
and and giving it a light nice long

2957
01:54:00,470 --> 01:53:58,560
broom so that you can hold it out far

2958
01:54:02,550 --> 01:54:00,480
away so you don't get the dust on the

2959
01:54:04,629 --> 01:54:02,560
crew member

2960
01:54:06,470 --> 01:54:04,639
and then uh i think steve set me up

2961
01:54:08,470 --> 01:54:06,480
pretty well here earlier

2962
01:54:11,350 --> 01:54:08,480
of having a drill that actually is

2963
01:54:13,430 --> 01:54:11,360

driven by the pistol grip tool

2964
01:54:15,750 --> 01:54:13,440
and uh the size of the drill will depend

2965
01:54:18,070 --> 01:54:15,760
on uh how deep do you want to go into

2966
01:54:20,070 --> 01:54:18,080
the asteroid as well as how many samples

2967
01:54:21,109 --> 01:54:20,080
do you want to collect um

2968
01:54:22,629 --> 01:54:21,119
and uh

2969
01:54:24,149 --> 01:54:22,639
we were leveraging a lot of the

2970
01:54:25,830 --> 01:54:24,159
technology that was done from our

2971
01:54:29,109 --> 01:54:25,840
science lab as well as being developed

2972
01:54:31,669 --> 01:54:29,119
for the mars 2020 mission

2973
01:54:34,790 --> 01:54:31,679
and then lastly to actually uh collect

2974
01:54:36,310 --> 01:54:34,800
those samples and seal them

2975
01:54:38,149 --> 01:54:36,320
again we're leveraging stuff that's

2976
01:54:40,790 --> 01:54:38,159
being developed for the mars 2020

2977
01:54:42,390 --> 01:54:40,800
mission both by atk jpl and several

2978
01:54:44,229 --> 01:54:42,400
other contractors

2979
01:54:45,669 --> 01:54:44,239
and then lastly you need to put those

2980
01:54:49,189 --> 01:54:45,679
samples into some kind of storage

2981
01:54:52,550 --> 01:54:50,390
so the goddard folks would be

2982
01:54:54,310 --> 01:54:52,560
disappointed me with me if i didn't have

2983
01:54:56,149 --> 01:54:54,320
an animation so

2984
01:54:58,550 --> 01:54:56,159
i'm going to show the the actual

2985
01:55:00,390 --> 01:54:58,560
drilling test now either the

2986
01:55:02,229 --> 01:55:00,400
gripper could be on the drill already or

2987
01:55:06,070 --> 01:55:02,239
it could be separated and you could

2988
01:55:08,790 --> 01:55:06,080

mount it and then put on on the drill

2989
01:55:09,830 --> 01:55:08,800
showing here that we would activate the

2990
01:55:11,589 --> 01:55:09,840
gripper

2991
01:55:13,350 --> 01:55:11,599
to be able to

2992
01:55:15,270 --> 01:55:13,360
make sure that the drill is already

2993
01:55:17,270 --> 01:55:15,280
anchored to the surface the crew member

2994
01:55:20,149 --> 01:55:17,280
could actually even let go

2995
01:55:22,950 --> 01:55:20,159
and then could drive the actual drill

2996
01:55:25,189 --> 01:55:22,960
with the pgt the sizing of the motor and

2997
01:55:27,990 --> 01:55:25,199
battery power should be adequate for a

2998
01:55:30,390 --> 01:55:28,000
typical eva activity and this is showing

2999
01:55:31,910 --> 01:55:30,400
a coring drill as the flutes are going

3000
01:55:33,669 --> 01:55:31,920
around the outside the core is being

3001
01:55:35,990 --> 01:55:33,679
collected on the inside

3002
01:55:36,950 --> 01:55:36,000
as you get to the end the core breaks

3003
01:55:38,790 --> 01:55:36,960
off

3004
01:55:41,510 --> 01:55:38,800
and then you can pull all of that back

3005
01:55:44,310 --> 01:55:41,520
into your sample tube

3006
01:55:45,669 --> 01:55:44,320
and then the astronaut would actually

3007
01:55:46,870 --> 01:55:45,679
could go around just different areas of

3008
01:55:50,070 --> 01:55:46,880
the asteroid

3009
01:55:51,510 --> 01:55:50,080
collect uh multiple samples and then be

3010
01:55:54,390 --> 01:55:51,520
able to actually

3011
01:55:57,189 --> 01:55:54,400
take the sample container and put it

3012
01:55:59,030 --> 01:55:57,199
either back into the toolbox or into

3013
01:56:02,470 --> 01:55:59,040

some other separate container that to be

3014
01:56:02,480 --> 01:56:05,990
so that's all i have

3015
01:56:06,000 --> 01:56:09,910
any questions

3016
01:56:15,189 --> 01:56:12,709
i had one for you can you elaborate on

3017
01:56:17,030 --> 01:56:15,199
how your telescoping tube is articulated

3018
01:56:19,270 --> 01:56:17,040
to extend and whether or not you've

3019
01:56:21,830 --> 01:56:19,280
considered the ability to add planetary

3020
01:56:24,550 --> 01:56:21,840
joints or other joints for bends in the

3021
01:56:26,790 --> 01:56:24,560
mechanism uh yes this one is actually

3022
01:56:29,830 --> 01:56:26,800
it's electronically driven however it

3023
01:56:32,790 --> 01:56:29,840
can be hand manipulated as well

3024
01:56:35,109 --> 01:56:32,800
and yes there actually are uh examples

3025
01:56:37,910 --> 01:56:35,119
where we've done uh articulating joints

3026
01:56:39,589 --> 01:56:37,920
i think the shuttle version actually had

3027
01:56:42,709 --> 01:56:39,599
two joints

3028
01:56:42,719 --> 01:56:46,149
other other questions

3029
01:56:46,159 --> 01:56:53,990
okay thanks dole appreciate it

3030
01:56:58,870 --> 01:56:56,229
so our next presenter is uh john lymer

3031
01:57:01,189 --> 01:56:58,880
from space systems loral

3032
01:57:03,350 --> 01:57:01,199
and his topic is arv

3033
01:57:05,830 --> 01:57:03,360
with robotic manipulators

3034
01:57:08,629 --> 01:57:05,840
uh and how that would be used to birth

3035
01:57:11,189 --> 01:57:08,639
the spacecraft and assist tv crew during

3036
01:57:13,350 --> 01:57:11,199
a spacewalk thanks steve

3037
01:57:15,669 --> 01:57:13,360
uh good afternoon i'm representing space

3038
01:57:18,310 --> 01:57:15,679

systems sorel this afternoon also known

3039
01:57:20,790 --> 01:57:18,320
as ssl as you can tell by our stylish

3040
01:57:22,870 --> 01:57:20,800
new logo on the bottom corner there

3041
01:57:24,709 --> 01:57:22,880
after we joined forces with mda you can

3042
01:57:26,550 --> 01:57:24,719
see that that logo looks suspiciously

3043
01:57:28,790 --> 01:57:26,560
like the mda one

3044
01:57:31,510 --> 01:57:28,800
anyway many of you people will remember

3045
01:57:33,589 --> 01:57:31,520
me as a very very long time fixture at

3046
01:57:35,430 --> 01:57:33,599
the mba office in toronto where we have

3047
01:57:36,390 --> 01:57:35,440
the robotics and automation division

3048
01:57:38,149 --> 01:57:36,400
there

3049
01:57:40,070 --> 01:57:38,159
i was chief engineer for all the space

3050
01:57:41,109 --> 01:57:40,080
station robotics the canadarm2 the

3051
01:57:43,030 --> 01:57:41,119
dexter

3052
01:57:45,750 --> 01:57:43,040
as well as orbital express and some of

3053
01:57:47,270 --> 01:57:45,760
the medical robots we have in clinical

3054
01:57:49,750 --> 01:57:47,280
trials right now

3055
01:57:50,950 --> 01:57:49,760
when we joined forces with

3056
01:57:52,470 --> 01:57:50,960
ssl

3057
01:57:55,510 --> 01:57:52,480
i move from toronto

3058
01:57:58,070 --> 01:57:55,520
where it's snowing today to palo alto

3059
01:57:59,109 --> 01:57:58,080
where it's not going to snow ever

3060
01:58:01,830 --> 01:57:59,119
and

3061
01:58:05,350 --> 01:58:01,840
in palo alto we have a very large ssl

3062
01:58:06,950 --> 01:58:05,360
factory there where we have 3000

3063
01:58:08,709 --> 01:58:06,960

very highly skilled engineers and

3064
01:58:11,030 --> 01:58:08,719
technicians where we make

3065
01:58:13,510 --> 01:58:11,040
the biggest the most powerful geo

3066
01:58:14,870 --> 01:58:13,520
communication satellites in the world

3067
01:58:17,270 --> 01:58:14,880
and so what we're doing is we're

3068
01:58:18,870 --> 01:58:17,280
combining the expertise in our toronto

3069
01:58:20,870 --> 01:58:18,880
office where we do robotics as well as

3070
01:58:22,550 --> 01:58:20,880
our pasadena office which is known for

3071
01:58:24,790 --> 01:58:22,560
the mars robots and

3072
01:58:25,830 --> 01:58:24,800
and now the darpa phoenix dextrous

3073
01:58:27,589 --> 01:58:25,840
robots

3074
01:58:29,430 --> 01:58:27,599
and we're creating a center of

3075
01:58:31,270 --> 01:58:29,440
excellence if you like in palo alto

3076
01:58:33,510 --> 01:58:31,280
where we have a very unique combination

3077
01:58:35,430 --> 01:58:33,520
of a complete spacecraft manufacturing

3078
01:58:36,709 --> 01:58:35,440
and design facility

3079
01:58:39,510 --> 01:58:36,719
and then all of this autonomous

3080
01:58:41,990 --> 01:58:39,520
capability from these other offices so

3081
01:58:45,109 --> 01:58:42,000
that now we can offer the us government

3082
01:58:46,950 --> 01:58:45,119
a complete turnkey and and spacecraft

3083
01:58:49,589 --> 01:58:46,960
