



DSITM
DEEP SPACE INDUSTRIES

David Gump, CEO
Asteroid Initiative
Idea Synthesis Workshop
Sept. 30, 2013

1
00:00:04,309 --> 00:00:01,750
are doing get ahead work for the eba

2
00:00:07,349 --> 00:00:04,319
crew there's also no bag for the crew to

3
00:00:09,589 --> 00:00:07,359
cut through when they arrive

4
00:00:12,629 --> 00:00:09,599
we then sep d mate again

5
00:00:14,870 --> 00:00:12,639
orion docks here and now the arms

6
00:00:16,950 --> 00:00:14,880
aid during the ebas

7
00:00:19,109 --> 00:00:16,960
just as the rms did during shuttle days

8
00:00:20,630 --> 00:00:19,119
and ssrms does

9
00:00:22,070 --> 00:00:20,640
uh now

10
00:00:23,990 --> 00:00:22,080
does it

11
00:00:26,150 --> 00:00:24,000
ssrms do they ever stand on the nfs's

12
00:00:28,310 --> 00:00:26,160
rms yeah

13
00:00:30,150 --> 00:00:28,320

so afterward the tug could then

14

00:00:33,030 --> 00:00:30,160

potentially be refueled replenish with

15

00:00:34,950 --> 00:00:33,040

xenon to go either get another one

16

00:00:36,790 --> 00:00:34,960

or to do other things that are

17

00:00:38,630 --> 00:00:36,800

extensible for the human exploration

18

00:00:40,069 --> 00:00:38,640

system

19

00:00:41,510 --> 00:00:40,079

tugs are a good thing to have in your

20

00:00:43,590 --> 00:00:41,520

back pocket if you're

21

00:00:45,430 --> 00:00:43,600

space faring nation

22

00:00:48,869 --> 00:00:45,440

so these are things that we are doing

23

00:00:51,029 --> 00:00:48,879

presently to advance the technology in

24

00:00:52,950 --> 00:00:51,039

some of these key areas we've got

25

00:00:54,869 --> 00:00:52,960

a refueling experiment up on space

26

00:00:57,430 --> 00:00:54,879

station right now that's involving

27

00:00:59,510 --> 00:00:57,440

advanced tools and i have no time but

28

00:01:01,990 --> 00:00:59,520

these the only point here is these are

29

00:01:03,910 --> 00:01:02,000

all photographs of hardware not cad

30

00:01:06,630 --> 00:01:03,920

renderings of what we're going to do but

31

00:01:08,310 --> 00:01:06,640

what we are doing now

32

00:01:10,630 --> 00:01:08,320

and these are those other missions take

33

00:01:14,630 --> 00:01:10,640

a picture quick

34

00:01:14,640 --> 00:01:17,270

thanks ben

35

00:01:21,990 --> 00:01:19,350

all right we keep proving how much how

36

00:01:23,270 --> 00:01:22,000

little time 10 minutes is um

37

00:01:25,350 --> 00:01:23,280

the next

38

00:01:27,990 --> 00:01:25,360

pair of speakers is

39

00:01:29,670 --> 00:01:28,000

michael esperman and manny liens from

40

00:01:31,910 --> 00:01:29,680

boeing company

41

00:01:34,230 --> 00:01:31,920

mike's the director of space science and

42

00:01:36,149 --> 00:01:34,240

advanced space utilization for boeing

43

00:01:38,550 --> 00:01:36,159

manny is the director of autonomous

44

00:01:40,230 --> 00:01:38,560

space capabilities and he will join the

45

00:01:42,230 --> 00:01:40,240

in the presentation they will address

46

00:01:44,469 --> 00:01:42,240

the inherent technical schedule and cost

47

00:01:46,710 --> 00:01:44,479

risks of the the challenging mission and

48

00:01:48,550 --> 00:01:46,720

discuss how designing the uh asteroid

49

00:01:50,310 --> 00:01:48,560

redirect systems to incorporate existing

50

00:01:52,630 --> 00:01:50,320

high heritage spacecraft systems and

51
00:01:54,870 --> 00:01:52,640
subsystems leveraging proven performance

52
00:01:56,389 --> 00:01:54,880
high reliability and associated

53
00:01:57,990 --> 00:01:56,399
investments and experience will reduce

54
00:01:59,749 --> 00:01:58,000
overall mission risk

55
00:02:01,910 --> 00:01:59,759
capitalizing on the extensive industry

56
00:02:04,230 --> 00:02:01,920
production and operations experience

57
00:02:06,149 --> 00:02:04,240
so mike

58
00:02:07,749 --> 00:02:06,159
my name is mike as

59
00:02:08,949 --> 00:02:07,759
jim said this is manny we're from the

60
00:02:10,070 --> 00:02:08,959
boeing company

61
00:02:11,510 --> 00:02:10,080
um we're today we're going to talk a

62
00:02:12,710 --> 00:02:11,520
little bit about

63
00:02:14,229 --> 00:02:12,720

maybe not so much the specific

64

00:02:15,589 --> 00:02:14,239

implementation of this mission but but

65

00:02:17,990 --> 00:02:15,599

ways to manage the risk that are

66

00:02:19,030 --> 00:02:18,000

inherent in just in a in a program of

67

00:02:21,270 --> 00:02:19,040

this uh

68

00:02:23,510 --> 00:02:21,280

magnitude which button is it jim

69

00:02:26,390 --> 00:02:23,520

for chart don't touch the bottom one um

70

00:02:27,990 --> 00:02:26,400

the full yeah okay figured it out so

71

00:02:30,070 --> 00:02:28,000

it's going to be broken into two parts

72

00:02:32,150 --> 00:02:30,080

i'm going to talk about uh similar

73

00:02:33,350 --> 00:02:32,160

concepts to what adam talked about a

74

00:02:35,190 --> 00:02:33,360

little bit what ben talked about how we

75

00:02:37,030 --> 00:02:35,200

maybe can leverage existing capabilities

76

00:02:38,390 --> 00:02:37,040

that are that exist within industry and

77

00:02:40,070 --> 00:02:38,400

that nasa has already invested in to

78

00:02:42,630 --> 00:02:40,080

really help manage and mitigate the

79

00:02:43,830 --> 00:02:42,640

asteroid system emission system risks

80

00:02:45,670 --> 00:02:43,840

and the man is going to talk about

81

00:02:47,750 --> 00:02:45,680

specifically some investments that have

82

00:02:48,869 --> 00:02:47,760

been done both by us and by nasa and

83

00:02:50,470 --> 00:02:48,879

autonomous rendezvous and docking

84

00:02:52,710 --> 00:02:50,480

terrain relative navigation how that can

85

00:02:55,110 --> 00:02:52,720

apply to the mission and also reduce the

86

00:02:57,509 --> 00:02:55,120

overall risk

87

00:02:59,190 --> 00:02:57,519

so as everybody

88

00:03:00,309 --> 00:02:59,200

i'm sure recognizes and has been said

89

00:03:01,910 --> 00:03:00,319

several times today it's a very

90

00:03:04,550 --> 00:03:01,920

ambitious program that nasa is trying to

91

00:03:06,869 --> 00:03:04,560

undertake lots of benefits to to the

92

00:03:08,070 --> 00:03:06,879

nation and to humanity

93

00:03:09,350 --> 00:03:08,080

and really trying to synergize the

94

00:03:10,550 --> 00:03:09,360

various things that are going on inside

95

00:03:12,470 --> 00:03:10,560

of nasa in terms of technology

96

00:03:14,149 --> 00:03:12,480

development mission execution

97

00:03:15,830 --> 00:03:14,159

science etc

98

00:03:17,430 --> 00:03:15,840

but there are a lot of as everybody

99

00:03:20,229 --> 00:03:17,440

realizes a lot of uncertainties on this

100

00:03:21,830 --> 00:03:20,239

particular mission uh which really drive

101

00:03:23,350 --> 00:03:21,840

up the risk it's already

102

00:03:25,350 --> 00:03:23,360

incorporating new technologies which

103

00:03:27,350 --> 00:03:25,360

have some inherent risks uh we're going

104

00:03:28,869 --> 00:03:27,360

further away than you know

105

00:03:30,869 --> 00:03:28,879

than we've done in a long time in terms

106

00:03:33,509 --> 00:03:30,879

of distance from earth

107

00:03:34,869 --> 00:03:33,519

so the asteroid they've talked about

108

00:03:36,869 --> 00:03:34,879

the uncertainty in its mass and that

109

00:03:38,470 --> 00:03:36,879

drive system performance parameters

110

00:03:39,910 --> 00:03:38,480

launch date launch vehicle those are

111

00:03:41,430 --> 00:03:39,920

trades that that

112

00:03:43,750 --> 00:03:41,440

are also uncertain

113

00:03:45,350 --> 00:03:43,760

and then a real risk i think is the very

114

00:03:47,509 --> 00:03:45,360

ambitious schedule that that has been

115

00:03:48,949 --> 00:03:47,519

proposed uh concurrent technology

116

00:03:50,229 --> 00:03:48,959

development at the same time that you're

117

00:03:51,830 --> 00:03:50,239

designing the mission and the mission

118

00:03:53,030 --> 00:03:51,840

systems

119

00:03:54,949 --> 00:03:53,040

you've got to you've got to really be

120

00:03:56,390 --> 00:03:54,959

careful about what you're doing there so

121

00:03:58,949 --> 00:03:56,400

really i think mission success is going

122

00:04:01,270 --> 00:03:58,959

to depend on effective and very

123

00:04:03,429 --> 00:04:01,280

very very strong risk management

124

00:04:06,070 --> 00:04:03,439

so my message here is that i think that

125

00:04:08,710 --> 00:04:06,080

the industry team both industry academia

126

00:04:10,229 --> 00:04:08,720

and nasa that nasa has

127

00:04:11,509 --> 00:04:10,239

to make a broader

128

00:04:12,789 --> 00:04:11,519

community involvement of this mission i

129

00:04:14,390 --> 00:04:12,799

think will really be a go a long way

130

00:04:15,589 --> 00:04:14,400

towards minimizing that risk

131

00:04:17,749 --> 00:04:15,599

there's an extensive amount of

132

00:04:19,430 --> 00:04:17,759

experience in industry

133

00:04:20,870 --> 00:04:19,440

and from our current production programs

134

00:04:22,790 --> 00:04:20,880

on the commercial side as well as the

135

00:04:25,189 --> 00:04:22,800

the existing nasa programs that can be

136

00:04:26,469 --> 00:04:25,199

used to mitigate risks and i've listed

137

00:04:28,629 --> 00:04:26,479

really five key ones there that i'm

138

00:04:30,550 --> 00:04:28,639

going to talk a bit more about as we go

139

00:04:31,830 --> 00:04:30,560

through the presentation first of all

140

00:04:33,350 --> 00:04:31,840

using flight proven systems high

141

00:04:35,270 --> 00:04:33,360

heritage systems will that as your point

142

00:04:37,350 --> 00:04:35,280

of departure to have definitely reduces

143

00:04:38,790 --> 00:04:37,360

the risk on the system

144

00:04:40,070 --> 00:04:38,800

utilizing a

145

00:04:41,510 --> 00:04:40,080

a prime integrator if you will to

146

00:04:43,430 --> 00:04:41,520

integrate the solar electric propulsion

147

00:04:45,350 --> 00:04:43,440

technologies into the mission i i think

148

00:04:47,909 --> 00:04:45,360

is also has a lot of merit

149

00:04:49,430 --> 00:04:47,919

you can leverage the experience that the

150

00:04:51,510 --> 00:04:49,440

industry partners have

151
00:04:53,510 --> 00:04:51,520
to to get that system integrated and

152
00:04:55,430 --> 00:04:53,520
working right a lot of best practices to

153
00:04:57,430 --> 00:04:55,440
bring to bear

154
00:04:59,510 --> 00:04:57,440
launching on sls really increases your

155
00:05:01,350 --> 00:04:59,520
margins increased margin increases your

156
00:05:05,510 --> 00:05:01,360
uh your ability to handle unforeseen

157
00:05:09,270 --> 00:05:07,189
ben mentioned designing the system for

158
00:05:10,390 --> 00:05:09,280
reuse i think that's a really a really

159
00:05:12,150 --> 00:05:10,400
smart move

160
00:05:14,550 --> 00:05:12,160
it maximizes a return on investment no

161
00:05:16,469 --> 00:05:14,560
matter what you do this even trying to

162
00:05:17,749 --> 00:05:16,479
to drive costs down and be affordable

163
00:05:19,830 --> 00:05:17,759

this is going to be a very expensive

164

00:05:21,670 --> 00:05:19,840

investment for the country so reusing

165

00:05:23,029 --> 00:05:21,680

that system only makes sense and there's

166

00:05:24,469 --> 00:05:23,039

some things you can do early on when you

167

00:05:25,830 --> 00:05:24,479

do the design to to enhance that

168

00:05:27,430 --> 00:05:25,840

reusability

169

00:05:29,749 --> 00:05:27,440

and implement implementing an integrated

170

00:05:31,110 --> 00:05:29,759

gnc system uh into the uh

171

00:05:32,790 --> 00:05:31,120

into the autonomous rendezvous and

172

00:05:33,909 --> 00:05:32,800

docking portion make it all resident in

173

00:05:35,110 --> 00:05:33,919

one vehicle

174

00:05:36,469 --> 00:05:35,120

we think there's some real benefits to

175

00:05:39,189 --> 00:05:36,479

that many probably touch on that but in

176

00:05:40,469 --> 00:05:39,199

terms of testing seamless

177

00:05:41,830 --> 00:05:40,479

seams

178

00:05:45,670 --> 00:05:41,840

interface requirements of that type of

179

00:05:46,469 --> 00:05:45,680

thing it seems like a smarter way to go

180

00:05:48,310 --> 00:05:46,479

so

181

00:05:51,350 --> 00:05:48,320

the first topic heritage systems

182

00:05:53,510 --> 00:05:51,360

reducing development execution risk

183

00:05:57,270 --> 00:05:53,520

there's a lot of uh spacecraft knowledge

184

00:05:58,870 --> 00:05:57,280

uh in america in the industry uh we've

185

00:06:01,110 --> 00:05:58,880

we've been uh you know we produce

186

00:06:02,629 --> 00:06:01,120

spacecraft for it well basically entire

187

00:06:05,990 --> 00:06:02,639

industries depend on the spacecraft that

188

00:06:07,189 --> 00:06:06,000

we produce for example xm radio

189

00:06:08,870 --> 00:06:07,199

directv

190

00:06:10,309 --> 00:06:08,880

so the reliability

191

00:06:12,230 --> 00:06:10,319

and mission success requirements on

192

00:06:13,749 --> 00:06:12,240

those types of platforms

193

00:06:15,270 --> 00:06:13,759

are you know they're equally as

194

00:06:17,350 --> 00:06:15,280

important as they are for a mission of

195

00:06:18,710 --> 00:06:17,360

this magnitude as well so you've got a

196

00:06:20,870 --> 00:06:18,720

lot of flight proven design and

197

00:06:22,950 --> 00:06:20,880

qualification experience that a resident

198

00:06:24,309 --> 00:06:22,960

in the industry partners

199

00:06:26,309 --> 00:06:24,319

very established and repeatable

200

00:06:27,990 --> 00:06:26,319

processes and tools and and the

201
00:06:31,430 --> 00:06:28,000
personnel who know how to build these

202
00:06:32,870 --> 00:06:31,440
platforms that's a real key

203
00:06:35,029 --> 00:06:32,880
benefit that that could be brought to

204
00:06:37,189 --> 00:06:35,039
bear here on this on this program

205
00:06:38,309 --> 00:06:37,199
of integrated and well-exercised supply

206
00:06:39,990 --> 00:06:38,319
chain

207
00:06:41,749 --> 00:06:40,000
even though you're going to build just

208
00:06:43,990 --> 00:06:41,759
maybe one vehicle for this particular

209
00:06:45,590 --> 00:06:44,000
mission if you need spare parts you you

210
00:06:47,189 --> 00:06:45,600
have to do some some testing something

211
00:06:48,790 --> 00:06:47,199
that you hadn't foreseen if you can pull

212
00:06:50,550 --> 00:06:48,800
in that supply chain to get those parts

213
00:06:52,629 --> 00:06:50,560

or build up an engineering design unit

214

00:06:54,710 --> 00:06:52,639

and pretty quick time

215

00:06:56,469 --> 00:06:54,720

that's a real benefit as well

216

00:06:58,870 --> 00:06:56,479

once again 15-year lifetime for most of

217

00:07:02,309 --> 00:06:58,880

the commercial geocom platforms that are

218

00:07:03,990 --> 00:07:02,319

built out there if not longer

219

00:07:06,070 --> 00:07:04,000

operational envelopes and limits we know

220

00:07:08,790 --> 00:07:06,080

what the the space vehicle is designed

221

00:07:10,710 --> 00:07:08,800

for and and we've tested that and we see

222

00:07:12,550 --> 00:07:10,720

it happen in real in operational

223

00:07:13,909 --> 00:07:12,560

experience so we know how the vehicle is

224

00:07:15,270 --> 00:07:13,919

going to operate

225

00:07:17,990 --> 00:07:15,280

established launch vehicle and payload

226

00:07:19,670 --> 00:07:18,000

interfaces up to ten thousand kilogram

227

00:07:21,270 --> 00:07:19,680

uh payloads can be accommodated on most

228

00:07:23,029 --> 00:07:21,280

of these platforms i know adam said that

229

00:07:25,029 --> 00:07:23,039

the laurel platform can go a little bit

230

00:07:26,550 --> 00:07:25,039

higher so more mass is going to be you

231

00:07:28,309 --> 00:07:26,560

know that gives you that margin that

232

00:07:30,070 --> 00:07:28,319

you're going to need to be successful

233

00:07:31,670 --> 00:07:30,080

uh and you know you uh as you're

234

00:07:33,589 --> 00:07:31,680

designing the mission uh depending on

235

00:07:35,110 --> 00:07:33,599

the trades that say been alluded to

236

00:07:37,270 --> 00:07:35,120

whether you do a two-piece spacecraft or

237

00:07:39,029 --> 00:07:37,280

a monolithic spacecraft you can you can

238

00:07:41,350 --> 00:07:39,039

draw on the industries either their

239

00:07:43,270 --> 00:07:41,360

system subsystems or the entire platform

240

00:07:46,070 --> 00:07:43,280

for a turnkey solution

241

00:07:47,909 --> 00:07:46,080

it gives flexibility to nasa and really

242

00:07:49,029 --> 00:07:47,919

what that does it allows nasa to focus

243

00:07:51,029 --> 00:07:49,039

on the hard things that need to be

244

00:07:53,029 --> 00:07:51,039

developed the spacecraft's going to be

245

00:07:54,869 --> 00:07:53,039

it'll be a tough engineering challenge

246

00:07:57,110 --> 00:07:54,879

but getting those technologies done and

247

00:07:58,230 --> 00:07:57,120

getting them validated trl 6 and above

248

00:08:00,710 --> 00:07:58,240

in the time frame that we're talking

249

00:08:05,510 --> 00:08:00,720

about that's a big job and that way the

250

00:08:05,520 --> 00:08:10,950

i didn't do that i did not do that

251
00:08:15,430 --> 00:08:12,469
i'm not going to update firefox right

252
00:08:23,510 --> 00:08:16,790
okay

253
00:08:24,950 --> 00:08:23,520
chart

254
00:08:27,749 --> 00:08:24,960
uh integration experience for solar

255
00:08:29,430 --> 00:08:27,759
electric propulsion technologies

256
00:08:33,110 --> 00:08:29,440
there are lots of uh

257
00:08:33,990 --> 00:08:33,120
lots lots of uh use of scp in in today's

258
00:08:36,149 --> 00:08:34,000
uh

259
00:08:37,430 --> 00:08:36,159
geocom and other applications space

260
00:08:38,949 --> 00:08:37,440
mission markets

261
00:08:40,389 --> 00:08:38,959
um a lot you know with the advanced

262
00:08:42,149 --> 00:08:40,399
solar echo propulsion that's been talked

263
00:08:44,310 --> 00:08:42,159

about for this mission is quite a leap

264

00:08:45,910 --> 00:08:44,320

in terms of power both for the thrusters

265

00:08:47,030 --> 00:08:45,920

and for the solar rays but there's a lot

266

00:08:49,190 --> 00:08:47,040

of uh

267

00:08:51,110 --> 00:08:49,200

there's there's over many many years of

268

00:08:53,110 --> 00:08:51,120

operational experience out there

269

00:08:55,190 --> 00:08:53,120

operating these systems

270

00:08:57,829 --> 00:08:55,200

doing you know station keeping a geo or

271

00:08:59,269 --> 00:08:57,839

in the uh in the context of the vehicle

272

00:09:02,389 --> 00:08:59,279

that boeing has recently developed at

273

00:09:04,389 --> 00:09:02,399

702 sp it actually uses the uh

274

00:09:05,990 --> 00:09:04,399

the solar propulsion to actually to

275

00:09:07,350 --> 00:09:06,000

orbit raise now granted it takes a

276

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

little bit longer to get on station but

277

00:09:10,949 --> 00:09:09,040

it really reduces your launch costs

278

00:09:12,310 --> 00:09:10,959

which is a real benefit point is there's

279

00:09:14,630 --> 00:09:12,320

a lot of experience on how to integrate

280

00:09:16,310 --> 00:09:14,640

step technology into into systems at an

281

00:09:17,269 --> 00:09:16,320

industry that could be applied here for

282

00:09:18,470 --> 00:09:17,279

nasa

283

00:09:19,829 --> 00:09:18,480

um

284

00:09:21,750 --> 00:09:19,839

lots of lessons learned from our

285

00:09:23,910 --> 00:09:21,760

experience in both production design and

286

00:09:26,150 --> 00:09:23,920

operations once again solid supplier

287

00:09:27,990 --> 00:09:26,160

relationships with with all the key

288

00:09:29,350 --> 00:09:28,000

producers

289

00:09:32,150 --> 00:09:29,360

some firms have indigenous solar

290

00:09:34,470 --> 00:09:32,160

reproduction tests and

291

00:09:36,870 --> 00:09:34,480

build facilities and capabilities that

292

00:09:39,110 --> 00:09:36,880

could be brought in state-of-the-art

293

00:09:40,550 --> 00:09:39,120

test equipment also exists

294

00:09:42,470 --> 00:09:40,560

once again the experience base is you

295

00:09:44,710 --> 00:09:42,480

know for for boeing anyhow it's well

296

00:09:47,030 --> 00:09:44,720

over 90 years of operational experience

297

00:09:48,790 --> 00:09:47,040

with step powered uh vehicles

298

00:09:51,030 --> 00:09:48,800

and there's you know the the ability to

299

00:09:52,870 --> 00:09:51,040

do low thrust trajectory design

300

00:09:55,110 --> 00:09:52,880

mission planning and the navigation

301

00:09:57,509 --> 00:09:55,120

expertise with that is also becoming

302

00:09:58,870 --> 00:09:57,519

more important and that can add to the

303

00:10:02,230 --> 00:09:58,880

mission success

304

00:10:07,829 --> 00:10:04,710

uh sls what a great asset to have for

305

00:10:09,750 --> 00:10:07,839

this mission um nasa is building the sls

306

00:10:12,230 --> 00:10:09,760

now uh they're actually ahead of

307

00:10:15,030 --> 00:10:12,240

schedule in many instances uh vehicles

308

00:10:16,190 --> 00:10:15,040

on on track to you know fly

309

00:10:19,030 --> 00:10:16,200

in the

310

00:10:20,630 --> 00:10:19,040

2017-2018 time frame

311

00:10:22,790 --> 00:10:20,640

that's really a

312

00:10:24,949 --> 00:10:22,800

fortuitous schedule coincidence that if

313

00:10:26,710 --> 00:10:24,959

you can launch on sls basically you get

314

00:10:28,630 --> 00:10:26,720

you get more mass

315

00:10:29,990 --> 00:10:28,640

you get you could possibly you

316

00:10:31,509 --> 00:10:30,000

demonstrate a gravity tractor

317

00:10:33,750 --> 00:10:31,519

demonstration deflection demonstration

318

00:10:36,150 --> 00:10:33,760

if you have a massive enough spacecraft

319

00:10:37,910 --> 00:10:36,160

you can launch on a direct injection

320

00:10:39,590 --> 00:10:37,920

trajectory to lunar gravity assist or

321

00:10:41,750 --> 00:10:39,600

straight to the target depending on what

322

00:10:43,190 --> 00:10:41,760

the target is it eliminates that spiral

323

00:10:44,790 --> 00:10:43,200

out phase and saves you about two years

324

00:10:46,310 --> 00:10:44,800

on the overall mission duration or one

325

00:10:47,990 --> 00:10:46,320

to three years depending on once again

326

00:10:50,470 --> 00:10:48,000

where you're going and how big it is

327

00:10:52,069 --> 00:10:50,480

but the additional sep technology

328

00:10:53,750 --> 00:10:52,079

technology maturation schedule that the

329

00:10:54,630 --> 00:10:53,760

sls provides i think is a real benefit

330

00:10:56,949 --> 00:10:54,640

too

331

00:10:57,670 --> 00:10:56,959

if we push back the notion launch date

332

00:10:59,590 --> 00:10:57,680

two

333

00:11:01,590 --> 00:10:59,600

when sls is flying a block block one

334

00:11:03,430 --> 00:11:01,600

configuration once again that gives

335

00:11:05,670 --> 00:11:03,440

the technology folks a little bit extra

336

00:11:07,750 --> 00:11:05,680

time to get the uh to get the step up to

337

00:11:09,190 --> 00:11:07,760

the right trl and a little bit of extra

338

00:11:14,069 --> 00:11:09,200

schedule margin is always good when

339

00:11:18,630 --> 00:11:16,150

designing for usability also maximizes

340

00:11:19,590 --> 00:11:18,640

the return of investment for nasa

341

00:11:20,870 --> 00:11:19,600

um

342

00:11:22,630 --> 00:11:20,880

after the

343

00:11:24,389 --> 00:11:22,640

asteroid retrieval mission is complete

344

00:11:26,069 --> 00:11:24,399

there's probably still

345

00:11:28,389 --> 00:11:26,079

five to ten years of remaining lifetime

346

00:11:30,230 --> 00:11:28,399

on the vehicle if not more

347

00:11:34,150 --> 00:11:30,240

you've got 50 kilowatts at beginning of

348

00:11:35,670 --> 00:11:34,160

life on station and translunar space now

349

00:11:38,150 --> 00:11:35,680

what a great asset once again to have

350

00:11:39,750 --> 00:11:38,160

for any future exploration architecture

351

00:11:41,590 --> 00:11:39,760

pieces that come out there

352

00:11:42,550 --> 00:11:41,600

that either need a tug or just a power

353

00:11:44,470 --> 00:11:42,560

supply

354

00:11:47,030 --> 00:11:44,480

or a lot of the other capabilities that

355

00:11:48,630 --> 00:11:47,040

the arm will have inherent in its design

356

00:11:50,949 --> 00:11:48,640

you could also refuel it if you designed

357

00:11:52,310 --> 00:11:50,959

that early on that once again sls can

358

00:11:54,550 --> 00:11:52,320

bring up quite a large quantity

359

00:11:57,030 --> 00:11:54,560

propellant to translunar space to refuel

360

00:11:57,990 --> 00:11:57,040

it or if it during the operational mode

361

00:11:59,670 --> 00:11:58,000

it can get back to earth you could

362

00:12:00,949 --> 00:11:59,680

refuel it even closer

363

00:12:02,389 --> 00:12:00,959

but there's a lot of applications that

364

00:12:03,910 --> 00:12:02,399

you could have there so

365

00:12:04,790 --> 00:12:03,920

thinking about it in terms of reuses

366

00:12:06,310 --> 00:12:04,800

should be

367

00:12:10,470 --> 00:12:06,320

one of the guiding principles in terms

368

00:12:13,829 --> 00:12:10,480

of the system engineering early on

369

00:12:16,389 --> 00:12:13,839

and integrated autonomous rendezvous

370

00:12:17,990 --> 00:12:16,399

capabilities into the overall spacecraft

371

00:12:20,310 --> 00:12:18,000

simplifies the design and operations of

372

00:12:22,069 --> 00:12:20,320

the mission the integrated system that

373

00:12:24,150 --> 00:12:22,079

has both air and d and terrain relative

374

00:12:25,750 --> 00:12:24,160

navigation sensors on it we feel is the

375

00:12:28,790 --> 00:12:25,760

lowest risk approach and having those

376

00:12:31,110 --> 00:12:28,800

integrated into the the flight system

377

00:12:32,550 --> 00:12:31,120

it basically decouples the the arnd

378

00:12:34,389 --> 00:12:32,560

stuff

379

00:12:36,829 --> 00:12:34,399

which is very relatively mature from the

380

00:12:39,829 --> 00:12:36,839

new the new technology propulsion

381

00:12:41,269 --> 00:12:39,839

development better integrates the gnc

382

00:12:42,790 --> 00:12:41,279

system performance overall because you

383

00:12:44,470 --> 00:12:42,800

don't have two interfaces you don't have

384

00:12:45,750 --> 00:12:44,480

two computers talking to each other

385

00:12:47,590 --> 00:12:45,760

streamlines the

386

00:12:49,670 --> 00:12:47,600

getting ready to fly simplifies

387

00:12:51,190 --> 00:12:49,680

interfaces and

388

00:12:54,069 --> 00:12:51,200

potentially you could use the sensors to

389

00:12:55,509 --> 00:12:54,079

do both both the the the tracking far

390

00:12:56,710 --> 00:12:55,519

away and in

391

00:12:58,790 --> 00:12:56,720

close

392

00:13:00,069 --> 00:12:58,800

and with that i will turn that over to

393

00:13:01,509 --> 00:13:00,079

manny and let him tell you a little bit

394

00:13:14,870 --> 00:13:01,519

more about

395

00:13:19,110 --> 00:13:16,790

okay so

396

00:13:20,949 --> 00:13:19,120

quickly

397

00:13:23,350 --> 00:13:20,959

we have the experience from the orbital

398

00:13:26,710 --> 00:13:23,360

express program back in 2007 of having

399

00:13:28,470 --> 00:13:26,720

flown optical navigation systems uh

400

00:13:29,750 --> 00:13:28,480

there's a picture of what we flew back

401
00:13:32,230 --> 00:13:29,760
in uh

402
00:13:35,350 --> 00:13:32,240
back back there six six years ago on

403
00:13:36,949 --> 00:13:35,360
board the astro spacecraft completed uh

404
00:13:39,269 --> 00:13:36,959
six autonomous rendezvous and docking

405
00:13:40,710 --> 00:13:39,279
scenarios uh and

406
00:13:43,030 --> 00:13:40,720
one point here which is not that

407
00:13:45,910 --> 00:13:43,040
commonly known although we use the

408
00:13:47,590 --> 00:13:45,920
nasa avgs system for corridor approach

409
00:13:50,790 --> 00:13:47,600
actually all the acquisition and track

410
00:13:52,790 --> 00:13:50,800
was using optical navigation from

411
00:13:53,990 --> 00:13:52,800
hundreds of kilometers on

412
00:13:55,790 --> 00:13:54,000
all the way in

413
00:13:58,150 --> 00:13:55,800

to capture

414

00:13:59,990 --> 00:13:58,160
contemporaneously with the the nasa

415

00:14:01,509 --> 00:14:00,000
system so just wanted to get that out

416

00:14:03,590 --> 00:14:01,519
there to make sure everybody under

417

00:14:04,550 --> 00:14:03,600
understands that so fast forward to

418

00:14:06,710 --> 00:14:04,560
today

419

00:14:08,389 --> 00:14:06,720
we have two different systems that uh

420

00:14:10,470 --> 00:14:08,399
one one in particular that we are

421

00:14:13,269 --> 00:14:10,480
developing for flight that being for

422

00:14:15,030 --> 00:14:13,279
commercial crew we call that vesta

423

00:14:16,710 --> 00:14:15,040
that is allowing us to do completely

424

00:14:19,189 --> 00:14:16,720
autonomous rendezvous

425

00:14:20,150 --> 00:14:19,199
and and docking

426

00:14:22,150 --> 00:14:20,160

we see

427

00:14:25,430 --> 00:14:22,160

really good applicability of a similar

428

00:14:28,870 --> 00:14:25,440

system for uh for uh asteroid and

429

00:14:31,110 --> 00:14:28,880

planetary type type missions as well so

430

00:14:32,470 --> 00:14:31,120

kind of put together sort of a notional

431

00:14:33,910 --> 00:14:32,480

con ops here and i don't have time to

432

00:14:36,550 --> 00:14:33,920

brief this in

433

00:14:39,430 --> 00:14:36,560

in detail but uh probably one of the

434

00:14:41,110 --> 00:14:39,440

important takeaways here is that uh so

435

00:14:42,829 --> 00:14:41,120

first of all a lot of similarity in our

436

00:14:43,829 --> 00:14:42,839

thinking in in

437

00:14:45,750 --> 00:14:43,839

terms and

438

00:14:48,470 --> 00:14:45,760

from what john brophy was saying earlier

439

00:14:50,230 --> 00:14:48,480

in terms of visible sensors and and

440

00:14:51,910 --> 00:14:50,240

ladar type sensors

441

00:14:53,670 --> 00:14:51,920

definitely having something that gives

442

00:14:56,310 --> 00:14:53,680

you long range track

443

00:14:59,350 --> 00:14:56,320

really good precision

444

00:15:01,590 --> 00:14:59,360

vision and feature identification in

445

00:15:04,230 --> 00:15:01,600

in sunlight is is excellent and the

446

00:15:06,389 --> 00:15:04,240

lidar sensor to give you range and and

447

00:15:08,790 --> 00:15:06,399

3d shape very important the thing we'd

448

00:15:10,389 --> 00:15:08,800

like to add into the mix there is long

449

00:15:12,069 --> 00:15:10,399

wave infrared

450

00:15:14,310 --> 00:15:12,079

i think we were among the first if not

451

00:15:16,710 --> 00:15:14,320

the first to fly an lwir sensor on

452

00:15:18,470 --> 00:15:16,720

orbital express and since then uh lots

453

00:15:20,310 --> 00:15:18,480

of folks are using them for autonomous

454

00:15:23,110 --> 00:15:20,320

rendezvous we'd like to throw that in

455

00:15:24,550 --> 00:15:23,120

here as as a suggestion for

456

00:15:26,470 --> 00:15:24,560

uh for

457

00:15:28,870 --> 00:15:26,480

this mission arm as well

458

00:15:30,629 --> 00:15:28,880

the the thing that that brings to you is

459

00:15:33,749 --> 00:15:30,639

is really good solar immunity sun

460

00:15:35,990 --> 00:15:33,759

immunity and uh ability to see in uh

461

00:15:38,230 --> 00:15:36,000

into dark shadows uh so it helps with

462

00:15:39,590 --> 00:15:38,240

shape determination so if you look

463

00:15:41,749 --> 00:15:39,600

through this you know using visible

464

00:15:43,829 --> 00:15:41,759

sensors to acquire at long range and

465

00:15:46,550 --> 00:15:43,839

then coming on stepping on in and then

466

00:15:48,949 --> 00:15:46,560

using these disparate sensors fusing the

467

00:15:50,870 --> 00:15:48,959

data to do the asteroid characterization

468

00:15:53,670 --> 00:15:50,880

tasks and and then to support the

469

00:15:55,030 --> 00:15:53,680

capture the d spin and then also the

470

00:15:56,790 --> 00:15:55,040

capability of

471

00:15:59,189 --> 00:15:56,800

of dual use on these sensors for

472

00:16:01,189 --> 00:15:59,199

inertial nav uh versus uh versus

473

00:16:03,350 --> 00:16:01,199

relative nav

474

00:16:06,069 --> 00:16:03,360

and just a quick one on the on the

475

00:16:07,350 --> 00:16:06,079

benefits uh i think i said some of this

476
00:16:08,310 --> 00:16:07,360
as to why

477
00:16:10,470 --> 00:16:08,320
a long

478
00:16:12,550 --> 00:16:10,480
long range or long wave infrared camera

479
00:16:13,590 --> 00:16:12,560
is uh is good and i think gosh i

480
00:16:16,150 --> 00:16:13,600
finished weight i feel like it's

481
00:16:17,110 --> 00:16:16,160
something else i should have said

482
00:16:18,949 --> 00:16:17,120
all right

483
00:16:20,629 --> 00:16:18,959
we have time for a question but well

484
00:16:22,230 --> 00:16:20,639
thank you and again

485
00:16:24,069 --> 00:16:22,240
we don't have type of questions so we'll

486
00:16:31,110 --> 00:16:24,079
catch them at the end

487
00:16:37,030 --> 00:16:34,230
all right we're cooking right along here

488
00:16:38,790 --> 00:16:37,040

our next speaker is john ringelberg he's

489

00:16:40,230 --> 00:16:38,800

a senior staff engineer at lockheed

490

00:16:41,829 --> 00:16:40,240

martin denver

491

00:16:43,749 --> 00:16:41,839

working in the civil space advanced

492

00:16:45,509 --> 00:16:43,759

programs group he's the principal

493

00:16:47,269 --> 00:16:45,519

investigator for an irat effort

494

00:16:49,670 --> 00:16:47,279

advancing autonomous rendezvous

495

00:16:51,430 --> 00:16:49,680

proximity operations docking and landing

496

00:16:52,870 --> 00:16:51,440

technologies

497

00:16:54,949 --> 00:16:52,880

his presentation will provide an

498

00:16:56,629 --> 00:16:54,959

overview of integrated sensing systems

499

00:16:58,470 --> 00:16:56,639

from previous missions with direct

500

00:17:00,470 --> 00:16:58,480

correlation to arm

501
00:17:02,150 --> 00:17:00,480
particular technologies for asteroid

502
00:17:03,990 --> 00:17:02,160
relative nav and characterization will

503
00:17:05,750 --> 00:17:04,000
be highlighted and a brief summary of

504
00:17:08,390 --> 00:17:05,760
solar electric propulsion heritage and

505
00:17:11,270 --> 00:17:08,400
technology will also be provided

506
00:17:12,309 --> 00:17:11,280
thanks john thanks um continuing on that

507
00:17:14,549 --> 00:17:12,319
theme

508