plus robotic system

3084
01:58:51,910 --> 01:58:49,599
for in space we can also offer the us

3085
01:58:53,990 --> 01:58:51,920
government autonomous vehicles and

3086
01:58:55,910 --> 01:58:54,000
underwater vehicles as well

3087
01:58:58,229 --> 01:58:55,920
so that's our plan over the next year

3088
01:59:00,790 --> 01:58:58,239

we're going to grow a new

3089
01:59:03,990 --> 01:59:00,800
facility there basically

3090
01:59:07,669 --> 01:59:05,589
um and so

3091
01:59:09,109 --> 01:59:07,679
one of the very first offerings out of

3092
01:59:13,270 --> 01:59:09,119
that division

3093
01:59:15,510 --> 01:59:13,280
is a response to this ar the the arm rfi

3094
01:59:17,830 --> 01:59:15,520
and we're offering a complete spacecraft

3095
01:59:20,149 --> 01:59:17,840
solution so that handles all of the

3096
01:59:21,510 --> 01:59:20,159
phases of the mission including the crew

3097
01:59:22,870 --> 01:59:21,520
support phase that we're talking about

3098
01:59:24,790 --> 01:59:22,880
this afternoon

3099
01:59:28,070 --> 01:59:24,800
and as we described on the last day of

3100
01:59:28,950 --> 01:59:28,080
september our vehicle has is a two-part

3101
01:59:30,790 --> 01:59:28,960
system

3102
01:59:33,030 --> 01:59:30,800
the first part is a

3103
01:59:33,910 --> 01:59:33,040
high-powered solar electric propulsion

3104
01:59:36,790 --> 01:59:33,920
tug

3105
01:59:38,870 --> 01:59:36,800
it runs at 50 kilowatts and for us

3106
01:59:41,270 --> 01:59:38,880
that's just the next incremental step in

3107
01:59:43,270 --> 01:59:41,280
what we're doing on on geosats

3108
01:59:44,790 --> 01:59:43,280
we've got 30 kilowatt systems flying and

3109
01:59:47,589 --> 01:59:44,800
have been flying

3110
01:59:50,149 --> 01:59:47,599
35 kilowatt systems in the pipe and 50

3111
01:59:52,470 --> 01:59:50,159
kilowatt for us is is the next step

3112
01:59:56,470 --> 01:59:52,480
we'll couple that with some

3113
01:59:58,470 --> 01:59:56,480

electric thrusters 40 kilowatts of those

3114
02:00:00,149 --> 01:59:58,480
and a whole lot of xenon and you've got

3115
02:00:01,750 --> 02:00:00,159
enough delta v here to do pretty much

3116
02:00:04,149 --> 02:00:01,760
anything you need running around the

3117
02:00:06,709 --> 02:00:04,159
solar system between asteroids

3118
02:00:09,350 --> 02:00:06,719
um we've decided to make this a separate

3119
02:00:11,430 --> 02:00:09,360
tug so that it can do other things so

3120
02:00:13,270 --> 02:00:11,440
we can get whatever we need to the

3121
02:00:15,030 --> 02:00:13,280
asteroid and bring it back and all that

3122
02:00:17,510 --> 02:00:15,040
but we can also do other missions too

3123
02:00:19,510 --> 02:00:17,520
this tug is separable it can join on to

3124
02:00:21,669 --> 02:00:19,520
other modules or other vehicles or other

3125
02:00:23,430 --> 02:00:21,679
types of vehicles to do other missions

3126
02:00:25,350 --> 02:00:23,440
throughout the solar system

3127
02:00:27,270 --> 02:00:25,360
so that's that idea the front end of

3128
02:00:30,070 --> 02:00:27,280
this thing is a robotic servicing

3129
02:00:32,070 --> 02:00:30,080
spacecraft which has all the dexterity

3130
02:00:33,990 --> 02:00:32,080
of the robots but also the sixth degree

3131
02:00:36,709 --> 02:00:34,000
of freedom maneuvering and and the

3132
02:00:38,310 --> 02:00:36,719
relative navigation sensing and the and

3133
02:00:39,910 --> 02:00:38,320
the fault tolerant computing so that we

3134
02:00:43,189 --> 02:00:39,920
don't run into things and all that kind

3135
02:00:45,910 --> 02:00:43,199
of stuff so that it it can be designed

3136
02:00:48,310 --> 02:00:45,920
first for the asteroid capture mission

3137
02:00:49,910 --> 02:00:48,320
but also again later for other things

3138
02:00:51,830 --> 02:00:49,920

satellite service thing is an obvious

3139
02:00:53,350 --> 02:00:51,840
one that everyone knows that mda has

3140
02:00:55,350 --> 02:00:53,360
been interested in for years and

3141
02:00:56,550 --> 02:00:55,360
continues to be interested in along with

3142
02:00:57,350 --> 02:00:56,560
other folks

3143
02:00:59,109 --> 02:00:57,360
and

3144
02:01:00,950 --> 02:00:59,119
most of the technology that's needed for

3145
02:01:03,350 --> 02:01:00,960
that for satellite servicing is also

3146
02:01:05,589 --> 02:01:03,360
applicable to this asteroid mission so

3147
02:01:07,430 --> 02:01:05,599
the id our idea is let's build these

3148
02:01:10,310 --> 02:01:07,440
modular blocks that we can take the

3149
02:01:12,310 --> 02:01:10,320
pieces of and then use for here but also

3150
02:01:14,950 --> 02:01:12,320
use them in other parts of the other

3151
02:01:19,430 --> 02:01:17,109
so just to go into the the

3152
02:01:21,350 --> 02:01:19,440
crew support part of this

3153
02:01:23,830 --> 02:01:21,360
the front end of this vehicle the the

3154
02:01:26,470 --> 02:01:23,840
separable vehicle uh as you can see in

3155
02:01:28,310 --> 02:01:26,480
this image is joined with the orion

3156
02:01:31,109 --> 02:01:28,320
vehicle when it shows up

3157
02:01:32,950 --> 02:01:31,119
um has two sets of robotics on it you

3158
02:01:34,950 --> 02:01:32,960
can see the very long one that's a 13

3159
02:01:37,750 --> 02:01:34,960
meter robot and then there's a set of

3160
02:01:39,990 --> 02:01:37,760
three um slightly more dexterous robots

3161
02:01:42,870 --> 02:01:40,000
they're about three meters apiece so

3162
02:01:45,830 --> 02:01:42,880
going into the longer robot first

3163
02:01:48,149 --> 02:01:45,840

the idea there is it's long enough that

3164
02:01:50,310 --> 02:01:48,159
it can reach out and touch the asteroid

3165
02:01:51,750 --> 02:01:50,320
or or almost touch the asteroid or place

3166
02:01:53,910 --> 02:01:51,760
instruments towards the asteroid before

3167
02:01:55,669 --> 02:01:53,920
we even capture it or deflect it so that

3168
02:01:56,790 --> 02:01:55,679
we can get a clue of what it is we're

3169
02:01:58,950 --> 02:01:56,800
dealing with

3170
02:01:59,910 --> 02:01:58,960
um and then once we do capture it which

3171
02:02:02,790 --> 02:01:59,920
could be

3172
02:02:04,950 --> 02:02:02,800
a bag or any of the solutions we heard

3173
02:02:06,870 --> 02:02:04,960
this morning which could be helped by

3174
02:02:08,390 --> 02:02:06,880
this 13 meter arm it's long enough that

3175
02:02:10,470 --> 02:02:08,400
it can actually reach most of the

3176
02:02:13,270 --> 02:02:10,480
surface area of the of the type of

3177
02:02:15,669 --> 02:02:13,280
asteroid we're talking about

3178
02:02:17,589 --> 02:02:15,679
uh it can also

3179
02:02:19,109 --> 02:02:17,599
help the crew

3180
02:02:23,030 --> 02:02:19,119
gain access to the surface of that

3181
02:02:25,030 --> 02:02:23,040
asteroid once it's back in moon orbit

3182
02:02:26,709 --> 02:02:25,040
one of the other benefits of this is

3183
02:02:28,790 --> 02:02:26,719
that because the robots are all on the

3184
02:02:30,950 --> 02:02:28,800
arv which is just one solution and we

3185
02:02:32,149 --> 02:02:30,960
heard earlier in this session we've

3186
02:02:34,550 --> 02:02:32,159
heard different solutions about where

3187
02:02:37,189 --> 02:02:34,560
those robots can be

3188
02:02:38,950 --> 02:02:37,199

is that we don't have to burden

3189
02:02:41,270 --> 02:02:38,960
the orion vehicle with the robots if we

3190
02:02:43,510 --> 02:02:41,280
put them on the arv

3191
02:02:44,709 --> 02:02:43,520
or at least our servicing vehicle and of

3192
02:02:47,270 --> 02:02:44,719
course they're available for other

3193
02:02:51,030 --> 02:02:47,280
missions

3194
02:02:53,270 --> 02:02:51,040
also it will allow a very low impact

3195
02:02:55,669 --> 02:02:53,280
birthing if we like for example if the

3196
02:02:57,109 --> 02:02:55,679
asteroid turns out to be nothing but a

3197
02:02:58,870 --> 02:02:57,119
dust bunny

3198
02:03:01,030 --> 02:02:58,880
then when the

3199
02:03:03,109 --> 02:03:01,040
orion comes to dock rather than having

3200
02:03:04,870 --> 02:03:03,119
the impulsive docket forces we can reach

3201
02:03:06,950 --> 02:03:04,880
out with the arm very very gently and do

3202
02:03:07,830 --> 02:03:06,960
a very gentle birthing which can of

3203
02:03:10,070 --> 02:03:07,840
course

3204
02:03:13,589 --> 02:03:10,080
cause a lot less disturbance to the

3205
02:03:17,350 --> 02:03:14,629
and then

3206
02:03:19,669 --> 02:03:17,360
the second set of robots which are the

3207
02:03:21,750 --> 02:03:19,679
three more dexterous robots and just see

3208
02:03:23,109 --> 02:03:21,760
if this

3209
02:03:26,790 --> 02:03:23,119
oh there we go

3210
02:03:28,550 --> 02:03:26,800
um so these three robots down here

3211
02:03:29,589 --> 02:03:28,560
a very similar sort of intention with

3212
02:03:30,709 --> 02:03:29,599
those

3213
02:03:33,350 --> 02:03:30,719

in that

3214
02:03:35,030 --> 02:03:33,360
they can handle instruments uh prior to

3215
02:03:36,709 --> 02:03:35,040
the crew

3216
02:03:38,229 --> 02:03:36,719
doing their sorties

3217
02:03:39,910 --> 02:03:38,239
they can

3218
02:03:41,750 --> 02:03:39,920
do very repetitive type things for

3219
02:03:44,790 --> 02:03:41,760
example a ram and spec you could do a

3220
02:03:46,790 --> 02:03:44,800
complete survey of some area at one m

3221
02:03:49,350 --> 02:03:46,800
one millimeter type increments

3222
02:03:51,669 --> 02:03:49,360
that was chosen by the ground

3223
02:03:53,189 --> 02:03:51,679
scientists prior to the crew going out

3224
02:03:56,629 --> 02:03:53,199
getting information

3225
02:03:58,629 --> 02:03:56,639
uh the crew can then go and do more uh

3226
02:04:01,109 --> 02:03:58,639
related science with those

3227
02:04:02,390 --> 02:04:01,119
or once the crew or the prospectors

3228
02:04:03,589 --> 02:04:02,400
they'll call them prospectors for now

3229
02:04:05,750 --> 02:04:03,599
because that's really what they're doing

3230
02:04:07,990 --> 02:04:05,760
once they pick interesting spots then

3231
02:04:09,430 --> 02:04:08,000
these arms can handle the the very

3232
02:04:12,149 --> 02:04:09,440
tedious

3233
02:04:13,510 --> 02:04:12,159
exercise of analyzing them or

3234
02:04:15,990 --> 02:04:13,520
positioning instruments around them or

3235
02:04:17,350 --> 02:04:16,000
collecting samples or anything like that

3236
02:04:18,470 --> 02:04:17,360
as we heard a bit earlier today

3237
02:04:21,430 --> 02:04:18,480
controlled from the ground because

3238
02:04:23,270 --> 02:04:21,440

there's no reason that we can't do

3239
02:04:25,510 --> 02:04:23,280
control of all of these robots from the

3240
02:04:27,030 --> 02:04:25,520
ground uh with a set of scientists

3241
02:04:29,350 --> 02:04:27,040
looking over somebody's shoulder saying

3242
02:04:31,030 --> 02:04:29,360
yeah i want that i want that and and we

3243
02:04:33,589 --> 02:04:31,040
can go and do it

3244
02:04:35,510 --> 02:04:33,599
um and so really what these robots are

3245
02:04:37,189 --> 02:04:35,520
about is assisting the crew taking the

3246
02:04:39,430 --> 02:04:37,199
repetitive

3247
02:04:41,510 --> 02:04:39,440
tasks associated with prospecting away

3248
02:04:43,830 --> 02:04:41,520
from the crew so that they can go and do

3249
02:04:45,430 --> 02:04:43,840
smarter things and and pick better sites

3250
02:04:48,390 --> 02:04:45,440
and look at interesting things to look

3251
02:04:50,550 --> 02:04:48,400
at later and that sort of thing

3252
02:04:52,229 --> 02:04:50,560
so the benefit of these two sets of

3253
02:04:54,390 --> 02:04:52,239
robots that we're talking about today is

3254
02:04:56,310 --> 02:04:54,400
that they already exist so in the top

3255
02:04:59,189 --> 02:04:56,320
right corner there you see the 13 meter

3256
02:05:01,589 --> 02:04:59,199
arm it was designed and built to capture

3257
02:05:03,990 --> 02:05:01,599
the hubble space telescope back in the

3258
02:05:05,430 --> 02:05:04,000
mid 2000s when there was a fear that the

3259
02:05:07,669 --> 02:05:05,440
hubble space telescope was going to

3260
02:05:09,430 --> 02:05:07,679
enter the atmosphere and and make it to

3261
02:05:12,229 --> 02:05:09,440
the ground basically and we were going

3262
02:05:13,589 --> 02:05:12,239
to do a robotic rescue mission

3263
02:05:14,709 --> 02:05:13,599

so that arm

3264
02:05:16,310 --> 02:05:14,719
has

3265
02:05:18,310 --> 02:05:16,320
bits and pieces stolen from the other

3266
02:05:20,390 --> 02:05:18,320
space station arms

3267
02:05:22,470 --> 02:05:20,400
the joints are from the dexter robot the

3268
02:05:24,470 --> 02:05:22,480
motors are the redundantly wound motors

3269
02:05:26,310 --> 02:05:24,480
from the canadarm2

3270
02:05:27,750 --> 02:05:26,320
and the end effector is from the space

3271
02:05:29,589 --> 02:05:27,760
shuttle arm

3272
02:05:31,589 --> 02:05:29,599
and we can replace that with any other

3273
02:05:33,510 --> 02:05:31,599
end effector because unless asteroids

3274
02:05:35,990 --> 02:05:33,520
come with grapple fixtures attached in

3275
02:05:38,390 --> 02:05:36,000
which case our capture problem is solved

3276
02:05:41,270 --> 02:05:38,400
we can put something a little more

3277
02:05:43,910 --> 02:05:41,280
appropriate for this mission on there

3278
02:05:47,350 --> 02:05:43,920
the electronics have been updated

3279
02:05:48,790 --> 02:05:47,360
canadarm2 uses 186s and 386s believe it

3280
02:05:50,310 --> 02:05:48,800
or not

3281
02:05:51,910 --> 02:05:50,320
we've upgraded the avionics on this

3282
02:05:54,790 --> 02:05:51,920
particular one to

3283
02:05:57,270 --> 02:05:54,800
red 750fx's which means you can do

3284
02:05:59,589 --> 02:05:57,280
more advanced control algorithms and

3285
02:06:02,069 --> 02:05:59,599
most importantly we've got a natural

3286
02:06:05,030 --> 02:06:02,079
feature based machine vision algorithm

3287
02:06:06,229 --> 02:06:05,040
running on that thing what it means is a

3288
02:06:09,109 --> 02:06:06,239

scientist

3289
02:06:11,189 --> 02:06:09,119
on his screen can say i want you to move

3290
02:06:13,270 --> 02:06:11,199
me there and he puts his cursor

3291
02:06:15,350 --> 02:06:13,280
somewhere or his mouse with his mouse

3292
02:06:18,149 --> 02:06:15,360
and the arm can go there

3293
02:06:19,990 --> 02:06:18,159
that's a very powerful way of

3294
02:06:21,910 --> 02:06:20,000
graphically commanding robots to do

3295
02:06:24,229 --> 02:06:21,920
things you want to do

3296
02:06:27,910 --> 02:06:24,239
for the dextrous arms we're proposing

3297
02:06:29,350 --> 02:06:27,920
copies of the darpa phoenix friend arms

3298
02:06:32,470 --> 02:06:29,360
they were designed for satellite

3299
02:06:34,390 --> 02:06:32,480
servicing they're they're very dexterous

3300
02:06:36,310 --> 02:06:34,400
and and they would

3301
02:06:38,149 --> 02:06:36,320
be perfectly capable of doing this kind

3302
02:06:40,709 --> 02:06:38,159
of a job

3303
02:06:42,870 --> 02:06:40,719
and so for my final slide

3304
02:06:44,790 --> 02:06:42,880
i just want to remind folks that robots

3305
02:06:47,030 --> 02:06:44,800
are not here to replace people

3306
02:06:48,709 --> 02:06:47,040
especially highly skilled people what

3307
02:06:50,950 --> 02:06:48,719
they're here to do is extend their

3308
02:06:52,709 --> 02:06:50,960
capabilities and make them

3309
02:06:54,229 --> 02:06:52,719
allow them to do things that they

3310
02:06:55,750 --> 02:06:54,239
couldn't do before and we've proven this

3311
02:06:57,830 --> 02:06:55,760
again and again

3312
02:06:59,350 --> 02:06:57,840
with a robot with the crew using the

3313
02:07:01,109 --> 02:06:59,360

best of them both

3314
02:07:03,270 --> 02:07:01,119
you can do pretty amazing things and i

3315
02:07:05,350 --> 02:07:03,280
think this is a perfect example of where

3316
02:07:15,990 --> 02:07:05,360
we can do that

3317
02:07:23,350 --> 02:07:20,550
on the um the 13 meter um

3318
02:07:24,149 --> 02:07:23,360
you i think you use the word soft birth

3319
02:07:27,189 --> 02:07:24,159
yeah

3320
02:07:28,310 --> 02:07:27,199
okay so if that was a

3321
02:07:31,189 --> 02:07:28,320
um

3322
02:07:33,189 --> 02:07:31,199
like a rubble we'll say a sand pile

3323
02:07:35,589 --> 02:07:33,199
how does that work without

3324
02:07:37,430 --> 02:07:35,599
dissipating it or moving it i mean

3325
02:07:40,790 --> 02:07:37,440
yeah the the

3326
02:07:42,709 --> 02:07:40,800
what i have in mind is rather than

3327
02:07:43,910 --> 02:07:42,719
for the docking mechanisms you need a

3328
02:07:46,229 --> 02:07:43,920
certain amount of

3329
02:07:48,229 --> 02:07:46,239
impact or impulse if you like to make

3330
02:07:50,149 --> 02:07:48,239
them to trip them

3331
02:07:51,270 --> 02:07:50,159
and that gets transferred to everything

3332
02:07:54,550 --> 02:07:51,280
in the stack

3333
02:07:56,550 --> 02:07:54,560
in the case of capture and birthing

3334
02:07:58,390 --> 02:07:56,560
the orion would station keep some

3335
02:08:00,149 --> 02:07:58,400
distance away from the

3336
02:08:01,910 --> 02:08:00,159
arv

3337
02:08:03,510 --> 02:08:01,920