00:17:16,870 --> 00:17:14,559
kind of the last few presentations of

509
00:17:18,549 --> 00:17:16,880
trying to leverage uh

510
00:17:20,789 --> 00:17:18,559
some of the work that's been done on

511
00:17:21,909 --> 00:17:20,799
either previous programs or on current

512
00:17:26,630 --> 00:17:21,919
programs

513
00:17:28,390 --> 00:17:26,640

is osiris-rex which is

514

00:17:30,830 --> 00:17:28,400

which is a mission

515

00:17:33,350 --> 00:17:30,840

lockheed has a strong role in but uh

516

00:17:34,630 --> 00:17:33,360

goddard leading this

517

00:17:36,070 --> 00:17:34,640

there's a lot of things that are being

518

00:17:38,470 --> 00:17:36,080

done on on

519

00:17:40,390 --> 00:17:38,480

osiris-rex that probably are very

520

00:17:42,230 --> 00:17:40,400

applicable to

521

00:17:44,070 --> 00:17:42,240

what's what's going to happen for what

522

00:17:45,190 --> 00:17:44,080

you need to do for the asteroid redirect

523

00:17:47,110 --> 00:17:45,200

mission

524

00:17:49,270 --> 00:17:47,120

there's particular areas that

525

00:17:51,430 --> 00:17:49,280

that it's a much bigger asteroid that

526

00:17:53,669 --> 00:17:51,440

osiris-rex is going to

527

00:17:55,350 --> 00:17:53,679

they're going to have a lot more time

528

00:17:57,669 --> 00:17:55,360

most likely

529

00:17:59,909 --> 00:17:57,679

station keeping

530

00:18:01,190 --> 00:17:59,919

mapping and characterizing the asteroid

531

00:18:02,870 --> 00:18:01,200

but there's still a lot of the

532

00:18:05,110 --> 00:18:02,880

capabilities particularly that are going

533

00:18:06,549 --> 00:18:05,120

into a size 4x that you can extend and

534

00:18:09,590 --> 00:18:06,559

apply to

535

00:18:11,909 --> 00:18:09,600

the asteroid redirect mission

536

00:18:14,470 --> 00:18:11,919

both both optical and and what was

537

00:18:16,310 --> 00:18:14,480

mentioned earlier lidar lidar usage for

538

00:18:17,590 --> 00:18:16,320

for osiris-rex and mapping there's

539

00:18:19,110 --> 00:18:17,600

there's there's

540

00:18:21,110 --> 00:18:19,120

some areas particularly for the optical

541

00:18:24,390 --> 00:18:21,120

navigation that we're doing some work

542

00:18:26,950 --> 00:18:24,400

that can improve the the resolution for

543

00:18:28,630 --> 00:18:26,960

or the accuracy for your targeting for

544

00:18:30,950 --> 00:18:28,640

what osiris-rex does which is the

545

00:18:32,549 --> 00:18:30,960

approach and sample capture contact and

546

00:18:34,230 --> 00:18:32,559

sample capture

547

00:18:35,430 --> 00:18:34,240

that's extensible whether it's whether

548

00:18:37,669 --> 00:18:35,440

it's the uh

549

00:18:39,430 --> 00:18:37,679

the bag capture or like a more of a

550

00:18:41,110 --> 00:18:39,440

robotic capture a close close-in

551
00:18:43,110 --> 00:18:41,120
approach such as that that ben talked

552
00:18:45,350 --> 00:18:43,120
about

553
00:18:48,950 --> 00:18:45,360
another mission

554
00:18:50,870 --> 00:18:48,960
further in the past but similar

555
00:18:53,029 --> 00:18:50,880
type operations

556
00:18:54,870 --> 00:18:53,039
wanted to mention the xss-11 mission

557
00:18:56,390 --> 00:18:54,880
which most of you probably are familiar

558
00:18:59,270 --> 00:18:56,400
with maybe not everybody but this

559
00:19:02,710 --> 00:18:59,280
mission was a afro mission

560
00:19:05,029 --> 00:19:02,720
very successful didn't do capture or

561
00:19:06,870 --> 00:19:05,039
contact but did a lot of proximity

562
00:19:08,870 --> 00:19:06,880
operations

563
00:19:10,950 --> 00:19:08,880

with with different non-cooperative

564

00:19:14,150 --> 00:19:10,960

targets and that's one of the key things

565

00:19:15,909 --> 00:19:14,160

that i wanted to point out here was

566

00:19:17,830 --> 00:19:15,919

what the asteroid redirect mission is

567

00:19:19,430 --> 00:19:17,840

going to do there's there's a need for

568

00:19:21,750 --> 00:19:19,440

being able to go up something you know

569

00:19:23,110 --> 00:19:21,760

almost nothing about you don't know the

570

00:19:24,630 --> 00:19:23,120

surface features you don't know it's

571

00:19:26,070 --> 00:19:24,640

spin rates you don't know how it's

572

00:19:29,430 --> 00:19:26,080

moving

573

00:19:31,590 --> 00:19:29,440

so missions like this

574

00:19:33,830 --> 00:19:31,600

lessons learned from that and work since

575

00:19:35,909 --> 00:19:33,840

that can be used to apply for going up

576

00:19:37,590 --> 00:19:35,919

to a non-cooperative target

577

00:19:39,510 --> 00:19:37,600

performing proximity operations

578

00:19:41,990 --> 00:19:39,520

characterizing and the other part of it

579

00:19:44,470 --> 00:19:42,000

is is the safe operations and proximity

580

00:19:45,909 --> 00:19:44,480

to to your target making sure your

581

00:19:48,549 --> 00:19:45,919

there was there was a lot of work done

582

00:19:51,350 --> 00:19:48,559

on this that that was

583

00:19:54,230 --> 00:19:51,360

a good bit of autonomous where it had to

584

00:19:56,070 --> 00:19:54,240

plan your maneuvers ahead of time on how

585

00:19:57,909 --> 00:19:56,080

what's your natural motion and force

586

00:20:00,070 --> 00:19:57,919

motion well for the for the asteroid

587

00:20:01,590 --> 00:20:00,080

mission for force motion circumnav

588

00:20:03,029 --> 00:20:01,600

around where on your target how are you

589

00:20:06,549 --> 00:20:03,039

going to do that safely how you plan

590

00:20:08,310 --> 00:20:06,559

ahead and this being so far out

591

00:20:11,110 --> 00:20:08,320

using using things you've done in the

592

00:20:13,029 --> 00:20:11,120

past to be able to build on those and do

593

00:20:15,110 --> 00:20:13,039

your safe operations in close proximity

594

00:20:17,590 --> 00:20:15,120

to a target that's so far away that you

595

00:20:20,950 --> 00:20:17,600

don't have may not have the continuous

596

00:20:22,549 --> 00:20:20,960

communication with

597

00:20:24,070 --> 00:20:22,559

another area that that we've been

598

00:20:26,789 --> 00:20:24,080

working on um

599

00:20:29,029 --> 00:20:26,799

kind of extensive extensible to this

600

00:20:31,190 --> 00:20:29,039

doing different irad and c-rad work

601
00:20:33,270 --> 00:20:31,200
we've we've done um

602
00:20:35,990 --> 00:20:33,280
is is particularly with the optical nav

603
00:20:38,549 --> 00:20:36,000
that was mentioned earlier as as

604
00:20:40,789 --> 00:20:38,559
one of the key features that's needed

605
00:20:43,590 --> 00:20:40,799
for approaching

606
00:20:46,149 --> 00:20:43,600
the asteroid whatever the arm target is

607
00:20:48,310 --> 00:20:46,159
we've done a lot of work in this area

608
00:20:50,070 --> 00:20:48,320
there's also a lot of other areas other

609
00:20:51,350 --> 00:20:50,080
people doing work in this area but we're

610
00:20:53,029 --> 00:20:51,360
kind of advancing this is something

611
00:20:55,830 --> 00:20:53,039
that's probably going to help out

612
00:20:56,870 --> 00:20:55,840
osiris-rex to some extent as far as the

613
00:20:59,190 --> 00:20:56,880

precision

614

00:21:01,430 --> 00:20:59,200

approach capability

615

00:21:03,270 --> 00:21:01,440

but using natural feature tracking to to

616

00:21:05,510 --> 00:21:03,280

map the surface

617

00:21:11,909 --> 00:21:05,520

and to plan out your approach for the

618

00:21:15,590 --> 00:21:13,190

another area

619

00:21:17,510 --> 00:21:15,600

our coherent technologies area

620

00:21:18,710 --> 00:21:17,520

disciplines a lot of work on the the

621

00:21:20,870 --> 00:21:18,720

laser

622

00:21:23,990 --> 00:21:20,880

or lidar type

623

00:21:25,350 --> 00:21:24,000

mapping and characterization uh

624

00:21:27,750 --> 00:21:25,360

two different methods we mentioned in

625

00:21:30,470 --> 00:21:27,760

the nrfi response

626
00:21:32,470 --> 00:21:30,480
that can be combined for particularly

627
00:21:34,710 --> 00:21:32,480
used for characterizing asteroids so you

628
00:21:35,669 --> 00:21:34,720
understand it for for the approach

629
00:21:37,669 --> 00:21:35,679
and and

630
00:21:39,350 --> 00:21:37,679
and capture part of it digital

631
00:21:41,510 --> 00:21:39,360
holographic imaging

632
00:21:43,909 --> 00:21:41,520
gives you some work we've done we've

633
00:21:45,270 --> 00:21:43,919
tested out coherent our coherent group

634
00:21:47,190 --> 00:21:45,280
does a lot of work on the terrestrial

635
00:21:48,549 --> 00:21:47,200
but also applying at the space

636
00:21:50,390 --> 00:21:48,559
applications

637
00:21:52,149 --> 00:21:50,400
um using that that's going to be

638
00:21:54,470 --> 00:21:52,159

important to characterize the asteroid

639

00:21:56,390 --> 00:21:54,480

as as you approach it and to understand

640

00:21:57,270 --> 00:21:56,400

what its motions are before you capture

641

00:22:00,230 --> 00:21:57,280

it

642

00:22:02,630 --> 00:22:00,240

another another area is the polar metric

643

00:22:04,230 --> 00:22:02,640

sensing hardware to say for asteroid

644

00:22:05,669 --> 00:22:04,240

composition mass you're going to need to

645

00:22:07,270 --> 00:22:05,679

understand the surface before you go up

646

00:22:09,190 --> 00:22:07,280

and grab it you're going to want to

647

00:22:11,350 --> 00:22:09,200

understand that anyway depending on what

648

00:22:13,669 --> 00:22:11,360

your which your capture and grab hold of

649

00:22:15,270 --> 00:22:13,679

technique is that whether that's robotic

650

00:22:17,029 --> 00:22:15,280

particularly if it's robotic you're

651
00:22:19,029 --> 00:22:17,039
going to understand that surface to the

652
00:22:23,990 --> 00:22:19,039
greatest extent possible before you try

653
00:22:27,029 --> 00:22:25,590
and then i also wanted to mention here

654
00:22:29,510 --> 00:22:27,039
um some of you familiar with there's a

655
00:22:32,230 --> 00:22:29,520
facility we have in denver called our

656
00:22:34,630 --> 00:22:32,240
space operation simulation center

657
00:22:36,789 --> 00:22:34,640
this is a large facility and that's not

658
00:22:37,669 --> 00:22:36,799
a real asteroid inside the sosc but it's

659
00:22:44,789 --> 00:22:37,679
a

660
00:22:46,870 --> 00:22:44,799
the need to

661
00:22:48,310 --> 00:22:46,880
if it helps the mission you could put an

662
00:22:50,470 --> 00:22:48,320
asteroid mounted

663
00:22:54,230 --> 00:22:50,480

inside there that's a seven meter

664

00:22:55,830 --> 00:22:54,240

correlated to the size of the ssc but

665

00:22:57,750 --> 00:22:55,840

that's going to be a key part i think of

666

00:22:58,870 --> 00:22:57,760

this mission kind of reducing the risk

667

00:23:01,029 --> 00:22:58,880

of some of the

668

00:23:03,510 --> 00:23:01,039

the technologies that make this a

669

00:23:05,909 --> 00:23:03,520

difficult mission how can you

670

00:23:07,909 --> 00:23:05,919

you want to ground test them in the best

671

00:23:11,110 --> 00:23:07,919

environment possible or most realistic

672

00:23:14,149 --> 00:23:11,120

flight like environment is possible so

673

00:23:17,190 --> 00:23:14,159

using facilities like sosc to test out

674

00:23:19,110 --> 00:23:17,200

those technologies for for the robotic

675

00:23:23,510 --> 00:23:19,120

mission to the asteroid approach and

676

00:23:28,390 --> 00:23:25,750

one thing i

677

00:23:29,909 --> 00:23:28,400

in our rfi response we covered the the

678

00:23:32,230 --> 00:23:29,919

sensing systems

679

00:23:34,230 --> 00:23:32,240

primarily and i wanted to focus on that

680

00:23:37,110 --> 00:23:34,240

during the few minutes here

681

00:23:38,630 --> 00:23:37,120

but also we we discussed scp a little

682

00:23:41,269 --> 00:23:38,640

bit at um

683

00:23:43,510 --> 00:23:41,279

um brian dempsey a guy at lockheed

684

00:23:45,669 --> 00:23:43,520

martin did our input for that rfi

685

00:23:47,269 --> 00:23:45,679

response and really we kind of covered

686

00:23:48,870 --> 00:23:47,279

what's already been covered some of the

687

00:23:51,110 --> 00:23:48,880

other presentations here the four key

688

00:23:53,590 --> 00:23:51,120

areas that need to be

689

00:23:55,669 --> 00:23:53,600

addressed to make to enable the scp for

690

00:23:57,350 --> 00:23:55,679

for this mission um thrusters the hall

691

00:23:59,430 --> 00:23:57,360

current thrusters

692

00:24:01,669 --> 00:23:59,440

seems to be the focus for most everyone

693

00:24:04,710 --> 00:24:01,679

here that's provide good

694

00:24:06,390 --> 00:24:04,720

high power to thrust to power ratio

695

00:24:07,909 --> 00:24:06,400

another point out is the power

696

00:24:10,310 --> 00:24:07,919

processing units are a very mature

697

00:24:12,950 --> 00:24:10,320

technology for for hall thrusters

698

00:24:15,269 --> 00:24:12,960

another area solar rays i was mentioned

699

00:24:16,390 --> 00:24:15,279

several times a lot of

700

00:24:18,310 --> 00:24:16,400

heritage

701
00:24:19,510 --> 00:24:18,320
and experience in industry that can

702
00:24:20,710 --> 00:24:19,520
support

703
00:24:22,470 --> 00:24:20,720
um what's

704
00:24:24,950 --> 00:24:22,480
what's what's what's needed to be done

705
00:24:26,390 --> 00:24:24,960
for the for the arm mission a lot of

706
00:24:27,909 --> 00:24:26,400
experience of that whether it's space

707
00:24:29,350 --> 00:24:27,919
station or all the missions you see

708
00:24:31,510 --> 00:24:29,360
listed there

709
00:24:33,830 --> 00:24:31,520
uh and then the same thing with we're

710
00:24:35,909 --> 00:24:33,840
going to xenon tanks

711
00:24:38,310 --> 00:24:35,919
we

712
00:24:39,909 --> 00:24:38,320
discussed a little bit in our response

713
00:24:41,669 --> 00:24:39,919

there is a trade whether you want to do

714

00:24:43,269 --> 00:24:41,679

a single large tank versus multiple

715

00:24:46,470 --> 00:24:43,279

small tanks there's advantages and

716

00:24:48,710 --> 00:24:46,480

disadvantages to each

717

00:24:50,630 --> 00:24:48,720

single large tank be less complex system

718

00:24:52,070 --> 00:24:50,640

but there's the smaller tanks probably

719

00:24:54,310 --> 00:24:52,080

have more applicability to other

720

00:24:55,269 --> 00:24:54,320

missions so there's more extensibility

721

00:24:57,029 --> 00:24:55,279

to

722

00:25:00,470 --> 00:24:57,039

other

723

00:25:04,710 --> 00:25:02,549

um continuing with the scp this is the

724

00:25:06,470 --> 00:25:04,720

last chart actually um

725

00:25:08,070 --> 00:25:06,480

one of the key things also going to be

726

00:25:10,070 --> 00:25:08,080

for the electric propulsion system is

727

00:25:12,789 --> 00:25:10,080

the integration and validation of the

728

00:25:14,870 --> 00:25:12,799

entire system um

729

00:25:16,230 --> 00:25:14,880

mentioned here some there is i think

730

00:25:17,750 --> 00:25:16,240

last presentation mentioned a lot

731

00:25:20,630 --> 00:25:17,760

there's a lot of experience actually

732

00:25:23,029 --> 00:25:20,640

more than you would expect in scp areas

733

00:25:29,590 --> 00:25:26,390

our the aehf mission um was a good

734

00:25:31,110 --> 00:25:29,600

demonstration of how you would use solar

735

00:25:32,630 --> 00:25:31,120

propulsion to raise it raise an orbit of

736

00:25:33,909 --> 00:25:32,640

a vehicle

737

00:25:36,149 --> 00:25:33,919

um

738

00:25:38,070 --> 00:25:36,159

and then some other areas the

739

00:25:41,269 --> 00:25:38,080

we there's been plenty of flight

740

00:25:42,950 --> 00:25:41,279

experience with uh with a 4.5 kilowatt

741

00:25:44,789 --> 00:25:42,960

hall thruster systems getting getting

742

00:25:46,310 --> 00:25:44,799

larger into the kill into the thruster

743

00:25:47,990 --> 00:25:46,320

systems

744

00:25:50,070 --> 00:25:48,000

um and then we've actually worked done

745

00:25:55,990 --> 00:25:50,080

some work developing even bigger

746

00:25:56,000 --> 00:26:00,950

i did i catch us up there that was great

747

00:26:00,960 --> 00:26:06,630

and that's it thanks

748

00:26:15,110 --> 00:26:08,310

all right so we're gonna we're gonna

749

00:26:25,430 --> 00:26:16,630

wake up

750

00:26:29,510 --> 00:26:26,789

all right we've had quite a few

751

00:26:31,830 --> 00:26:29,520

questions coming from virtually

752

00:26:33,830 --> 00:26:31,840

from our listeners i'm trying to see if

753

00:26:35,269 --> 00:26:33,840

there's one from a recent one there was

754

00:26:36,789 --> 00:26:35,279

a lot of discussion about using

755

00:26:38,630 --> 00:26:36,799

electromagnetism

756

00:26:40,070 --> 00:26:38,640

but that's probably a longer discussion

757

00:26:41,669 --> 00:26:40,080

because there's been three or four

758

00:26:42,470 --> 00:26:41,679

things come in about that

759

00:26:44,310 --> 00:26:42,480

um

760

00:26:46,310 --> 00:26:44,320

so here was a question on a recent one

761

00:26:48,950 --> 00:26:46,320

about robotic capture being vulnerable

762

00:26:50,549 --> 00:26:48,960

to surface dust and or shorting the sep

763

00:26:52,950 --> 00:26:50,559

thrusters and that came in after the

764

00:26:59,909 --> 00:26:52,960

goddard presentation you want to address

765

00:27:05,350 --> 00:27:01,830

the question was about dust and the

766

00:27:08,950 --> 00:27:06,789

well hopefully the dust doesn't get all

767

00:27:11,590 --> 00:27:08,960

around to the sep thrusters but back in

768

00:27:13,110 --> 00:27:11,600

constellation days we

769

00:27:14,950 --> 00:27:13,120

uh built a

770

00:27:17,510 --> 00:27:14,960

chamber at goddard

771

00:27:19,909 --> 00:27:17,520

to specifically either rain down dust or

772

00:27:21,830 --> 00:27:19,919

simulated regolith on mechanisms or have

773

00:27:27,190 --> 00:27:21,840

it

774

00:27:29,190 --> 00:27:27,200

only to do

775

00:27:32,549 --> 00:27:29,200

particle redistribution analysis which

776

00:27:34,549 --> 00:27:32,559

we hone for hubble space telescope

777

00:27:36,310 --> 00:27:34,559

eba operations where we were very

778

00:27:38,630 --> 00:27:36,320

contamination sensitive

779

00:27:40,870 --> 00:27:38,640

but specifically for the work that was

780

00:27:43,669 --> 00:27:40,880

going to be done with stuff driving

781

00:27:45,669 --> 00:27:43,679

around and walking around on the moon

782

00:27:47,909 --> 00:27:45,679

we had this chamber available so yes

783

00:27:51,110 --> 00:27:47,919

that is a real issue whoever sent that

784

00:27:52,630 --> 00:27:51,120

in as a very observant questioner

785

00:27:58,950 --> 00:27:52,640

and we've got facilities in place that

786

00:28:02,389 --> 00:28:00,230

good point good point a lot of

787

00:28:05,269 --> 00:28:02,399

operational experience on mars

788

00:28:06,549 --> 00:28:05,279

from our friends uh who are up there now

789

00:28:08,789 --> 00:28:06,559

driving around

790

00:28:09,990 --> 00:28:08,799

yeah good point brian

791

00:28:11,590 --> 00:28:10,000

we'll hold do you have something that's

792

00:28:13,430 --> 00:28:11,600

pressing otherwise i'd like to go to the

793

00:28:16,389 --> 00:28:13,440

next presentation but we'll get back to

794

00:28:19,269 --> 00:28:16,399

a lot of the questions

795

00:28:21,110 --> 00:28:19,279

as we go on our next presenter is

796

00:28:23,909 --> 00:28:21,120

virtual

797

00:28:26,070 --> 00:28:23,919

jonathan roble from honeybee robotics

798

00:28:27,990 --> 00:28:26,080

jonathan works there in the robotic

799

00:28:29,190 --> 00:28:28,000

spacecraft mechanisms corporation in

800

00:28:31,669 --> 00:28:29,200

longmont

801
00:28:33,430 --> 00:28:31,679
colorado honeybee develops technology

802
00:28:35,110 --> 00:28:33,440
and products for next-gen

803
00:28:38,870 --> 00:28:35,120
advanced robotic and spacecraft missions

804
00:28:40,630 --> 00:28:38,880
for nasa dod academia and industry

805
00:28:42,710 --> 00:28:40,640
jonathan will discuss several enabling

806
00:28:44,710 --> 00:28:42,720
component technologies for asteroid

807
00:28:46,470 --> 00:28:44,720
rendezvous proximity operations

808
00:28:47,909 --> 00:28:46,480
characterization and capture as well as

809
00:28:50,389 --> 00:28:47,919
technology

810
00:28:52,389 --> 00:28:50,399
can enable retrieval of a portion of the

811
00:28:55,190 --> 00:28:52,399
asteroids on the surface

812
00:28:57,590 --> 00:28:55,200
jonathan are you out there

813
00:29:00,950 --> 00:28:59,909

you here hear me all right yes

814

00:29:04,070 --> 00:29:00,960

thank you

815

00:29:05,669 --> 00:29:04,080

introduction i appreciate the

816

00:29:07,029 --> 00:29:05,679

opportunity to present the synthesis

817

00:29:08,870 --> 00:29:07,039

workshop

818

00:29:10,950 --> 00:29:08,880

uh like you said i'd like to just cover

819

00:29:12,630 --> 00:29:10,960

some of honeybees technologies that can

820

00:29:14,870 --> 00:29:12,640

contribute to asteroid redirection

821

00:29:16,470 --> 00:29:14,880

systems

822

00:29:18,149 --> 00:29:16,480

for background

823

00:29:20,470 --> 00:29:18,159

just like to say honeybee robotics is

824

00:29:23,269 --> 00:29:20,480

founded in 1983 has been developing

825

00:29:24,549 --> 00:29:23,279

spacecraft mechanisms and systems for 30

826
00:29:26,310 --> 00:29:24,559
years

827
00:29:28,230 --> 00:29:26,320
we consider our participation in nasa

828
00:29:29,990 --> 00:29:28,240
missions a key aspect of our business

829
00:29:33,269 --> 00:29:30,000
and take pride in the performance of our

830
00:29:35,510 --> 00:29:33,279
contributions including the 2003

831
00:29:36,870 --> 00:29:35,520
uh mars exploration rover rock abrasion

832
00:29:39,110 --> 00:29:36,880
tools

833
00:29:41,590 --> 00:29:39,120
the 2011 mars science laboratory

834
00:29:44,310 --> 00:29:41,600
robotics sample manipulation system and

835
00:29:47,669 --> 00:29:44,320
dust removal tool end effector

836
00:29:50,870 --> 00:29:47,679
phoenix mars lander tega dust cover and

837
00:29:53,590 --> 00:29:50,880
icy soil acquisition device

838
00:29:56,389 --> 00:29:53,600

honeybee robotics has

839

00:29:58,070 --> 00:29:56,399

done successfully 300 plus excavation on

840

00:30:03,029 --> 00:29:58,080

mars and

841

00:30:07,350 --> 00:30:04,950

as you can see honeybee robotics has

842

00:30:09,909 --> 00:30:07,360

technology suitable for topics two three

843

00:30:12,230 --> 00:30:09,919

four five and six of nasa's asteroid

844

00:30:13,909 --> 00:30:12,240

initiative but currently i'd like to

845

00:30:16,789 --> 00:30:13,919

talk to topic two

846

00:30:19,750 --> 00:30:16,799

of asteroid redirection systems

847

00:30:22,310 --> 00:30:19,760

and our sensing technologies

848

00:30:24,630 --> 00:30:22,320

for rendezvous prox ops characteristic

849

00:30:25,909 --> 00:30:24,640

characterization and capture

850

00:30:27,430 --> 00:30:25,919

we have some

851
00:30:30,070 --> 00:30:27,440
technologies to think that really help

852
00:30:31,669 --> 00:30:30,080
you see the asteroid

853
00:30:34,789 --> 00:30:31,679
one of them is our laser induced

854
00:30:36,470 --> 00:30:34,799
breakdown spectroscopy that's lids

855
00:30:38,549 --> 00:30:36,480
it's currently implemented

856
00:30:41,029 --> 00:30:38,559
in our terrestrial applications it

857
00:30:42,950 --> 00:30:41,039
allows us to vaporize and ionize surface

858
00:30:44,630 --> 00:30:42,960
material so you create a puff of plasma

859
00:30:46,630 --> 00:30:44,640
at the surface we're then able to

860
00:30:54,230 --> 00:30:46,640
capture the emission spectrum as the

861
00:30:58,230 --> 00:30:56,230
the mission spectra is representative of

862
00:31:01,350 --> 00:30:58,240
the surface material without any

863
00:31:02,630 --> 00:31:01,360

contaminants from physical

864

00:31:04,470 --> 00:31:02,640

interaction

865

00:31:06,549 --> 00:31:04,480

and so we're there by attaining a

866

00:31:11,509 --> 00:31:06,559

surface material composition uh without

867

00:31:15,830 --> 00:31:13,269

as some of the presenters mentioned

868

00:31:18,149 --> 00:31:15,840

before you're coming upon the asteroid

869

00:31:20,789 --> 00:31:18,159

possibly very little information about

870

00:31:21,909 --> 00:31:20,799

its uh composition materials and bulk

871

00:31:23,909 --> 00:31:21,919

structure

872

00:31:25,509 --> 00:31:23,919

and we think this is a

873

00:31:27,909 --> 00:31:25,519

excellent way of

874

00:31:31,350 --> 00:31:27,919

helping reduce that uncertainty before

875

00:31:33,110 --> 00:31:31,360

physical interaction with the asteroid

876

00:31:36,310 --> 00:31:33,120

this is pretty simple

877

00:31:38,710 --> 00:31:36,320

similar to the msl chemcam

878

00:31:40,710 --> 00:31:38,720

and this is a pertinent president for

879

00:31:42,389 --> 00:31:40,720

performing this type of observation

880

00:31:44,549 --> 00:31:42,399

however we prefer

881

00:31:46,149 --> 00:31:44,559

proposing to do it at a standoff

882

00:31:47,830 --> 00:31:46,159

distance so that you don't have to be

883

00:31:49,350 --> 00:31:47,840

quite

884

00:31:52,549 --> 00:31:49,360

as close to the

885

00:31:56,070 --> 00:31:52,559

material of surface material

886

00:31:58,149 --> 00:31:56,080

the other technology is a 3d lidar

887

00:31:59,430 --> 00:31:58,159

it's an improvement to machine vision

888

00:32:01,269 --> 00:31:59,440

that assists with

889

00:32:04,630 --> 00:32:01,279

detail-oriented operations while

890

00:32:06,310 --> 00:32:04,640

maintaining global awareness

891

00:32:08,710 --> 00:32:06,320

it's operating much in the way that the

892

00:32:11,190 --> 00:32:08,720

human eye does so there's a central area

893

00:32:13,590 --> 00:32:11,200

of high resolution for detail work

894

00:32:16,230 --> 00:32:13,600

combined with the low area larger area

895

00:32:17,750 --> 00:32:16,240

of low resolution for context and motion

896

00:32:19,269 --> 00:32:17,760

tracking

897

00:32:20,230 --> 00:32:19,279

this is achieved

898

00:32:23,190 --> 00:32:20,240

by

899

00:32:28,070 --> 00:32:25,830

produce a higher res

900

00:32:31,669 --> 00:32:28,080

laser pattern on an area of interest

901
00:32:33,750 --> 00:32:31,679
while doing a sparse laser pattern on

902
00:32:36,070 --> 00:32:33,760
the global area not

903
00:32:37,509 --> 00:32:36,080
thereby able to detect dynamic changes

904
00:32:39,750 --> 00:32:37,519
in the field of view

905
00:32:42,870 --> 00:32:39,760
and focus that laser scan pattern on an

906
00:32:45,430 --> 00:32:42,880
area of interest while maintaining a

907
00:32:47,269 --> 00:32:45,440
global awareness

908
00:32:49,029 --> 00:32:47,279
it allows us to map and track the

909
00:32:50,870 --> 00:32:49,039
surface of the asteroid and this is

910
00:32:53,909 --> 00:32:50,880
again significantly important for

911
00:32:55,029 --> 00:32:53,919
conducting proximity operations

912
00:32:57,350 --> 00:32:55,039
around

913
00:32:59,509 --> 00:32:57,360

uncharacterized object

914

00:33:01,110 --> 00:32:59,519

something that might might have sizable

915

00:33:03,190 --> 00:33:01,120

relief

916

00:33:05,830 --> 00:33:03,200

especially where you're looking to land

917

00:33:07,269 --> 00:33:05,840

a spacecraft and do anchoring operations

918

00:33:08,830 --> 00:33:07,279

that could be looking for a very

919

00:33:10,710 --> 00:33:08,840

specific

920

00:33:11,509 --> 00:33:10,720

placement

921

00:33:13,509 --> 00:33:11,519

so

922

00:33:16,070 --> 00:33:13,519

both of these technologies allow

923

00:33:18,870 --> 00:33:16,080

spacecraft to characterize its otherwise

924

00:33:21,029 --> 00:33:18,880

unknown target and operate inside of a

925

00:33:23,029 --> 00:33:21,039

feedback loop

926
00:33:25,190 --> 00:33:23,039
and control algorithms

927
00:33:27,590 --> 00:33:25,200
for proximity apps

928
00:33:29,830 --> 00:33:27,600
now in addition to these

929
00:33:30,950 --> 00:33:29,840
technologies if to further characterize

930
00:33:35,190 --> 00:33:30,960
the

931
00:33:37,430 --> 00:33:35,200
asteroid before interaction we have

932
00:33:41,029 --> 00:33:37,440
some past work with impactors which

933
00:33:43,190 --> 00:33:41,039
would in addition to giving you

934
00:33:45,909 --> 00:33:43,200
composition it could give you property

935
00:33:48,389 --> 00:33:45,919
information uh by characterizing the

936
00:33:50,710 --> 00:33:48,399
ejective plume from impact

937
00:33:52,470 --> 00:33:50,720
this is our across

938
00:33:53,909 --> 00:33:52,480

technology

939

00:33:56,789 --> 00:33:53,919

in addition

940

00:33:57,830 --> 00:33:56,799

we can touch it um with a touch and go

941

00:34:00,549 --> 00:33:57,840

sampler

942

00:34:03,190 --> 00:34:00,559

that allows you to use a tethered sample

943

00:34:04,870 --> 00:34:03,200

collection to assay the surface before

944

00:34:08,790 --> 00:34:04,880

committing to it

945

00:34:13,109 --> 00:34:10,310

basically a

946

00:34:15,829 --> 00:34:13,119

propelled drill

947

00:34:18,149 --> 00:34:15,839

furthermore we can harpoon sample it and

948

00:34:19,270 --> 00:34:18,159

these will be talked about in other

949

00:34:20,790 --> 00:34:19,280

discussions

950

00:34:22,950 --> 00:34:20,800

which

951
00:34:24,790 --> 00:34:22,960
can again give you that a priori

952
00:34:27,510 --> 00:34:24,800
knowledge before uh

953
00:34:31,990 --> 00:34:29,750
we can drill with honeybees extensive

954
00:34:33,829 --> 00:34:32,000
history and robotic joint and sample

955
00:34:35,270 --> 00:34:33,839
collection

956
00:34:38,470 --> 00:34:35,280
can

957
00:34:41,510 --> 00:34:38,480
get below just the surface properties

958
00:34:43,829 --> 00:34:41,520
of the asteroid

959
00:34:45,669 --> 00:34:43,839
to understand how it's going to act

960
00:34:47,669 --> 00:34:45,679
when you attempt to apply

961
00:34:49,829 --> 00:34:47,679
redirect forces to it and

962
00:34:51,430 --> 00:34:49,839
touch down on it

963
00:34:53,190 --> 00:34:51,440

once you're down there we can

964

00:34:55,909 --> 00:34:53,200

inhale it as we say

965

00:34:59,190 --> 00:34:55,919

with a pneumatic sampler and excavation

966

00:35:02,950 --> 00:34:59,200

system that allows us to collect

967

00:35:04,710 --> 00:35:02,960

either cutting tailings or loose surface

968

00:35:05,670 --> 00:35:04,720

materials

969

00:35:07,910 --> 00:35:05,680

and

970

00:35:11,750 --> 00:35:07,920

we can snare small objects

971

00:35:15,750 --> 00:35:13,910

and then we can also anchor to it with a

972

00:35:17,510 --> 00:35:15,760

self-opposed multi-mode anchoring

973

00:35:18,630 --> 00:35:17,520

technologies that we have

974

00:35:20,710 --> 00:35:18,640

developed

975

00:35:22,310 --> 00:35:20,720

through past work

976
00:35:25,430 --> 00:35:22,320
that allow you to

977
00:35:26,950 --> 00:35:25,440
touch down and produce a firm base

978
00:35:29,349 --> 00:35:26,960
station with it

979
00:35:31,190 --> 00:35:29,359
lastly we have done work with

980
00:35:32,550 --> 00:35:31,200
full asteroid capture if it's small

981
00:35:34,390 --> 00:35:32,560
enough

982
00:35:36,710 --> 00:35:34,400
and these are just some of the

983
00:35:37,430 --> 00:35:36,720
capabilities that we have

984
00:35:39,030 --> 00:35:37,440
and

985
00:35:42,310 --> 00:35:39,040
others will be talked about more in the

986
00:35:43,589 --> 00:35:42,320
different topics we think that

987
00:35:45,670 --> 00:35:43,599
the

988
00:35:48,150 --> 00:35:45,680

past work that honeybees done has

989

00:35:49,670 --> 00:35:48,160

prepared us to support a asteroid

990

00:35:52,310 --> 00:35:49,680

redirect mission

991

00:35:53,270 --> 00:35:52,320

and uh if you guys have any questions uh

992

00:35:55,030 --> 00:35:53,280

i guess

993

00:35:57,030 --> 00:35:55,040

i'll stick it out afterwards or open

994

00:35:59,190 --> 00:35:57,040

them now if there's time

995

00:36:01,589 --> 00:35:59,200

okay great jonathan um i think we have

996

00:36:02,710 --> 00:36:01,599

time for one or two questions preferably

997

00:36:04,150 --> 00:36:02,720

first of all

998

00:36:12,069 --> 00:36:04,160

focused on something directly for

999

00:36:15,349 --> 00:36:13,109

okay

1000

00:36:17,670 --> 00:36:15,359

jonathan and if if not i encourage you

1001
00:36:19,990 --> 00:36:17,680
guys to contact us at info honeybee

1002
00:36:21,910 --> 00:36:20,000
robotics.com with any uh

1003
00:36:24,069 --> 00:36:21,920
follow-up information requests okay

1004
00:36:27,430 --> 00:36:24,079
thank you

1005
00:36:30,150 --> 00:36:29,190
and and if you can we would appreciate

1006
00:36:35,109 --> 00:36:30,160
if you can stick around for our

1007
00:36:39,589 --> 00:36:37,670
okay our next speaker stephen warwick

1008
00:36:41,030 --> 00:36:39,599
from northrop grumman he's a system

1009
00:36:42,390 --> 00:36:41,040
engineer in the system engineering

1010
00:36:43,829 --> 00:36:42,400
directorate

1011
00:36:45,829 --> 00:36:43,839
he earned his bachelor's degree in

1012
00:36:48,069 --> 00:36:45,839
physics from leicester university in the

1013
00:36:50,550 --> 00:36:48,079

united kingdom and his master's at

1014

00:36:52,310 --> 00:36:50,560

cranfield university steve will talk

1015

00:36:54,150 --> 00:36:52,320

about an integrated sensor system to

1016

00:36:56,790 --> 00:36:54,160

support asteroid characterization

1017

00:36:58,630 --> 00:36:56,800

proximity operations and capture

1018

00:37:00,230 --> 00:36:58,640

thank you very much and it's a pleasure

1019

00:37:02,069 --> 00:37:00,240

to be here this afternoon i'm here on

1020

00:37:03,829 --> 00:37:02,079

behalf of northrop grumman and i'm going

1021

00:37:05,829 --> 00:37:03,839

to be talking about the integrated

1022

00:37:07,910 --> 00:37:05,839

sensor system what we hope to do with

1023

00:37:09,910 --> 00:37:07,920

this was look at a layered approach that

1024

00:37:12,550 --> 00:37:09,920

will give us information as we approach

1025

00:37:13,589 --> 00:37:12,560

the asteroid and one of these buttons

1026
00:37:15,109 --> 00:37:13,599
works

1027
00:37:19,430 --> 00:37:15,119
top one

1028
00:37:21,510 --> 00:37:19,440
there we go

1029
00:37:23,109 --> 00:37:21,520
all right this is part of three talks

1030
00:37:25,829 --> 00:37:23,119
that northrop grumman will be giving

1031
00:37:27,910 --> 00:37:25,839
over the next two days provided people

1032
00:37:30,150 --> 00:37:27,920
in washington have any sense

1033
00:37:31,670 --> 00:37:30,160