for argument's sake let's say six meters

3338
02:08:05,430 --> 02:08:03,520

that's a nice safe

3339
02:08:07,430 --> 02:08:05,440
distance the arm would reach out very

3340
02:08:10,149 --> 02:08:07,440
gently because we can move this arm we

3341
02:08:11,990 --> 02:08:10,159
have the ability to shape the command so

3342
02:08:13,589 --> 02:08:12,000
the acceleration deceleration transfer

3343
02:08:14,950 --> 02:08:13,599
of momentum and all that can be very

3344
02:08:16,629 --> 02:08:14,960
well controlled

3345
02:08:19,910 --> 02:08:16,639
you can move the arm out there

3346
02:08:21,830 --> 02:08:19,920
capture the station kept orion and move

3347
02:08:23,830 --> 02:08:21,840
it very gently into a birthing fixture

3348
02:08:25,109 --> 02:08:23,840
that rather than needing

3349
02:08:27,430 --> 02:08:25,119
force

3350
02:08:29,030 --> 02:08:27,440
to join with can more or less just be

3351
02:08:32,069 --> 02:08:29,040
placed into its capture envelope and

3352
02:08:33,589 --> 02:08:32,079
then the mechanism mechanism just closes

3353
02:08:40,470 --> 02:08:33,599
and there's no

3354
02:08:45,189 --> 02:08:41,830
any other questions in the room or

3355
02:08:45,199 --> 02:08:51,910
thanks john all right

3356
02:08:57,189 --> 02:08:54,709
so our next presenter is frank

3357
02:09:00,069 --> 02:08:57,199
eichstadt if i butchered your name i

3358
02:09:01,189 --> 02:09:00,079
apologize i'm german as well

3359
02:09:03,189 --> 02:09:01,199
um

3360
02:09:03,990 --> 02:09:03,199
and his presentation is from

3361
02:09:05,430 --> 02:09:04,000
airing

3362
02:09:07,109 --> 02:09:05,440
space systems and he's going to talk a

3363
02:09:09,750 --> 02:09:07,119

little bit about their uh

3364
02:09:11,350 --> 02:09:09,760
eva capabilities yeah that's um

3365
02:09:13,430 --> 02:09:11,360
presumably what i would talk about when

3366
02:09:15,830 --> 02:09:13,440
i was asked to write on the topic of

3367
02:09:17,430 --> 02:09:15,840
this rfi i wasn't like really sure

3368
02:09:20,229 --> 02:09:17,440
whether to paint with a big brush or a

3369
02:09:22,550 --> 02:09:20,239
small brushes so i'm

3370
02:09:24,709 --> 02:09:22,560
approaching this topic with a relatively

3371
02:09:26,709 --> 02:09:24,719
large brush because the time that we're

3372
02:09:27,910 --> 02:09:26,719
at in the in the formation of this

3373
02:09:30,069 --> 02:09:27,920
mission

3374
02:09:32,310 --> 02:09:30,079
uh this initiative really

3375
02:09:35,189 --> 02:09:32,320
i think this is the time to pursue

3376
02:09:41,669 --> 02:09:35,199
rather large ideas

3377
02:09:44,790 --> 02:09:43,350
we talk about the concept of tools in

3378
02:09:46,149 --> 02:09:44,800
the upper left-hand corner you'll see an

3379
02:09:48,790 --> 02:09:46,159
image that you're probably all familiar

3380
02:09:51,030 --> 02:09:48,800
with from 2001 a space odyssey where ape

3381
02:09:52,629 --> 02:09:51,040
throws a bone up in the air and before

3382
02:09:55,830 --> 02:09:52,639
before you know it we're looking at

3383
02:09:59,030 --> 02:09:55,840
space stations um the message here is

3384
02:10:01,510 --> 02:09:59,040
that all these pictures that you see

3385
02:10:03,430 --> 02:10:01,520
are essentially tools all the way up to

3386
02:10:05,430 --> 02:10:03,440
the scale of an aircraft carrier or a

3387
02:10:06,470 --> 02:10:05,440
space station

3388
02:10:09,669 --> 02:10:06,480

we're really

3389
02:10:15,270 --> 02:10:09,679
talking in very broad terms about what

3390
02:10:17,030 --> 02:10:15,280
technologies we will apply to let humans

3391
02:10:19,669 --> 02:10:17,040
do the best job possible exploring

3392
02:10:22,310 --> 02:10:19,679
asteroids not only on this mission i

3393
02:10:24,790 --> 02:10:22,320
think but in the larger sense

3394
02:10:26,229 --> 02:10:24,800
what happens later

3395
02:10:29,109 --> 02:10:26,239
this i think

3396
02:10:31,910 --> 02:10:29,119
is expressed as an asteroid exploration

3397
02:10:34,709 --> 02:10:31,920
initiative not necessarily a mission

3398
02:10:36,709 --> 02:10:34,719
and my question to the group in general

3399
02:10:40,310 --> 02:10:36,719
is when are you finished

3400
02:10:43,669 --> 02:10:40,320
um it's very important when you look at

3401
02:10:45,589 --> 02:10:43,679
tools um to know exactly what it is

3402
02:10:47,430 --> 02:10:45,599
you're going to do with these tools

3403
02:10:49,669 --> 02:10:47,440
before you get started i mean i think we

3404
02:10:51,669 --> 02:10:49,679
know at this point we need a toolbox

3405
02:10:53,589 --> 02:10:51,679
what it's full of is going to depend on

3406
02:10:54,870 --> 02:10:53,599
what we intend to accomplish at these

3407
02:10:57,669 --> 02:10:54,880
asteroids

3408
02:10:59,510 --> 02:10:57,679
and without knowing what we're going to

3409
02:11:02,470 --> 02:10:59,520
accomplish we have to really start off

3410
02:11:05,350 --> 02:11:02,480
with very general uh capabilities like

3411
02:11:06,390 --> 02:11:05,360
drilling like picking like grabbing

3412
02:11:09,830 --> 02:11:06,400
and as

3413
02:11:11,510 --> 02:11:09,840

we learn more as we

3414
02:11:13,350 --> 02:11:11,520
penetrate

3415
02:11:14,870 --> 02:11:13,360
further and further into this quest for

3416
02:11:16,470 --> 02:11:14,880
knowledge about asteroids we're going to

3417
02:11:18,069 --> 02:11:16,480
come to know much more about what kind

3418
02:11:20,629 --> 02:11:18,079
of tools we need

3419
02:11:23,510 --> 02:11:20,639
and on recurring missions i think it's

3420
02:11:24,870 --> 02:11:23,520
important that we build capability as we

3421
02:11:27,350 --> 02:11:24,880
build knowledge

3422
02:11:30,149 --> 02:11:27,360
on what these tools are supposed to do

3423
02:11:33,189 --> 02:11:30,159
that's why i was so refreshed to see

3424
02:11:34,870 --> 02:11:33,199
several concepts today with regards to

3425
02:11:37,030 --> 02:11:34,880
enhancements to the architecture that

3426
02:11:39,189 --> 02:11:37,040
occur over multiple missions

3427
02:11:42,709 --> 02:11:39,199
so that at some point maybe

3428
02:11:45,270 --> 02:11:42,719
we end up with an asteroid repository

3429
02:11:48,069 --> 02:11:45,280
that could satisfy the investigation of

3430
02:11:50,229 --> 02:11:48,079
many asteroids over multiple missions

3431
02:11:53,750 --> 02:11:50,239
and when nasa takes off and does the

3432
02:11:56,950 --> 02:11:53,760
next great thing that this asteroid

3433
02:11:59,030 --> 02:11:56,960
laboratory in lunar orbit continues to

3434
02:12:01,109 --> 02:11:59,040
serve some function and continues to

3435
02:12:03,589 --> 02:12:01,119
allow people to build knowledge not of

3436
02:12:05,350 --> 02:12:03,599
just this first asteroid but of

3437
02:12:08,390 --> 02:12:05,360
subsequent asteroids that might be

3438
02:12:11,830 --> 02:12:08,400

collected at this laboratory

3439
02:12:13,510 --> 02:12:11,840
so in in addressing these unknowns uh we

3440
02:12:14,950 --> 02:12:13,520
need to retire the unknowns

3441
02:12:16,790 --> 02:12:14,960
progressively

3442
02:12:18,950 --> 02:12:16,800
and i think it's going to take more than

3443
02:12:20,790 --> 02:12:18,960
one mission i think this this initial

3444
02:12:23,350 --> 02:12:20,800
mission great we can demonstrate that we

3445
02:12:24,229 --> 02:12:23,360
can go get one we can bust a chunk off

3446
02:12:25,990 --> 02:12:24,239
of it

3447
02:12:27,589 --> 02:12:26,000
but just like you know you don't build

3448
02:12:29,589 --> 02:12:27,599
hubble look at one star i don't think

3449
02:12:31,430 --> 02:12:29,599
you build this architecture to look at

3450
02:12:33,510 --> 02:12:31,440
one rock i think you build an

3451
02:12:35,910 --> 02:12:33,520
architecture that has some

3452
02:12:38,149 --> 02:12:35,920
forward compatibility

3453
02:12:40,229 --> 02:12:38,159
another thing i was asked to look at

3454
02:12:42,229 --> 02:12:40,239
from oceaneering's perspective we have

3455
02:12:43,910 --> 02:12:42,239
worked somewhat with some environmental

3456
02:12:45,910 --> 02:12:43,920
control life support systems we're

3457
02:12:48,390 --> 02:12:45,920
developing a new suit

3458
02:12:50,790 --> 02:12:48,400
and we work a lot with eva tools

3459
02:12:52,310 --> 02:12:50,800
so we're looking at

3460
02:12:54,470 --> 02:12:52,320
architectural approaches that could

3461
02:12:55,830 --> 02:12:54,480
reduce the overall mass of eva

3462
02:12:57,669 --> 02:12:55,840
capability

3463
02:13:00,229 --> 02:12:57,679

and one of those things would be to

3464
02:13:02,069 --> 02:13:00,239
tailor the capacity of eva

3465
02:13:03,990 --> 02:13:02,079
and tailor the capacity of your

3466
02:13:06,229 --> 02:13:04,000
environmental control systems to match

3467
02:13:07,830 --> 02:13:06,239
the number of crew days on a particular

3468
02:13:09,109 --> 02:13:07,840
mission

3469
02:13:11,030 --> 02:13:09,119
another thing that could be done to

3470
02:13:13,990 --> 02:13:11,040
reduce the overall mass of the eva

3471
02:13:14,950 --> 02:13:14,000
system would be to forego the use of a

3472
02:13:17,510 --> 02:13:14,960
plus

3473
02:13:20,790 --> 02:13:17,520
and support your suited subjects using

3474
02:13:23,510 --> 02:13:20,800
umbilicals that are slaved from the

3475
02:13:24,790 --> 02:13:23,520
spacecraft eclipse system itself

3476
02:13:25,990 --> 02:13:24,800
you could then

3477
02:13:28,629 --> 02:13:26,000
consider

3478
02:13:30,950 --> 02:13:28,639
basing those umbilicals on the asteroid

3479
02:13:32,709 --> 02:13:30,960
recovery vehicle rather than on them on

3480
02:13:34,550 --> 02:13:32,719
the orion itself so that once you have

3481
02:13:36,149 --> 02:13:34,560
the umbilicals in place

3482
02:13:39,109 --> 02:13:36,159
they remain in place you don't need to

3483
02:13:42,629 --> 02:13:39,119
fly them up on a repeated basis in order

3484
02:13:45,030 --> 02:13:42,639
to have that that light essentially

3485
02:13:47,189 --> 02:13:45,040
low transported mass approach to

3486
02:13:49,589 --> 02:13:47,199
supporting eva

3487
02:13:51,830 --> 02:13:49,599
assuming that both eva crew members are

3488
02:13:53,990 --> 02:13:51,840

operating in a relatively common work

3489
02:13:56,149 --> 02:13:54,000
space you might have a dual user

3490
02:13:59,430 --> 02:13:56,159
umbilical which would be similar to uh

3491
02:14:01,350 --> 02:13:59,440
in um surface supported diving if you

3492
02:14:03,510 --> 02:14:01,360
have one hose going down and splitting

3493
02:14:05,669 --> 02:14:03,520
off to support two divers you end up

3494
02:14:08,470 --> 02:14:05,679
carrying a lot less hose so there are

3495
02:14:11,270 --> 02:14:08,480
there are generic ways that you could

3496
02:14:13,270 --> 02:14:11,280
reduce the overall transported mass to

3497
02:14:15,350 --> 02:14:13,280
support eva in this particular type of

3498
02:14:17,510 --> 02:14:15,360
an operating environment

3499
02:14:19,510 --> 02:14:17,520
and then the question arises do you eva

3500
02:14:21,510 --> 02:14:19,520
or don't you eva and i think

3501
02:14:23,669 --> 02:14:21,520
naturally on the earliest missions when

3502
02:14:25,350 --> 02:14:23,679
you're you're taking your baby steps and

3503
02:14:27,030 --> 02:14:25,360
and you're learning what it is you want

3504
02:14:29,350 --> 02:14:27,040
to be able to do

3505
02:14:31,750 --> 02:14:29,360
eva is going to be extremely important

3506
02:14:34,229 --> 02:14:31,760
but over time i think automation

3507
02:14:36,470 --> 02:14:34,239
technology and robotics is going to

3508
02:14:38,550 --> 02:14:36,480
allow us to do a lot more

3509
02:14:39,990 --> 02:14:38,560
and a lot more detailed exploration as

3510
02:14:41,510 --> 02:14:40,000
we understand what challenges we're

3511
02:14:43,990 --> 02:14:41,520
trying to face

3512
02:14:46,629 --> 02:14:44,000
so at some point in time this might we

3513
02:14:49,109 --> 02:14:46,639

might not have to go to this uh

3514
02:14:50,870 --> 02:14:49,119
asteroid repository with people at all

3515
02:14:52,470 --> 02:14:50,880
or it might become a man tended or a

3516
02:14:55,910 --> 02:14:52,480
robotically tended

3517
02:14:58,709 --> 02:14:55,920
um asteroid laboratory if you will

3518
02:15:00,229 --> 02:14:58,719
and no longer have to host eva

3519
02:15:03,270 --> 02:15:00,239
so if we look at the accelerating

3520
02:15:05,830 --> 02:15:03,280
advancements of extra-vehicular robotics

3521
02:15:08,069 --> 02:15:05,840
and the time frame by which this mission

3522
02:15:09,270 --> 02:15:08,079
might fly we may find that we should be

3523
02:15:12,069 --> 02:15:09,280
designing

3524
02:15:14,950 --> 02:15:12,079
with uh transparency to

3525
02:15:16,550 --> 02:15:14,960
the influx of much much greater robotic

3526
02:15:18,470 --> 02:15:16,560
technology

3527
02:15:21,510 --> 02:15:18,480
within the next 10 to 12 years let's say

3528
02:15:27,189 --> 02:15:24,069
we can then look as as some people have

3529
02:15:29,430 --> 02:15:27,199
described at uh integrating the robotic

3530
02:15:31,510 --> 02:15:29,440
capabilities into the asteroid recovery

3531
02:15:33,350 --> 02:15:31,520
vehicle rather than hosting them on

3532
02:15:35,510 --> 02:15:33,360
board the orion

3533
02:15:37,350 --> 02:15:35,520
i think these particular robotic

3534
02:15:39,990 --> 02:15:37,360
capabilities are going to be tailored to

3535
02:15:41,750 --> 02:15:40,000
this particular work environment and in

3536
02:15:44,149 --> 02:15:41,760
the interest of not

3537
02:15:46,149 --> 02:15:44,159
scarring or changing the orion design to

3538
02:15:48,550 --> 02:15:46,159

any great degree we should really look

3539
02:15:51,430 --> 02:15:48,560
at hosting all of those capabilities on

3540
02:15:56,950 --> 02:15:51,440
the asteroid recovery vehicle to the

3541
02:16:01,350 --> 02:15:59,910
let's see what else i got here

3542
02:16:02,629 --> 02:16:01,360
we talked about

3543
02:16:06,310 --> 02:16:02,639
hosting

3544
02:16:09,030 --> 02:16:06,320
stowage and putting capacity on the

3545
02:16:13,910 --> 02:16:11,750
assets at the asteroid and if we're

3546
02:16:16,870 --> 02:16:13,920
looking for high efficiency packing for

3547
02:16:18,390 --> 02:16:16,880
example someone talked about putting 27

3548
02:16:21,109 --> 02:16:18,400
ctbes

3549
02:16:23,669 --> 02:16:21,119
someplace well ctvs have not

3550
02:16:25,750 --> 02:16:23,679
traditionally been extremely high

3551
02:16:27,109 --> 02:16:25,760
efficiency packaging

3552
02:16:29,589 --> 02:16:27,119
if you look at the lower right hand

3553
02:16:32,469 --> 02:16:29,599
corner you can see the progress vehicle

3554
02:16:34,389 --> 02:16:32,479
uses custom tailored packaging for each

3555
02:16:37,509 --> 02:16:34,399
particular nook and cranny in that

3556
02:16:40,469 --> 02:16:37,519
vehicle to get the maximum amount of

3557
02:16:43,429 --> 02:16:40,479
volume useful volume in terms of you

3558
02:16:46,309 --> 02:16:43,439
know not not space filler or not padding

3559
02:16:48,150 --> 02:16:46,319
not foam but tools so we should really

3560
02:16:50,150 --> 02:16:48,160
be looking for ways to

3561
02:16:52,150 --> 02:16:50,160
increase the efficiency

3562
02:16:54,709 --> 02:16:52,160
of our packaging approaches along the

3563
02:16:56,950 --> 02:16:54,719

left side you'll see some some ad hoc

3564
02:16:58,870 --> 02:16:56,960
highly efficient means of transporting

3565
02:17:00,469 --> 02:16:58,880
things people in other parts of the

3566
02:17:02,950 --> 02:17:00,479
world have a different approach for how

3567
02:17:04,950 --> 02:17:02,960
to be efficient one guy even carrying a

3568
02:17:07,110 --> 02:17:04,960
cow on board his motorcycle it's not

3569
02:17:08,950 --> 02:17:07,120
something i'd suggest we do but i think

3570
02:17:12,150 --> 02:17:08,960
we can become much more efficient than

3571
02:17:14,469 --> 02:17:12,160
we are in packaging

3572
02:17:17,270 --> 02:17:14,479
this this concept was talked about

3573
02:17:19,429 --> 02:17:17,280
earlier the idea of putting some sort of

3574
02:17:22,309 --> 02:17:19,439
a adapter in between

3575
02:17:25,190 --> 02:17:22,319
the um the asteroid recovery vehicle and

3576
02:17:27,110 --> 02:17:25,200
the orion or building capability into

3577
02:17:29,669 --> 02:17:27,120
the asteroid recovery vehicle in this

3578
02:17:32,309 --> 02:17:29,679
case i refer to it as a closet where you

3579
02:17:35,110 --> 02:17:32,319
could cash things it's very important

3580
02:17:36,230 --> 02:17:35,120
that we recognize as people go on these

3581
02:17:38,230 --> 02:17:36,240
missions there are going to be

3582
02:17:40,549 --> 02:17:38,240
contingencies that they have to protect

3583
02:17:42,469 --> 02:17:40,559
against that might be in terms of

3584
02:17:44,469 --> 02:17:42,479
carrying additional food might be in

3585
02:17:46,709 --> 02:17:44,479
terms of carrying additional supplies

3586
02:17:48,309 --> 02:17:46,719
but as you retire the risk during that

3587
02:17:50,309 --> 02:17:48,319
mission during which

3588
02:17:52,629 --> 02:17:50,319