um today i'm talking about integrated

1034
00:37:34,390 --> 00:37:31,680
sensing systems tomorrow we're looking

1035
00:37:36,550 --> 00:37:34,400
at the asteroid deflection system that's

1036
00:37:38,790 --> 00:37:36,560
given by jim munger that's pushing the

1037
00:37:40,069 --> 00:37:38,800
larger objects and then also tomorrow

1038
00:37:43,030 --> 00:37:40,079

afternoon we're looking at asteroid

1039

00:37:44,950 --> 00:37:43,040

capture with uh howard ella

1040

00:37:47,190 --> 00:37:44,960

so what we were hoping to do when we

1041

00:37:49,270 --> 00:37:47,200

took a look at this is produce a layered

1042

00:37:52,390 --> 00:37:49,280

sensing approach that is going to buy

1043

00:37:54,390 --> 00:37:52,400

down risk as we fly towards the asteroid

1044

00:37:56,310 --> 00:37:54,400

this is going to be something unusual in

1045

00:37:58,390 --> 00:37:56,320

nasa land because we are not going to

1046

00:38:00,390 --> 00:37:58,400

know what we're really going to do until

1047

00:38:01,589 --> 00:38:00,400

we get close to the object

1048

00:38:03,670 --> 00:38:01,599

we're going to be launching with a

1049

00:38:04,870 --> 00:38:03,680

significant amount of risk in the

1050

00:38:07,109 --> 00:38:04,880

program

1051
00:38:08,870 --> 00:38:07,119
and when we were looking at what sensors

1052
00:38:11,430 --> 00:38:08,880
were useful to us and what would help us

1053
00:38:12,470 --> 00:38:11,440
buy down the risk we had a straw man

1054
00:38:15,270 --> 00:38:12,480
mission

1055
00:38:17,109 --> 00:38:15,280
and we gave a orbit condition code of

1056
00:38:19,270 --> 00:38:17,119
one if you know these things that's

1057
00:38:22,230 --> 00:38:19,280
actually knowing the orbit very well

1058
00:38:24,150 --> 00:38:22,240
uh h mag of 28.5 that's the brightness

1059
00:38:25,990 --> 00:38:24,160
of the object from the ground but what

1060
00:38:28,790 --> 00:38:26,000
we don't know about the object at all is

1061
00:38:30,550 --> 00:38:28,800
the real diameter the mass the spin rate

1062
00:38:32,470 --> 00:38:30,560
whether there's a binary with the object

1063
00:38:35,589 --> 00:38:32,480

or any kind of debris field and what

1064

00:38:37,589 --> 00:38:35,599

this series of sensors is going to do is

1065

00:38:39,430 --> 00:38:37,599

find that information out

1066

00:38:40,870 --> 00:38:39,440

and reduce the risk to the capture

1067

00:38:43,349 --> 00:38:40,880

vehicle

1068

00:38:45,829 --> 00:38:43,359

all right so starting 10 000 kilometers

1069

00:38:47,589 --> 00:38:45,839

or more away from the the asteroid and

1070

00:38:48,950 --> 00:38:47,599

we suggested uh visible and

1071

00:38:51,910 --> 00:38:48,960

near-infrared

1072

00:38:53,589 --> 00:38:51,920

banned telescopes maybe six inch optics

1073

00:38:55,510 --> 00:38:53,599

and they have quite a large field of

1074

00:38:58,069 --> 00:38:55,520

view and would be scanning those to look

1075

00:38:59,589 --> 00:38:58,079

for the asteroid one of the things about

1076
00:39:01,190 --> 00:38:59,599
approaching one of these asteroids is

1077
00:39:04,069 --> 00:39:01,200
even when the orbit condition is

1078
00:39:05,990 --> 00:39:04,079
relatively good we're still not 100 sure

1079
00:39:07,430 --> 00:39:06,000
where they are the the mission is going

1080
00:39:08,870 --> 00:39:07,440
to have to find the asteroid as it

1081
00:39:11,190 --> 00:39:08,880
approaches

1082
00:39:13,510 --> 00:39:11,200
and the goal here is to improve the

1083
00:39:15,430 --> 00:39:13,520
orbit accuracy know our distance to the

1084
00:39:17,910 --> 00:39:15,440
object as well i mean there's some other

1085
00:39:20,710 --> 00:39:17,920
information we may be able to find out

1086
00:39:22,470 --> 00:39:20,720
we may be able to get a spin state from

1087
00:39:24,630 --> 00:39:22,480
a light curve as well using this

1088
00:39:26,790 --> 00:39:24,640

instrument but primarily this is about

1089

00:39:28,550 --> 00:39:26,800

finding the asteroid and there on the

1090

00:39:30,790 --> 00:39:28,560

slide on the right and you can see the

1091

00:39:32,870 --> 00:39:30,800

advantage of infrared over visible it

1092

00:39:35,349 --> 00:39:32,880

gives you a better idea of the size of

1093

00:39:37,910 --> 00:39:35,359

the object you're going to be looking at

1094

00:39:39,430 --> 00:39:37,920

okay we get closer to the object and

1095

00:39:41,349 --> 00:39:39,440

from 100 kilometers or so we're

1096

00:39:42,630 --> 00:39:41,359

suggesting a radar ground penetrating

1097

00:39:43,829 --> 00:39:42,640

radar

1098

00:39:45,430 --> 00:39:43,839

obviously that gives you

1099

00:39:48,470 --> 00:39:45,440

characterization of the shape of the

1100

00:39:50,550 --> 00:39:48,480

object uh it improves your ranging to

1101
00:39:52,870 --> 00:39:50,560
the object now you know even to higher

1102
00:39:54,230 --> 00:39:52,880
accuracy how where the object is

1103
00:39:55,910 --> 00:39:54,240
and you're going to get some information

1104
00:39:57,670 --> 00:39:55,920
about the spin state or the tumbling

1105
00:39:59,430 --> 00:39:57,680
nature of the asteroid and of course

1106
00:40:00,710 --> 00:39:59,440
because it's ground penetrating radar

1107
00:40:02,630 --> 00:40:00,720
that's going to give you your first

1108
00:40:04,790 --> 00:40:02,640
indication of whether you're dealing

1109
00:40:06,550 --> 00:40:04,800
with a monolithic rock or you're dealing

1110
00:40:08,550 --> 00:40:06,560
with one of these rubble piles and

1111
00:40:11,190 --> 00:40:08,560
that's obviously going to be critical

1112
00:40:15,109 --> 00:40:11,200
for the for the safety of the capture

1113
00:40:18,069 --> 00:40:15,119

spacecraft as it approaches the object

1114

00:40:20,069 --> 00:40:18,079

getting closer still 50 kilometers or so

1115

00:40:23,349 --> 00:40:20,079

uh lidar radar

1116

00:40:26,550 --> 00:40:23,359

and be able to generate a 3d model of

1117

00:40:27,910 --> 00:40:26,560

the asteroid as it spans and obviously

1118

00:40:29,190 --> 00:40:27,920

we don't expect these objects to be

1119

00:40:30,790 --> 00:40:29,200

circular they're going to be quite

1120

00:40:33,430 --> 00:40:30,800

irregular this will give us our

1121

00:40:34,790 --> 00:40:33,440

indication of of what nature of

1122

00:40:37,670 --> 00:40:34,800

irregular object we're going to be

1123

00:40:42,230 --> 00:40:40,309

and getting closer still and we quite

1124

00:40:45,430 --> 00:40:42,240

like this one this is a

1125

00:40:48,069 --> 00:40:45,440

cubesat we uh and back in 2010 northrop

1126
00:40:50,150 --> 00:40:48,079
launched a cubesat called mayflower the

1127
00:40:51,990 --> 00:40:50,160
next generation of that plymouth is a

1128
00:40:53,190 --> 00:40:52,000
three axis stabilized three by one

1129
00:40:56,069 --> 00:40:53,200
cubesat

1130
00:40:57,190 --> 00:40:56,079
and it also has some delta v on board 20

1131
00:40:58,790 --> 00:40:57,200
25

1132
00:41:01,670 --> 00:40:58,800
and meters a second

1133
00:41:04,069 --> 00:41:01,680
and it has capacity for a reasonable

1134
00:41:06,069 --> 00:41:04,079
amount of solar array on there as well

1135
00:41:07,190 --> 00:41:06,079
and it has its own instrument suite

1136
00:41:09,750 --> 00:41:07,200
called dark

1137
00:41:10,630 --> 00:41:09,760
that has a camera radar and lidar of its

1138
00:41:12,309 --> 00:41:10,640

own

1139

00:41:14,870 --> 00:41:12,319

and what you get from that is the

1140

00:41:16,630 --> 00:41:14,880

ability for the capture spacecraft to be

1141

00:41:17,750 --> 00:41:16,640

set a reasonable distance away from the

1142

00:41:19,990 --> 00:41:17,760

asteroid

1143

00:41:21,670 --> 00:41:20,000

safe from any debris or any other

1144

00:41:23,510 --> 00:41:21,680

problem that the asteroid

1145

00:41:25,589 --> 00:41:23,520

may threaten them to capture vehicle

1146

00:41:28,069 --> 00:41:25,599

with and get very very close with one of

1147

00:41:30,150 --> 00:41:28,079

these objects and with one of these

1148

00:41:32,710 --> 00:41:30,160

cubesats um

1149

00:41:35,349 --> 00:41:32,720

down to 50 meters or so range

1150

00:41:37,589 --> 00:41:35,359

a real advantage of this is we realize

1151

00:41:39,270 --> 00:41:37,599

that as you approach the asteroid and

1152

00:41:41,510 --> 00:41:39,280

station keep with the asteroid using the

1153

00:41:43,910 --> 00:41:41,520

cubesat and you watch it for a couple of

1154

00:41:45,990 --> 00:41:43,920

days then relative to the the primary

1155

00:41:47,190 --> 00:41:46,000

spacecraft you're going to see very slow

1156

00:41:49,589 --> 00:41:47,200

acceleration and that's the

1157

00:41:51,190 --> 00:41:49,599

gravitational field of the asteroid and

1158

00:41:52,710 --> 00:41:51,200

i'll give you your first indications of

1159

00:41:56,309 --> 00:41:52,720

the true mass of the asteroid that

1160

00:42:00,950 --> 00:41:58,230

and getting closer still and this is

1161

00:42:02,790 --> 00:42:00,960

another q-type concept if the if the

1162

00:42:04,790 --> 00:42:02,800

ball there looks familiar that's because

1163

00:42:08,870 --> 00:42:04,800

we developed it with honeybee

1164

00:42:11,990 --> 00:42:08,880

uh for a discovery program in 2010 and

1165

00:42:14,150 --> 00:42:12,000

also an at ames research center we call

1166

00:42:16,470 --> 00:42:14,160

these impactors really we've also used

1167

00:42:18,309 --> 00:42:16,480

the name thumpers they're intended to

1168

00:42:20,950 --> 00:42:18,319

impact very slowly

1169

00:42:23,990 --> 00:42:20,960

meters a second the accelerometers

1170

00:42:26,630 --> 00:42:24,000

inside the ball give you uh

1171

00:42:28,630 --> 00:42:26,640

more information on the composition of

1172

00:42:30,630 --> 00:42:28,640

the asteroid whether you're hitting dust

1173

00:42:32,710 --> 00:42:30,640

grains or solid rock

1174

00:42:34,470 --> 00:42:32,720

and then there's another version the the

1175

00:42:36,710 --> 00:42:34,480

one you cube sound that's got cameras on

1176

00:42:38,470 --> 00:42:36,720

board and an electrostatic probe to give

1177

00:42:39,910 --> 00:42:38,480

you any idea of any kind of electrical

1178

00:42:42,069 --> 00:42:39,920

field that the

1179

00:42:44,790 --> 00:42:42,079

asteroid may have in any kind of dust

1180

00:42:46,710 --> 00:42:44,800

environment around it both the cubesat

1181

00:42:48,470 --> 00:42:46,720

concepts we've shown here they are

1182

00:42:50,710 --> 00:42:48,480

moderately low trl as it stands at the

1183

00:42:53,910 --> 00:42:50,720

moment but we've shown that you can go

1184

00:42:57,349 --> 00:42:53,920

from concept to launch with a cubesat in

1185

00:42:58,630 --> 00:42:57,359

six months or so so we would expect uh

1186

00:43:01,030 --> 00:42:58,640

if we were going to do something like

1187

00:43:02,950 --> 00:43:01,040

this to actually be flying

1188

00:43:04,790 --> 00:43:02,960

uh the cubesats ahead of time in low

1189

00:43:06,230 --> 00:43:04,800

earth orbit

1190

00:43:08,550 --> 00:43:06,240

and

1191

00:43:10,710 --> 00:43:08,560

the uh

1192

00:43:13,589 --> 00:43:10,720

sorry let me uh

1193

00:43:15,750 --> 00:43:13,599

but in both cases they uh are they're

1194

00:43:17,270 --> 00:43:15,760

not exquisite technology they are they

1195

00:43:20,150 --> 00:43:17,280

are commercial off-the-shelf type

1196

00:43:22,309 --> 00:43:20,160

technology and we achieve redundancy by

1197

00:43:25,190 --> 00:43:22,319

having multiple copies of of all the

1198

00:43:26,550 --> 00:43:25,200

cubesats we've shown here

1199

00:43:29,589 --> 00:43:26,560

so in summary hopefully what we're

1200

00:43:31,190 --> 00:43:29,599

showing here is a series a layered

1201
00:43:33,750 --> 00:43:31,200
approach that's going to buy down the

1202
00:43:35,829 --> 00:43:33,760
risk as we actually fly the mission and

1203
00:43:37,829 --> 00:43:35,839
how we get close to the object how we

1204
00:43:39,349 --> 00:43:37,839
find out what the object really is and

1205
00:43:42,390 --> 00:43:39,359
how we can model

1206
00:43:44,710 --> 00:43:42,400
the composition the shape the tumble and

1207
00:43:47,109 --> 00:43:44,720
spin of the object on the ground in such

1208
00:43:49,270 --> 00:43:47,119
a way that safe capture of the asteroid

1209
00:43:51,349 --> 00:43:49,280
can be achieved

1210
00:44:10,550 --> 00:43:51,359
all right

1211
00:44:13,510 --> 00:44:11,910
can you give us a

1212
00:44:15,030 --> 00:44:13,520
an idea of what a ground penetrating

1213
00:44:17,910 --> 00:44:15,040

radar might cost

1214

00:44:23,670 --> 00:44:17,920

uh i i'm afraid i can't no i don't have

1215

00:44:27,270 --> 00:44:25,510

anybody else

1216

00:44:29,030 --> 00:44:27,280

anything uh coming in

1217

00:44:32,950 --> 00:44:29,040

from

1218

00:44:32,960 --> 00:44:36,630

thank you

1219

00:44:40,710 --> 00:44:39,589

um our next presenter

1220

00:44:45,190 --> 00:44:40,720

is

1221

00:44:46,950 --> 00:44:45,200

rich

1222

00:44:48,870 --> 00:44:46,960

works in business development and civil

1223

00:44:51,349 --> 00:44:48,880

space and technologies at ball aerospace

1224

00:44:53,030 --> 00:44:51,359

he's primarily responsible for the

1225

00:44:55,430 --> 00:44:53,040

pursuit and formulation of instruments

1226
00:44:56,950 --> 00:44:55,440
in spacecraft for science missions he

1227
00:44:59,670 --> 00:44:56,960
received a doctorate in planetary

1228
00:45:01,589 --> 00:44:59,680
sciences from caltech in 1994

1229
00:45:03,430 --> 00:45:01,599
his talk will

1230
00:45:04,470 --> 00:45:03,440
evaluate sensing requirements for arm

1231
00:45:11,349 --> 00:45:04,480
and

1232
00:45:12,870 --> 00:45:11,359
along with several other folks in the

1233
00:45:13,910 --> 00:45:12,880
room i think so

1234
00:45:15,910 --> 00:45:13,920
um

1235
00:45:18,630 --> 00:45:15,920
it's getting better now though at least

1236
00:45:20,230 --> 00:45:18,640
at least in a lot of areas um

1237
00:45:22,710 --> 00:45:20,240
so this this is a

1238
00:45:23,829 --> 00:45:22,720

sound kind of familiar to uh

1239

00:45:25,190 --> 00:45:23,839

you know it's kind of along the same

1240

00:45:26,950 --> 00:45:25,200

theme of several other talks so i'm

1241

00:45:29,270 --> 00:45:26,960

gonna i'm gonna focus uh more on a

1242

00:45:31,750 --> 00:45:29,280

couple of things toward the end but we

1243

00:45:33,589 --> 00:45:31,760

looked at the uh the not nominal arm

1244

00:45:35,270 --> 00:45:33,599

scenario to say what are the kind of

1245

00:45:36,870 --> 00:45:35,280

what's the minimum base set of sensors

1246

00:45:38,230 --> 00:45:36,880

that you might need for this

1247

00:45:39,990 --> 00:45:38,240

um

1248

00:45:41,670 --> 00:45:40,000

just to get to the punch line i see a

1249

00:45:43,270 --> 00:45:41,680

minimum set being a narrow and wide

1250

00:45:45,670 --> 00:45:43,280

field of view visible imagers and an

1251

00:45:47,670 --> 00:45:45,680

imaging lidar sounds like a similar

1252

00:45:49,750 --> 00:45:47,680

conclusion although there's some nuances

1253

00:45:51,030 --> 00:45:49,760

there uh what senses are available want

1254

00:45:53,990 --> 00:45:51,040

to talk to that a little bit are there

1255

00:45:55,670 --> 00:45:54,000

some gaps in uh in the sensing

1256

00:45:57,510 --> 00:45:55,680

technology we heard a lot about there

1257

00:45:58,790 --> 00:45:57,520

are a lot of high trl

1258

00:46:00,870 --> 00:45:58,800

things available right now i think

1259

00:46:03,430 --> 00:46:00,880

that's true in the hardware side i'm i'm

1260

00:46:05,349 --> 00:46:03,440

more concerned about uh in this the

1261

00:46:06,950 --> 00:46:05,359

fully autonomous software for prox ops

1262

00:46:08,390 --> 00:46:06,960

there's a lot of work going on there

1263

00:46:10,790 --> 00:46:08,400

fantastic work in a lot of different

1264

00:46:12,790 --> 00:46:10,800

locations but you got to piece all that

1265

00:46:15,510 --> 00:46:12,800

together and make it make it uh

1266

00:46:17,589 --> 00:46:15,520

robust uh and fully autonomous for for

1267

00:46:19,430 --> 00:46:17,599

flight ops here that that that to me is

1268

00:46:20,950 --> 00:46:19,440

the the a big kicker that we need to

1269

00:46:22,630 --> 00:46:20,960

concentrate on

1270

00:46:25,510 --> 00:46:22,640

um this is also as we've heard

1271

00:46:27,670 --> 00:46:25,520

applicable to a number of um other other

1272

00:46:30,790 --> 00:46:27,680

mission concepts recon missions to small

1273

00:46:33,990 --> 00:46:30,800

bodies arnd orbital remediation

1274

00:46:36,230 --> 00:46:34,000

satellite servicing so

1275

00:46:39,589 --> 00:46:36,240

leave it at that so this is my rendition

1276

00:46:41,750 --> 00:46:39,599

of what the mission looks like

1277

00:46:43,829 --> 00:46:41,760

several different uh

1278

00:46:45,750 --> 00:46:43,839

distances here and what kind of sensors

1279

00:46:49,190 --> 00:46:45,760

you you can see here

1280

00:46:51,430 --> 00:46:49,200

being being needed to be applied for for

1281

00:46:54,390 --> 00:46:51,440

navigation and prox ops

1282

00:46:56,309 --> 00:46:54,400

the narrow field of view imagery far out

1283

00:46:58,150 --> 00:46:56,319

as you get getting closer and closer you

1284

00:47:00,630 --> 00:46:58,160

start bringing in lidar in order to get

1285

00:47:02,710 --> 00:47:00,640

to get bearing information then pose

1286

00:47:04,150 --> 00:47:02,720

information further in uh need to get

1287

00:47:06,150 --> 00:47:04,160

surface features and have the surface

1288

00:47:08,390 --> 00:47:06,160

features blended in to the to the pose

1289

00:47:10,470 --> 00:47:08,400

model as well

1290

00:47:12,630 --> 00:47:10,480

but what's missing out of all these that

1291

00:47:14,950 --> 00:47:12,640

i see is that you you don't really have

1292

00:47:16,710 --> 00:47:14,960

any kind of information solid

1293

00:47:19,109 --> 00:47:16,720

information anyway about mechanical

1294

00:47:21,829 --> 00:47:19,119

properties of the target now i've

1295

00:47:23,510 --> 00:47:21,839

heard a lot of good good talk and i want

1296

00:47:25,990 --> 00:47:23,520

to hear more discussion about

1297

00:47:28,549 --> 00:47:26,000

this airbag technique being

1298

00:47:30,390 --> 00:47:28,559

robust to to any any range of mechanical

1299

00:47:32,390 --> 00:47:30,400

properties that would scare me thinking

1300

00:47:35,270 --> 00:47:32,400

about this is going to be a you know

1301
00:47:37,430 --> 00:47:35,280
tens of minute kind of operation to to

1302
00:47:38,950 --> 00:47:37,440
go in and move in maneuver around

1303
00:47:40,950 --> 00:47:38,960
something like that

1304
00:47:42,950 --> 00:47:40,960
and encapsulate it and then have some

1305
00:47:44,630 --> 00:47:42,960
other diaphragm come around it and then

1306
00:47:48,069 --> 00:47:44,640
release the airbags in the meantime

1307
00:47:49,589 --> 00:47:48,079
nothing has touched the surface at all

1308
00:47:50,470 --> 00:47:49,599
i think there might be a range of

1309
00:47:53,030 --> 00:47:50,480
different

1310
00:47:54,309 --> 00:47:53,040
conops we might think about here

1311
00:47:55,430 --> 00:47:54,319
depending on whether we've got good

1312
00:47:57,589 --> 00:47:55,440
information about the mechanical

1313
00:47:58,870 --> 00:47:57,599

properties or not of this object so i

1314

00:48:00,790 --> 00:47:58,880

would think you would want to be

1315

00:48:03,829 --> 00:48:00,800

informed of that ahead of time not just

1316

00:48:07,270 --> 00:48:04,549

so

1317

00:48:09,430 --> 00:48:07,280

getting back though to flat flash lidar

1318

00:48:10,470 --> 00:48:09,440

um there are a number of different uh

1319

00:48:11,750 --> 00:48:10,480

candidate

1320

00:48:13,349 --> 00:48:11,760

technologies out there that are high

1321

00:48:16,150 --> 00:48:13,359

tier all right now we we have one at

1322

00:48:17,750 --> 00:48:16,160

ball as well uh this uh vns the vision

1323

00:48:18,829 --> 00:48:17,760

navigation center

1324

00:48:22,790 --> 00:48:18,839

flew on

1325

00:48:24,309 --> 00:48:22,800

sts-134 here you can see a visible image

1326

00:48:26,470 --> 00:48:24,319

along with the

1327

00:48:28,870 --> 00:48:26,480

there's a visible camera along with that

1328

00:48:30,390 --> 00:48:28,880

the vns flash lighter intensity image is

1329

00:48:32,549 --> 00:48:30,400

here and the range images here as it's

1330

00:48:35,190 --> 00:48:32,559

approaching the this docking ring on on

1331

00:48:37,030 --> 00:48:35,200

the iss and flash lighter as you may

1332

00:48:39,349 --> 00:48:37,040

know you know illuminates an entire

1333

00:48:41,750 --> 00:48:39,359

field of view all at once all the pixels

1334

00:48:43,910 --> 00:48:41,760

come back with with a range in real time

1335

00:48:45,270 --> 00:48:43,920

this uh this particular device operates

1336

00:48:47,190 --> 00:48:45,280

at 30 hertz

1337

00:48:48,549 --> 00:48:47,200

uh you can enhance this with adaptive

1338

00:48:50,230 --> 00:48:48,559

beam steering

1339

00:48:52,470 --> 00:48:50,240

we've done some of that a ball of this

1340

00:48:55,349 --> 00:48:52,480

this unit didn't have that

1341

00:48:57,829 --> 00:48:55,359

but there are ways to enhance the uh

1342

00:48:58,549 --> 00:48:57,839

the operability of this for

1343

00:49:00,630 --> 00:48:58,559

for

1344

00:49:02,950 --> 00:49:00,640

high dynamic range targets

1345

00:49:04,630 --> 00:49:02,960

and we've also looked at ways to enhance

1346

00:49:09,030 --> 00:49:04,640

the radiometric performance you can make

1347

00:49:11,510 --> 00:49:09,910

by

1348

00:49:13,109 --> 00:49:11,520

some pretty simple tweaks to this this

1349

00:49:14,710 --> 00:49:13,119

was made to look at rector reflectors on

1350

00:49:15,910 --> 00:49:14,720

the iss but

1351
00:49:17,510 --> 00:49:15,920
you can see you're seeing a lot of the

1352
00:49:19,109 --> 00:49:17,520
skin of the

1353
00:49:20,230 --> 00:49:19,119
iss where the erect reflectors aren't

1354
00:49:21,910 --> 00:49:20,240
there's a retro right there that very

1355
00:49:24,069 --> 00:49:21,920
bright object

1356
00:49:25,430 --> 00:49:24,079
but you can you can tweak this by

1357
00:49:26,870 --> 00:49:25,440
removing the

1358
00:49:28,950 --> 00:49:26,880
optical parametric oscillator for

1359
00:49:30,309 --> 00:49:28,960
instance get about five times the

1360
00:49:31,990 --> 00:49:30,319
performance on that there are a number

1361
00:49:33,670 --> 00:49:32,000
of different things you can do to if

1362
00:49:36,630 --> 00:49:33,680
you're willing to compromise eye safety

1363
00:49:39,750 --> 00:49:36,640

you can make this uh you know be able to

1364

00:49:42,150 --> 00:49:39,760

see a lot on the dark target

1365

00:49:44,630 --> 00:49:42,160

um as i mentioned the technology gap i

1366

00:49:46,790 --> 00:49:44,640

see is this the really the need for

1367

00:49:49,510 --> 00:49:46,800

robust real-time fully autonomous

1368

00:49:51,109 --> 00:49:49,520

proximity ops uh you know this this has

1369

00:49:52,390 --> 00:49:51,119

been uh looked at from a number of

1370

00:49:54,950 --> 00:49:52,400

different angles that you know we've

1371

00:49:56,390 --> 00:49:54,960

heard about the socs uh as i understand

1372

00:49:58,230 --> 00:49:56,400

there's gonna be a morpheus landing test

1373

00:50:00,470 --> 00:49:58,240

that looks at terrain relative nav and

1374

00:50:02,470 --> 00:50:00,480

hazard avoidance in the loop as part of

1375

00:50:04,630 --> 00:50:02,480

that those are all great things they

1376

00:50:07,510 --> 00:50:04,640

move us the right direction

1377

00:50:09,670 --> 00:50:07,520

one example of data here is to fuse

1378

00:50:11,910 --> 00:50:09,680

visible data from the camera

1379

00:50:12,630 --> 00:50:11,920

with the lighter image and be able to to

1380

00:50:15,270 --> 00:50:12,640

get

1381

00:50:17,430 --> 00:50:15,280

uh information real time and you know

1382

00:50:19,990 --> 00:50:17,440

that's that's uh doesn't matter what the

1383

00:50:22,630 --> 00:50:20,000

elimination conditions are

1384

00:50:24,150 --> 00:50:22,640

so that that needs to be

1385

00:50:25,430 --> 00:50:24,160

you need to know exactly what features

1386

00:50:27,510 --> 00:50:25,440

you're seeing on the on the target as

1387

00:50:29,670 --> 00:50:27,520

well so you get the full pose estimation

1388

00:50:31,510 --> 00:50:29,680

in in real time so you you know where

1389

00:50:33,030 --> 00:50:31,520

you are relative to all those features

1390

00:50:36,150 --> 00:50:33,040

on the asteroid as you're doing these

1391

00:50:37,430 --> 00:50:36,160

these proximity operations

1392

00:50:38,950 --> 00:50:37,440

as is

1393

00:50:40,950 --> 00:50:38,960

as i mentioned i don't i don't see this

1394

00:50:41,829 --> 00:50:40,960

as it's being done in pieces right now

1395

00:50:43,349 --> 00:50:41,839

um

1396

00:50:46,150 --> 00:50:43,359

there needs to be a

1397

00:50:47,990 --> 00:50:46,160

uh you know a full end-to-end uh

1398

00:50:49,910 --> 00:50:48,000

simulation that brings all this together

1399

00:50:51,510 --> 00:50:49,920

i think to really make this robust that

1400

00:50:55,270 --> 00:50:51,520

i think that's gonna be a major

1401

00:50:56,069 --> 00:50:55,280

uh hurdle in this in this mission

1402

00:50:57,829 --> 00:50:56,079

um

1403

00:50:59,589 --> 00:50:57,839

as you saw in john brophy's talk as well

1404

00:51:02,150 --> 00:50:59,599

there was a this picture was up in the

1405

00:51:05,030 --> 00:51:02,160

upper right hand corner of a possible

1406

00:51:06,390 --> 00:51:05,040

augmentation to uh to to

1407

00:51:08,549 --> 00:51:06,400

some of the

1408

00:51:10,790 --> 00:51:08,559

sensors that might be on this this was

1409

00:51:12,870 --> 00:51:10,800

uh you know not really a cubesat a

1410

00:51:14,309 --> 00:51:12,880

sphere set uh i guess

1411

00:51:16,390 --> 00:51:14,319

you saw it's on the last one there was a

1412

00:51:18,309 --> 00:51:16,400

sphere as well this is actually pretty

1413

00:51:20,630 --> 00:51:18,319

high trl now we've we've developed this

1414

00:51:22,069 --> 00:51:20,640

we've done testing over the past uh four

1415

00:51:25,510 --> 00:51:22,079

or five years of ball and we have this

1416

00:51:26,470 --> 00:51:25,520

up around tro5 right now as a as a

1417

00:51:28,630 --> 00:51:26,480

as a

1418

00:51:29,589 --> 00:51:28,640

potential payload for small body body

1419

00:51:31,750 --> 00:51:29,599

missions

1420

00:51:33,670 --> 00:51:31,760

and uh this is you know just one

1421

00:51:34,630 --> 00:51:33,680

scenario that that might play out down

1422

00:51:36,710 --> 00:51:34,640

the bottom here where you have a

1423

00:51:39,349 --> 00:51:36,720

spacecraft in close proximity to a small

1424

00:51:40,790 --> 00:51:39,359

body asteroid in this case

1425

00:51:42,470 --> 00:51:40,800

deploying it off the back end letting it

1426

00:51:43,990 --> 00:51:42,480

free fall down you don't have to make

1427

00:51:46,309 --> 00:51:44,000

this very shock tolerant you know in a

1428

00:51:47,990 --> 00:51:46,319

low g situation it's like dropping your

1429

00:51:49,910 --> 00:51:48,000

pencil from you know about a meter off

1430

00:51:52,630 --> 00:51:49,920

the ground here it'll bounce around the

1431

00:51:54,549 --> 00:51:52,640

surface eventually settle down

1432

00:51:56,230 --> 00:51:54,559

in this particular scenario we were

1433

00:51:58,230 --> 00:51:56,240

using this to try to measure the the

1434

00:51:59,910 --> 00:51:58,240

inherent strength of the object not just

1435

00:52:01,990 --> 00:51:59,920

from the coefficient of restitution from

1436

00:52:04,390 --> 00:52:02,000

from hitting the surface it does have

1437

00:52:06,630 --> 00:52:04,400

accelerometers as a package on this but

1438

00:52:08,630 --> 00:52:06,640

but also by having a small explosive

1439

00:52:11,030 --> 00:52:08,640

charge on it

1440

00:52:13,510 --> 00:52:11,040

to to make a cratering experiment the

1441

00:52:14,710 --> 00:52:13,520

size of the crater is is a direct

1442

00:52:16,390 --> 00:52:14,720

function of what the strength of the

1443

00:52:19,750 --> 00:52:16,400

material is you know the deep impact

1444

00:52:22,390 --> 00:52:19,760

experiment showed that as well uh that

1445

00:52:23,910 --> 00:52:22,400

was one of the premises of it anyway um

1446

00:52:26,150 --> 00:52:23,920

so you know what the size of the crater

1447

00:52:27,750 --> 00:52:26,160

here will inform you a lot about the the

1448

00:52:29,510 --> 00:52:27,760

strength of the material

1449

00:52:30,470 --> 00:52:29,520

is it competent rock or is it a rubble

1450

00:52:31,270 --> 00:52:30,480

pile

1451
00:52:32,470 --> 00:52:31,280
um

1452
00:52:34,470 --> 00:52:32,480
you know this

1453
00:52:35,750 --> 00:52:34,480
but note that there are limitations to

1454
00:52:38,150 --> 00:52:35,760
this you're not going to drop this and

1455
00:52:41,349 --> 00:52:38,160
have one of these spheres be captured in

1456
00:52:44,549 --> 00:52:41,359
a system unless the object is of

1457
00:52:45,910 --> 00:52:44,559
uh you know 100 meters or so or larger

1458
00:52:48,470 --> 00:52:45,920
it's just not going to be a large enough

1459
00:52:50,069 --> 00:52:48,480
gravitational well for it to be captured

1460
00:52:52,309 --> 00:52:50,079
so this is more of a scenario for maybe

1461
00:52:54,069 --> 00:52:52,319
the go grab a rock scenario rather than

1462
00:52:55,109 --> 00:52:54,079
going grabbing the entire entire

1463
00:52:57,510 --> 00:52:55,119

asteroid

1464

00:52:59,670 --> 00:52:57,520

also you know for concepts of it'd be

1465

00:53:01,750 --> 00:52:59,680

nice to have a small free flyer

1466

00:53:03,910 --> 00:53:01,760

something includes maybe a contact probe

1467

00:53:05,829 --> 00:53:03,920

like a little hummingbird to have a

1468

00:53:08,390 --> 00:53:05,839

proboscis to go into touch and go

1469

00:53:10,630 --> 00:53:08,400

surface measurements on the surface

1470

00:53:13,190 --> 00:53:10,640

it also provide a very unique vantage

1471

00:53:14,470 --> 00:53:13,200

point for for imaging the capture

1472

00:53:16,309 --> 00:53:14,480

sequence i think

1473

00:53:18,390 --> 00:53:16,319

you know for for public outreach of this

1474

00:53:20,309 --> 00:53:18,400

would be really nice to have a

1475

00:53:22,950 --> 00:53:20,319

secondary spacecraft watching the entire

1476

00:53:24,470 --> 00:53:22,960

process happen

1477

00:53:26,390 --> 00:53:24,480

so in conclusion

1478

00:53:28,870 --> 00:53:26,400

the arm sensing requirements we see

1479

00:53:31,430 --> 00:53:28,880

being needed for for capture

1480

00:53:33,349 --> 00:53:31,440

one range two pose estimation for a

1481

00:53:35,030 --> 00:53:33,359

resolved target and three high

1482

00:53:36,630 --> 00:53:35,040

resolution visible imaging that's

1483

00:53:37,829 --> 00:53:36,640

actually correlated to that pose

1484

00:53:39,750 --> 00:53:37,839

estimation

1485

00:53:42,390 --> 00:53:39,760

uh those measurements need to be made

1486

00:53:43,670 --> 00:53:42,400

autonomously in real time there are

1487

00:53:45,510 --> 00:53:43,680

mature sensors for making these

1488

00:53:48,549 --> 00:53:45,520

measurements but the software

1489

00:53:50,230 --> 00:53:48,559

is where the development needs to be

1490

00:53:52,470 --> 00:53:50,240

separate flight elements to contact or

1491

00:53:54,069 --> 00:53:52,480

perturb the target surface i think can

1492

00:53:55,270 --> 00:53:54,079

reduce mission risk

1493

00:54:01,589 --> 00:53:55,280

thanks

1494

00:54:05,829 --> 00:54:04,230

we have time for a question for rich if

1495

00:54:08,069 --> 00:54:05,839

in the room

1496

00:54:08,950 --> 00:54:08,079

or virtually

1497

00:54:10,950 --> 00:54:08,960

go ahead

1498

00:54:12,390 --> 00:54:10,960

go to a mic though please

1499

00:54:14,630 --> 00:54:12,400

i can say it really loud how much do

1500

00:54:16,470 --> 00:54:14,640

those surface probes the mass estimates

1501
00:54:18,870 --> 00:54:16,480
for those

1502
00:54:20,230 --> 00:54:18,880
questions yeah the the how much what was

1503
00:54:23,270 --> 00:54:20,240
the mass system up for the surface

1504
00:54:25,270 --> 00:54:23,280
probes um it can vary quite a bit but

1505
00:54:27,109 --> 00:54:25,280
the kind of minimum mass that we see as

1506
00:54:30,630 --> 00:54:27,119
being viable is uh you know on the order

1507
00:54:33,510 --> 00:54:30,640
of five six kilos uh the instantiation

1508
00:54:34,950 --> 00:54:33,520
you saw there had a a couple of kilos of

1509
00:54:36,789 --> 00:54:34,960
actual high explosive on them in

1510
00:54:41,109 --> 00:54:36,799
addition to that so they were they were

1511
00:54:41,119 --> 00:54:44,549
any others

1512
00:54:49,510 --> 00:54:47,349
okay thank you that was a suggestion

1513
00:54:52,309 --> 00:54:49,520

what was the suggestion

1514

00:54:55,190 --> 00:54:52,319

the suggestion was to put an array of

1515

00:54:56,870 --> 00:54:55,200

different sensors and devices

1516

00:55:00,789 --> 00:54:56,880

up and relay the coordinates and

1517

00:55:04,390 --> 00:55:03,030

an array of sensors well actually what

1518

00:55:06,150 --> 00:55:04,400

we were thinking about was an array of

1519

00:55:07,670 --> 00:55:06,160

sensors some of them have geophones on

1520

00:55:09,750 --> 00:55:07,680

them some of them have explosive charges

1521

00:55:12,150 --> 00:55:09,760

you can make a crude seismic network

1522

00:55:14,549 --> 00:55:12,160

that way uh it's hard to place these

1523

00:55:16,390 --> 00:55:14,559

with uh with any control

1524

00:55:18,470 --> 00:55:16,400

so you have to be willing to uh

1525

00:55:20,549 --> 00:55:18,480

to have that uncertainty in the in that

1526

00:55:22,950 --> 00:55:20,559

sensor net but that that is a good

1527

00:55:29,270 --> 00:55:25,910

okay thanks rich

1528

00:55:31,990 --> 00:55:29,280

our next speaker is mark haynes from the

1529

00:55:34,309 --> 00:55:32,000

jet propulsion laboratory

1530

00:55:37,190 --> 00:55:34,319

mark received his phd in applied physics

1531

00:55:39,510 --> 00:55:37,200

from the university of michigan in 2012.

1532

00:55:41,430 --> 00:55:39,520

he joined jpl in june of this year and

1533

00:55:43,030 --> 00:55:41,440

his background is radar

1534

00:55:45,670 --> 00:55:43,040

microwave scattering and inverse

1535

00:55:47,109 --> 00:55:45,680

scattering and medical imaging

1536

00:55:49,030 --> 00:55:47,119

in this presentation he'll give an

1537

00:55:51,109 --> 00:55:49,040

overview of possible applications of

1538

00:55:53,190 --> 00:55:51,119

radar as an asteroid characterization

1539

00:55:55,670 --> 00:55:53,200

and avionics tool

1540

00:55:57,109 --> 00:55:55,680

all right uh good afternoon uh thank you

1541

00:55:58,390 --> 00:55:57,119

for having me

1542

00:56:00,390 --> 00:55:58,400

uh

1543

00:56:02,230 --> 00:56:00,400

like you said um i'm gonna be talking

1544

00:56:04,150 --> 00:56:02,240

about a couple ways in which radar could

1545

00:56:05,430 --> 00:56:04,160

aid future asteroid missions it's a

1546

00:56:06,630 --> 00:56:05,440

pretty general talk there's a lot of

1547

00:56:08,230 --> 00:56:06,640

overlap with some of the other things

1548

00:56:11,270 --> 00:56:08,240

but hopefully we'll generate some more

1549

00:56:12,630 --> 00:56:11,280

detailed discussion later

1550

00:56:14,950 --> 00:56:12,640

so the applications i'm going to talk

1551

00:56:17,030 --> 00:56:14,960

about are aimed at addressing the

1552

00:56:18,870 --> 00:56:17,040

following points of the rfi mostly

1553

00:56:21,430 --> 00:56:18,880

characterization and

1554

00:56:23,589 --> 00:56:21,440

some avionics in general when these

1555

00:56:25,910 --> 00:56:23,599

systems are envisioned as integrated

1556

00:56:27,589 --> 00:56:25,920

sensing systems to be used as an

1557

00:56:29,670 --> 00:56:27,599

avionics tool with the possibility of

1558

00:56:31,349 --> 00:56:29,680

secondary science so real quick just

1559

00:56:33,270 --> 00:56:31,359

some features of radar

1560

00:56:35,030 --> 00:56:33,280

uh it's self-illuminating it works in

1561

00:56:37,990 --> 00:56:35,040

the shadow it can see through dust it's

1562

00:56:39,510 --> 00:56:38,000

very fast it works at a near far range

1563

00:56:41,670 --> 00:56:39,520

and the echoes contain sort of three

1564

00:56:43,430 --> 00:56:41,680

pieces of information how far away you

1565

00:56:45,109 --> 00:56:43,440

are relative motion in the form of

1566

00:56:46,710 --> 00:56:45,119

doppler and then also lots of

1567

00:56:47,349 --> 00:56:46,720

information on the physical scattering

1568

00:56:49,190 --> 00:56:47,359

of

1569

00:56:51,030 --> 00:56:49,200

the body

1570

00:56:52,950 --> 00:56:51,040

so just to give it some context where

1571

00:56:53,990 --> 00:56:52,960

radar has been used in the past

1572

00:56:57,670 --> 00:56:54,000

most everyone's familiar with the

1573

00:56:59,510 --> 00:56:57,680

goldstone arecibo asteroid

1574

00:57:01,589 --> 00:56:59,520

in terms of planetary missions cassini

1575

00:57:03,190 --> 00:57:01,599

magellan had radars that shared the

1576

00:57:05,510 --> 00:57:03,200

communications dish

1577

00:57:07,829 --> 00:57:05,520

there have been three sounding missions

1578

00:57:09,430 --> 00:57:07,839

two to mars mro and mars express and

1579

00:57:11,109 --> 00:57:09,440

then the rosetta concert radar heading

1580

00:57:13,349 --> 00:57:11,119

to the comet

1581

00:57:14,870 --> 00:57:13,359

um

1582

00:57:16,470 --> 00:57:14,880

old mars rovers have gotten where they

1583

00:57:18,630 --> 00:57:16,480

needed to go with the help of landing

1584

00:57:21,109 --> 00:57:18,640

radar and the apollo and shuttle use

1585

00:57:22,870 --> 00:57:21,119

rendezvous radars and to this we can add

1586

00:57:24,150 --> 00:57:22,880

all the earth science remote sensing

1587

00:57:26,870 --> 00:57:24,160

systems

1588

00:57:30,150 --> 00:57:26,880

however for all the asteroid missions to

1589

00:57:31,030 --> 00:57:30,160

date there have been no in-situ radars

1590

00:57:33,270 --> 00:57:31,040

so

1591

00:57:35,030 --> 00:57:33,280

those were or these are primarily

1592

00:57:37,349 --> 00:57:35,040

science missions and so some of the

1593

00:57:38,549 --> 00:57:37,359

aspects of arm and

1594

00:57:40,069 --> 00:57:38,559

other parts of the initiative are a

1595

00:57:42,549 --> 00:57:40,079

little more pragmatic and so a few other

1596

00:57:44,390 --> 00:57:42,559

utilities of radar

1597

00:57:47,270 --> 00:57:44,400

can come out and contribute

1598

00:57:49,589 --> 00:57:47,280

so the first is radar sounding with the

1599

00:57:51,190 --> 00:57:49,599

simple purpose of mapping the regolith

1600

00:57:53,109 --> 00:57:51,200

so this is to get the internal structure

1601
00:57:55,829 --> 00:57:53,119
the bulk dielectric properties and so by

1602
00:57:57,750 --> 00:57:55,839
extension the density distribution

1603
00:57:59,589 --> 00:57:57,760
where to anchor redirect thrusters where

1604
00:58:01,430 --> 00:57:59,599
to pick up samples or possibly boulders

1605
00:58:02,870 --> 00:58:01,440
and of course help improve trajectory

1606
00:58:04,950 --> 00:58:02,880
estimations

1607
00:58:08,470 --> 00:58:04,960
so radar is the only active modality

1608
00:58:09,589 --> 00:58:08,480
capable of subsurface imaging

1609
00:58:11,270 --> 00:58:09,599
and there are two ways you can think

1610
00:58:13,030 --> 00:58:11,280
about doing this what i would call

1611
00:58:14,710 --> 00:58:13,040
scanline projection so this is like

1612
00:58:16,470 --> 00:58:14,720
ground penetrating radar

1613
00:58:18,150 --> 00:58:16,480

and the other is direct conversion so in

1614

00:58:19,910 --> 00:58:18,160

the first case

1615

00:58:22,069 --> 00:58:19,920

this is

1616

00:58:23,510 --> 00:58:22,079

relatively fast it gives you a basic

1617

00:58:25,670 --> 00:58:23,520

anatomy of what you're looking at

1618

00:58:27,589 --> 00:58:25,680

boundaries

1619

00:58:29,910 --> 00:58:27,599

edges this is similar to the way the

1620

00:58:31,910 --> 00:58:29,920

marxist and chirad mars polar images

1621

00:58:33,430 --> 00:58:31,920

were processed

1622

00:58:34,950 --> 00:58:33,440

the second is dielectric conversion so

1623

00:58:35,750 --> 00:58:34,960

for this you voxelize the body you're

1624

00:58:37,109 --> 00:58:35,760

interested in you have an

1625

00:58:38,630 --> 00:58:37,119

electromagnetic scattering model an

1626
00:58:40,710 --> 00:58:38,640
iterative dielectric estimation

1627
00:58:42,069 --> 00:58:40,720
technique and you solve the inverse

1628
00:58:44,309 --> 00:58:42,079
problem

1629
00:58:46,549 --> 00:58:44,319
so this is a little closer to the way

1630
00:58:48,549 --> 00:58:46,559
rosetta concert is going to be working

1631
00:58:49,990 --> 00:58:48,559
and the advantage of this is it gives

1632
00:58:51,829 --> 00:58:50,000
you the actual physical properties of

1633
00:58:53,510 --> 00:58:51,839
the body of interest

1634
00:58:55,349 --> 00:58:53,520
um the depth of penetration and the

1635
00:58:56,549 --> 00:58:55,359
resolution trade off with frequency but

1636
00:58:58,309 --> 00:58:56,559
generally you need a pretty low

1637
00:59:00,470 --> 00:58:58,319
frequency radar to do sounding so we're

1638
00:59:03,109 --> 00:59:00,480

talking hundreds of megahertz or even

1639

00:59:07,030 --> 00:59:04,710

okay so the next application is

1640

00:59:07,829 --> 00:59:07,040

tomography and you can think of this as

1641

00:59:11,589 --> 00:59:07,839

an

1642

00:59:12,950 --> 00:59:11,599

astrotomography is pretty well

1643

00:59:14,549 --> 00:59:12,960

understood

1644

00:59:16,390 --> 00:59:14,559

the echoes that come back contain range

1645

00:59:18,390 --> 00:59:16,400

information as well as doppler in terms

1646

00:59:19,829 --> 00:59:18,400

of what party asteroid is spinning

1647

00:59:21,030 --> 00:59:19,839

towards your way

1648

00:59:22,470 --> 00:59:21,040

you come back in a series of delay

1649

00:59:24,630 --> 00:59:22,480

doppler images these go into a shape

1650

00:59:26,470 --> 00:59:24,640

reconstruction algorithm and out pop the

1651
00:59:28,630 --> 00:59:26,480
size the shape the spin spin axis your

1652
00:59:29,910 --> 00:59:28,640
range of target the relative motion so

1653
00:59:31,670 --> 00:59:29,920
anything you can think to do with that

1654
00:59:33,270 --> 00:59:31,680
information you can get it from

1655
00:59:34,630 --> 00:59:33,280
radiotomography

1656
00:59:36,710 --> 00:59:34,640
the frequencies are generally a little

1657
00:59:37,829 --> 00:59:36,720
bit higher this is for resolution and

1658
00:59:39,990 --> 00:59:37,839
you don't want it to penetrate too

1659
00:59:42,309 --> 00:59:40,000
deeply and it only requires course

1660
00:59:44,230 --> 00:59:42,319
antenna pointing because

1661
00:59:45,510 --> 00:59:44,240
all the information is contained

1662
00:59:46,789 --> 00:59:45,520
in the echoes

1663
00:59:49,589 --> 00:59:46,799

so there are a lot of computing

1664

00:59:52,069 --> 00:59:49,599

technologies for tomography um

1665

00:59:53,910 --> 00:59:52,079

some things that are

1666

00:59:56,390 --> 00:59:53,920

unique maybe to radar

1667

00:59:57,910 --> 00:59:56,400

uh the first is

1668

01:00:00,549 --> 00:59:57,920

using the doppler and sort of

1669

01:00:03,030 --> 01:00:00,559

differential mode so to reassess rates

1670

01:00:05,030 --> 01:00:03,040

of change of spin due to deflection or

1671

01:00:07,270 --> 01:00:05,040

what have you

1672

01:00:09,750 --> 01:00:07,280

and the second this one's kind of new

1673

01:00:12,789 --> 01:00:09,760

it's to use delay doppler images as a

1674

01:00:14,630 --> 01:00:12,799

form of gps proxy so if you want to give

1675

01:00:16,630 --> 01:00:14,640

the spacecraft a better idea of where it

1676
01:00:18,230 --> 01:00:16,640
was you turn the radar on the body you

1677
01:00:19,750 --> 01:00:18,240
take a couple echoes and you go to a

1678
01:00:22,150 --> 01:00:19,760
table look up and you say okay now here

1679
01:00:23,430 --> 01:00:22,160
i am relative to the body and the

1680
01:00:25,670 --> 01:00:23,440
advantage is this is a direct

1681
01:00:28,630 --> 01:00:25,680
measurement and um

1682
01:00:30,789 --> 01:00:28,640
relatively fast

1683
01:00:32,309 --> 01:00:30,799
so this is the grab bag slide this has

1684
01:00:34,630 --> 01:00:32,319
some other uh

1685
01:00:37,670 --> 01:00:34,640
some overlap with some other sessions

1686
01:00:40,470 --> 01:00:37,680
so if they're gonna be multiple crafts

1687
01:00:41,990 --> 01:00:40,480
moving around rendezvous radar is

1688
01:00:43,510 --> 01:00:42,000

something to use i think the idea would

1689

01:00:46,390 --> 01:00:43,520

be to try to integrate it maybe with the

1690

01:00:48,309 --> 01:00:46,400

sounding radar to save on hardware

1691

01:00:50,230 --> 01:00:48,319

if you have a radar you can always use

1692

01:00:52,230 --> 01:00:50,240

it for altimetry and landing

1693

01:00:54,230 --> 01:00:52,240

the caveat of course in microgravity

1694

01:00:56,870 --> 01:00:54,240

with low velocities

1695

01:00:57,670 --> 01:00:56,880

is that laser rangefinders do just fine

1696

01:01:00,069 --> 01:00:57,680

um

1697

01:01:02,069 --> 01:01:00,079

but you can always use this as a backup

1698

01:01:03,510 --> 01:01:02,079

uh the next uh these two applications

1699

01:01:07,030 --> 01:01:03,520

are sort of

1700

01:01:08,710 --> 01:01:07,040

deflection rather than redirection

1701

01:01:09,990 --> 01:01:08,720

so you have two spacecraft one orbiting

1702

01:01:12,870 --> 01:01:10,000

the body another one that's going to hit

1703

01:01:14,390 --> 01:01:12,880

it you can use the delay doppler and get

1704

01:01:15,910 --> 01:01:14,400

a better sense of how it's now spinning

1705

01:01:17,349 --> 01:01:15,920

or how it's now moving

1706

01:01:18,789 --> 01:01:17,359

the advantage is it could look through

1707

01:01:20,789 --> 01:01:18,799

the ejecta and it can maybe even track

1708

01:01:23,109 --> 01:01:20,799

the ejecta

1709

01:01:24,950 --> 01:01:23,119

and finally

1710

01:01:25,990 --> 01:01:24,960

so this is this is a little different a

1711

01:01:28,470 --> 01:01:26,000

little new

1712

01:01:31,430 --> 01:01:28,480

uh this is a case of uh a single

1713

01:01:33,109 --> 01:01:31,440

spacecraft based uh redeflection impact

1714

01:01:33,990 --> 01:01:33,119

base reflection

1715

01:01:35,430 --> 01:01:34,000

uh

1716

01:01:36,950 --> 01:01:35,440

so let's say you're three to four days

1717

01:01:38,390 --> 01:01:36,960

out from the body you turn the comm

1718

01:01:40,069 --> 01:01:38,400

antenna on the asteroid

1719

01:01:41,910 --> 01:01:40,079

you do the tomography problem

1720

01:01:45,670 --> 01:01:41,920

give the craft an idea of

1721

01:01:49,670 --> 01:01:45,680

where and when exactly it's going to hit

1722

01:01:53,270 --> 01:01:51,670

okay in terms of system configurations

1723

01:01:55,190 --> 01:01:53,280

uh to do tomography and sounding you

1724

01:01:56,470 --> 01:01:55,200

actually only need one antenna which is

1725

01:01:57,829 --> 01:01:56,480

uh kind of nice

1726

01:02:00,069 --> 01:01:57,839

for sounding though it needs its own

1727

01:02:01,349 --> 01:02:00,079

separate low frequency antenna

1728

01:02:02,789 --> 01:02:01,359

um

1729

01:02:04,470 --> 01:02:02,799

if you double up on the communication

1730

01:02:06,549 --> 01:02:04,480

dish you'll be at the higher frequencies

1731

01:02:09,190 --> 01:02:06,559

probably of the dsn and so you're

1732

01:02:11,270 --> 01:02:09,200

limited to some of those applications

1733

01:02:13,990 --> 01:02:11,280

in terms of power what you need to run

1734

01:02:16,710 --> 01:02:14,000

these systems it just goes with range

1735

01:02:19,349 --> 01:02:16,720

to give you some examples

1736

01:02:21,750 --> 01:02:19,359

earth observing radars typically operate

1737

01:02:24,309 --> 01:02:21,760

in one kilowatt peak power range

1738

01:02:25,670 --> 01:02:24,319

airborne systems 10 watts um and if

1739

01:02:27,910 --> 01:02:25,680

you're really close for whatever reason

1740

01:02:29,349 --> 01:02:27,920

you could use your cell phone

1741

01:02:30,390 --> 01:02:29,359

and so

1742

01:02:32,390 --> 01:02:30,400

uh

1743

01:02:34,309 --> 01:02:32,400

scanline sounding ultimate retargeting

1744

01:02:36,230 --> 01:02:34,319

and some tomography there are candidates

1745

01:02:37,589 --> 01:02:36,240

for onboard processing uh direct

1746

01:02:38,870 --> 01:02:37,599

conversion and more sophisticated

1747

01:02:40,390 --> 01:02:38,880

demography are probably gonna have to be

1748

01:02:42,390 --> 01:02:40,400

sent back

1749

01:02:43,270 --> 01:02:42,400

and um i'll just wrap this up by saying

1750

01:02:44,630 --> 01:02:43,280

that

1751

01:02:45,589 --> 01:02:44,640

you know electromagnetic scattering

1752

01:02:50,630 --> 01:02:45,599

models

1753

01:02:52,230 --> 01:02:50,640

have gotten to the point where we can

1754

01:02:56,470 --> 01:02:52,240

actually simulate these systems end to

1755

01:02:57,990 --> 01:02:56,480

end before turning a screw and so we can

1756

01:02:59,670 --> 01:02:58,000

tweak the frequencies really assess

1757

01:03:03,589 --> 01:02:59,680

whether or not they're going to work at

1758

01:03:07,670 --> 01:03:05,349

so that's it again these applications

1759

01:03:10,870 --> 01:03:07,680

were mostly uh characterization and

1760

01:03:18,390 --> 01:03:10,880

avionics based and

1761

01:03:18,400 --> 01:03:28,069

okay we've got time for questions

1762

01:03:34,870 --> 01:03:31,349

see any online although we are delayed a

1763

01:03:34,880 --> 01:03:38,870

yep i got one

1764

01:03:42,549 --> 01:03:40,710

is there is there any advantage of

1765

01:03:44,950 --> 01:03:42,559

having a lot of power you know you said

1766

01:03:46,630 --> 01:03:44,960

a kilowatt from earth orbiting systems

1767

01:03:48,789 --> 01:03:46,640

but we're gonna have a spacecraft that

1768

01:03:51,349 --> 01:03:48,799

might have a lot of power

1769

01:03:52,549 --> 01:03:51,359

will that provide you any advantages oh

1770

01:03:53,670 --> 01:03:52,559

yeah

1771

01:03:56,390 --> 01:03:53,680

um

1772

01:03:58,789 --> 01:03:56,400

uh snr it will always help

1773

01:04:00,950 --> 01:03:58,799

and then you can just do these um

1774

01:04:03,910 --> 01:04:00,960

you can have much uh higher orbits you

1775

01:04:13,349 --> 01:04:03,920

can do the same work much further away

1776

01:04:16,710 --> 01:04:14,950

all right thank you

1777

01:04:18,390 --> 01:04:16,720

all right let's see

1778

01:04:19,270 --> 01:04:18,400

we got to check um

1779

01:04:22,069 --> 01:04:19,280

we

1780

01:04:26,069 --> 01:04:22,079

had intended the next presenter to be um

1781

01:04:26,079 --> 01:04:32,230

is

1782

01:04:35,190 --> 01:04:33,510

okay great

1783

01:04:38,069 --> 01:04:35,200

thank you

1784

01:04:43,470 --> 01:04:40,870

paul is a project manager for mda

1785

01:04:45,990 --> 01:04:43,480

mda of course is the uh

1786

01:04:47,510 --> 01:04:46,000

macdonald associates is the canadian

1787

01:04:50,309 --> 01:04:47,520

space agency prime contractor for

1788

01:04:52,549 --> 01:04:50,319

robotics on space shuttle and iss

1789

01:04:53,910 --> 01:04:52,559

paul will be discussing how the arm can

1790

01:04:55,349 --> 01:04:53,920

benefit from state-of-the-art

1791

01:04:57,750 --> 01:04:55,359

developments in the area of rendezvous

1792

01:05:00,549 --> 01:04:57,760

and proxima proximity operations and in

1793

01:05:02,870 --> 01:05:00,559

satellite servicing domains well

1794

01:05:05,190 --> 01:05:02,880

okay thank you everybody um so we

1795

01:05:06,630 --> 01:05:05,200

started off uh looking at this problem

1796

01:05:08,950 --> 01:05:06,640

we had a good time by the way looking at

1797

01:05:11,750 --> 01:05:08,960

this problem but we broke it down the

1798

01:05:13,829 --> 01:05:11,760

same way we would break down any

1799

01:05:14,789 --> 01:05:13,839

satellite operation that we've done in

1800

01:05:16,789 --> 01:05:14,799

the past

1801

01:05:19,349 --> 01:05:16,799

so we broke it down into rendezvous

1802

01:05:20,950 --> 01:05:19,359

proximity operations and capture

1803

01:05:23,109 --> 01:05:20,960

today's presentation is on the

1804

01:05:24,470 --> 01:05:23,119

rendezvous and the proximity operations

1805

01:05:27,829 --> 01:05:24,480

and tomorrow i will be giving a

1806

01:05:33,109 --> 01:05:30,950

so just to give a very quick overview

1807

01:05:35,349 --> 01:05:33,119

mda has been focused on these type of

1808

01:05:37,750 --> 01:05:35,359

activities for decades

1809

01:05:40,470 --> 01:05:37,760

so it started back in the 70s with the

1810

01:05:42,309 --> 01:05:40,480

development of canadarm or srms for the

1811

01:05:43,190 --> 01:05:42,319

shuttle program

1812

01:05:44,470 --> 01:05:43,200

and

1813

01:05:45,670 --> 01:05:44,480

includes

1814

01:05:47,510 --> 01:05:45,680

significant

1815

01:05:48,950 --> 01:05:47,520

rendezvous and capture of the hubble

1816

01:05:51,670 --> 01:05:48,960

space telescope

1817

01:05:54,150 --> 01:05:51,680

four times from from the shuttle

1818

01:05:57,910 --> 01:05:54,160

we've also actually captured the shuttle

1819

01:05:59,510 --> 01:05:57,920

from station using canadarm2 as well

1820

01:06:01,430 --> 01:05:59,520

then we've done different developments

1821

01:06:03,430 --> 01:06:01,440

and i'll echo some of the sentiments of

1822

01:06:04,470 --> 01:06:03,440

other folks here but we

1823

01:06:07,990 --> 01:06:04,480

provided

1824

01:06:09,910 --> 01:06:08,000

scanning lidar systems for xss-11

1825

01:06:13,750 --> 01:06:09,920

and the robotic

1826
01:06:15,910 --> 01:06:13,760
autonomous systems for orbital express

1827
01:06:17,910 --> 01:06:15,920
in recent times the canadian space

1828
01:06:20,309 --> 01:06:17,920
agency has invested over 50 million

1829
01:06:22,950 --> 01:06:20,319
dollars in in prototyping for what they

1830
01:06:26,870 --> 01:06:22,960
call the next generation canadarm

1831
01:06:31,270 --> 01:06:26,880
and in all of that it uh it has included

1832
01:06:33,990 --> 01:06:31,280
rendezvous and proximity operations

1833
01:06:35,430 --> 01:06:34,000
so so just to draw the parallels and i

1834
01:06:38,470 --> 01:06:35,440
know that everybody's walked through

1835
01:06:40,470 --> 01:06:38,480
this as well the the typical operational

1836
01:06:42,069 --> 01:06:40,480
steps include long range and short range

1837
01:06:44,470 --> 01:06:42,079
rendezvous

1838
01:06:47,829 --> 01:06:44,480

scanning and mapping rate matching close

1839

01:06:50,230 --> 01:06:47,839

proximity operations etc

1840

01:06:51,910 --> 01:06:50,240

and uh just on the right we're showing

1841

01:06:54,470 --> 01:06:51,920

some of the heritage that we have in

1842

01:06:57,190 --> 01:06:54,480

addressing that

1843

01:06:58,230 --> 01:06:57,200

so for the next section uh on the

1844

01:06:59,589 --> 01:06:58,240

integrated

1845

01:07:02,069 --> 01:06:59,599

sensor suite

1846

01:07:04,230 --> 01:07:02,079

uh focus on on these aspects of the

1847

01:07:06,069 --> 01:07:04,240

conops

1848

01:07:07,670 --> 01:07:06,079

so

1849

01:07:10,630 --> 01:07:07,680

i i believe the gentleman from ball

1850

01:07:12,069 --> 01:07:10,640

aerospace had almost the exact same uh

1851
01:07:13,589 --> 01:07:12,079
instrument suite which i think is good

1852
01:07:15,190 --> 01:07:13,599
we're starting to synthesize we're all

1853
01:07:18,230 --> 01:07:15,200
starting to come together

1854
01:07:20,950 --> 01:07:18,240
what we were proposing was for far field

1855
01:07:22,470 --> 01:07:20,960
long range to have a narrow angle

1856
01:07:24,390 --> 01:07:22,480
camera

1857
01:07:26,470 --> 01:07:24,400
that picks up bearing information and

1858
01:07:28,710 --> 01:07:26,480
then as you get closer you actually

1859
01:07:32,150 --> 01:07:28,720
combine the narrow angle camera with a

1860
01:07:34,549 --> 01:07:32,160
lidar and the laser altimeter that mda

1861
01:07:37,349 --> 01:07:34,559
is developing for osiris-rex would be

1862
01:07:39,510 --> 01:07:37,359
coupled with the narrow angle camera

1863
01:07:41,430 --> 01:07:39,520

which would give you bearing and range

1864

01:07:44,069 --> 01:07:41,440

and then as you get closer you'd have a

1865

01:07:45,510 --> 01:07:44,079

wider angle camera

1866

01:07:47,589 --> 01:07:45,520

that begins to give you detailed

1867

01:07:49,829 --> 01:07:47,599

features of the asteroid and then that

1868

01:07:52,549 --> 01:07:49,839

would be coupled with flashlifter

1869

01:07:53,990 --> 01:07:52,559

and mda has been doing work

1870

01:07:56,309 --> 01:07:54,000

similar to

1871

01:07:57,670 --> 01:07:56,319

slam or simultaneous localization and

1872

01:07:59,029 --> 01:07:57,680

mapping

1873

01:08:01,190 --> 01:07:59,039

we have

1874

01:08:05,109 --> 01:08:01,200

two coupled

1875

01:08:07,270 --> 01:08:05,119

phonak robots in a lab where we

1876

01:08:08,789 --> 01:08:07,280

basically generate models using

1877

01:08:11,430 --> 01:08:08,799

three-dimensional and two-dimensional

1878

01:08:13,510 --> 01:08:11,440

data we generate those models we port

1879

01:08:17,910 --> 01:08:13,520

them back and use the models to do close

1880

01:08:21,510 --> 01:08:19,430

also following down the concept of

1881

01:08:23,829 --> 01:08:21,520

operations to look at close proximity

1882

01:08:26,149 --> 01:08:23,839

capture and autonomy

1883

01:08:28,630 --> 01:08:26,159

mda has done a lot of work not only in

1884

01:08:30,550 --> 01:08:28,640

orbital robotics but also in rover

1885

01:08:32,709 --> 01:08:30,560

systems

1886

01:08:34,070 --> 01:08:32,719

and

1887

01:08:35,910 --> 01:08:34,080

just to give you an idea of the state of

1888

01:08:37,829 --> 01:08:35,920

the arts so on the international space

1889

01:08:39,430 --> 01:08:37,839

station right now there's the dexter

1890

01:08:41,590 --> 01:08:39,440

robot or what we call the special

1891

01:08:43,430 --> 01:08:41,600

purpose dexterous manipulator

1892

01:08:44,229 --> 01:08:43,440

and canadarm2

1893

01:08:46,229 --> 01:08:44,239

and

1894

01:08:48,149 --> 01:08:46,239

those

1895

01:08:50,309 --> 01:08:48,159

robots are currently being operated from

1896

01:08:52,470 --> 01:08:50,319

the ground so to give an idea of where

1897

01:08:53,910 --> 01:08:52,480

it's come to originally they had to have

1898

01:08:57,030 --> 01:08:53,920

the operator in the loop in close

1899

01:08:58,550 --> 01:08:57,040

proximity now the ground crew is at

1900

01:09:01,669 --> 01:08:58,560

johnson space center or the canadian

1901

01:09:03,590 --> 01:09:01,679

space agency the astronauts are asleep

1902

01:09:06,470 --> 01:09:03,600

and they they begin to go and do all

1903

01:09:10,309 --> 01:09:06,480

these dexterous tasks

1904

01:09:13,189 --> 01:09:10,319

at uh goddard also mentioned the rrm

1905

01:09:14,950 --> 01:09:13,199

mission or the robotic refueling mission

1906

01:09:17,189 --> 01:09:14,960

uh that focused on unprepared and

1907

01:09:20,550 --> 01:09:17,199

uncooperative capture

1908

01:09:23,189 --> 01:09:20,560

fill and drain valve refueling and mli

1909

01:09:25,189 --> 01:09:23,199

blanket removal and again all of those

1910

01:09:27,349 --> 01:09:25,199

all of those tasks were done

1911

01:09:28,550 --> 01:09:27,359

with a 15 degree of freedom manipulator

1912

01:09:29,749 --> 01:09:28,560

on the end of

1913

01:09:31,590 --> 01:09:29,759

a

1914

01:09:34,229 --> 01:09:31,600

30 foot long

1915

01:09:36,390 --> 01:09:34,239

canadarm2 operated from the ground all

1916

01:09:38,470 --> 01:09:36,400

happening successfully

1917

01:09:41,269 --> 01:09:38,480

mda has also been looking at low

1918

01:09:43,030 --> 01:09:41,279

bandwidth high latency situations

1919

01:09:44,870 --> 01:09:43,040

and we've had a variety of contracts

1920

01:09:47,189 --> 01:09:44,880

with the canadian space agency looking

1921

01:09:49,590 --> 01:09:47,199

at variable autonomy and variable

1922

01:09:53,030 --> 01:09:49,600

autonomy we consider it a spectrum

1923

01:09:54,709 --> 01:09:53,040

and it ranges from teleoperation to

1924

01:09:57,030 --> 01:09:54,719

rigorous rehearsed

1925

01:09:58,390 --> 01:09:57,040

scripted operations to supervised

1926

01:10:00,630 --> 01:09:58,400

autonomy

1927

01:10:02,709 --> 01:10:00,640

not dissimilar to how the curiosity

1928

01:10:05,350 --> 01:10:02,719

rover landed on mars that there comes a

1929

01:10:07,270 --> 01:10:05,360

point where operator in the loop does no

1930

01:10:09,110 --> 01:10:07,280

longer make sense

1931

01:10:10,870 --> 01:10:09,120

via ground control we've actually

1932

01:10:13,350 --> 01:10:10,880

demonstrated this in conjunction with

1933

01:10:15,030 --> 01:10:13,360

boeing for orbital express

1934

01:10:17,590 --> 01:10:15,040

where the manipulator

1935

01:10:21,910 --> 01:10:17,600

close the loop with cameras as the

1936

01:10:26,790 --> 01:10:23,910

and i don't have a concluding slide just

1937

01:10:32,630 --> 01:10:26,800

for the sake of time

1938

01:10:36,310 --> 01:10:35,350

um we have time for questions

1939

01:10:39,030 --> 01:10:36,320

if

1940

01:10:40,709 --> 01:10:39,040

any in the room or virtually

1941

01:10:43,189 --> 01:10:40,719

there is a question here

1942

01:10:44,870 --> 01:10:43,199

why uh the user sorry

1943

01:10:47,030 --> 01:10:44,880

why the use of both a scanning and a

1944

01:11:06,390 --> 01:10:47,040

flash lighter

1945

01:11:09,830 --> 01:11:08,470

it gives you

1946

01:11:12,149 --> 01:11:09,840

your six degrees of freedom

1947

01:11:14,229 --> 01:11:12,159

instantaneous estimation similar to that

1948

01:11:16,390 --> 01:11:14,239

of a video camera

1949

01:11:17,750 --> 01:11:16,400

and then you you match that model with

1950

01:11:20,630 --> 01:11:17,760

the model that you've

1951

01:11:22,149 --> 01:11:20,640

created using your your laser altimeter

1952

01:11:31,430 --> 01:11:22,159

or your scanning ladder

1953

01:11:34,790 --> 01:11:33,510

i don't think i can answer that

1954

01:11:38,390 --> 01:11:34,800

i don't think i'm able to answer that

1955

01:11:38,400 --> 01:11:43,510

go ahead if you could go to a mic please

1956

01:11:49,110 --> 01:11:45,830

it's a quick one uh no one so far has

1957

01:11:51,669 --> 01:11:49,120

mentioned the use of automotive radars

1958

01:11:55,030 --> 01:11:51,679

in the rendezvous but tyvac were funded

1959

01:11:56,870 --> 01:11:55,040

to do this under the edison call last

1960

01:12:03,750 --> 01:11:56,880

year i believe and it seems like it's a

1961

01:12:07,030 --> 01:12:05,990

automotive radars uh

1962

01:12:12,229 --> 01:12:07,040

i'm

1963

01:12:14,390 --> 01:12:12,239

to that anyone else want to come in yes

1964

01:12:19,430 --> 01:12:14,400

really high frequencies if you could go

1965

01:12:23,750 --> 01:12:21,590

automotive radars uh they tend to work

1966

01:12:25,270 --> 01:12:23,760

it who asks the question

1967

01:12:26,229 --> 01:12:25,280

anyway sorry

1968

01:12:27,910 --> 01:12:26,239

they tend to work at really high

1969

01:12:29,350 --> 01:12:27,920

frequencies and so they're you know

1970

01:12:30,790 --> 01:12:29,360

expensive and

1971

01:12:32,470 --> 01:12:30,800

but um

1972

01:12:34,149 --> 01:12:32,480

but uh the rendezvous is mostly in the

1973

01:12:35,750 --> 01:12:34,159

protocol i think a lot of that so you

1974

01:12:40,310 --> 01:12:35,760

can still use the antennas and still use

1975

01:12:50,149 --> 01:12:42,390

anything else

1976

01:12:56,229 --> 01:12:52,870

david gump is our next speaker

1977

01:12:58,550 --> 01:12:56,239

david is ceo of deep space industries

1978

01:13:00,310 --> 01:12:58,560

dsi is focusing on low-cost scouting

1979

01:13:01,830 --> 01:13:00,320

missions to characterize asteroid

1980

01:13:03,110 --> 01:13:01,840

resources

1981

01:13:05,030 --> 01:13:03,120

and developing and parallel the

1982

01:13:07,270 --> 01:13:05,040

technologies to process asteroid

1983

01:13:09,189 --> 01:13:07,280

material into useful products

1984

01:13:11,590 --> 01:13:09,199

his presentation outlines reasons for

1985

01:13:13,350 --> 01:13:11,600

replacing the textile return of a small

1986

01:13:16,390 --> 01:13:13,360

asteroid with a mission that returns

1987

01:13:17,669 --> 01:13:16,400

multiple samples from a larger target

1988

01:13:20,070 --> 01:13:17,679

the goal is achievement of better

1989

01:13:21,910 --> 01:13:20,080

results for both science and industry

1990

01:13:24,390 --> 01:13:21,920

while reducing several types of mission

1991

01:13:28,709 --> 01:13:26,630

thank you

1992

01:13:31,669 --> 01:13:28,719

the textile approach the baseline that

1993

01:13:33,350 --> 01:13:31,679

nasa has now i think has unacceptable

1994

01:13:35,750 --> 01:13:33,360

risk for

1995

01:13:38,149 --> 01:13:35,760

failure because if all you're going on

1996

01:13:39,590 --> 01:13:38,159

is the magnitude

1997

01:13:44,070 --> 01:13:39,600

the

1998

01:13:45,990 --> 01:13:44,080

for say 200 tons return could encounter

1999

01:13:47,990 --> 01:13:46,000