those particular assets are going to be

3589
02:17:53,990 --> 02:17:52,639
of value to you you can say hey we don't

3590
02:17:55,990 --> 02:17:54,000
need this anymore we're going to leave

3591
02:17:58,150 --> 02:17:56,000
this stuff here and it'd be nice to have

3592
02:17:59,830 --> 02:17:58,160
a closet to put it into where you could

3593
02:18:03,429 --> 02:17:59,840
leave it behind for subsequent crew

3594
02:18:07,669 --> 02:18:05,349
we've talked about functional allocation

3595
02:18:09,110 --> 02:18:07,679
amongst various spacecraft i think it's

3596
02:18:11,190 --> 02:18:09,120
also important to look at functional

3597
02:18:13,429 --> 02:18:11,200
allocation among serial missions in a

3598
02:18:14,469 --> 02:18:13,439
overall series and a campaign of

3599
02:18:16,950 --> 02:18:14,479
missions

3600
02:18:19,030 --> 02:18:16,960
and recognize that what we're really

3601
02:18:20,629 --> 02:18:19,040
looking at right now is the challenge of

3602
02:18:23,589 --> 02:18:20,639
getting off the dime

3603
02:18:26,389 --> 02:18:23,599
on exploring asteroids but we need to

3604
02:18:28,950 --> 02:18:26,399
look at this as a multi-decadal thing if

3605
02:18:31,349 --> 02:18:28,960
you really want to achieve efficiencies

3606
02:18:32,950 --> 02:18:31,359
at the broadest level things that might

3607
02:18:34,870 --> 02:18:32,960
not look efficient at a mission by

3608
02:18:37,270 --> 02:18:34,880
mission level may you may realize that

3609
02:18:39,429 --> 02:18:37,280
efficiency after three or four missions

3610
02:18:43,429 --> 02:18:39,439
or over over the course of an entire

3611
02:18:47,750 --> 02:18:46,070
so this really gets down to the point of

3612
02:18:49,589 --> 02:18:47,760
whether we're looking to optimize at a

3613
02:18:51,589 --> 02:18:49,599

very global level

3614
02:18:53,270 --> 02:18:51,599
or whether we're looking to optimize at

3615
02:18:56,629 --> 02:18:53,280
a point mission level

3616
02:18:59,270 --> 02:18:56,639
and uh that you know as the

3617
02:19:02,309 --> 02:18:59,280
thank you as the strategies for this

3618
02:19:03,830 --> 02:19:02,319
entire initiative formulate we need to

3619
02:19:05,429 --> 02:19:03,840
look at

3620
02:19:08,549 --> 02:19:05,439
at what level do we really choose to

3621
02:19:11,830 --> 02:19:08,559
optimize this architecture

3622
02:19:11,840 --> 02:19:15,750
we have time for one or two questions

3623
02:19:15,760 --> 02:19:19,030
go ahead joe

3624
02:19:23,750 --> 02:19:22,150
so the um question was um wondering if

3625
02:19:25,509 --> 02:19:23,760
you could expand on what you mean by

3626
02:19:27,030 --> 02:19:25,519
extending the reach of umbilicals are

3627
02:19:29,910 --> 02:19:27,040
you talking about longer umbilicals or

3628
02:19:32,830 --> 02:19:29,920
what yeah if you had um

3629
02:19:35,990 --> 02:19:32,840
long enough umbilicals that you could

3630
02:19:39,190 --> 02:19:36,000
uh support an eva to the farthest reach

3631
02:19:40,389 --> 02:19:39,200
away from the the uh orion vehicle as

3632
02:19:42,309 --> 02:19:40,399
possible

3633
02:19:44,150 --> 02:19:42,319
and there are some limits to how long

3634
02:19:46,309 --> 02:19:44,160
you can go with umbilicals before you

3635
02:19:47,750 --> 02:19:46,319
run out you just run into too much

3636
02:19:49,750 --> 02:19:47,760
overhead in terms of fluid pressure and

3637
02:19:51,030 --> 02:19:49,760
things like this um

3638
02:19:52,950 --> 02:19:51,040

but that's what i was talking about is

3639
02:19:54,710 --> 02:19:52,960
it extended length umbilical you know

3640
02:19:57,590 --> 02:19:54,720
what that practically

3641
02:20:02,070 --> 02:19:59,830
but i can actually answer that question

3642
02:20:03,670 --> 02:20:02,080
so we did do a trade study on ebay

3643
02:20:05,270 --> 02:20:03,680
umbilical lengths versus going to the

3644
02:20:07,590 --> 02:20:05,280
places to determine

3645
02:20:09,429 --> 02:20:07,600
what the manifested umbilicals were on

3646
02:20:11,110 --> 02:20:09,439
orion versus the if you look at the

3647
02:20:13,030 --> 02:20:11,120
umbilicals that were used in sky lab

3648
02:20:14,469 --> 02:20:13,040
which were rather lengthy and it

3649
02:20:16,389 --> 02:20:14,479
actually turned out that the use of the

3650
02:20:17,990 --> 02:20:16,399
places was lighter weight

3651
02:20:19,830 --> 02:20:18,000
because of the the length of the

3652
02:20:21,830 --> 02:20:19,840
umbilicals the mass of the umbilicals

3653
02:20:23,270 --> 02:20:21,840
and the pressure loss as you talk

3654
02:20:25,190 --> 02:20:23,280
so several of the topics that our

3655
02:20:27,190 --> 02:20:25,200
speaker brought up were the exact trades

3656
02:20:28,830 --> 02:20:27,200
that we were doing so i very much agree

3657
02:20:31,830 --> 02:20:28,840
with some of the questions you were

3658
02:20:36,870 --> 02:20:31,840
posing thank you

3659
02:20:42,950 --> 02:20:39,830
so we have one last presentation before

3660
02:20:45,030 --> 02:20:42,960
we'll take a break and that presentation

3661
02:20:46,469 --> 02:20:45,040
comes from ben reed good friend and

3662
02:20:47,990 --> 02:20:46,479
colleague from the goddard space flight

3663
02:20:49,910 --> 02:20:48,000

center and i think ben's going to talk

3664
02:20:51,429 --> 02:20:49,920
to us about uh some of the things

3665
02:20:53,190 --> 02:20:51,439
they've been working on in terms of eva

3666
02:20:54,230 --> 02:20:53,200
systems and robotics

3667
02:20:57,429 --> 02:20:54,240
up at cod

3668
02:20:59,110 --> 02:20:57,439
thank you steve thank you mark and uh

3669
02:21:01,429 --> 02:20:59,120
well i've got my thank yous out i've got

3670
02:21:02,550 --> 02:21:01,439
the program for the folks that have gone

3671
02:21:04,150 --> 02:21:02,560
before me

3672
02:21:06,950 --> 02:21:04,160
let's see thank you doug for talking

3673
02:21:08,870 --> 02:21:06,960
about the docking system on hst that was

3674
02:21:13,349 --> 02:21:08,880
good working with you on that

3675
02:21:15,590 --> 02:21:13,359
uh paul rrm thank you it was a we could

3676
02:21:17,590 --> 02:21:15,600
not have done it without the dexter and

3677
02:21:19,190 --> 02:21:17,600
ssrms so thank you

3678
02:21:20,309 --> 02:21:19,200
for your help there

3679
02:21:23,270 --> 02:21:20,319
doyle

3680
02:21:25,349 --> 02:21:23,280
pgt all the tools you showed for atk

3681
02:21:27,750 --> 02:21:25,359
built for all the hubble missions it's

3682
02:21:31,349 --> 02:21:27,760
great working with you on that as well

3683
02:21:32,950 --> 02:21:31,359
uh john lymon the 13 meter arm for hrsdm

3684
02:21:35,110 --> 02:21:32,960
it's too bad we weren't able to fly that

3685
02:21:37,110 --> 02:21:35,120
but when the crew came available

3686
02:21:38,830 --> 02:21:37,120
we had to go with uh

3687
02:21:41,990 --> 02:21:38,840
with the the tried and

3688
02:21:43,349 --> 02:21:42,000

true uh and aaron

3689
02:21:45,110 --> 02:21:43,359
looking forward to getting one of your

3690
02:21:48,469 --> 02:21:45,120
tools at the end of one of our robotic

3691
02:21:52,309 --> 02:21:48,479
arms in the uh in the next couple weeks

3692
02:21:54,389 --> 02:21:52,319
okay next chart please let's see

3693
02:21:56,389 --> 02:21:54,399
all right so you all have been heard

3694
02:21:58,790 --> 02:21:56,399
this throughout most of the day

3695
02:22:01,030 --> 02:21:58,800
i was going to talk about the advantages

3696
02:22:03,590 --> 02:22:01,040
that robotics bring

3697
02:22:05,349 --> 02:22:03,600
um to some of the the problems we have

3698
02:22:06,389 --> 02:22:05,359
here right we've got

3699
02:22:08,070 --> 02:22:06,399
um

3700
02:22:10,230 --> 02:22:08,080
we always have mass problems we've got

3701
02:22:12,870 --> 02:22:10,240
limited eva time

3702
02:22:14,950 --> 02:22:12,880
we've got signal uh latency because of

3703
02:22:18,230 --> 02:22:14,960
the the distance to it uh this is this

3704
02:22:20,950 --> 02:22:18,240
is a really hard mission um

3705
02:22:23,670 --> 02:22:20,960
and i am incredibly proud and happy to

3706
02:22:26,150 --> 02:22:23,680
be to be helping any way that that i can

3707
02:22:27,990 --> 02:22:26,160
or that we can at goddard to to help the

3708
02:22:29,670 --> 02:22:28,000
agency do it um

3709
02:22:32,790 --> 02:22:29,680
it's our job to do the tough things and

3710
02:22:35,030 --> 02:22:32,800
by golly when someone chose this

3711
02:22:37,510 --> 02:22:35,040
they were not lacking with hard things

3712
02:22:39,110 --> 02:22:37,520
to do so some of the advantages that