very easily something at 500 tons or a

2000

01:13:50,390 --> 01:13:48,000

thousand tons

2001

01:13:52,070 --> 01:13:50,400

even if your target has been

2002

01:13:54,390 --> 01:13:52,080

considerate and actually flown by earth

2003

01:13:57,669 --> 01:13:54,400

for a rater observation you still only

2004

01:13:58,790 --> 01:13:57,679

know volume you don't know mass

2005

01:14:00,229 --> 01:13:58,800

the other point i'd like to make during

2006

01:14:02,390 --> 01:14:00,239

the presentation is that scouting

2007

01:14:04,390 --> 01:14:02,400

missions are really essential to bring

2008

01:14:06,550 --> 01:14:04,400

down mass uncertainty as well as other

2009

01:14:08,790 --> 01:14:06,560

uncertainties

2010

01:14:10,790 --> 01:14:08,800

we also believe that

2011

01:14:11,750 --> 01:14:10,800

you ought to be fishing where the fish

2012

01:14:13,830 --> 01:14:11,760

are

2013

01:14:16,470 --> 01:14:13,840

you know the vast majority of asteroids

2014

01:14:19,270 --> 01:14:16,480

are not seven meters in size

2015

01:14:21,270 --> 01:14:19,280

and for repeatability and sustainability

2016

01:14:23,990 --> 01:14:21,280

you ought to have a gathering of

2017

01:14:27,350 --> 01:14:24,000

materials approach which is applicable

2018

01:14:29,189 --> 01:14:27,360

to a vast range of asteroid sizes not

2019

01:14:31,189 --> 01:14:29,199

just the special case

2020

01:14:33,590 --> 01:14:31,199

and besides this just easier and we

2021

01:14:36,070 --> 01:14:33,600

ought to be going easier on this than

2022

01:14:37,669 --> 01:14:36,080

making our life hard to detect

2023

01:14:39,189 --> 01:14:37,679

to get enough photons to actually do

2024

01:14:41,430 --> 01:14:39,199

characterization

2025

01:14:43,030 --> 01:14:41,440

when you're out in the deep dark

2026

01:14:44,630 --> 01:14:43,040

people have already pointed out that

2027

01:14:47,510 --> 01:14:44,640

it's going to be hard to actually

2028

01:14:49,430 --> 01:14:47,520

acquire for closing the target if it's

2029

01:14:50,790 --> 01:14:49,440

an extremely tiny one

2030

01:14:53,189 --> 01:14:50,800

large

2031

01:14:54,630 --> 01:14:53,199

neos are easier to land on because they

2032

01:14:57,350 --> 01:14:54,640

spin slower

2033

01:14:59,830 --> 01:14:57,360

and perhaps most importantly

2034

01:15:02,390 --> 01:14:59,840

congress your customer has said they are

2035

01:15:04,229 --> 01:15:02,400

interested in medium and large asteroids

2036

01:15:07,990 --> 01:15:04,239

things big enough to kill their

2037

01:15:11,189 --> 01:15:09,590

they want them both detected and

2038

01:15:12,390 --> 01:15:11,199

characterized which scouting missions

2039

01:15:13,990 --> 01:15:12,400

can do

2040

01:15:16,310 --> 01:15:14,000

we don't have any photographs of things

2041

01:15:18,790 --> 01:15:16,320

a little smaller than 500 meters

2042

01:15:21,110 --> 01:15:18,800

and so we don't know if they do in fact

2043

01:15:23,510 --> 01:15:21,120

transition from rubble piles down to

2044

01:15:25,669 --> 01:15:23,520

monoliths or whether they stay monoliths

2045

01:15:27,590 --> 01:15:25,679

down stay rubble piles down to smaller

2046

01:15:31,990 --> 01:15:27,600

sizes

2047

01:15:35,830 --> 01:15:32,000

angeles or you know really mess with

2048

01:15:40,550 --> 01:15:38,630

so we think in general terms because of

2049

01:15:43,110 --> 01:15:40,560

all these questions you ought to design

2050

01:15:44,870 --> 01:15:43,120

the program both for the retrieval

2051

01:15:47,270 --> 01:15:44,880

mission and for scouting missions before

2052

01:15:48,229 --> 01:15:47,280

you leap into designing a specific

2053

01:15:49,990 --> 01:15:48,239

mission

2054

01:15:52,709 --> 01:15:50,000

and there ought to be demonstrated a

2055

01:15:55,750 --> 01:15:52,719

method that's generally useful and not

2056

01:15:58,390 --> 01:15:55,760

limited to rare situations of of small

2057

01:15:59,590 --> 01:15:58,400

asteroids coupled with a billion dollar

2058

01:16:01,990 --> 01:15:59,600

sls

2059

01:16:03,270 --> 01:16:02,000

that is not a sustainable approach we

2060

01:16:05,110 --> 01:16:03,280

don't believe

2061

01:16:06,950 --> 01:16:05,120

we think the basic program that we would

2062

01:16:09,430 --> 01:16:06,960

propose would be modeled on cots you've

2063

01:16:12,149 --> 01:16:09,440

now got two successful cuts

2064

01:16:15,590 --> 01:16:12,159

systems in operation as well as the the

2065

01:16:17,350 --> 01:16:15,600

iled that nasa has a in place for the

2066

01:16:19,110 --> 01:16:17,360

google lunar xprize

2067

01:16:21,350 --> 01:16:19,120

competitors

2068

01:16:22,950 --> 01:16:21,360

very simple you do fixed price and below

2069

01:16:24,070 --> 01:16:22,960

cost so there has to be private

2070

01:16:26,229 --> 01:16:24,080

investment

2071

01:16:28,390 --> 01:16:26,239

companies competing companies get paid

2072

01:16:29,430 --> 01:16:28,400

for achieving milestones and not just

2073

01:16:31,350 --> 01:16:29,440

submitting

2074

01:16:34,470 --> 01:16:31,360

monthly invoices

2075

01:16:37,030 --> 01:16:34,480

nasa would specify what it needs for its

2076

01:16:39,350 --> 01:16:37,040

applications and its needs and industry

2077

01:16:41,990 --> 01:16:39,360

would fund the delta for everything else

2078

01:16:43,030 --> 01:16:42,000

in the fullness of time most likely

2079

01:16:44,630 --> 01:16:43,040

on a

2080

01:16:46,229 --> 01:16:44,640

nasa would be

2081

01:16:48,550 --> 01:16:46,239

forced through budget

2082

01:16:51,030 --> 01:16:48,560

requirements to go for a disposable

2083

01:16:53,350 --> 01:16:51,040

spacecraft

2084

01:16:56,070 --> 01:16:53,360

industry to serve commercial needs

2085

01:16:58,630 --> 01:16:56,080

ongoing wants a reusable spacecraft

2086

01:17:01,510 --> 01:16:58,640

industry would pay for the delta between

2087

01:17:03,430 --> 01:17:01,520

what's required to support nasa's needs

2088

01:17:05,030 --> 01:17:03,440

and what's necessary for commercial

2089

01:17:06,950 --> 01:17:05,040

markets

2090

01:17:08,950 --> 01:17:06,960

and the resulting system then is

2091

01:17:11,110 --> 01:17:08,960

sustainable it's in place it's serving

2092

01:17:13,910 --> 01:17:11,120

commercial customers for propellant and

2093

01:17:16,709 --> 01:17:13,920

for materials in orbit if there's a year

2094

01:17:19,110 --> 01:17:16,719

or two pause in nasa funding for for

2095

01:17:23,430 --> 01:17:19,120

asteroid missions nothing comes to a

2096

01:17:28,550 --> 01:17:25,669

another good thing about the gather

2097

01:17:30,709 --> 01:17:28,560

materials approach is that the arv size

2098

01:17:32,870 --> 01:17:30,719

is independent of the asteroid size you

2099

01:17:34,470 --> 01:17:32,880

could do smaller arvs

2100

01:17:35,590 --> 01:17:34,480

in the early days to reduce mission

2101

01:17:37,270 --> 01:17:35,600

costs

2102

01:17:39,189 --> 01:17:37,280

and the collection process can be

2103

01:17:40,870 --> 01:17:39,199

selective

2104

01:17:42,950 --> 01:17:40,880

there are different colored boulders on

2105

01:17:45,110 --> 01:17:42,960

iroquois hitacaba for example you might

2106

01:17:46,870 --> 01:17:45,120

want to go for a specific color you

2107

01:17:49,110 --> 01:17:46,880

might want to go for sand and gravel

2108

01:17:51,430 --> 01:17:49,120

because the processing step that you're

2109

01:17:53,189 --> 01:17:51,440

going to bring it back to put it into

2110

01:17:55,510 --> 01:17:53,199

would like it already crushed you can

2111

01:17:57,590 --> 01:17:55,520

gather the already crushed materials if

2112

01:17:59,910 --> 01:17:57,600

you've developed at the beginning a

2113

01:18:01,669 --> 01:17:59,920

gathering of materials approach as to as

2114

01:18:03,830 --> 01:18:01,679

opposed to a swallowing of an asteroid

2115

01:18:06,149 --> 01:18:03,840

approach

2116

01:18:08,550 --> 01:18:06,159

we believe scouting missions can

2117

01:18:11,350 --> 01:18:08,560

collectively among them deliver

2118

01:18:12,550 --> 01:18:11,360

as much material as orion's 100 kilogram

2119

01:18:14,630 --> 01:18:12,560

return limit

2120

01:18:16,229 --> 01:18:14,640

and to be coming from diverse sources

2121

01:18:18,229 --> 01:18:16,239

better for scientists better for

2122

01:18:20,149 --> 01:18:18,239

resource discovery

2123

01:18:21,830 --> 01:18:20,159

you know you'll get much richer data

2124

01:18:24,790 --> 01:18:21,840

from that kind of approach to supplying

2125

01:18:28,070 --> 01:18:24,800

things for the orion sls flight

2126

01:18:30,630 --> 01:18:28,080

we've done some of the initial math

2127

01:18:32,310 --> 01:18:30,640

on this chart the vertical is kilometers

2128

01:18:34,070 --> 01:18:32,320

per second delta v

2129

01:18:36,229 --> 01:18:34,080

we've found as a rule of thumb the

2130

01:18:39,350 --> 01:18:36,239

outbound delta v and the inbound return

2131

01:18:42,550 --> 01:18:39,360

delta v are roughly the same

2132

01:18:46,630 --> 01:18:42,560

this is starting from uh c3 of zero when

2133

01:18:50,470 --> 01:18:48,229

you could launch a scout mission with

2134

01:18:52,790 --> 01:18:50,480

that first arrow in 2015

2135

01:18:54,390 --> 01:18:52,800

it would get there a year later in 2016

2136

01:18:57,350 --> 01:18:54,400

at the second area you gather some

2137

01:18:59,510 --> 01:18:57,360

material you get back a year later in in

2138

01:19:01,590 --> 01:18:59,520

2017

2139

01:19:03,750 --> 01:19:01,600

and then you have a full year to analyze

2140

01:19:05,830 --> 01:19:03,760

that material before you have to launch

2141

01:19:08,390 --> 01:19:05,840

the retrieval mission with only about

2142

01:19:10,550 --> 01:19:08,400

two kilometers per second required it

2143

01:19:12,470 --> 01:19:10,560

takes a year to to get there and then

2144

01:19:13,990 --> 01:19:12,480

you have quite a bit of time before you

2145

01:19:15,750 --> 01:19:14,000

have to do your return you could

2146

01:19:19,510 --> 01:19:15,760

actually return for less than two

2147

01:19:20,390 --> 01:19:19,520

kilometers per second that's 2001 gp

2148

01:19:22,870 --> 01:19:20,400

two

2149

01:19:26,310 --> 01:19:22,880

this this other one track we've done uh

2150

01:19:29,030 --> 01:19:26,320

2013 bs45 is very convenient you could

2151
01:19:31,910 --> 01:19:29,040
do scout missions at several points

2152
01:19:34,229 --> 01:19:31,920
along this this track and still have

2153
01:19:37,669 --> 01:19:34,239
time in the outer years to do your arn

2154
01:19:41,910 --> 01:19:37,679
mission again at a fairly low

2155
01:19:44,310 --> 01:19:42,790
so

2156
01:19:46,070 --> 01:19:44,320
we think that if you

2157
01:19:48,310 --> 01:19:46,080
design this program so it serves both

2158
01:19:50,470 --> 01:19:48,320
nasa and commercial needs nasa will get

2159
01:19:52,149 --> 01:19:50,480
the propellant and materials in orbit

2160
01:19:54,229 --> 01:19:52,159
that it needs to make getting to mars

2161
01:19:56,630 --> 01:19:54,239
less expensive industry gets what it

2162
01:19:59,189 --> 01:19:56,640
needs for its grandiose plans

2163
01:20:01,270 --> 01:19:59,199

and everyone benefits it's synergistic

2164

01:20:03,750 --> 01:20:01,280

and in the short term what we need to do

2165

01:20:05,830 --> 01:20:03,760

is commission several precursors to do

2166

01:20:07,910 --> 01:20:05,840

rendezvous and sample return missions

2167

01:20:09,350 --> 01:20:07,920

previous speakers have have

2168

01:20:11,669 --> 01:20:09,360

described

2169

01:20:14,390 --> 01:20:11,679

ar arvs

2170

01:20:15,990 --> 01:20:14,400

loaded with instruments just to find out

2171

01:20:18,950 --> 01:20:16,000

what the mass of the target that they're

2172

01:20:20,790 --> 01:20:18,960

already committed to getting would be

2173

01:20:22,390 --> 01:20:20,800

you need that information

2174

01:20:24,550 --> 01:20:22,400

before you launch

2175

01:20:26,070 --> 01:20:24,560

before you've committed to that target

2176
01:20:27,430 --> 01:20:26,080
the other thing we think we need in the

2177
01:20:29,430 --> 01:20:27,440
short term as a

2178
01:20:31,669 --> 01:20:29,440
baa for

2179
01:20:33,750 --> 01:20:31,679
asteroid recovery mission ideas

2180
01:20:35,030 --> 01:20:33,760
on on how to gather mission material

2181
01:20:37,430 --> 01:20:35,040
from any size

2182
01:20:40,390 --> 01:20:37,440
nea and and how to structure it so it

2183
01:20:41,669 --> 01:20:40,400
works on an industry based approach

2184
01:20:44,470 --> 01:20:41,679
and

2185
01:20:47,270 --> 01:20:44,480
finally with arv size unhitched from

2186
01:20:49,350 --> 01:20:47,280
from asteroid size

2187
01:20:50,870 --> 01:20:49,360
we should be optimizing for for the

2188
01:20:53,669 --> 01:20:50,880

least cost

2189

01:20:55,110 --> 01:20:53,679

it's it's very grand to set a really big

2190

01:20:57,350 --> 01:20:55,120

technical goal

2191

01:21:00,550 --> 01:20:57,360

like a you know a gigawatt of onboard

2192

01:21:01,910 --> 01:21:00,560

power for your iron propulsion

2193

01:21:04,070 --> 01:21:01,920

but if that turns out to cost you a

2194

01:21:06,229 --> 01:21:04,080

billion dollars a mission

2195

01:21:08,310 --> 01:21:06,239

you might do it once but you'll never do

2196

01:21:10,070 --> 01:21:08,320

it again

2197

01:21:12,470 --> 01:21:10,080

in the future where all of us will have

2198

01:21:14,310 --> 01:21:12,480

to be much more sensitive to designing

2199

01:21:15,590 --> 01:21:14,320

least cost combinations that can be

2200

01:21:17,110 --> 01:21:15,600

sustained

2201
01:21:18,870 --> 01:21:17,120
versus

2202
01:21:19,910 --> 01:21:18,880
setting a technical goal that's really

2203
01:21:21,910 --> 01:21:19,920
ambitious

2204
01:21:23,510 --> 01:21:21,920
and hoping that in the fullness of time

2205
01:21:24,709 --> 01:21:23,520
that results in a capability that can be

2206
01:21:34,310 --> 01:21:24,719
used again

2207
01:21:39,510 --> 01:21:37,110
okay do we have a question

2208
01:21:42,070 --> 01:21:39,520
is is there a business model for

2209
01:21:43,910 --> 01:21:42,080
paying you by the kilogram

2210
01:21:46,470 --> 01:21:43,920
yes for return of sample

2211
01:21:48,149 --> 01:21:46,480
yes that on a per kilogram basis you

2212
01:21:49,590 --> 01:21:48,159
know will be a lot cheaper than

2213
01:21:51,030 --> 01:21:49,600

osiris-rex

2214

01:21:51,830 --> 01:21:51,040

um

2215

01:21:53,830 --> 01:21:51,840

and

2216

01:21:56,470 --> 01:21:53,840

it's valuable to both parties we'll

2217

01:21:57,910 --> 01:21:56,480

we'll need samples for our own needs we

2218

01:21:59,669 --> 01:21:57,920

we want to supply propellant to

2219

01:22:01,830 --> 01:21:59,679

communication satellites to transfer

2220

01:22:03,669 --> 01:22:01,840

stages you know a lot of the the new

2221

01:22:06,070 --> 01:22:03,679

launch vehicles that rely on on air

2222

01:22:07,350 --> 01:22:06,080

launch they have a ceiling on how much

2223

01:22:11,430 --> 01:22:07,360

they can launch

2224

01:22:12,870 --> 01:22:11,440

just to leo and use a transfer stage

2225

01:22:15,350 --> 01:22:12,880

that's space-based

2226

01:22:16,709 --> 01:22:15,360

refueled from asteroid resources

2227

01:22:18,790 --> 01:22:16,719

they gain a whole other order of

2228

01:22:21,030 --> 01:22:18,800

magnitude capabilities so we think

2229

01:22:27,990 --> 01:22:21,040

there's a lot of commercial demand for

2230

01:22:28,000 --> 01:22:31,270

anything other questions

2231

01:22:31,280 --> 01:22:36,390

thanks

2232

01:22:42,950 --> 01:22:40,950

okay um our last presenter um in the

2233

01:22:45,750 --> 01:22:42,960

formal agenda

2234

01:22:48,470 --> 01:22:45,760

is a combination presentation by bill

2235

01:22:50,310 --> 01:22:48,480

botkey from southwest research and and

2236

01:22:52,390 --> 01:22:50,320

robert jedecki

2237

01:22:53,590 --> 01:22:52,400

from university of hawaii

2238

01:22:55,990 --> 01:22:53,600

um

2239

01:22:58,550 --> 01:22:56,000

dr botkey is director of the center for

2240

01:23:00,790 --> 01:22:58,560

lunar origin and evolution of nasa's

2241

01:23:02,229 --> 01:23:00,800

lunar science institute and director of

2242

01:23:04,310 --> 01:23:02,239

the department of space studies at

2243

01:23:06,709 --> 01:23:04,320

southwest research institute in boulder

2244

01:23:09,430 --> 01:23:06,719

also a flood survivor

2245

01:23:11,189 --> 01:23:09,440

and professor uh robert jedikis of the

2246

01:23:13,750 --> 01:23:11,199

university of hawaii and the asteroid

2247

01:23:15,270 --> 01:23:13,760

terrestrial impact last alert system or

2248

01:23:16,870 --> 01:23:15,280

atlas

2249

01:23:18,790 --> 01:23:16,880

the population of asteroids that are

2250

01:23:21,189 --> 01:23:18,800

temporarily captured in orbit around

2251

01:23:22,629 --> 01:23:21,199

this earth what bill and robert call

2252

01:23:25,189 --> 01:23:22,639

many moons

2253

01:23:27,510 --> 01:23:25,199

are new and highly compelling targets

2254

01:23:29,189 --> 01:23:27,520

for human exploration because of their

2255

01:23:31,270 --> 01:23:29,199

proximity to earth and their low

2256

01:23:32,950 --> 01:23:31,280

geocentric velocities

2257

01:23:34,709 --> 01:23:32,960

they believe this population can help

2258

01:23:36,870 --> 01:23:34,719

nasa address perhaps

2259

01:23:38,950 --> 01:23:36,880

exploration's most problematic issue

2260

01:23:40,950 --> 01:23:38,960

that is identifying a near-earth

2261

01:23:42,629 --> 01:23:40,960

asteroid population that asteroids

2262

01:23:44,310 --> 01:23:42,639

astronauts and their tools can interact

2263

01:23:45,510 --> 01:23:44,320

with within cost and scheduling

2264

01:23:47,270 --> 01:23:45,520

constraints

2265

01:23:50,070 --> 01:23:47,280

and here they'll briefly discuss what

2266

01:23:52,149 --> 01:23:50,080

many moons are what their orbits sizes

2267

01:23:53,750 --> 01:23:52,159

and physical properties may be like what

2268

01:23:55,510 --> 01:23:53,760

can be done to find them and how human

2269

01:23:57,189 --> 01:23:55,520

and robotic spacecraft can potentially

2270

01:23:59,830 --> 01:23:57,199

interact with them and i will say they

2271

01:24:01,669 --> 01:23:59,840

both submitted separate rfi responses

2272

01:24:03,189 --> 01:24:01,679

but the topics were so complementary

2273

01:24:05,510 --> 01:24:03,199

we're having them present to and they

2274

01:24:06,550 --> 01:24:05,520

graciously agreed to present together so

2275

01:24:08,149 --> 01:24:06,560

go ahead

2276

01:24:09,590 --> 01:24:08,159

thank you very much oh well robert and i

2277

01:24:11,189 --> 01:24:09,600

work closely together so this is no

2278

01:24:12,070 --> 01:24:11,199

we're actually very happy to be talking

2279

01:24:13,750 --> 01:24:12,080

together

2280

01:24:15,510 --> 01:24:13,760

so this is very different from the other

2281

01:24:17,510 --> 01:24:15,520

talks i think you've seen this session

2282

01:24:19,189 --> 01:24:17,520

so far we've mostly talked about of the

2283

01:24:20,470 --> 01:24:19,199

arm mission we're going to propose a

2284

01:24:21,910 --> 01:24:20,480

different mission no one asked us they

2285

01:24:23,590 --> 01:24:21,920

should have asked us beforehand but we

2286

01:24:25,189 --> 01:24:23,600

think we have a

2287

01:24:27,830 --> 01:24:25,199

mission concept

2288

01:24:30,070 --> 01:24:27,840

for a human mission which we're calling

2289

01:24:31,510 --> 01:24:30,080

uh admission to a mini moon and what

2290

01:24:32,870 --> 01:24:31,520

we're excited about this is maybe one of

2291

01:24:35,430 --> 01:24:32,880

the most exciting ideas i think i've

2292

01:24:38,310 --> 01:24:35,440

seen in my career in a sense that this

2293

01:24:40,550 --> 01:24:38,320

has the promise to help achieve nasa's

2294

01:24:42,950 --> 01:24:40,560

human spaceflight goals but at lower

2295

01:24:44,390 --> 01:24:42,960

costs and reduce risk than the things

2296

01:24:45,990 --> 01:24:44,400

that are being presented today

2297

01:24:47,350 --> 01:24:46,000

so to give you a feeling for this i have

2298

01:24:48,790 --> 01:24:47,360

to describe many moods that means i have

2299

01:24:50,629 --> 01:24:48,800

to give you something of a background on

2300

01:24:52,709 --> 01:24:50,639

the near earth object population so

2301

01:24:54,470 --> 01:24:52,719

first of all what are minimums

2302

01:24:55,910 --> 01:24:54,480

well let's start with sort of a top view

2303

01:24:58,070 --> 01:24:55,920

of the solar system so what you're

2304

01:24:59,430 --> 01:24:58,080

looking at here in green are is the main

2305

01:25:01,110 --> 01:24:59,440

asteroid belt and then you can see the

2306

01:25:02,470 --> 01:25:01,120

orbits of the terrestrial planets and

2307

01:25:04,629 --> 01:25:02,480

jupiter out here

2308

01:25:06,470 --> 01:25:04,639

now the asteroid belt provides the

2309

01:25:08,070 --> 01:25:06,480

source for our nearest object population

2310

01:25:09,669 --> 01:25:08,080

through different dynamical processes in

2311

01:25:11,510 --> 01:25:09,679

the rest the near-earth objects are the

2312

01:25:13,590 --> 01:25:11,520

objects here in red these are bodies

2313

01:25:14,950 --> 01:25:13,600

across the earth's path or in some cases

2314

01:25:16,629 --> 01:25:14,960

come very close to the earth and they're

2315

01:25:18,709 --> 01:25:16,639

what we're talking about today

2316

01:25:20,550 --> 01:25:18,719

now the armed mission candidates are a

2317

01:25:22,629 --> 01:25:20,560

subset of that population they just

2318

01:25:24,470 --> 01:25:22,639

happen to be the objects they're on very

2319

01:25:26,390 --> 01:25:24,480

low eccentricity very low inclination

2320

01:25:28,229 --> 01:25:26,400

orbits so they're really much smaller

2321

01:25:29,430 --> 01:25:28,239

than this near earth object population

2322

01:25:31,430 --> 01:25:29,440

but what's interesting is while

2323

01:25:33,669 --> 01:25:31,440

everyone's focusing on these guys these

2324

01:25:35,350 --> 01:25:33,679

objects actually do some special things

2325

01:25:36,310 --> 01:25:35,360

if you look at them and you think about

2326

01:25:37,669 --> 01:25:36,320

something we're going to call the

2327

01:25:39,270 --> 01:25:37,679

lagrange points i'm not going to spend a

2328

01:25:41,189 --> 01:25:39,280

lot of time going in the dynamics of

2329

01:25:43,910 --> 01:25:41,199

lagrange points but essentially when you

2330

01:25:45,990 --> 01:25:43,920

have objects on earth like orbits

2331

01:25:47,750 --> 01:25:46,000

they tend to spend a lot of time in

2332

01:25:50,070 --> 01:25:47,760

special regions where the gravitational

2333

01:25:51,510 --> 01:25:50,080

forces of the sun and the earth are very

2334

01:25:52,870 --> 01:25:51,520

comparable to one another and so when

2335

01:25:54,790 --> 01:25:52,880

you combine with the orbital motion it

2336

01:25:57,030 --> 01:25:54,800

actually creates a pathway where things

2337

01:25:58,870 --> 01:25:57,040

can go in from orbiting the sun to

2338

01:26:01,510 --> 01:25:58,880

actually going into orbit around the

2339

01:26:02,709 --> 01:26:01,520

earth itself okay so this pathway is

2340

01:26:05,110 --> 01:26:02,719

very interesting for the following

2341

01:26:07,669 --> 01:26:05,120

reason and that some asteroids actually

2342

01:26:09,189 --> 01:26:07,679

enter into a lagrange point like l1 they

2343

01:26:10,550 --> 01:26:09,199

rattle around the earth moon system for

2344

01:26:13,030 --> 01:26:10,560

a time and then eventually they may

2345

01:26:15,110 --> 01:26:13,040

escape out l2 or so so these are

2346

01:26:16,950 --> 01:26:15,120

temporarily captured asteroids but the

2347

01:26:18,550 --> 01:26:16,960

ones that we make a full orbit around

2348

01:26:20,870 --> 01:26:18,560

the earth we call mini boots okay that's

2349

01:26:22,310 --> 01:26:20,880

our that's our formal name for it okay

2350

01:26:24,070 --> 01:26:22,320

but what's interesting here is that some

2351

01:26:26,149 --> 01:26:24,080

objects are very are only temporarily

2352

01:26:28,149 --> 01:26:26,159

kept over a short time scale but others

2353

01:26:30,470 --> 01:26:28,159

are more are captured over a much longer

2354

01:26:31,990 --> 01:26:30,480

time scale some cases up to years even

2355

01:26:33,910 --> 01:26:32,000

decades depending on how you look at it

2356

01:26:35,750 --> 01:26:33,920

or so so this makes them very

2357

01:26:37,430 --> 01:26:35,760

interesting targets for something we

2358

01:26:38,229 --> 01:26:37,440

might want to visit in the near future

2359

01:26:40,310 --> 01:26:38,239

okay

2360

01:26:41,910 --> 01:26:40,320

so if this just gives you a feeling for

2361

01:26:43,510 --> 01:26:41,920

me also for the people on webex it's the

2362

01:26:45,270 --> 01:26:43,520

feeling for some of the trajectories of

2363

01:26:46,790 --> 01:26:45,280

these objects some are very simple they

2364

01:26:49,430 --> 01:26:46,800

just make one sort of orbit around the

2365

01:26:50,709 --> 01:26:49,440

earth some may make multiple passes and

2366

01:26:52,229 --> 01:26:50,719

then all of a sudden you can get crazy

2367

01:26:53,510 --> 01:26:52,239

trajectories as these things interact

2368

01:26:54,950 --> 01:26:53,520

with the moon and they interact with

2369

01:26:55,910 --> 01:26:54,960

resonances with the earth and the rest

2370

01:26:57,750 --> 01:26:55,920

you know that's where i have a whole

2371

01:27:00,550 --> 01:26:57,760

rogues gallery of things basically the

2372

01:27:01,830 --> 01:27:00,560

entire sphere of out to about four lunar

2373

01:27:03,430 --> 01:27:01,840

distances can be filled with these

2374

01:27:04,790 --> 01:27:03,440

objects

2375

01:27:06,470 --> 01:27:04,800

so the question is how many of these

2376

01:27:08,470 --> 01:27:06,480

guys exist okay that might be some of

2377

01:27:10,149 --> 01:27:08,480

the questions you want to know to answer

2378

01:27:11,830 --> 01:27:10,159

that we had to do some dynamical studies

2379

01:27:13,750 --> 01:27:11,840

this is some work done by mikhail

2380

01:27:15,669 --> 01:27:13,760

granvik and robert jediki just over the

2381

01:27:17,750 --> 01:27:15,679

last sort of recent history what they

2382

01:27:19,669 --> 01:27:17,760

did is they looked at the orbits of

2383

01:27:21,510 --> 01:27:19,679

essentially the arm candidates and this

2384

01:27:23,110 --> 01:27:21,520

is of the plot in some major axis and

2385

01:27:24,950 --> 01:27:23,120

eccentricity and then numerical

2386

01:27:27,430 --> 01:27:24,960

calculations to see how many objects

2387

01:27:28,709 --> 01:27:27,440

would be captured over time and just

2388

01:27:29,830 --> 01:27:28,719

give you the bottom line here's a lot i

2389

01:27:31,590 --> 01:27:29,840

could say in this plot but i don't have

2390

01:27:33,430 --> 01:27:31,600

time it's basically on the order of ten

2391

01:27:35,430 --> 01:27:33,440

the minus four to ten minus fifth of the

2392

01:27:36,790 --> 01:27:35,440

population is captured at any given time

2393

01:27:39,910 --> 01:27:36,800

or for those like think of percentages

2394

01:27:41,189 --> 01:27:39,920

it's about 0.001 so it's not very large

2395

01:27:43,510 --> 01:27:41,199

so what does that mean in terms of the

2396

01:27:44,870 --> 01:27:43,520

entire population well let's go back to

2397

01:27:46,870 --> 01:27:44,880

let's think back to the plot i just

2398

01:27:48,310 --> 01:27:46,880

showed you in white i'm showing a plot

2399

01:27:50,149 --> 01:27:48,320

of diameter and kilometers versus

2400

01:27:51,910 --> 01:27:50,159

cumulative number and right here we have

2401

01:27:54,070 --> 01:27:51,920

what we think the main main belt

2402

01:27:55,430 --> 01:27:54,080

asteroid population is like and yellow

2403

01:27:56,950 --> 01:27:55,440

is our best estimate of the near earth

2404

01:27:58,950 --> 01:27:56,960

object population remember that's just a

2405

01:28:01,590 --> 01:27:58,960

sort of a in a sense it's a dynamically

2406

01:28:03,270 --> 01:28:01,600

escaped subset of the main belt from

2407

01:28:05,030 --> 01:28:03,280

there we have the population of arm

2408

01:28:06,870 --> 01:28:05,040

candidates that's just a subset of the

2409

01:28:08,229 --> 01:28:06,880

near earth object population so if we

2410

01:28:10,310 --> 01:28:08,239

take that best estimate we have for the

2411

01:28:12,310 --> 01:28:10,320

armed population and we multiply it by

2412

01:28:14,070 --> 01:28:12,320

about 10 to the minus fifth or so we end

2413

01:28:15,750 --> 01:28:14,080

up with a population of model minions

2414

01:28:17,430 --> 01:28:15,760

okay so these are objects there's not a

2415

01:28:19,030 --> 01:28:17,440

lot of these guys but they're in steady

2416

01:28:21,189 --> 01:28:19,040

state so at any given time there's

2417

01:28:23,110 --> 01:28:21,199

several meter-sized guys to visit in the

2418

01:28:24,629 --> 01:28:23,120

earth moon system so what does that mean

2419

01:28:25,910 --> 01:28:24,639

what's the bottom line on that so

2420

01:28:27,750 --> 01:28:25,920

essentially what we're talking about is

2421

01:28:30,390 --> 01:28:27,760

a few objects which are maybe on the

2422

01:28:31,990 --> 01:28:30,400

order of a washing machine or so okay we

2423

01:28:33,669 --> 01:28:32,000

maybe have a dozen objects or so which

2424

01:28:35,110 --> 01:28:33,679

are maybe about the size of a beach ball

2425

01:28:37,110 --> 01:28:35,120

and then every once in a while we have a

2426

01:28:39,189 --> 01:28:37,120

larger object okay so they're not very

2427

01:28:41,669 --> 01:28:39,199

big but there's always something to go

2428

01:28:42,709 --> 01:28:41,679

visit okay and ultimately we're pretty

2429

01:28:43,830 --> 01:28:42,719

we're reasonably happy with these

2430

01:28:45,350 --> 01:28:43,840

numbers but we like to do more

2431

01:28:47,110 --> 01:28:45,360

observational work and robert's going to

2432

01:28:49,189 --> 01:28:47,120

talk about that and a better theoretical

2433

01:28:50,629 --> 01:28:49,199

study to understand this but even so

2434

01:28:52,149 --> 01:28:50,639

these objects are very interesting from

2435

01:28:54,229 --> 01:28:52,159

a science perspective

2436

01:28:55,910 --> 01:28:54,239

say okay so how long do they last

2437

01:28:57,990 --> 01:28:55,920

typically our numerical simulations

2438

01:28:59,189 --> 01:28:58,000

suggest they last on the order of about

2439

01:29:01,430 --> 01:28:59,199

three orbits around the earth moon

2440

01:29:02,390 --> 01:29:01,440

system or about 10 months and you can

2441

01:29:03,830 --> 01:29:02,400

see here there's something of a

2442

01:29:05,669 --> 01:29:03,840

long-lived tail where they can last much

2443

01:29:06,950 --> 01:29:05,679

longer or so so that's pretty short to

2444

01:29:08,629 --> 01:29:06,960

think about a human mission to these

2445

01:29:10,149 --> 01:29:08,639

things but keep in mind if you had a

2446

01:29:12,229 --> 01:29:10,159

robotic precursor go out to these

2447