3713
02:22:41,349 --> 02:22:39,120

robotic springs you've already heard

3714
02:22:43,510 --> 02:22:41,359
multiple dissimilar technologies for

3715
02:22:47,910 --> 02:22:43,520
capture

3716
02:22:52,469 --> 02:22:47,920
if it's a a rubble pile as opposed to

3717
02:22:57,270 --> 02:22:54,630
different tools

3718
02:23:00,150 --> 02:22:57,280
that are picked up or let go with a

3719
02:23:04,389 --> 02:23:00,160
on-orbit tool changeout mechanism allows

3720
02:23:06,389 --> 02:23:04,399
to have failure attempts but uh uh with

3721
02:23:07,830 --> 02:23:06,399
still possibility for success it's not

3722
02:23:11,190 --> 02:23:07,840
one and done

3723
02:23:15,270 --> 02:23:12,950
it also allows you once you've got the

3724
02:23:18,309 --> 02:23:15,280
asteroid and you're on the long cruise

3725
02:23:20,230 --> 02:23:18,319
back to earth i believe that's what uh

3726
02:23:23,830 --> 02:23:20,240
several years before we get back is that

3727
02:23:25,830 --> 02:23:23,840
right so during that time rather than um

3728
02:23:29,429 --> 02:23:25,840
just be cruising and having the

3729
02:23:31,429 --> 02:23:29,439
astronauts train for multiple possible

3730
02:23:33,429 --> 02:23:31,439
scenarios once they are

3731
02:23:35,990 --> 02:23:33,439
present with the asteroid

3732
02:23:39,590 --> 02:23:36,000
it allows get ahead work

3733
02:23:41,510 --> 02:23:39,600
we can pick up sampling coring tools

3734
02:23:43,030 --> 02:23:41,520
the drill that we've seen in a couple of

3735
02:23:44,790 --> 02:23:43,040
these talks

3736
02:23:47,830 --> 02:23:44,800
to get a sense for what is the

3737
02:23:50,150 --> 02:23:47,840
consistency what is the chemistry um so

3738
02:23:52,309 --> 02:23:50,160

that we we don't have to waste eva crew

3739
02:23:53,830 --> 02:23:52,319
time for multiple scenarios but rather

3740
02:23:54,790 --> 02:23:53,840
just the one that's going to present

3741
02:23:56,150 --> 02:23:54,800
them

3742
02:23:58,550 --> 02:23:56,160
um

3743
02:24:00,389 --> 02:23:58,560
augmenting eba crew member efficiency we

3744
02:24:01,830 --> 02:24:00,399
talked about that or several people have

3745
02:24:04,230 --> 02:24:01,840
prior to me

3746
02:24:07,429 --> 02:24:04,240
translation aids

3747
02:24:09,750 --> 02:24:07,439
i believe mark it is two eva days with a

3748
02:24:11,830 --> 02:24:09,760
break in between the day off so in that

3749
02:24:13,429 --> 02:24:11,840
day off right they set it up to drill in

3750
02:24:15,429 --> 02:24:13,439
a particular spot but the techniques

3751
02:24:17,110 --> 02:24:15,439
we've seen here today and so they don't

3752
02:24:18,630 --> 02:24:17,120
have to be out there holding the pgt if

3753
02:24:20,150 --> 02:24:18,640
they don't want to if that doesn't make

3754
02:24:22,550 --> 02:24:20,160
sense

3755
02:24:24,550 --> 02:24:22,560
robots don't fatigue as quickly as a

3756
02:24:26,790 --> 02:24:24,560
crew member's arm does and as we heard

3757
02:24:28,870 --> 02:24:26,800
with previous talks let them do the hard

3758
02:24:32,469 --> 02:24:28,880
difficult work that require

3759
02:24:35,110 --> 02:24:32,479
you know a human being present

3760
02:24:36,550 --> 02:24:35,120
so we presently are

3761
02:24:38,309 --> 02:24:36,560
uh

3762
02:24:40,389 --> 02:24:38,319
working to purchase

3763
02:24:43,429 --> 02:24:40,399

an engineering arm

3764
02:24:45,030 --> 02:24:43,439
with a path to flight we are roughly one

3765
02:24:46,550 --> 02:24:45,040
year from receipt of this engineering

3766
02:24:49,270 --> 02:24:46,560
arm you see it here

3767
02:24:50,870 --> 02:24:49,280
and it is from a previous

3768
02:24:53,270 --> 02:24:50,880
most likely will be from a previous

3769
02:24:54,630 --> 02:24:53,280
presenter that you've seen here today

3770
02:24:57,590 --> 02:24:54,640
um

3771
02:24:58,950 --> 02:24:57,600
it does uh we do leverage off of the

3772
02:25:02,230 --> 02:24:58,960
tremendous

3773
02:25:06,870 --> 02:25:02,240
successful heritage of the mars arms

3774
02:25:10,469 --> 02:25:08,150
darpa

3775
02:25:12,309 --> 02:25:10,479
spent a lot of money developing this arm

3776
02:25:15,910 --> 02:25:12,319
and we picked it up from where they left

3777
02:25:20,870 --> 02:25:15,920
off and have continued to uh uh

3778
02:25:22,830 --> 02:25:20,880
uh improve on it before we place this

3779
02:25:25,510 --> 02:25:22,840
this procurement

3780
02:25:26,870 --> 02:25:25,520
um at the end you see the tool drive

3781
02:25:30,790 --> 02:25:26,880
system we'll talk about tools on the

3782
02:25:33,030 --> 02:25:30,800
next chart um and we are working on a uh

3783
02:25:35,510 --> 02:25:33,040
our software system we about half of the

3784
02:25:37,190 --> 02:25:35,520
money we spend on this program you never

3785
02:25:40,150 --> 02:25:37,200
ever get to see and of course that is in

3786
02:25:41,910 --> 02:25:40,160
the software so we have not ignored that

3787
02:25:43,670 --> 02:25:41,920
in the beginning we are

3788
02:25:46,070 --> 02:25:43,680

well on our way towards having a system

3789
02:25:48,469 --> 02:25:46,080
that will be robust to unstructured

3790
02:25:50,230 --> 02:25:48,479
environments um and i don't think you

3791
02:25:55,750 --> 02:25:50,240
get any more in structure than an

3792
02:25:58,309 --> 02:25:56,790
so

3793
02:25:59,750 --> 02:25:58,319
tools you've already seen this tool in a

3794
02:26:02,070 --> 02:25:59,760
couple of charts this is one of the

3795
02:26:04,550 --> 02:26:02,080
tools we have up on

3796
02:26:06,389 --> 02:26:04,560
rrm

3797
02:26:08,870 --> 02:26:06,399
this tool comes from a lot of

3798
02:26:10,550 --> 02:26:08,880
hubble tool heritage

3799
02:26:12,550 --> 02:26:10,560
and

3800
02:26:16,150 --> 02:26:12,560
one thing that

3801
02:26:18,150 --> 02:26:16,160
we were forced to do with rrm which was

3802
02:26:21,429 --> 02:26:18,160
a module that's up on space station now

3803
02:26:22,790 --> 02:26:21,439
is 18 months from concept to launch

3804
02:26:24,870 --> 02:26:22,800
we didn't have a lot of room we didn't

3805
02:26:27,750 --> 02:26:24,880
have a lot of mass but we wanted to do

3806
02:26:28,950 --> 02:26:27,760
lots of things so it forced us to fly

3807
02:26:30,950 --> 02:26:28,960
nothing but

3808
02:26:32,230 --> 02:26:30,960
multi-function tools there is no tool on

3809
02:26:34,230 --> 02:26:32,240
that module

3810
02:26:35,750 --> 02:26:34,240
that does one thing the tool you see in

3811
02:26:37,910 --> 02:26:35,760
the bottom right hand corner here is

3812
02:26:39,349 --> 02:26:37,920
what we call a wire cutter tool which

3813
02:26:42,389 --> 02:26:39,359

guess what

3814
02:26:43,750 --> 02:26:42,399
cuts wire but it also is a parallel jaw

3815
02:26:44,870 --> 02:26:43,760
gripper

3816
02:26:46,870 --> 02:26:44,880
do you see

3817
02:26:49,510 --> 02:26:46,880
here

3818
02:26:52,469 --> 02:26:49,520
and it has a blade that extends out of

3819
02:26:54,550 --> 02:26:52,479
the tip for uh slicing thermal blanket

3820
02:26:58,150 --> 02:26:54,560
tape so this does at least three

3821
02:26:59,830 --> 02:26:58,160
functions um nominal in this tool when

3822
02:27:00,950 --> 02:26:59,840
as designed

3823
02:27:03,590 --> 02:27:00,960
so we think

3824
02:27:05,270 --> 02:27:03,600
as you are limited in mass for the eva

3825
02:27:07,110 --> 02:27:05,280
tools or we are

3826
02:27:11,030 --> 02:27:07,120
that we want all of them to be

3827
02:27:14,710 --> 02:27:13,030
practicing on the ground

3828
02:27:17,990 --> 02:27:14,720
so

3829
02:27:20,309 --> 02:27:18,000
we nasa have uh gotten ourselves into

3830
02:27:23,030 --> 02:27:20,319
situations in the past where things

3831
02:27:26,870 --> 02:27:23,040
didn't go exactly as planned uh such as

3832
02:27:29,990 --> 02:27:26,880
the capturing of satellites for repair

3833
02:27:31,830 --> 02:27:30,000
in the shuttle in the 80s

3834
02:27:34,150 --> 02:27:31,840
so we tried to

3835
02:27:35,190 --> 02:27:34,160
read well the lessons learned from those

3836
02:27:38,070 --> 02:27:35,200
missions

3837
02:27:41,830 --> 02:27:40,070
develop our technology development

3838
02:27:43,510 --> 02:27:41,840

campaign

3839
02:27:46,070 --> 02:27:43,520
with that in mind so we have spent

3840
02:27:49,270 --> 02:27:46,080
tremendous amount of time and effort on

3841
02:27:51,590 --> 02:27:49,280
producing motion simulation platforms

3842
02:27:53,590 --> 02:27:51,600
uh for contact dynamics so you see in

3843
02:27:55,910 --> 02:27:53,600
the bottom here we performed a high

3844
02:27:57,910 --> 02:27:55,920
fidelity near real time i say near real

3845
02:28:00,550 --> 02:27:57,920
time because there was a 20 millisecond

3846
02:28:02,469 --> 02:28:00,560
delay between contact and motion and it

3847
02:28:04,309 --> 02:28:02,479
took us good nine months to drive that

3848
02:28:06,230 --> 02:28:04,319
from 80 millisecond delay to 20

3849
02:28:09,030 --> 02:28:06,240
millisecond delay

3850
02:28:11,750 --> 02:28:09,040
but we are now at about 20 millisecond

3851
02:28:13,910 --> 02:28:11,760
for full 60 degree of freedom contact

3852
02:28:15,830 --> 02:28:13,920
dynamics so that we can

3853
02:28:18,630 --> 02:28:15,840
practice again and again

3854
02:28:20,870 --> 02:28:18,640
autonomous capture either of of course a

3855
02:28:23,270 --> 02:28:20,880
satellite which is

3856
02:28:25,270 --> 02:28:23,280
where we spend a lot of our efforts

3857
02:28:26,389 --> 02:28:25,280
but as well as asteroids you see in the

3858
02:28:28,710 --> 02:28:26,399
top picture

3859
02:28:30,389 --> 02:28:28,720
and with one touch software

3860
02:28:32,150 --> 02:28:30,399
reconfiguration

3861
02:28:35,349 --> 02:28:32,160
it's easy to change the inertial

3862
02:28:37,349 --> 02:28:35,359
properties of the client from

3863
02:28:40,550 --> 02:28:37,359

100 ton to

3864
02:28:43,190 --> 02:28:40,560
10 tons to 1000 tons

3865
02:28:45,030 --> 02:28:43,200
spherical non-spherical

3866
02:28:46,710 --> 02:28:45,040
to see how that would affect your tool

3867
02:28:48,309 --> 02:28:46,720
your capture technique or your drilling

3868
02:28:53,110 --> 02:28:48,319
technique whatever it is you happen to

3869
02:28:56,950 --> 02:28:55,270
we also have a

3870
02:29:06,230 --> 02:28:56,960
a

3871
02:29:09,030 --> 02:29:06,240
bring together modeling techniques to

3872
02:29:10,550 --> 02:29:09,040
simulate what's going to happen

3873
02:29:12,309 --> 02:29:10,560
i won't read all the words on the chart

3874
02:29:14,070 --> 02:29:12,319
i know we're a little behind so i will

3875
02:29:15,910 --> 02:29:14,080
go through this quickly but in the

3876
02:29:18,230 --> 02:29:15,920
bottom right hand corner you see this

3877
02:29:20,630 --> 02:29:18,240
the left-hand image is

3878
02:29:23,190 --> 02:29:20,640
an image that we produced a synthetic

3879
02:29:25,990 --> 02:29:23,200
image of what hubble would look like

3880
02:29:27,670 --> 02:29:26,000
from a camera doing

3881
02:29:29,429 --> 02:29:27,680
autonomous tracking

3882
02:29:32,469 --> 02:29:29,439
during the last hubble mission so this

3883
02:29:34,389 --> 02:29:32,479
is what we trained our cameras against

3884
02:29:36,389 --> 02:29:34,399
and during the mission we used our

3885
02:29:38,710 --> 02:29:36,399
natural feature recognition algorithms

3886
02:29:42,150 --> 02:29:38,720
with the visible camera in the back of

3887
02:29:44,150 --> 02:29:42,160
the shuttle on sts-125

3888
02:29:46,469 --> 02:29:44,160

to autonomously track the two vehicles

3889
02:29:48,150 --> 02:29:46,479
coming together and you see how closely

3890
02:29:49,990 --> 02:29:48,160
they they match each other so this is

3891
02:29:51,429 --> 02:29:50,000
the type of thing that we would do for

3892
02:29:52,710 --> 02:29:51,439
an asteroid mission we put in the

3893
02:29:54,469 --> 02:29:52,720
synthetic imagery and that's what you

3894
02:29:56,950 --> 02:29:54,479
see in the upper right hand of an

3895
02:29:59,030 --> 02:29:56,960
asteroid to train our natural feature

3896
02:30:03,190 --> 02:29:59,040
algorithms against

3897
02:30:08,630 --> 02:30:05,510
so we stand by

3898
02:30:10,230 --> 02:30:08,640
eager to help the agency with whatever

3899
02:30:12,870 --> 02:30:10,240
path it uh

3900
02:30:17,670 --> 02:30:12,880
it decides to go for this mission thanks

3901
02:30:20,550 --> 02:30:18,550
thank you

3902
02:30:24,630 --> 02:30:20,560
we have time for uh one or two questions

3903
02:30:26,870 --> 02:30:25,510
um

3904
02:30:28,309 --> 02:30:26,880
could you say a little bit more about

3905
02:30:29,510 --> 02:30:28,319
the arm that you're getting ready to

3906
02:30:33,429 --> 02:30:29,520
procure

3907
02:30:36,550 --> 02:30:33,439
uh sure it is uh i believe bo correct me

3908
02:30:38,550 --> 02:30:36,560
2.2 meters tip to tip from shoulder out

3909
02:30:40,230 --> 02:30:38,560
to the tip so it's got two one meter

3910
02:30:41,510 --> 02:30:40,240
segments roughly seven degrees of

3911
02:30:42,870 --> 02:30:41,520
freedom

3912
02:30:44,469 --> 02:30:42,880
um

3913
02:30:47,670 --> 02:30:44,479

as you saw at the software there it does

3914
02:30:50,389 --> 02:30:47,680
have collision avoidance

3915
02:30:51,590 --> 02:30:50,399
workarounds for singularities

3916
02:30:53,270 --> 02:30:51,600
because

3917
02:30:56,070 --> 02:30:53,280
we have

3918
02:30:57,750 --> 02:30:56,080
originally developed this arm once we

3919
02:30:59,830 --> 02:30:57,760
took it over from darpa

3920
02:31:01,429 --> 02:30:59,840
for satellite servicing we are very much

3921
02:31:02,710 --> 02:31:01,439
interested in

3922
02:31:05,349 --> 02:31:02,720
um

3923
02:31:07,349 --> 02:31:05,359
compliance control during contact right

3924
02:31:10,389 --> 02:31:07,359
so we're going to go up against a a

3925
02:31:12,710 --> 02:31:10,399
client satellite that's around a

3926
02:31:15,990 --> 02:31:12,720
thousand kilograms maybe two thousand

3927
02:31:17,030 --> 02:31:16,000
maybe four thousand reconfigurable um

3928
02:31:18,150 --> 02:31:17,040
and we're not going to be touching it

3929
02:31:19,990 --> 02:31:18,160
through the center of mass we're going

3930
02:31:22,230 --> 02:31:20,000
to be touching it on the side probably

3931
02:31:24,870 --> 02:31:22,240
where the marmon ring is and so

3932
02:31:27,270 --> 02:31:24,880
being able to autonomously track the tip

3933
02:31:29,110 --> 02:31:27,280
of the arm to reach out and touch it

3934
02:31:31,670 --> 02:31:29,120
and not impart too much loads into it

3935
02:31:32,950 --> 02:31:31,680
before we we close the grasp

3936
02:31:35,590 --> 02:31:32,960
has required

3937
02:31:37,190 --> 02:31:35,600
close coordination between the machine

3938
02:31:40,230 --> 02:31:37,200

vision algorithms

3939
02:31:41,590 --> 02:31:40,240
the camera system the speed of the arm

3940
02:31:42,870 --> 02:31:41,600
we talked about the speed of the arm

3941
02:31:45,190 --> 02:31:42,880
being one of the limiting factors in

3942
02:31:47,830 --> 02:31:45,200
orbit um and the compliance control so

3943
02:31:49,590 --> 02:31:47,840
it doesn't impart too much load um so

3944
02:31:52,550 --> 02:31:49,600
all of that work has been ongoing for

3945
02:31:54,950 --> 02:31:52,560
several years now that has led up to us

3946
02:31:56,790 --> 02:31:54,960
putting in the the put getting the

3947
02:31:59,429 --> 02:31:56,800
paperwork together to go out and

3948
02:32:01,830 --> 02:31:59,439
purchase uh an engineering arm

3949
02:32:03,910 --> 02:32:01,840
we do have a posable alarm in the lab

3950
02:32:05,670 --> 02:32:03,920
now it was delivered since i came to

3951
02:32:07,750 --> 02:32:05,680
houston a couple days ago

3952
02:32:09,349 --> 02:32:07,760
so it's just freshly arrived so it's a

3953
02:32:10,550 --> 02:32:09,359
life-size

3954
02:32:12,950 --> 02:32:10,560
scale

3955
02:32:15,270 --> 02:32:12,960
articulating arm that we will be using

3956
02:32:19,110 --> 02:32:15,280
for reach and access studies over the

3957
02:32:21,429 --> 02:32:19,120
coming weeks months and and years

3958
02:32:23,429 --> 02:32:21,439
and any of you ever in the

3959
02:32:25,110 --> 02:32:23,439
washington dc area encourage you to get

3960
02:32:27,110 --> 02:32:25,120
in touch with me and come on out we'll

3961
02:32:30,230 --> 02:32:27,120
we'll show you what we have in the lab

3962
02:32:31,990 --> 02:32:30,240
we uh we like to give tours don't we bo

3963
02:32:34,950 --> 02:32:32,000

yes

3964
02:32:34,960 --> 02:32:41,750
all right thanks ben thank you very much

3965
02:32:45,429 --> 02:32:43,750
so uh mark and i have been sitting on

3966
02:32:46,710 --> 02:32:45,439
these chairs for

3967
02:32:48,630 --> 02:32:46,720
two and a half hours now so we're going

3968
02:32:49,830 --> 02:32:48,640
to take a break here in houston for

3969
02:32:52,070 --> 02:32:49,840
those uh

3970
02:32:53,510 --> 02:32:52,080
those online are participating via nasa

3971
02:32:54,870 --> 02:32:53,520
tv

3972
02:32:57,670 --> 02:32:54,880
for those in the room here let's try to