01:29:13,910 --> 01:29:12,239

objects you could very easily stabilize

2448

01:29:15,350 --> 01:29:13,920

them it doesn't take much of a velocity

2449

01:29:17,189 --> 01:29:15,360

kick to actually put them into an orbit

2450

01:29:18,310 --> 01:29:17,199

which will last a hundred years or so so

2451

01:29:19,830 --> 01:29:18,320

in a sense you can think about them

2452

01:29:21,669 --> 01:29:19,840

almost as a mini arm being able to do

2453

01:29:23,510 --> 01:29:21,679

lots of interesting things here

2454

01:29:25,110 --> 01:29:23,520

okay so i want to close my portion of

2455

01:29:26,790 --> 01:29:25,120

talk just by saying why these things are

2456

01:29:28,310 --> 01:29:26,800

scientifically interesting why we might

2457

01:29:29,590 --> 01:29:28,320

want to go see these guys

2458

01:29:31,189 --> 01:29:29,600

so the first of all to understand is

2459

01:29:32,790 --> 01:29:31,199

that these objects are essentially the

2460

01:29:34,550 --> 01:29:32,800

precursors or the meteoroids that are

2461

01:29:36,070 --> 01:29:34,560

delivering meteorites to the earth and

2462

01:29:37,430 --> 01:29:36,080

so you have a sense you get you can get

2463

01:29:38,870 --> 01:29:37,440

samples that are outside the atmosphere

2464

01:29:40,390 --> 01:29:38,880

before any contamination or anything

2465

01:29:41,669 --> 01:29:40,400

else has taken place and they can

2466

01:29:43,350 --> 01:29:41,679

actually tell us about the original

2467

01:29:45,510 --> 01:29:43,360

building blocks which made the planets

2468

01:29:47,189 --> 01:29:45,520

and they also provide information on

2469

01:29:48,629 --> 01:29:47,199

possibly how life got going depending if

2470

01:29:50,470 --> 01:29:48,639

you get organics and volatiles and all

2471

01:29:52,149 --> 01:29:50,480

the rest this is a major nasa goal

2472

01:29:53,910 --> 01:29:52,159

that's demonstrated by the osiris-rex

2473

01:29:55,590 --> 01:29:53,920

mission that's out there there's also

2474

01:29:57,510 --> 01:29:55,600

the fact that these samples can be very

2475

01:29:59,350 --> 01:29:57,520

large and if you like it you can bring

2476

01:30:01,189 --> 01:29:59,360

the entire thing home depending on how

2477

01:30:02,390 --> 01:30:01,199

you want to do it and that's a key goal

2478

01:30:03,830 --> 01:30:02,400

regarding the study of asteroid

2479

01:30:04,709 --> 01:30:03,840

resources and we've already had talks on

2480

01:30:05,830 --> 01:30:04,719

that

2481

01:30:07,030 --> 01:30:05,840

finally there's something else to keep

2482

01:30:09,270 --> 01:30:07,040

in mind while everyone talks about

2483

01:30:11,110 --> 01:30:09,280

asteroids being rubble piles versus uh

2484

01:30:12,950 --> 01:30:11,120

solid objects there's one more issue to

2485

01:30:14,550 --> 01:30:12,960

keep in mind all of the asteroids we're

2486

01:30:16,229 --> 01:30:14,560

dealing with are small enough that

2487

01:30:17,590 --> 01:30:16,239

essentially they in some cases they may

2488

01:30:19,750 --> 01:30:17,600

literally be held together not by

2489

01:30:21,430 --> 01:30:19,760

necessarily gravity by electrostatic

2490

01:30:22,870 --> 01:30:21,440

cohesive forces this is becoming more

2491

01:30:24,390 --> 01:30:22,880

and more recognized in the small body

2492

01:30:26,550 --> 01:30:24,400

community so some of these objects may

2493

01:30:28,629 --> 01:30:26,560

literally be sand castles and if that's

2494

01:30:30,390 --> 01:30:28,639

true we really would be very important

2495

01:30:31,669 --> 01:30:30,400

to understand that nature before we send

2496

01:30:33,510 --> 01:30:31,679

humans out there to interact with them

2497

01:30:35,910 --> 01:30:33,520

in some fashion and so a mission to a

2498

01:30:36,950 --> 01:30:35,920

mini moon can buy down risk by

2499

01:30:38,550 --> 01:30:36,960

understanding these objects their

2500

01:30:40,629 --> 01:30:38,560

natural laboratories to understand these

2501
01:30:41,669 --> 01:30:40,639
really poorly understood processes and

2502
01:30:42,950 --> 01:30:41,679
so with that i'm going to hand it over

2503
01:30:54,390 --> 01:30:42,960
to robert and robert's going to tell you

2504
01:30:57,590 --> 01:30:56,070
thank you bill so i'm sure you're all

2505
01:30:59,189 --> 01:30:57,600
wondering uh just a couple theorists

2506
01:31:01,430 --> 01:30:59,199
standing up here talking about this

2507
01:31:02,870 --> 01:31:01,440
vapor these vapor moons up there going

2508
01:31:04,790 --> 01:31:02,880
around the earth can we actually find

2509
01:31:07,030 --> 01:31:04,800
them are they actually there

2510
01:31:09,110 --> 01:31:07,040
and uh the whole idea started up about

2511
01:31:11,189 --> 01:31:09,120
20 years ago when i was working in at

2512
01:31:12,629 --> 01:31:11,199
kid peak arizona i was working with a

2513
01:31:14,550 --> 01:31:12,639

project called the space watch project

2514

01:31:16,470 --> 01:31:14,560

looking for asteroids and every once in

2515

01:31:17,910 --> 01:31:16,480

a while we'd find a geocentric object

2516

01:31:20,229 --> 01:31:17,920

and it would have this very elliptical

2517

01:31:22,070 --> 01:31:20,239

high inclination high semi-major axis

2518

01:31:23,750 --> 01:31:22,080

orbit around the earth and i would

2519

01:31:24,790 --> 01:31:23,760

report it to the minor planet center and

2520

01:31:25,669 --> 01:31:24,800

they would write back to me saying oh

2521

01:31:27,430 --> 01:31:25,679

rob don't worry about it it's a

2522

01:31:28,870 --> 01:31:27,440

geocentric object i said what if it's a

2523

01:31:30,550 --> 01:31:28,880

natural geocentric object it's a very

2524

01:31:31,990 --> 01:31:30,560

strange orbit they said ah there are no

2525

01:31:33,189 --> 01:31:32,000

natural geocentric objects other than

2526

01:31:34,709 --> 01:31:33,199

the moon

2527

01:31:36,550 --> 01:31:34,719

they said they're all artificial and i

2528

01:31:37,430 --> 01:31:36,560

thought that was very odd so 20 years go

2529

01:31:39,510 --> 01:31:37,440

by

2530

01:31:40,950 --> 01:31:39,520

and a couple years ago i found this

2531

01:31:42,070 --> 01:31:40,960

postdoc who was willing to work with me

2532

01:31:43,270 --> 01:31:42,080

on this project and we did the

2533

01:31:44,950 --> 01:31:43,280

simulations and actually figured out

2534

01:31:46,870 --> 01:31:44,960

that yeah a very small fraction of the

2535

01:31:48,070 --> 01:31:46,880

population can go into orbit around the

2536

01:31:50,390 --> 01:31:48,080

earth

2537

01:31:51,910 --> 01:31:50,400

and they uh they can be captured by the

2538

01:31:53,750 --> 01:31:51,920

earth immune system unfortunately we

2539

01:31:56,149 --> 01:31:53,760

published our paper a few years after

2540

01:31:58,870 --> 01:31:56,159

the discovery of the first mini moon

2541

01:32:00,390 --> 01:31:58,880

2006 rh120 if only we had done this 10

2542

01:32:02,229 --> 01:32:00,400

years earlier we would have predicted

2543

01:32:03,830 --> 01:32:02,239

this object and the great thing about

2544

01:32:05,590 --> 01:32:03,840

this object is it's really a poster

2545

01:32:06,550 --> 01:32:05,600

child for many moons

2546

01:32:12,629 --> 01:32:06,560

it's

2547

01:32:15,189 --> 01:32:12,639

geocentric orbit we're all exactly what

2548

01:32:16,470 --> 01:32:15,199

we predicted on our model the duration

2549

01:32:18,629 --> 01:32:16,480

of time that it spent in orbit around

2550

01:32:20,550 --> 01:32:18,639

the earth was the average of what we

2551
01:32:22,070 --> 01:32:20,560
predicted minimum should spend around

2552
01:32:23,590 --> 01:32:22,080
the earth

2553
01:32:25,510 --> 01:32:23,600
basically everything it did was was

2554
01:32:27,030 --> 01:32:25,520
right even its size at 3 meters which is

2555
01:32:27,750 --> 01:32:27,040
about the you know height of a typical

2556
01:32:30,390 --> 01:32:27,760
uh

2557
01:32:32,470 --> 01:32:30,400
high diving board at a city pool right

2558
01:32:33,750 --> 01:32:32,480
even its size is about the right order

2559
01:32:35,830 --> 01:32:33,760
of magnitude that we expect from our

2560
01:32:37,990 --> 01:32:35,840
modeling one object like this goes into

2561
01:32:39,510 --> 01:32:38,000
orbit around the earth every 10 years

2562
01:32:41,350 --> 01:32:39,520
the surveys have been operating for 10

2563
01:32:43,270 --> 01:32:41,360

or 20 years at different uh levels of

2564

01:32:44,550 --> 01:32:43,280

efficiency so it's about the right order

2565

01:32:46,229 --> 01:32:44,560

magnitude for us to be finding these

2566

01:32:47,270 --> 01:32:46,239

objects so it was the poster child for

2567

01:32:49,110 --> 01:32:47,280

minimum

2568

01:32:51,669 --> 01:32:49,120

it was found at the time because it was

2569

01:32:53,510 --> 01:32:51,679

bright and very slow moving

2570

01:32:55,430 --> 01:32:53,520

and so it was it was relatively easy to

2571

01:32:56,950 --> 01:32:55,440

find by the catalina sky survey but this

2572

01:32:58,229 --> 01:32:56,960

is just we think this is just the tip of

2573

01:32:59,590 --> 01:32:58,239

the whole meaning and iceberg we think

2574

01:33:03,030 --> 01:32:59,600

there are many more out there and we

2575

01:33:07,110 --> 01:33:04,950

we've done a lot of simulations using

2576

01:33:08,470 --> 01:33:07,120

different assets on the ground if you're

2577

01:33:10,550 --> 01:33:08,480

on the ground you want to probably be

2578

01:33:13,030 --> 01:33:10,560

using visible light you would really

2579

01:33:15,030 --> 01:33:13,040

like a survey that's got a wide field

2580

01:33:17,030 --> 01:33:15,040

telescope that can get you extremely

2581

01:33:19,030 --> 01:33:17,040

faint limiting magnitudes that can take

2582

01:33:20,950 --> 01:33:19,040

very short exposures so something like

2583

01:33:22,229 --> 01:33:20,960

the large synoptic survey telescope that

2584

01:33:23,669 --> 01:33:22,239

should be operational about five or ten

2585

01:33:25,510 --> 01:33:23,679

years would be a really premier

2586

01:33:27,430 --> 01:33:25,520

instrument for finding these mini moons

2587

01:33:29,030 --> 01:33:27,440

but that's still you know a decade or so

2588

01:33:30,950 --> 01:33:29,040

in the future right now there is an

2589

01:33:32,629 --> 01:33:30,960

asset available the subaru telescope

2590

01:33:35,110 --> 01:33:32,639

eight meter telescope on the summit of

2591

01:33:37,750 --> 01:33:35,120

mauna kea hawaii and they're just

2592

01:33:38,709 --> 01:33:37,760

installing the hyper super prime cam

2593

01:33:40,790 --> 01:33:38,719

camera

2594

01:33:43,750 --> 01:33:40,800

and uh this is a phenomenal uh

2595

01:33:45,030 --> 01:33:43,760

instrument and we think that if we had

2596

01:33:47,110 --> 01:33:45,040

time on this telescope we would be able

2597

01:33:49,270 --> 01:33:47,120

to find mini moons in a regular way uh

2598

01:33:50,790 --> 01:33:49,280

we think that there's a 40 probability

2599

01:33:52,790 --> 01:33:50,800

of finding a mini moon on any night we

2600

01:33:54,550 --> 01:33:52,800

go observing with that telescope

2601

01:33:56,629 --> 01:33:54,560

which means that there's about a 90

2602

01:33:58,629 --> 01:33:56,639

percent chance of finding a mini moon if

2603

01:34:01,830 --> 01:33:58,639

we had five ninths in the telescope the

2604

01:34:03,750 --> 01:34:01,840

one missing key is that i would require

2605

01:34:04,870 --> 01:34:03,760

a wideband filter to optimize that's

2606

01:34:06,310 --> 01:34:04,880

optimized for the detection these

2607

01:34:08,229 --> 01:34:06,320

minimums right now they use relatively

2608

01:34:10,870 --> 01:34:08,239

narrow band filters for doing astronomy

2609

01:34:12,629 --> 01:34:10,880

and astrophysics and for doing asteroids

2610

01:34:14,149 --> 01:34:12,639

science you want or discovery you want

2611

01:34:16,149 --> 01:34:14,159

it very wide you want to basically learn

2612

01:34:17,590 --> 01:34:16,159

as much light as you possibly can but if

2613

01:34:19,590 --> 01:34:17,600

you really want to find a lot of minions

2614

01:34:21,669 --> 01:34:19,600

uh you know dozens at a time you want to

2615

01:34:23,510 --> 01:34:21,679

go to space so we've done simulations

2616

01:34:24,790 --> 01:34:23,520

from space and we think that if you're

2617

01:34:27,030 --> 01:34:24,800

going to go to space the best place to

2618

01:34:28,870 --> 01:34:27,040

be would be at L1 L1 is a location about

2619

01:34:30,470 --> 01:34:28,880

four lunar distances away from the earth

2620

01:34:32,790 --> 01:34:30,480

it's in the direction of sun so you're

2621

01:34:34,390 --> 01:34:32,800

looking sort of back towards the earth

2622

01:34:35,590 --> 01:34:34,400

and you're going to see the mini means

2623

01:34:38,310 --> 01:34:35,600

sort of distributed around the earth as

2624

01:34:41,030 --> 01:34:38,320

shown in this figure here

2625

01:34:44,070 --> 01:34:41,040

if you put a 1 meter diameter mirror

2626

01:34:45,830 --> 01:34:44,080

with an infrared camera at I1 we think

2627

01:34:48,149 --> 01:34:45,840

that there will be 30 detectable mini

2628

01:34:49,910 --> 01:34:48,159

moons on the sky plane at any time so

2629

01:34:51,510 --> 01:34:49,920

that you'd have dozens of mini moons

2630

01:34:52,550 --> 01:34:51,520

that were available you could you're not

2631

01:34:54,390 --> 01:34:52,560

they're not you know they're going to

2632

01:34:56,149 --> 01:34:54,400

come in and out of visibility so that

2633

01:34:57,510 --> 01:34:56,159

over the course of a month or six months

2634

01:34:59,109 --> 01:34:57,520

or a year you're going to see many many

2635

01:35:01,030 --> 01:34:59,119

dozens of mini moons

2636

01:35:02,790 --> 01:35:01,040

and that's extremely interesting to us

2637

01:35:04,709 --> 01:35:02,800

it's also interesting to us because 1 in

2638

01:35:06,390 --> 01:35:04,719

100 mini moons actually become large

2639

01:35:07,750 --> 01:35:06,400

bolide meteors right so that you can

2640

01:35:09,109 --> 01:35:07,760

find these things before they strike the

2641

01:35:10,629 --> 01:35:09,119

earth

2642

01:35:12,790 --> 01:35:10,639

and then you get the side benefit of if

2643

01:35:15,350 --> 01:35:12,800

you have a spacecraft like this at I1

2644

01:35:17,189 --> 01:35:15,360

looking back at the earth it's really a

2645

01:35:18,870 --> 01:35:17,199

early asteroid impact warning system as

2646

01:35:20,149 --> 01:35:18,880

well just like you've got satellites up

2647

01:35:22,390 --> 01:35:20,159

on orbit around the earth looking for

2648

01:35:24,070 --> 01:35:22,400

hurricanes and tornadoes uh this would

2649

01:35:25,669 --> 01:35:24,080

be an early impact warning system for

2650

01:35:29,910 --> 01:35:25,679

asteroids so not only finding many moons

2651
01:35:32,790 --> 01:35:31,590
so if we find them can you actually

2652
01:35:34,310 --> 01:35:32,800
visit them

2653
01:35:36,229 --> 01:35:34,320
those orbits that we showed look kind of

2654
01:35:37,590 --> 01:35:36,239
like crazy straws right and so i worked

2655
01:35:39,510 --> 01:35:37,600
with a mathematician at the university

2656
01:35:41,189 --> 01:35:39,520
of hawaii who was quite excited about

2657
01:35:42,550 --> 01:35:41,199
doing calculations to see whether or not

2658
01:35:44,870 --> 01:35:42,560
you could actually devise orbits to

2659
01:35:46,950 --> 01:35:44,880
these crazy straw uh objects

2660
01:35:49,270 --> 01:35:46,960
and uh what we found actually

2661
01:35:50,149 --> 01:35:49,280
is that if you or what we first of all

2662
01:35:52,149 --> 01:35:50,159
started

2663
01:35:53,430 --> 01:35:52,159

simulating was it let's we thought well

2664

01:35:54,950 --> 01:35:53,440

these things are only over for 10 months

2665

01:35:56,149 --> 01:35:54,960

you can't possibly get emissions you

2666

01:35:57,669 --> 01:35:56,159

know up and running and send it out in

2667

01:35:59,750 --> 01:35:57,679

10 months so what we thought instead is

2668

01:36:01,030 --> 01:35:59,760

let's put a spacecraft in geosynchronous

2669

01:36:02,790 --> 01:36:01,040

orbit and just let it stay there and

2670

01:36:04,390 --> 01:36:02,800

just store it there in hibernation until

2671

01:36:05,990 --> 01:36:04,400

we find the mini moon once we find the

2672

01:36:07,990 --> 01:36:06,000

minimum so we got the spacecraft here in

2673

01:36:09,830 --> 01:36:08,000

geocentric orbit and once we find a mini

2674

01:36:10,870 --> 01:36:09,840

moon as it's coming into the earth moon

2675

01:36:12,229 --> 01:36:10,880

system

2676

01:36:14,229 --> 01:36:12,239

we sort of triggered the spacecraft and

2677

01:36:15,510 --> 01:36:14,239

we say okay now now we have the orbit

2678

01:36:17,189 --> 01:36:15,520

for this object we've bounced radar off

2679

01:36:19,109 --> 01:36:17,199

it we've got a great orbit we can

2680

01:36:21,109 --> 01:36:19,119

deorbit it from geosync and make it

2681

01:36:22,870 --> 01:36:21,119

rendezvous with the

2682

01:36:25,030 --> 01:36:22,880

asteroid we can match its speed and

2683

01:36:26,870 --> 01:36:25,040

velocity we found out that every single

2684

01:36:28,229 --> 01:36:26,880

one of the 17 000 mini moons that we

2685

01:36:29,510 --> 01:36:28,239

created in our simulations we could

2686

01:36:30,629 --> 01:36:29,520

actually get to with this kind of a

2687

01:36:34,870 --> 01:36:30,639

scenario

2688

01:36:36,229 --> 01:36:34,880

looking at storing the spacecraft at I1

2689

01:36:38,070 --> 01:36:36,239
or I2 to see whether or not there's any

2690

01:36:40,070 --> 01:36:38,080
difference we our preliminary work

2691

01:36:41,669 --> 01:36:40,080
suggests that it's possible to get to

2692

01:36:44,870 --> 01:36:41,679
the mini moons all the mini moons even

2693

01:36:46,310 --> 01:36:44,880
if you're store starting at I1 or I2

2694

01:36:47,910 --> 01:36:46,320
for human machine landing you'd probably

2695

01:36:49,189 --> 01:36:47,920
want a mini moon that was on a longer

2696

01:36:50,550 --> 01:36:49,199
term orbit you wouldn't want something

2697

01:36:51,430 --> 01:36:50,560
that's just there for 10 months you'd

2698

01:36:54,149 --> 01:36:51,440
probably want something that was going

2699

01:36:55,669 --> 01:36:54,159
to be there for years so you could take

2700

01:36:57,109 --> 01:36:55,679
you could you might get lucky you might

2701
01:36:58,950 --> 01:36:57,119
find one of these at these mini moons

2702
01:37:00,870 --> 01:36:58,960
that are in a long-term stable orbit or

2703
01:37:02,310 --> 01:37:00,880
you could do as bill suggested that you

2704
01:37:04,950 --> 01:37:02,320
could launch a precursor mission to go

2705
01:37:07,189 --> 01:37:04,960
and stabilize a minimum orbit to make it

2706
01:37:09,430 --> 01:37:07,199
stable for centuries or so

2707
01:37:12,149 --> 01:37:09,440
uh when at that kind of level you should

2708
01:37:13,510 --> 01:37:12,159
be able to have an orion a a mission

2709
01:37:15,990 --> 01:37:13,520
that you could do get to with orion

2710
01:37:18,390 --> 01:37:16,000
spacecraft um sort of in a two to three

2711
01:37:19,669 --> 01:37:18,400
week time frame so you know these mini

2712
01:37:21,030 --> 01:37:19,679
moons are at the sort of the distance of

2713
01:37:22,790 --> 01:37:21,040

the moon on average right so it's about

2714

01:37:24,229 --> 01:37:22,800

the same amount of time as it takes to

2715

01:37:25,910 --> 01:37:24,239

get to the moon and come back and have a

2716

01:37:27,270 --> 01:37:25,920

mission to the moon so you know we're

2717

01:37:29,510 --> 01:37:27,280

talking about very reasonable time

2718

01:37:30,870 --> 01:37:29,520

frames for manned missions to these mini

2719

01:37:34,310 --> 01:37:30,880

moons

2720

01:37:35,910 --> 01:37:34,320

of advantages they offer a great way to

2721

01:37:37,510 --> 01:37:35,920

test arm technologies i mean i've been

2722

01:37:39,109 --> 01:37:37,520

really impressed by all the great ideas

2723

01:37:40,870 --> 01:37:39,119

you guys have been talking about

2724

01:37:43,910 --> 01:37:40,880

and i think that all of them can be

2725

01:37:45,910 --> 01:37:43,920

applied easy more easily to the minimum

2726

01:37:47,109 --> 01:37:45,920

idea these things are right in our

2727

01:37:48,550 --> 01:37:47,119

backyard they're going around the earth

2728

01:37:50,070 --> 01:37:48,560

they're extremely low delta-v targets

2729

01:37:51,590 --> 01:37:50,080

they're smaller asteroids they're easier

2730

01:37:54,550 --> 01:37:51,600

to capture easier to bring back easier

2731

01:37:58,790 --> 01:37:56,229

and in scientifically it'd be extremely

2732

01:38:00,629 --> 01:37:58,800

interesting to bring back an entire

2733

01:38:02,070 --> 01:38:00,639

intact one-half meter or one meter

2734

01:38:03,830 --> 01:38:02,080

diameter asteroid bring it back to the

2735

01:38:05,270 --> 01:38:03,840

earth and uh the interesting thing is

2736

01:38:07,189 --> 01:38:05,280

the mini moons are detectable with our

2737

01:38:08,950 --> 01:38:07,199

existing assets we just need to apply

2738

01:38:10,790 --> 01:38:08,960

something like subaru telescope to

2739

01:38:12,229 --> 01:38:10,800

finding these objects or we could be a

2740

01:38:14,229 --> 01:38:12,239

little more ambitious develop an

2741

01:38:16,070 --> 01:38:14,239

asteroid impact warning system put it l1

2742

01:38:17,750 --> 01:38:16,080

that will also find the minimums for us

2743

01:38:19,910 --> 01:38:17,760

so at the very least we think many moons

2744

01:38:21,510 --> 01:38:19,920

warn an in-depth study to determine

2745

01:38:24,310 --> 01:38:21,520

whether or not they're useful for the

2746

01:38:31,350 --> 01:38:24,320

spacecraft industry

2747

01:38:36,310 --> 01:38:34,550

any questions for bill and robert

2748

01:38:39,189 --> 01:38:36,320

yeah you said of the

2749

01:38:41,669 --> 01:38:39,199

17 000 in your simulation that all of

2750

01:38:43,669 --> 01:38:41,679

them you could get to them

2751

01:38:48,310 --> 01:38:43,679

when leaving from geo what was your

2752

01:38:52,870 --> 01:38:50,390

it was a couple for a few kilometers per

2753

01:38:55,510 --> 01:38:52,880

second a few columns okay thanks

2754

01:38:56,470 --> 01:38:55,520

so geo is the wrong place to wait

2755

01:38:57,510 --> 01:38:56,480

yeah

2756

01:39:00,390 --> 01:38:57,520

um

2757

01:39:02,870 --> 01:39:00,400

we we know that now

2758

01:39:04,550 --> 01:39:02,880

you you might repeat that

2759

01:39:05,990 --> 01:39:04,560

yeah yeah we know that now we we've

2760

01:39:07,990 --> 01:39:06,000

since learned we're simulating what

2761

01:39:09,910 --> 01:39:08,000

would happen if uh wait from when we're

2762

01:39:11,669 --> 01:39:09,920

waiting at I1 or It

2763

01:39:15,030 --> 01:39:11,679

and how much delta v does it take to

2764

01:39:17,750 --> 01:39:15,040

stabilize the the asteroid itself

2765

01:39:22,070 --> 01:39:17,760

do you know that answer that um

2766

01:39:26,070 --> 01:39:24,149

okay so the question was how much how

2767

01:39:27,910 --> 01:39:26,080

much delta v does it take to stabilize

2768

01:39:29,430 --> 01:39:27,920

these uh mini moons uh the question is

2769

01:39:30,470 --> 01:39:29,440

we don't know because we haven't had we

2770

01:39:32,390 --> 01:39:30,480

haven't gotten the funding yet to do

2771

01:39:34,629 --> 01:39:32,400

that study if they fund us we'll let you

2772

01:39:36,149 --> 01:39:34,639

know but but typically what you can

2773

01:39:37,590 --> 01:39:36,159

think about though is you think about

2774

01:39:38,790 --> 01:39:37,600

the difference between you know the many

2775

01:39:40,709 --> 01:39:38,800

more orbits we showed and then the

2776

01:39:42,149 --> 01:39:40,719

long-lived tail it doesn't take very

2777

01:39:43,750 --> 01:39:42,159

much velocity to put them onto a

2778

01:39:45,030 --> 01:39:43,760

long-term stable orbit so i would think

2779

01:39:47,109 --> 01:39:45,040

the velocity requirements are going to

2780

01:39:48,950 --> 01:39:47,119

be very very small so you could think

2781

01:39:50,629 --> 01:39:48,960

about even doing this in a

2782

01:39:52,229 --> 01:39:50,639

you know rather than putting some

2783

01:39:53,910 --> 01:39:52,239

mechanism on it you might even be able

2784

01:39:55,109 --> 01:39:53,920

to do this by a gravity tractor in some

2785

01:39:56,470 --> 01:39:55,119

sense in some cases we're talking about

2786

01:39:57,750 --> 01:39:56,480

small enough objects that that's very

2787

01:40:01,990 --> 01:39:57,760

viable to do so there's all sorts of

2788

01:40:05,189 --> 01:40:03,750

how many of these objects have i know

2789

01:40:06,830 --> 01:40:05,199

we're not haven't been looking for them

2790

01:40:10,229 --> 01:40:06,840

very much but how many have been

2791

01:40:13,590 --> 01:40:10,239

cataloged one in just one just one

2792

01:40:15,189 --> 01:40:13,600

one object and uh and and and that even

2793

01:40:17,030 --> 01:40:15,199

that is very consistent with our models

2794

01:40:18,550 --> 01:40:17,040

with our simulation so we've taken our

2795

01:40:20,070 --> 01:40:18,560

mini moon model run it through

2796

01:40:21,830 --> 01:40:20,080

simulations of existing surveys to

2797

01:40:23,669 --> 01:40:21,840

predict how many would be found and the

2798

01:40:25,510 --> 01:40:23,679

answer is basically the one object that

2799

01:40:27,030 --> 01:40:25,520

was found because in order to find these

2800

01:40:29,189 --> 01:40:27,040

things you need to design a specific

2801
01:40:30,950 --> 01:40:29,199
strategy the asteroid surveys that are

2802
01:40:32,310 --> 01:40:30,960
in operation right now are not really

2803
01:40:34,149 --> 01:40:32,320
looking for these things in fact you

2804
01:40:36,310 --> 01:40:34,159
know we think probably a project like

2805
01:40:38,229 --> 01:40:36,320
pan stars that i used to work on has

2806
01:40:39,590 --> 01:40:38,239
probably detected these things but just

2807
01:40:41,109 --> 01:40:39,600
detecting something is different than

2808
01:40:42,149 --> 01:40:41,119
discovering and realizing it's a mini

2809
01:40:43,750 --> 01:40:42,159
moon because many moons have got

2810
01:40:44,950 --> 01:40:43,760
different sky motions and different

2811
01:40:46,950 --> 01:40:44,960
properties and they're different they're

2812
01:40:51,590 --> 01:40:46,960
more difficult to link than heliocentric

2813
01:40:55,990 --> 01:40:53,270

what about your what about your data

2814

01:40:57,189 --> 01:40:56,000

from 20 years ago

2815

01:40:58,870 --> 01:40:57,199

yeah i thought about going back and

2816

01:41:01,750 --> 01:40:58,880

looking that up

2817

01:41:03,669 --> 01:41:01,760

the thing is that with those objects we

2818

01:41:05,430 --> 01:41:03,679

we only had what would happen typically

2819

01:41:06,950 --> 01:41:05,440

is i would we would track them for a few

2820

01:41:08,310 --> 01:41:06,960

hours on one night

2821

01:41:09,590 --> 01:41:08,320

and then we'd send them into the minor

2822

01:41:11,270 --> 01:41:09,600

planet center they'd say don't worry

2823

01:41:12,550 --> 01:41:11,280

about it and then we'd stop it we

2824

01:41:19,030 --> 01:41:12,560

wouldn't bother looking at for the next

2825

01:41:23,189 --> 01:41:20,470

there was perhaps another aspect to

2826

01:41:25,830 --> 01:41:23,199

consider is that uh uh near earth object

2827

01:41:28,310 --> 01:41:25,840

surveys are strongly discouraged from

2828

01:41:30,709 --> 01:41:28,320

tracking geocentric uh objects for

2829

01:41:33,750 --> 01:41:30,719

reasons that have to do with

2830

01:41:36,870 --> 01:41:33,760

uh space space surveillance issues

2831

01:41:38,470 --> 01:41:36,880

so so uh only recently has become

2832

01:41:39,830 --> 01:41:38,480

people have become aware that maybe they

2833

01:41:42,070 --> 01:41:39,840

should

2834

01:41:44,550 --> 01:41:42,080

consider other possibilities

2835

01:41:47,590 --> 01:41:44,560

there's also another possible detection

2836

01:41:48,709 --> 01:41:47,600

of mini moons at roughly the same time

2837

01:41:50,629 --> 01:41:48,719

that we were finding these things at

2838

01:41:53,510 --> 01:41:50,639

spacewatch 20 years ago the air force

2839

01:41:54,629 --> 01:41:53,520

did a radar survey looking for objects

2840

01:41:56,310 --> 01:41:54,639

and they found

2841

01:41:58,709 --> 01:41:56,320

it's recently been declassified and they

2842

01:42:00,709 --> 01:41:58,719

found three objects that were on

2843

01:42:02,310 --> 01:42:00,719

extremely unusual orbits that they that

2844

01:42:04,950 --> 01:42:02,320

they they did not think were consistent

2845

01:42:06,470 --> 01:42:04,960

with any artificial known uh satellites

2846

01:42:07,750 --> 01:42:06,480

or even debris from any satellites

2847

01:42:09,830 --> 01:42:07,760

because the orbits were so strange

2848

01:42:12,149 --> 01:42:09,840

however those orbits are extremely like

2849

01:42:13,830 --> 01:42:12,159

mini moon orbits and at the time they

2850

01:42:15,270 --> 01:42:13,840

speculated whether or not they could be

2851
01:42:17,030 --> 01:42:15,280
natural objects but nothing was done

2852
01:42:19,189 --> 01:42:17,040
about it

2853
01:42:24,310 --> 01:42:19,199
okay anything else

2854
01:42:30,709 --> 01:42:25,350
all right

2855
01:42:32,310 --> 01:42:30,719
portion of our our program on time it's

2856
01:42:34,870 --> 01:42:32,320
4 15.

2857
01:42:35,830 --> 01:42:34,880
what we have left

2858
01:42:37,910 --> 01:42:35,840
is

2859
01:42:39,750 --> 01:42:37,920
first of all there was one presenter

2860
01:42:42,629 --> 01:42:39,760
joel cersel

2861
01:42:43,990 --> 01:42:42,639
who had a presentation another session

2862
01:42:46,149 --> 01:42:44,000
that he really feels like belongs here

2863
01:42:47,990 --> 01:42:46,159

so i want to give him five minutes or so

2864

01:42:50,070 --> 01:42:48,000

to be able to give a brief

2865

01:42:52,470 --> 01:42:50,080

uh talk of that and romero would like to

2866

01:42:54,550 --> 01:42:52,480

help ask your help for that um we also

2867

01:42:55,830 --> 01:42:54,560

need to go back and and address some of

2868

01:42:58,390 --> 01:42:55,840

the questions and several of the first

2869

01:43:00,149 --> 01:42:58,400

presenters uh didn't have a chance to to

2870

01:43:03,350 --> 01:43:00,159

receive questions and then the third

2871

01:43:05,750 --> 01:43:03,360

thing um between now and 5 30 or is to

2872

01:43:07,990 --> 01:43:05,760

talk through some key top you know

2873

01:43:11,510 --> 01:43:08,000

preparations for wednesday's outbrief

2874

01:43:13,669 --> 01:43:11,520

um and we have um

2875

01:43:16,149 --> 01:43:13,679

we we have a start at that that we'll

2876

01:43:18,470 --> 01:43:16,159

talk from so but i think as long as it's

2877

01:43:20,390 --> 01:43:18,480

been right here i think at the risk of

2878

01:43:22,550 --> 01:43:20,400

losing the audience we'll take a short

2879

01:43:23,750 --> 01:43:22,560

break for um

2880

01:43:26,950 --> 01:43:23,760

10 minutes

2881

01:43:29,590 --> 01:43:26,960

and and try to get back here by 26 after

2882

01:47:11,510 --> 01:43:29,600

so that we start at 4 30.

2883

01:47:11,520 --> 01:47:22,470

figure out

2884

01:47:22,480 --> 01:47:48,390

okay

2885

01:47:48,400 --> 01:48:01,990

i'm done

2886

01:48:02,000 --> 01:48:28,070

lately

2887

01:48:28,080 --> 01:48:51,350

is

2888

01:48:51,360 --> 01:49:09,510

foreign

2889

01:49:09,520 --> 01:49:36,229

and uh

2890

01:49:36,239 --> 01:49:50,870

um

2891

01:49:50,880 --> 01:50:09,270

you check that out

2892

01:50:56,550 --> 01:50:28,629

okay

2893

01:56:50,229 --> 01:50:58,910

so we were talking about

2894

01:56:53,109 --> 01:56:51,750

no that's good

2895

01:56:56,709 --> 01:56:53,119

all right um

2896

01:56:59,270 --> 01:56:56,719

as we said uh we have one uh edition for

2897

01:57:01,350 --> 01:56:59,280

a short discussion by dr joel cercelle

2898

01:57:02,950 --> 01:57:01,360

he's um his his paper is in another

2899

01:57:04,149 --> 01:57:02,960

session but it really fits better here

2900

01:57:05,350 --> 01:57:04,159

so we're going to give him about five

2901
01:57:06,629 --> 01:57:05,360
minutes to talk

2902
01:57:08,070 --> 01:57:06,639
through that then we'll go back through

2903
01:57:10,470 --> 01:57:08,080
some of the questions that we hadn't

2904
01:57:12,629 --> 01:57:10,480
gotten to and then we'll talk through

2905
01:57:14,629 --> 01:57:12,639
what we want to talk about on wednesday

2906
01:57:16,790 --> 01:57:14,639
dr cersel is the president and founder

2907
01:57:18,950 --> 01:57:16,800
of ics associates which specializes in

2908
01:57:20,550 --> 01:57:18,960
helping clients become more innovative

2909
01:57:22,310 --> 01:57:20,560
and effective at systems engineering and

2910
01:57:24,470 --> 01:57:22,320
project management

2911
01:57:25,910 --> 01:57:24,480
joel has over 25 years of experience

2912
01:57:28,070 --> 01:57:25,920
developing advanced technology and

2913
01:57:30,629 --> 01:57:28,080

innovation products he spent 14 years at

2914

01:57:32,550 --> 01:57:30,639

jpl and two years as a senior program

2915

01:57:34,709 --> 01:57:32,560

manager for the air force joel received

2916

01:57:36,470 --> 01:57:34,719

his phd and master's in mechanical

2917

01:57:38,229 --> 01:57:36,480

engineering from caltech with his

2918

01:57:40,310 --> 01:57:38,239

doctoral dissertation in space

2919

01:57:41,589 --> 01:57:40,320

propulsion plasma physics

2920

01:57:46,229 --> 01:57:41,599

joel

2921

01:57:49,510 --> 01:57:47,910

i'll go fast

2922

01:58:00,390 --> 01:57:49,520

because i'm not going to say much i'm

2923

01:58:04,470 --> 01:58:02,390

has been put in place

2924

01:58:07,270 --> 01:58:04,480

one of the co-architects of this concept

2925

01:58:10,550 --> 01:58:07,280

is james french who you may know from

2926

01:58:13,270 --> 01:58:10,560

being the architect of um

2927

01:58:15,350 --> 01:58:13,280

blue origins satellites he was also the

2928

01:58:16,390 --> 01:58:15,360

chief engineer of amrock the company

2929

01:58:18,550 --> 01:58:16,400

that made the

2930

01:58:20,870 --> 01:58:18,560

hybrid rockets that are in use in virgin

2931

01:58:22,870 --> 01:58:20,880

galactic systems

2932

01:58:24,870 --> 01:58:22,880

another person who worked with us is

2933

01:58:27,430 --> 01:58:24,880

greg maranac who was

2934

01:58:28,790 --> 01:58:27,440

one of the co-founders of the xprize

2935

01:58:31,350 --> 01:58:28,800

foundation

2936

01:58:33,270 --> 01:58:31,360

so we're very excited about this it's a

2937

01:58:35,910 --> 01:58:33,280

radically different approach

2938

01:58:37,350 --> 01:58:35,920

for nearest object redirection

2939

01:58:39,589 --> 01:58:37,360

i'm just going to tell you a couple

2940

01:58:41,189 --> 01:58:39,599

simple things about it number one is

2941

01:58:44,149 --> 01:58:41,199

what is the goal of it we call it

2942

01:58:47,669 --> 01:58:45,430

not to be confused with honeybee

2943

01:58:49,910 --> 01:58:47,679

robotics which is spelled differently or

2944

01:58:51,350 --> 01:58:49,920

there's a bumblebee asteroid deflection

2945

01:58:52,870 --> 01:58:51,360

system that they've been working on in

2946

01:58:54,310 --> 01:58:52,880

scotland that's not presented here this

2947

01:58:55,189 --> 01:58:54,320

year this week

2948

01:58:57,350 --> 01:58:55,199

um

2949

01:58:59,589 --> 01:58:57,360

because it it basically goes out and

2950

01:59:01,270 --> 01:58:59,599

gathers things in a way that's analogous

2951
01:59:03,589 --> 01:59:01,280
to bees and that's all i'm going to say

2952
01:59:05,189 --> 01:59:03,599
about the technical approach

2953
01:59:06,950 --> 01:59:05,199
i'm going to say why we're doing it's

2954
01:59:09,270 --> 01:59:06,960
very important to ask the question why

2955
01:59:10,629 --> 01:59:09,280
are we doing this i think arm is a very

2956
01:59:12,790 --> 01:59:10,639
cool mission

2957
01:59:15,109 --> 01:59:12,800
as currently conceived and the why that

2958
01:59:17,430 --> 01:59:15,119
nasa has is to give astronauts something

2959
01:59:19,109 --> 01:59:17,440
to do that's really cool if that's what

2960
01:59:21,430 --> 01:59:19,119
you want to do but we have a different

2961
01:59:23,589 --> 01:59:21,440
goal which and if again it may also give

2962
01:59:24,629 --> 01:59:23,599
astronauts something much more powerful

2963
01:59:25,990 --> 01:59:24,639

to do

2964

01:59:28,550 --> 01:59:26,000

um so i'm going to give you a

2965

01:59:30,149 --> 01:59:28,560

description of the mission I attributes

2966

01:59:32,950 --> 01:59:30,159

this is the why

2967

01:59:34,550 --> 01:59:32,960

this is the how what i'm not going to do

2968

01:59:36,790 --> 01:59:34,560

is i'm not going to give you the what

2969

01:59:39,750 --> 01:59:36,800

how does it work technically

2970

01:59:41,030 --> 01:59:39,760

that has to go for another place

2971

01:59:42,229 --> 01:59:41,040

um

2972

01:59:44,390 --> 01:59:42,239

talk a little bit about what it would

2973

01:59:45,510 --> 01:59:44,400

take to be successful from the larger

2974

01:59:47,109 --> 01:59:45,520

perspective

2975

01:59:48,310 --> 01:59:47,119

and i'm going to tell you how to contact

2976

01:59:49,990 --> 01:59:48,320

me if you want to discuss the

2977

01:59:50,870 --> 01:59:50,000

proprietary systems and approaches

2978

01:59:52,870 --> 01:59:50,880

because

2979

01:59:57,030 --> 01:59:52,880

when we do this it's going to change

2980

01:59:58,709 --> 01:59:57,040

everything about everything in space

2981

02:00:00,470 --> 01:59:58,719

so why

2982

02:00:02,589 --> 02:00:00,480

the goal is simple

2983

02:00:04,790 --> 02:00:02,599

to make humanity a species that uses

2984

02:00:06,950 --> 02:00:04,800

extraterrestrial resources for practical

2985

02:00:08,950 --> 02:00:06,960

purposes but not to do it with pie in

2986

02:00:10,870 --> 02:00:08,960

the sky to do it with a system that

2987

02:00:14,390 --> 02:00:10,880

today every element of the system is at

2988

02:00:16,470 --> 02:00:14,400

trl4 or above

2989

02:00:18,870 --> 02:00:16,480

it's a and to pilot

2990

02:00:20,950 --> 02:00:18,880

that means to really no no kidding do it

2991

02:00:23,270 --> 02:00:20,960

an affordable method

2992

02:00:25,750 --> 02:00:23,280

to use in a practical way hundreds of

2993

02:00:27,350 --> 02:00:25,760

tons of extraterrestrial resources which

2994

02:00:29,430 --> 02:00:27,360

honeybee does

2995

02:00:31,030 --> 02:00:29,440

to radically reduce and once we do that

2996

02:00:34,229 --> 02:00:31,040

it will radically reduce the cost of

2997

02:00:35,669 --> 02:00:34,239

space operations for all kinds of

2998

02:00:39,430 --> 02:00:35,679

further missions

2999

02:00:41,510 --> 02:00:39,440

so for example when honeybee is in place

3000

02:00:44,950 --> 02:00:41,520

we will have demonstrated the ability to

3001

02:00:47,189 --> 02:00:44,960

essentially convert 1000 ton neo

3002

02:00:49,109 --> 02:00:47,199

to a propellant depot that could be used

3003

02:00:51,430 --> 02:00:49,119

to fill the tanks of a manned mars

3004

02:00:54,070 --> 02:00:51,440

mission at the top of the gravity well

3005

02:00:56,149 --> 02:00:54,080

that collapses the cost of human

3006

02:00:57,910 --> 02:00:56,159

exploration of mars

3007

02:00:59,189 --> 02:00:57,920

it allows you it puts it allows you to

3008

02:01:01,350 --> 02:00:59,199

put in place an inexpensive

3009

02:01:04,070 --> 02:01:01,360

transportation system to go anywhere in

3010

02:01:05,430 --> 02:01:04,080

cis lunar space which includes leo to

3011

02:01:07,910 --> 02:01:05,440

geo

3012

02:01:09,510 --> 02:01:07,920

what it therefore a falcon 9 would have

3013

02:01:12,870 --> 02:01:09,520

the ability to launch

3014

02:01:15,510 --> 02:01:12,880

two 5 000 kilogram geos

3015

02:01:17,990 --> 02:01:15,520

and that's the big class and a 2 500

3016

02:01:20,149 --> 02:01:18,000

kilogram geo all on one falcon line

3017

02:01:21,910 --> 02:01:20,159

launch so someone who is in that

3018

02:01:24,149 --> 02:01:21,920

business tell me how much that saves in

3019

02:01:25,910 --> 02:01:24,159

launch cost i don't know the number i'm

3020

02:01:28,950 --> 02:01:25,920

assuming it's somewhere in the 10 to the

3021

02:01:33,750 --> 02:01:31,430

what does honeybee do it captures

3022

02:01:35,109 --> 02:01:33,760

a neo into cis lunar space a lot like

3023

02:01:37,350 --> 02:01:35,119

arm

3024

02:01:40,390 --> 02:01:37,360

but it's radically different

3025

02:01:43,109 --> 02:01:40,400

in the sense that it uses very simple

3026

02:01:44,950 --> 02:01:43,119

common sense systems nothing

3027

02:01:47,109 --> 02:01:44,960

suffic nothing very high tech or

3028

02:01:49,189 --> 02:01:47,119

advanced there's no

3029

02:01:51,589 --> 02:01:49,199

high power electric processing there's

3030

02:01:54,149 --> 02:01:51,599

no 50 kilowatt solar array there's no

3031

02:01:56,149 --> 02:01:54,159

plasma propulsion and john brophy

3032

02:01:57,589 --> 02:01:56,159

remembers when we did n star i mean i

3033

02:01:59,350 --> 02:01:57,599

i'm a big passionate believer in

3034

02:02:02,550 --> 02:01:59,360

electric propulsion i just don't think

3035

02:02:04,229 --> 02:02:02,560

it's the right choice for this mission

3036

02:02:07,430 --> 02:02:04,239

however unlike arm it does require

3037

02:02:10,149 --> 02:02:07,440

careful selection of the target object

3038

02:02:12,229 --> 02:02:10,159

and so i'm a big believer in the talk

3039

02:02:14,310 --> 02:02:12,239

that mr gump gave

3040

02:02:15,270 --> 02:02:14,320

that said you have to do prospecting

3041

02:02:17,189 --> 02:02:15,280

first

3042

02:02:19,669 --> 02:02:17,199

i used to have a manager who had used to

3043

02:02:21,109 --> 02:02:19,679

assign me to do powerpoint presentations

3044

02:02:22,870 --> 02:02:21,119

and we called it the bring me a rock

3045

02:02:24,310 --> 02:02:22,880

powerpoint method he'd say i want a

3046

02:02:25,990 --> 02:02:24,320

powerpoint presentation about something

3047

02:02:27,830 --> 02:02:26,000

i don't know what it is so i'd bring it

3048

02:02:29,270 --> 02:02:27,840

to him and then he'd have me redo it a

3049

02:02:30,870 --> 02:02:29,280

hundred times if we called it bring me a

3050

02:02:32,629 --> 02:02:30,880

rock bring me a rock maybe a way for

3051
02:02:35,189 --> 02:02:32,639
managers to get powerpoint presentations

3052
02:02:38,390 --> 02:02:35,199
done it should not be the way that nasa

3053
02:02:41,189 --> 02:02:38,400
plans a multi-billion dollar mission

3054
02:02:43,750 --> 02:02:41,199
so um at the technical level if you

3055
02:02:46,149 --> 02:02:43,760
compare honeybee to the baseline arm

3056
02:02:47,589 --> 02:02:46,159
mission concept instead of delivering

3057
02:02:49,109 --> 02:02:47,599
and john i read your different papers

3058
02:02:50,709 --> 02:02:49,119
like there's a little spread in the data

3059
02:02:52,870 --> 02:02:50,719
in terms of the cost it's an evolving

3060
02:02:55,430 --> 02:02:52,880
concept that's all good instead of

3061
02:02:56,910 --> 02:02:55,440
delivering in round numbers 15 tons by

3062
02:02:59,750 --> 02:02:56,920
the way ton is

3063
02:03:01,589 --> 02:02:59,760

t-o-n-n-e-s i just i noticed a lot of

3064

02:03:05,030 --> 02:03:01,599

typos on that in people's talks and i'm

3065

02:03:06,470 --> 02:03:05,040

bad at spelling so instead of 15 tons to

3066

02:03:08,629 --> 02:03:06,480

low c3

3067

02:03:10,390 --> 02:03:08,639

you require only about 3000 kilograms to

3068

02:03:14,310 --> 02:03:10,400

a low c3

3069

02:03:15,990 --> 02:03:14,320

um instead of a long trip time out and

3070

02:03:17,910 --> 02:03:16,000

back it's short

3071

02:03:19,830 --> 02:03:17,920

and it's short i won't tell you exactly

3072

02:03:21,510 --> 02:03:19,840

how but it's more like a very impulsive

3073

02:03:22,550 --> 02:03:21,520

trajectory

3074

02:03:25,430 --> 02:03:22,560

um

3075

02:03:27,669 --> 02:03:25,440

probably reduces the cost a lot and then

3076

02:03:29,830 --> 02:03:27,679

very oh interesting it

3077

02:03:31,350 --> 02:03:29,840

switching from mac to windows to stored

3078

02:03:33,350 --> 02:03:31,360

the

3079

02:03:35,350 --> 02:03:33,360

formatting but anyway instead of

3080

02:03:36,310 --> 02:03:35,360

returning a thousand ton object that now

3081

02:03:37,589 --> 02:03:36,320

you got to figure out what you're going

3082

02:03:40,709 --> 02:03:37,599

to do with it

3083

02:03:43,589 --> 02:03:40,719

it returns the object in such a way that

3084

02:03:46,629 --> 02:03:43,599

we have a functioning fully functioning

3085

02:03:48,709 --> 02:03:46,639

orbiting propellant depot

3086

02:03:50,149 --> 02:03:48,719

um how to get it done i totally agree

3087

02:03:52,310 --> 02:03:50,159

with mr gump's

3088

02:03:54,310 --> 02:03:52,320

point on this it's got to be about

3089

02:03:56,310 --> 02:03:54,320

public private partnership

3090

02:03:59,189 --> 02:03:56,320

a combination of venture capitalists

3091

02:04:01,669 --> 02:03:59,199

aerospace companies nasa and jpl i think

3092

02:04:03,270 --> 02:04:01,679

that's the right way to do it it's what

3093

02:04:04,870 --> 02:04:03,280

we need to do is we need to pull

3094

02:04:07,750 --> 02:04:04,880

together as a community to understand

3095

02:04:08,550 --> 02:04:07,760

it's time to stop screwing around

3096

02:04:10,069 --> 02:04:08,560

with

3097

02:04:12,870 --> 02:04:10,079

high paid tourists that we called

3098

02:04:14,709 --> 02:04:12,880

astronauts in space it started time to

3099

02:04:15,750 --> 02:04:14,719

start doing something really important

3100

02:04:17,189 --> 02:04:15,760

in space

3101
02:04:19,109 --> 02:04:17,199
and this is this is the beginning of

3102
02:04:20,950 --> 02:04:19,119
that process

3103
02:04:22,950 --> 02:04:20,960
so what i'm asking you to do is i'm

3104
02:04:25,030 --> 02:04:22,960
asking you to think not like a 20th

3105
02:04:28,229 --> 02:04:25,040
century architect

3106
02:04:30,069 --> 02:04:28,239
enterprise but like a 21st century

3107
02:04:31,750 --> 02:04:30,079
enterprise if you're interested in

3108
02:04:34,229 --> 02:04:31,760
finding out about it we can talk about

3109
02:04:35,990 --> 02:04:34,239
it under nda and that's my contact

3110
02:04:43,669 --> 02:04:36,000
information so

3111
02:04:47,510 --> 02:04:45,510
all right um

3112
02:04:49,189 --> 02:04:47,520
any questions for a quick question for

3113
02:04:53,109 --> 02:04:49,199

joel or

3114

02:04:54,870 --> 02:04:53,119

we'll go on to um

3115

02:04:56,790 --> 02:04:54,880

okay then we'll go on to

3116

02:04:58,470 --> 02:04:56,800

revisiting uh

3117

02:04:59,830 --> 02:04:58,480

romero could you bring up the

3118

02:05:02,950 --> 02:04:59,840

introduction

3119

02:05:02,960 --> 02:05:08,790

my contact information is

3120

02:05:14,149 --> 02:05:11,910

and then if you would go ahead um

3121

02:05:16,629 --> 02:05:14,159

two slides

3122

02:05:18,550 --> 02:05:16,639

just as a reminder for um this will also

3123

02:05:19,430 --> 02:05:18,560

be a good time place for us to start

3124

02:05:23,430 --> 02:05:19,440

when we

3125

02:05:25,910 --> 02:05:23,440

set the question

3126

02:05:28,229 --> 02:05:25,920

so what i'd like to do is see where

3127

02:05:29,750 --> 02:05:28,239

we get to in the next 15 minutes or so

3128

02:05:32,069 --> 02:05:29,760

or if we don't have enough questions you

3129

02:05:34,069 --> 02:05:32,079

know we'll go into the next phase but

3130

02:05:36,709 --> 02:05:34,079

so does anyone want to bring back one of

3131

02:05:40,310 --> 02:05:36,719

the presenters or or bring up a point we

3132

02:05:42,310 --> 02:05:40,320

do have several um from um the chat and

3133

02:05:43,350 --> 02:05:42,320

we can start with those unless somebody

3134

02:05:45,990 --> 02:05:43,360

has something

3135

02:05:53,750 --> 02:05:46,000

so go ahead heather if you'd go to a mic

3136

02:05:57,669 --> 02:05:55,350

so i'm going to just start at the

3137

02:05:59,750 --> 02:05:57,679

beginning so john brophy there was

3138

02:06:01,270 --> 02:05:59,760

someone who addressed does the material

3139

02:06:03,830 --> 02:06:01,280
of the bag need to be electrically

3140

02:06:09,589 --> 02:06:03,840
conductive to prevent static charge

3141

02:06:09,599 --> 02:06:12,149
yes

3142

02:06:16,149 --> 02:06:14,310
okay well that was quick all right don't

3143

02:06:18,229 --> 02:06:16,159
sit down don't sit down you're not

3144

02:06:19,830 --> 02:06:18,239
you've got a couple here so somebody

3145

02:06:23,350 --> 02:06:19,840
wants to know how you match the spin

3146

02:06:27,350 --> 02:06:25,990
okay so to match the spin rate um

3147

02:06:29,750 --> 02:06:27,360
you just have to

3148

02:06:32,390 --> 02:06:29,760
there's attitude control thrusters on

3149

02:06:33,990 --> 02:06:32,400
the spacecraft and so you just spin up

3150

02:06:35,350 --> 02:06:34,000
use that to spin up the spacecraft to

3151

02:06:38,390 --> 02:06:35,360

the same

3152

02:06:39,669 --> 02:06:38,400

rotation rate as the asteroid

3153

02:06:42,830 --> 02:06:39,679

we're matching the instantaneous

3154

02:06:44,390 --> 02:06:42,840

rotation right you might want to verify

3155

02:06:46,229 --> 02:06:44,400

yeah

3156

02:06:48,470 --> 02:06:46,239

okay so people are adding more details

3157

02:06:50,229 --> 02:06:48,480

so we watch it long enough to

3158

02:06:51,910 --> 02:06:50,239

be able to know exactly it's spin

3159

02:06:54,229 --> 02:06:51,920

characteristic and project that into the

3160

02:06:56,790 --> 02:06:54,239

future and so that you can then

3161

02:06:58,149 --> 02:06:56,800

match the instantaneous spin right at

3162

02:07:00,149 --> 02:06:58,159

the time you're going to go grab the

3163

02:07:01,910 --> 02:07:00,159

ester and that's for high spin rates

3164

02:07:03,510 --> 02:07:01,920

right for lower spin rates we don't even

3165

02:07:07,030 --> 02:07:03,520

have to bother with that you sure that

3166

02:07:10,229 --> 02:07:08,870

you were presenting john so you were the

3167

02:07:13,510 --> 02:07:10,239

lucky one

3168

02:07:15,189 --> 02:07:13,520

okay uh so then there was a like four or

3169

02:07:17,350 --> 02:07:15,199

five or six different comments that came

3170

02:07:19,990 --> 02:07:17,360

in about electromagnetism so i'm going

3171

02:07:21,350 --> 02:07:20,000

to just kind of describe in general what

3172

02:07:23,910 --> 02:07:21,360

they were and then we can have that

3173

02:07:25,990 --> 02:07:23,920

discussion so should electromagnetism be

3174

02:07:27,109 --> 02:07:26,000

used as a backup to the capture bag as a

3175

02:07:30,709 --> 02:07:27,119

secure

3176

02:07:32,550 --> 02:07:30,719

the um asteroid

3177

02:07:34,069 --> 02:07:32,560

magnetic components within a bag could

3178

02:07:35,510 --> 02:07:34,079

help de-spin

3179

02:07:37,589 --> 02:07:35,520

concept

3180

02:07:40,709 --> 02:07:37,599

generate electromagnetic charge for tow

3181

02:07:42,390 --> 02:07:40,719

and capture what about a tractor beam

3182

02:07:44,790 --> 02:07:42,400

um

3183

02:07:46,470 --> 02:07:44,800

i like the tractor building

3184

02:07:48,750 --> 02:07:46,480

so let's see

3185

02:07:50,550 --> 02:07:48,760

i those were sort of the gist of the

3186

02:07:52,790 --> 02:07:50,560

electromagnetism but there were quite a

3187

02:07:53,830 --> 02:07:52,800

few different threads about that so okay

3188

02:07:56,149 --> 02:07:53,840

so the

3189

02:07:58,550 --> 02:07:56,159

i think the the notion is can you use

3190

02:08:00,470 --> 02:07:58,560

some kind of electromagnetic forces on

3191

02:08:02,870 --> 02:08:00,480

the asteroid to help control it or

3192

02:08:05,030 --> 02:08:02,880

de-tumble it and uh

3193

02:08:06,790 --> 02:08:05,040

that requires you to know a lot about

3194

02:08:08,550 --> 02:08:06,800

the asteroid and how conductive it is

3195

02:08:10,390 --> 02:08:08,560

and how

3196

02:08:11,669 --> 02:08:10,400

you know how you can apply those forces

3197

02:08:12,950 --> 02:08:11,679

so

3198

02:08:15,030 --> 02:08:12,960

probably

3199

02:08:17,030 --> 02:08:15,040

wouldn't be the first approach that we

3200

02:08:20,950 --> 02:08:17,040

would attempt to capture an asteroid

3201

02:08:26,149 --> 02:08:24,149

uh there was a question about if you

3202

02:08:27,910 --> 02:08:26,159

were attached to a nickel iron asteroid

3203

02:08:34,550 --> 02:08:27,920

could you chemically produce hydrogen

3204

02:08:39,430 --> 02:08:35,589

no

3205

02:08:41,350 --> 02:08:39,440

but it would be awesome to find a a

3206

02:08:44,390 --> 02:08:41,360

whole nickel iron asteroid but we

3207

02:08:47,750 --> 02:08:44,400

probably wouldn't bring that back

3208

02:08:53,270 --> 02:08:50,390

all right we talked about that one um

3209

02:08:54,550 --> 02:08:53,280

there was sort of a discussion

3210

02:08:55,990 --> 02:08:54,560

and there really wasn't a question that

3211

02:08:58,069 --> 02:08:56,000

came out of it there was a discussion

3212

02:09:00,069 --> 02:08:58,079

that might be worth capturing about the

3213

02:09:01,910 --> 02:09:00,079

trade between designing a vehicle for

3214

02:09:04,629 --> 02:09:01,920

worst case masses when you have large

3215

02:09:06,950 --> 02:09:04,639

uncertainties versus funding precursor

3216

02:09:09,350 --> 02:09:06,960

robotic precursor missions so there was

3217

02:09:11,270 --> 02:09:09,360

a quite a few different threads about

3218

02:09:12,950 --> 02:09:11,280

that and and um

3219

02:09:15,189 --> 02:09:12,960

in discussing with jim he thought we

3220

02:09:17,109 --> 02:09:15,199

ought to just capture that as a yeah

3221

02:09:18,950 --> 02:09:17,119

well that i mean that that is a you know

3222

02:09:20,229 --> 02:09:18,960

that's a serious issue and that is one

3223

02:09:23,430 --> 02:09:20,239

of the key

3224

02:09:25,189 --> 02:09:23,440

uh drivers for the characterization uh

3225

02:09:25,990 --> 02:09:25,199

the observation campaign

3226

02:09:27,510 --> 02:09:26,000

uh

3227

02:09:29,830 --> 02:09:27,520

the characterization part of that

3228

02:09:32,550 --> 02:09:29,840

campaign and so you have to

3229

02:09:35,430 --> 02:09:32,560

do the right characterizations to

3230

02:09:37,910 --> 02:09:35,440

to limit the uncertainty in the size and

3231

02:09:41,109 --> 02:09:37,920

mass and spin state of the object so

3232

02:09:41,990 --> 02:09:41,119

that it's within the capabilities of

3233

02:09:44,629 --> 02:09:42,000

your

3234

02:09:45,669 --> 02:09:44,639

flight system with appropriate margins

3235

02:09:46,629 --> 02:09:45,679

and

3236

02:09:50,470 --> 02:09:46,639

in the

3237

02:09:52,709 --> 02:09:50,480

period over the last uh

3238

02:09:55,910 --> 02:09:52,719

uh seven or eight months it's clear that

3239

02:09:57,109 --> 02:09:55,920

that such an observation campaign is is

3240

02:09:59,030 --> 02:09:57,119

possible

3241

02:10:01,109 --> 02:09:59,040

and and is

3242

02:10:02,870 --> 02:10:01,119

and part of the reason for that is

3243

02:10:04,229 --> 02:10:02,880

uh you know someone had mentioned in one

3244

02:10:06,069 --> 02:10:04,239

of their talks that there weren't a lot

3245

02:10:07,589 --> 02:10:06,079

of these small objects but uh the

3246

02:10:09,510 --> 02:10:07,599

current population models you know

3247

02:10:11,270 --> 02:10:09,520

suggested basically that all the

3248

02:10:14,149 --> 02:10:11,280

near-earth asteroids to first order are

3249

02:10:15,910 --> 02:10:14,159

small and there are just a scattering of

3250

02:10:16,950 --> 02:10:15,920

larger ones and so

3251

02:10:20,149 --> 02:10:16,960

um

3252

02:10:22,950 --> 02:10:20,159

there are lots of objects potentially to

3253

02:10:25,189 --> 02:10:22,960

to discover and um

3254

02:10:26,709 --> 02:10:25,199

and characterize so we can as i

3255

02:10:28,950 --> 02:10:26,719

mentioned earlier there's the likelihood

3256

02:10:30,790 --> 02:10:28,960

that we'd have 15 to 20

3257

02:10:35,189 --> 02:10:30,800

good well characterized objects that we

3258

02:10:40,629 --> 02:10:38,310

there were a few comments about

3259

02:10:41,430 --> 02:10:40,639

having the mission thought out further

3260

02:10:43,189 --> 02:10:41,440

for

3261

02:10:45,910 --> 02:10:43,199

better integration and long-term

3262

02:10:47,430 --> 02:10:45,920

purposes for the asteroid just a couple

3263

02:10:49,830 --> 02:10:47,440

along that thread

3264

02:10:52,069 --> 02:10:49,840

um and i have a couple of my own though

3265

02:10:54,950 --> 02:10:52,079

that was the end of the virtual ones

3266

02:10:57,350 --> 02:10:54,960

okay if that's okay so um

3267

02:10:59,030 --> 02:10:57,360

the the one was for boeing and i was

3268

02:11:01,910 --> 02:10:59,040

wondering what updates you've done to

3269

02:11:11,830 --> 02:11:01,920

your arnd sensor suite since orbital

3270

02:11:14,470 --> 02:11:12,550

uh

3271

02:11:16,870 --> 02:11:14,480

actually we've done we've done quite a

3272

02:11:18,229 --> 02:11:16,880

lot uh as i mentioned we're uh we're

3273

02:11:21,430 --> 02:11:18,239

developing the vesta system for

3274

02:11:23,109 --> 02:11:21,440

commercial crew and so uh we are headed

3275

02:11:25,830 --> 02:11:23,119

for a critical design review on that

3276

02:11:27,350 --> 02:11:25,840
system here in uh in december

3277

02:11:28,870 --> 02:11:27,360
so that's uh

3278

02:11:32,390 --> 02:11:28,880
that could give you a sense of the

3279

02:11:33,510 --> 02:11:32,400
maturity so the uh the sensors uh three

3280

02:11:35,990 --> 02:11:33,520
different sensor types are in

3281

02:11:39,910 --> 02:11:36,000
development uh the ones i talked about

3282

02:11:44,229 --> 02:11:41,510
beyond that we've done quite a lot of

3283

02:11:46,310 --> 02:11:44,239
work on on the software uh which we

3284

02:11:48,709 --> 02:11:46,320
which we call this star that initially

3285

02:11:50,870 --> 02:11:48,719
flew on orbital express and since then

3286

02:11:53,510 --> 02:11:50,880
we've we've been uh maturing that

3287

02:11:54,950 --> 02:11:53,520
software to make it specifically

3288

02:11:57,910 --> 02:11:54,960

applicable to the international space

3289

02:11:59,430 --> 02:11:57,920

station and so a lot of the the track

3290

02:12:00,149 --> 02:11:59,440

modes that uh

3291

02:12:01,830 --> 02:12:00,159

uh

3292

02:12:03,189 --> 02:12:01,840

there have been papers written you can

3293

02:12:06,470 --> 02:12:03,199

look at this but the different track

3294

02:12:08,229 --> 02:12:06,480

modes that we had on orbital express are

3295

02:12:10,390 --> 02:12:08,239

now being updated

3296

02:12:12,870 --> 02:12:10,400

uh including specific feature track

3297

02:12:13,750 --> 02:12:12,880

modes that are applicable to station and

3298

02:12:19,109 --> 02:12:13,760

those

3299

02:12:20,709 --> 02:12:19,119

are also applicable to natural bodies

3300

02:12:22,069 --> 02:12:20,719

the sorts of

3301

02:12:23,589 --> 02:12:22,079

you know you're looking for features

3302

02:12:24,950 --> 02:12:23,599

they don't have to be any particular

3303

02:12:26,870 --> 02:12:24,960

feature

3304

02:12:28,790 --> 02:12:26,880

so there's a lot of flexibility there in

3305

02:12:30,950 --> 02:12:28,800

terms of what what the details of those

3306

02:12:31,910 --> 02:12:30,960

those features are and we're also doing

3307

02:12:33,350 --> 02:12:31,920

uh

3308

02:12:34,390 --> 02:12:33,360

you know integrated testing in the

3309

02:12:36,229 --> 02:12:34,400

laboratory

3310

02:12:39,430 --> 02:12:36,239

and that's going on today

3311

02:12:41,109 --> 02:12:39,440

so a good bit of

3312

02:12:43,830 --> 02:12:41,119

what i what i talked about there's

3313

02:12:45,910 --> 02:12:43,840

actually hardware in the lab today and

3314

02:12:47,990 --> 02:12:45,920

software integrated in the lab today

3315

02:12:49,270 --> 02:12:48,000

that's doing doing testing on an optical

3316

02:12:52,069 --> 02:12:49,280

range

3317

02:12:54,550 --> 02:12:52,079

thank you and are they the same

3318

02:12:57,109 --> 02:12:54,560

exact sensors or you've updated them the

3319

02:12:58,390 --> 02:12:57,119

same class as i they are updated from

3320

02:13:01,270 --> 02:12:58,400

what we flew on

3321

02:13:03,270 --> 02:13:01,280

orbital express yeah

3322

02:13:05,350 --> 02:13:03,280

it's uh you i think that you mentioned

3323

02:13:07,270 --> 02:13:05,360

one of the sensors is a 3d lighter is

3324

02:13:08,870 --> 02:13:07,280

that scanning or flash or

3325

02:13:11,270 --> 02:13:08,880

uh

3326

02:13:16,550 --> 02:13:11,280

yeah so so at this point let me let me

3327

02:13:21,270 --> 02:13:18,709

that i i probably like to not say right

3328

02:13:22,790 --> 02:13:21,280

now but but

3329

02:13:24,790 --> 02:13:22,800

okay

3330

02:13:25,990 --> 02:13:24,800

but you didn't have one in orbital

3331

02:13:27,589 --> 02:13:26,000

express

3332

02:13:29,750 --> 02:13:27,599

we had a we had a lidar on orbital

3333

02:13:32,069 --> 02:13:29,760

express we had a rangefinder that was a

3334

02:13:34,310 --> 02:13:32,079

scalar that delivered a scalar range so

3335

02:13:38,470 --> 02:13:34,320

this is a this is this is a 3d yeah this

3336

02:13:43,830 --> 02:13:40,310

all right my next question was sort of

3337

02:13:46,470 --> 02:13:43,840

general there were several r d sensor

3338

02:13:49,270 --> 02:13:46,480

presentations made for sort of a suite

3339

02:13:51,830 --> 02:13:49,280

of sensors and i noticed some contained

3340

02:13:53,510 --> 02:13:51,840

ir cameras and some contain only visible

3341

02:13:55,990 --> 02:13:53,520

cameras and we've had a lot of

3342

02:13:57,990 --> 02:13:56,000

discussion and debate about that and

3343

02:13:59,830 --> 02:13:58,000

i don't know if it's appropriate to just

3344

02:14:01,910 --> 02:13:59,840

capture it or if anyone in the room

3345

02:14:03,750 --> 02:14:01,920

wants a comment about who did include an

3346

02:14:06,229 --> 02:14:03,760

ir camera in their suite the benefit of

3347

02:14:08,470 --> 02:14:06,239

that versus just the visible camera and

3348

02:14:11,350 --> 02:14:08,480

there are certain obvious benefits but

3349

02:14:13,030 --> 02:14:11,360

if anyone wants to address that

3350

02:14:14,790 --> 02:14:13,040

so since i'm i'm standing at the

3351
02:14:16,709 --> 02:14:14,800
microphone like i could start by saying

3352
02:14:20,629 --> 02:14:16,719
that we we include a a long wave

3353
02:14:26,950 --> 02:14:23,510
and and i sort of said why but uh the

3354
02:14:28,069 --> 02:14:26,960
ability to uh to track at night or in

3355
02:14:29,750 --> 02:14:28,079
poor lighting

3356
02:14:31,750 --> 02:14:29,760
when the uh

3357
02:14:34,470 --> 02:14:31,760
or at or at low sun angles

3358
02:14:38,310 --> 02:14:34,480
is a is a good reason to uh to have the

3359
02:14:40,870 --> 02:14:39,430
okay

3360
02:14:46,310 --> 02:14:40,880
are there questions

3361
02:14:50,709 --> 02:14:49,510
oh we have one go ahead and then

3362
02:14:53,030 --> 02:14:50,719
for the

3363
02:14:54,870 --> 02:14:53,040

baseline arv vehicle we've seen some

3364

02:14:57,430 --> 02:14:54,880

engineering sketches

3365

02:14:59,270 --> 02:14:57,440

can anyone describe what tonnage it's

3366

02:15:01,430 --> 02:14:59,280

designed to retrieve or what delta v's

3367

02:15:04,790 --> 02:15:01,440

it achieves outbound and inbound there

3368

02:15:10,229 --> 02:15:06,950

okay yeah so for the i feel weird

3369

02:15:13,109 --> 02:15:11,350

i'll do this

3370

02:15:15,430 --> 02:15:13,119

okay so the

3371

02:15:18,149 --> 02:15:15,440

for the baseline vehicle it was designed

3372

02:15:23,109 --> 02:15:20,550

asteroid masses up to about a thousand

3373

02:15:25,510 --> 02:15:23,119

metric tons and i say about because it

3374

02:15:27,910 --> 02:15:25,520

depends a lot on the specifics of the

3375

02:15:30,470 --> 02:15:27,920

asteroid and it's its orbit and the

3376

02:15:31,350 --> 02:15:30,480

characteristics and also on when you can

3377

02:15:37,030 --> 02:15:31,360

launch

3378

02:15:38,709 --> 02:15:37,040

forth but so you know roughly a thousand

3379

02:15:40,629 --> 02:15:38,719

metric tons is

3380

02:15:41,750 --> 02:15:40,639

is the limit

3381

02:15:44,149 --> 02:15:41,760

so

3382

02:15:47,750 --> 02:15:44,159

and it it uses we can store up to as i

3383

02:15:50,470 --> 02:15:47,760

said about 10 tons of xenon and 400 tons

3384

02:15:52,629 --> 02:15:50,480

400 kilograms of hydrazine so those all

3385

02:15:55,430 --> 02:15:52,639

fit into that as well as the aster the

3386

02:15:58,229 --> 02:15:55,440

capture mechanism size they're all uh

3387

02:16:00,149 --> 02:15:58,239

interrelated to some degree

3388

02:16:01,109 --> 02:16:00,159

oh i'm sorry yeah the delta v

3389

02:16:03,270 --> 02:16:01,119

uh

3390

02:16:04,470 --> 02:16:03,280

so the inbound delta v is on the order

3391

02:16:07,270 --> 02:16:04,480

of

3392

02:16:09,430 --> 02:16:07,280

100 to 200 meters per second

3393

02:16:12,629 --> 02:16:09,440

that again depends on the asteroid and

3394

02:16:16,550 --> 02:16:12,639

part of that goes to

3395

02:16:19,510 --> 02:16:16,560

getting the asteroid into the long term

3396

02:16:22,550 --> 02:16:19,520

dro after the lunar gravity assist the

3397

02:16:24,550 --> 02:16:22,560

outbound delta v depends on

3398

02:16:26,390 --> 02:16:24,560

whether you're spiraling out from earth

3399

02:16:29,030 --> 02:16:26,400

orbit or just doing the heliocentric

3400

02:16:31,589 --> 02:16:29,040

phase and so it could be

3401

02:16:33,349 --> 02:16:31,599

on the order of four to six kilometers

3402

02:16:35,990 --> 02:16:33,359

per second

3403

02:16:40,950 --> 02:16:36,000

maybe more depending on how low in earth

3404

02:16:40,960 --> 02:16:44,549

questions

3405

02:16:44,559 --> 02:16:57,110

yeah no go ahead you go ahead first

3406

02:17:01,429 --> 02:17:00,150

my question is to some extent rhetoric

3407

02:17:04,629 --> 02:17:01,439

because it

3408

02:17:06,549 --> 02:17:04,639

it is addressed to the whole community

3409

02:17:07,589 --> 02:17:06,559

and this question is

3410

02:17:11,429 --> 02:17:07,599

why

3411

02:17:13,349 --> 02:17:11,439

the as a target orbit was chosen the

3412

02:17:16,150 --> 02:17:13,359

cis lunar orbit

3413

02:17:17,589 --> 02:17:16,160

because some other alternative options

3414

02:17:19,030 --> 02:17:17,599

do exist

3415

02:17:20,950 --> 02:17:19,040

for example

3416

02:17:21,750 --> 02:17:20,960

we can transfer

3417

02:17:33,429 --> 02:17:21,760

the

3418

02:17:34,950 --> 02:17:33,439

with period for example one year and in

3419

02:17:38,629 --> 02:17:34,960

this case

3420

02:17:42,389 --> 02:17:38,639

checked

3421

02:17:43,830 --> 02:17:42,399

is only several meters per second

3422

02:17:47,190 --> 02:17:43,840

and

3423

02:17:50,230 --> 02:17:47,200

we can reach this asteroid

3424

02:17:51,750 --> 02:17:50,240

in the ideal case two times

3425

02:17:54,230 --> 02:17:51,760

per year

3426

02:17:56,389 --> 02:17:54,240

and the arrival delta v

3427

02:18:00,150 --> 02:17:56,399

will be almost in

3428

02:18:02,150 --> 02:18:00,160

ideally zero and departure also

3429

02:18:06,629 --> 02:18:02,160

almost zero

3430

02:18:10,549 --> 02:18:08,230

all right well i'll take a crack at that

3431

02:18:14,389 --> 02:18:10,559

we look we talked a lot about where to

3432

02:18:16,230 --> 02:18:14,399

deliver the asteroid to

3433

02:18:18,389 --> 02:18:16,240

and uh the selection of the distant

3434

02:18:20,150 --> 02:18:18,399

retrograde orbit around the moon

3435

02:18:22,309 --> 02:18:20,160

appeared to be a good choice because it

3436

02:18:24,950 --> 02:18:22,319

was an orbit that

3437

02:18:27,750 --> 02:18:24,960

both the app the asteroid retrieval

3438

02:18:28,549 --> 02:18:27,760

vehicle with a thousand ton asteroid in

3439

02:18:31,429 --> 02:18:28,559

tow

3440

02:18:32,309 --> 02:18:31,439

could get to for a reasonable delta v

3441

02:18:41,349 --> 02:18:32,319

and

3442

02:18:43,589 --> 02:18:41,359

multiple opportunities

3443

02:18:46,629 --> 02:18:43,599

per year

3444

02:18:48,629 --> 02:18:46,639

oh okay yeah and if you lose control

3445

02:18:50,309 --> 02:18:48,639

after a couple hundred years or whatever

3446

02:18:53,190 --> 02:18:50,319

yeah it won't hit the earth even though

3447

02:18:54,709 --> 02:18:53,200

it's of a size it's not a hazard

3448

02:18:58,230 --> 02:18:54,719

it's kind of a belt and suspenders

3449

02:18:58,240 --> 02:19:04,709

all right another question

3450

02:19:08,389 --> 02:19:06,709

yeah everyone's picking on john here but

3451

02:19:11,190 --> 02:19:08,399

uh um

3452

02:19:12,309 --> 02:19:11,200

my question is also to you uh a question

3453

02:19:14,870 --> 02:19:12,319

i'm sorry

3454

02:19:17,429 --> 02:19:14,880

but i was curious though about uh the

3455

02:19:19,110 --> 02:19:17,439

dependence on the arm mission today in

3456

02:19:21,110 --> 02:19:19,120

terms of the sonatic period of the

3457

02:19:22,709 --> 02:19:21,120

asteroids in this sense and that you

3458

02:19:24,070 --> 02:19:22,719

probably have a launch window to launch

3459

02:19:25,750 --> 02:19:24,080

arm okay so then you have to go after

3460

02:19:27,110 --> 02:19:25,760

this asteroid but if you miss it the

3461

02:19:28,150 --> 02:19:27,120

sonatic periods of these objects are

3462

02:19:30,469 --> 02:19:28,160

such that you're never gonna be able to

3463

02:19:32,150 --> 02:19:30,479

go back to that one again so how how

3464

02:19:35,270 --> 02:19:32,160

many backup targets do you need to make

3465

02:19:36,709 --> 02:19:35,280

sure you can fulfill your mission

3466

02:19:39,110 --> 02:19:36,719

one no

3467

02:19:40,629 --> 02:19:39,120

so yeah that's a really good point and

3468

02:19:43,669 --> 02:19:40,639

that's why what you really want what you

3469

02:19:45,669 --> 02:19:43,679

need for a robust mission is to have

3470

02:19:47,589 --> 02:19:45,679

multiple backup targets in multiple

3471

02:19:49,429 --> 02:19:47,599

years

3472

02:19:51,670 --> 02:19:49,439

uh you know the programmatics are such

3473

02:19:53,510 --> 02:19:51,680

that you're we're not sure you know when

3474

02:19:54,870 --> 02:19:53,520

you could launch or if you run into

3475

02:19:56,790 --> 02:19:54,880

technical difficulties and you have to

3476

02:19:59,510 --> 02:19:56,800

launch six months or a year later

3477

02:20:01,510 --> 02:19:59,520

uh you need to have a robust series of

3478

02:20:02,389 --> 02:20:01,520

targets in multiple years that you can

3479

02:20:04,230 --> 02:20:02,399

go to

3480

02:20:06,309 --> 02:20:04,240

and uh and that's why

3481

02:20:08,630 --> 02:20:06,319

um yeah so you know because of the

3482

02:20:10,150 --> 02:20:08,640

synodic period problem if you miss it

3483

02:20:12,710 --> 02:20:10,160

you've got to go to a different target

3484

02:20:14,950 --> 02:20:12,720

unless uh it depends on you know it's

3485

02:20:16,309 --> 02:20:14,960

not quite that black and white because

3486

02:20:18,469 --> 02:20:16,319

if you change launch vehicles if you

3487

02:20:21,429 --> 02:20:18,479

plan to fly in an atlas 5 for example

3488

02:20:23,190 --> 02:20:21,439

and spiral out from earth orbit

3489

02:20:24,950 --> 02:20:23,200

if you miss that launch and you have an

3490

02:20:27,429 --> 02:20:24,960

opportunity to launch on a falcon heavy

3491

02:20:29,830 --> 02:20:27,439

for example you can then

3492

02:20:31,590 --> 02:20:29,840

make up that year to year and a half

3493

02:20:33,030 --> 02:20:31,600

slip by launching by eliminating the

3494

02:20:34,870 --> 02:20:33,040

spiral out time and going directly so

3495

02:20:36,230 --> 02:20:34,880

you have some flexibility there as well

3496

02:20:38,230 --> 02:20:36,240

you may want to talk about the launch

3497

02:20:40,870 --> 02:20:38,240

window in the same

3498

02:20:42,950 --> 02:20:40,880

sense because scp does change the

3499

02:20:45,590 --> 02:20:42,960

dynamics of that significance oh you may

3500

02:20:47,670 --> 02:20:45,600

want to repeat that okay so

3501

02:20:49,429 --> 02:20:47,680

and and jim's right so the other uh

3502

02:20:51,110 --> 02:20:49,439

part of this is uh with electric

3503

02:20:53,670 --> 02:20:51,120

propulsion you get a

3504

02:20:55,750 --> 02:20:53,680

longer launch period than you normally

3505

02:20:57,590 --> 02:20:55,760

get with um uh

3506

02:20:59,830 --> 02:20:57,600

ballistic interplanetary spacecraft and

3507

02:21:02,389 --> 02:20:59,840

so you have additional flexibility don

3508

02:21:03,750 --> 02:21:02,399

is a good example of that

3509

02:21:05,270 --> 02:21:03,760

i won't bore you with all the details

3510

02:21:06,469 --> 02:21:05,280

but at the very end it was going to

3511

02:21:07,830 --> 02:21:06,479

launch in

3512

02:21:09,270 --> 02:21:07,840

the beginning of july and it wound up

3513

02:21:11,349 --> 02:21:09,280

launching at the end of september but it

3514

02:21:13,030 --> 02:21:11,359

could still do this multiple

3515

02:21:14,070 --> 02:21:13,040

main belt asteroid rendezvous mission

3516

02:21:15,670 --> 02:21:14,080

because of the use of electric

3517

02:21:19,349 --> 02:21:15,680

propulsion so you get that added

3518

02:21:24,950 --> 02:21:20,469

okay

3519

02:21:29,270 --> 02:21:27,510

one last one

3520

02:21:31,750 --> 02:21:29,280

we've been talking a lot about solar

3521

02:21:35,190 --> 02:21:31,760

electric propulsion and one of the

3522

02:21:38,230 --> 02:21:35,200

comments early on early comments was

3523

02:21:40,150 --> 02:21:38,240

launching into a highly elliptical orbit

3524

02:21:42,550 --> 02:21:40,160

we've been looking at small orbital

3525

02:21:43,429 --> 02:21:42,560

debris and it's getting a whole lot

3526

02:21:44,550 --> 02:21:43,439

worse

3527

02:21:47,190 --> 02:21:44,560

and

3528

02:21:49,510 --> 02:21:47,200

one of the things that we looked at was

3529

02:21:52,309 --> 02:21:49,520

that a highly elliptical orbit like

3530

02:21:54,790 --> 02:21:52,319

we're planning for sls a couple of the

3531

02:21:57,349 --> 02:21:54,800

first couple of missions gets you out of

3532

02:21:58,150 --> 02:21:57,359

that problem very quickly

3533

02:22:00,710 --> 02:21:58,160

but

3534

02:22:01,750 --> 02:22:00,720

uh is there i've heard a lot of comments

3535

02:22:02,469 --> 02:22:01,760

about

3536

02:22:05,429 --> 02:22:02,479

the

3537

02:22:07,110 --> 02:22:05,439

van allen belts and trying to avoid

3538

02:22:10,309 --> 02:22:07,120

exposure to that

3539

02:22:12,710 --> 02:22:10,319

has the small orbital debris exposure

3540

02:22:13,910 --> 02:22:12,720

which is getting worse and worse as time

3541

02:22:17,110 --> 02:22:13,920

goes by

3542

02:22:21,110 --> 02:22:17,120

has anybody been figuring that into

3543

02:22:23,670 --> 02:22:21,120

how they do their launch to avoid

3544

02:22:31,190 --> 02:22:23,680

having to slowly spiral out through the

3545

02:22:33,910 --> 02:22:32,790

all right so

3546

02:22:36,389 --> 02:22:33,920

um

3547

02:22:38,389 --> 02:22:36,399

so the the reference mission that we

3548

02:22:40,469 --> 02:22:38,399

spent most of the time on uh launches

3549

02:22:43,190 --> 02:22:40,479

directly to the lunar gravity assist so

3550

02:22:45,510 --> 02:22:43,200

eliminates that problem entirely um

3551
02:22:47,590 --> 02:22:45,520
there is a wide range of intermediate

3552
02:22:49,510 --> 02:22:47,600
orbits that you could launch to

3553
02:22:50,469 --> 02:22:49,520
including gto and other elliptical

3554
02:22:51,590 --> 02:22:50,479
orbits

3555
02:22:53,270 --> 02:22:51,600
but we haven't spent a lot of time

3556
02:22:55,110 --> 02:22:53,280
looking at the orbital debris problem we

3557
02:22:57,429 --> 02:22:55,120
did spend a little time looking at the

3558
02:23:00,230 --> 02:22:57,439
radiation degradation on the solar rays

3559
02:23:02,790 --> 02:23:00,240
and the need to make them bigger

3560
02:23:03,750 --> 02:23:02,800
to accommodate that but certainly if you

3561
02:23:08,870 --> 02:23:03,760
were

3562
02:23:10,469 --> 02:23:08,880
choice to launch on an elv and spiral

3563
02:23:12,550 --> 02:23:10,479

out from some elliptical earth orbit you

3564

02:23:14,469 --> 02:23:12,560

would definitely have to accommodate or

3565

02:23:16,150 --> 02:23:14,479

make accommodations for that orbital

3566

02:23:18,710 --> 02:23:16,160

debris issue or make sure that you

3567

02:23:20,309 --> 02:23:18,720

understood it

3568

02:23:21,750 --> 02:23:20,319

okay thank you

3569

02:23:23,590 --> 02:23:21,760

for one more

3570

02:23:25,830 --> 02:23:23,600

one more

3571

02:23:28,950 --> 02:23:25,840

i think this this one is for Ima i think

3572

02:23:31,110 --> 02:23:28,960

Ima mentioned some sort of

3573

02:23:32,790 --> 02:23:31,120

a concept about laser measurements that

3574

02:23:34,790 --> 02:23:32,800

i wasn't familiar with is some

3575

02:23:36,150 --> 02:23:34,800

holographic

3576

02:23:37,590 --> 02:23:36,160

something

3577

02:23:38,790 --> 02:23:37,600

can you explain a little bit more what

3578

02:23:41,830 --> 02:23:38,800

that does

3579

02:23:48,309 --> 02:23:46,230

is it a point cloud or is it

3580

02:23:50,469 --> 02:23:48,319

unfortunately

3581

02:23:53,670 --> 02:23:50,479

no

3582

02:23:55,230 --> 02:23:53,680

it sorry but i can put you in touch with

3583

02:23:58,710 --> 02:23:55,240

somebody

3584

02:24:00,469 --> 02:23:58,720

is it something that is a new concept or

3585

02:24:02,389 --> 02:24:00,479

this is something that it's something

3586

02:24:06,150 --> 02:24:02,399

they've been working working on for

3587

02:24:10,230 --> 02:24:08,150

mostly for terrestrial

3588

02:24:12,630 --> 02:24:10,240

but it's also they've been looking at

3589

02:24:17,030 --> 02:24:15,190

okay all right thank you

3590

02:24:19,190 --> 02:24:17,040

um we come to our last item but it's a

3591

02:24:22,070 --> 02:24:19,200

big item for our last 30 minutes in this

3592

02:24:24,870 --> 02:24:22,080

session um and i just want to um remind

3593

02:24:26,550 --> 02:24:24,880

us uh what the purpose of this wednesday

3594

02:24:29,670 --> 02:24:26,560

session briefing what's what's being

3595

02:24:31,590 --> 02:24:29,680

asked of us um and there were five top

3596

02:24:33,349 --> 02:24:31,600

michelle talked it this morning at the

3597

02:24:35,190 --> 02:24:33,359

plenary but there were five main

3598

02:24:36,870 --> 02:24:35,200

categories that we wanted to we were

3599

02:24:38,870 --> 02:24:36,880

asked to present what our session

3600

02:24:40,710 --> 02:24:38,880

purpose was what our rfi selection

3601
02:24:43,030 --> 02:24:40,720
process and agenda we've talked those

3602
02:24:45,270 --> 02:24:43,040
already in here we'll make slight mods

3603
02:24:47,110 --> 02:24:45,280
to the agenda but we're basically he'll

3604
02:24:49,750 --> 02:24:47,120
um and then key topics discussed and

3605
02:24:51,510 --> 02:24:49,760
findings oh and i forgot to get the

3606
02:24:54,790 --> 02:24:51,520
um

3607
02:24:54,800 --> 02:25:07,110
no

3608
02:25:11,190 --> 02:25:09,030
so we have about four charts that we put

3609
02:25:12,950 --> 02:25:11,200
together a few of us just based on

3610
02:25:14,630 --> 02:25:12,960
having read the rfi's

3611
02:25:16,790 --> 02:25:14,640
just for a starting point for the

3612
02:25:18,389 --> 02:25:16,800
audience because otherwise 40 people

3613
02:25:21,429 --> 02:25:18,399

creating four charts probably doesn't

3614

02:25:23,670 --> 02:25:21,439

work so well but um so the first first

3615

02:25:25,510 --> 02:25:23,680

part of that is and and i should ask add

3616

02:25:27,510 --> 02:25:25,520

a little more the first part of it is

3617

02:25:29,270 --> 02:25:27,520

what key topics did we discuss and then

3618

02:25:31,990 --> 02:25:29,280

what findings

3619

02:25:33,349 --> 02:25:32,000

and uh for findings uh what we're asked

3620

02:25:35,030 --> 02:25:33,359

to provide is a summary of the most

3621

02:25:36,870 --> 02:25:35,040

promising ideas including their

3622

02:25:38,469 --> 02:25:36,880

innovativeness and potential for

3623

02:25:39,990 --> 02:25:38,479

improving mission system performance and

3624

02:25:41,830 --> 02:25:40,000

affordability

3625

02:25:43,429 --> 02:25:41,840

any technology development needed to

3626

02:25:46,950 --> 02:25:43,439

mature the ideas to the point where they

3627

02:25:48,630 --> 02:25:46,960

can be incorporated into system designs

3628

02:25:49,910 --> 02:25:48,640

relationships are linkages between the

3629

02:25:51,830 --> 02:25:49,920

ideas that could help with mission

3630

02:25:53,349 --> 02:25:51,840

system concept integration and further

3631

02:25:54,710 --> 02:25:53,359

studies are next steps and i will admit

3632

02:25:56,150 --> 02:25:54,720

that when we put this together we didn't

3633

02:25:57,590 --> 02:25:56,160

have guidance

3634

02:25:59,110 --> 02:25:57,600

so they probably don't match quite

3635

02:26:01,830 --> 02:25:59,120

exactly

3636

02:26:03,590 --> 02:26:01,840

but we'll go through it and as we'll

3637

02:26:05,910 --> 02:26:03,600

just kind of talk through and and open

3638

02:26:08,550 --> 02:26:05,920

it up for comments as we do the first

3639

02:26:10,550 --> 02:26:08,560

thing we thought we did would do is and

3640

02:26:12,630 --> 02:26:10,560

and again uh you know some of this we

3641

02:26:14,469 --> 02:26:12,640

may be off on how we did it because it

3642

02:26:15,990 --> 02:26:14,479

may not have been quite talked

3643

02:26:17,990 --> 02:26:16,000

as we were going through it but the

3644

02:26:20,309 --> 02:26:18,000

first thing we did is kind of divided

3645

02:26:21,910 --> 02:26:20,319

our topics into these six these five

3646

02:26:23,270 --> 02:26:21,920

categories and then on the next two

3647

02:26:25,110 --> 02:26:23,280

charts we'll talk a little bit more

3648

02:26:27,590 --> 02:26:25,120

detail of each of these five

3649

02:26:30,950 --> 02:26:27,600

um but we kind of we kind of heard a lot

3650

02:26:33,030 --> 02:26:30,960

about uh vehicle systems you know use of

3651

02:26:34,870 --> 02:26:33,040

spacecraft buses that kind of stuff

3652

02:26:37,030 --> 02:26:34,880

there's a large category in sensing

3653

02:26:39,190 --> 02:26:37,040

systems and algorithms

3654

02:26:40,710 --> 02:26:39,200

mission enhancements to the base

3655

02:26:42,950 --> 02:26:40,720

reference mission

3656

02:26:44,630 --> 02:26:42,960

extensibility considerations and

3657

02:26:47,030 --> 02:26:44,640

alternate mission scenarios and concept

3658

02:26:48,230 --> 02:26:47,040

of operations

3659

02:26:50,389 --> 02:26:48,240

we'll go through them next but does

3660

02:26:52,469 --> 02:26:50,399

anybody have any comments at this point

3661

02:26:54,389 --> 02:26:52,479

do they sound about right for the types

3662

02:26:55,110 --> 02:26:54,399

of things we heard it's kind of hard as

3663

02:27:00,950 --> 02:26:55,120

as

3664

02:27:03,030 --> 02:27:00,960

so i i realize how hard that is to do so

3665

02:27:05,270 --> 02:27:03,040

i guess i guess i would comment that i

3666

02:27:07,429 --> 02:27:05,280

heard an awful lot about different

3667

02:27:09,270 --> 02:27:07,439

business strategies you know it's sort

3668

02:27:10,710 --> 02:27:09,280

of i don't know if it fits well with

3669

02:27:13,349 --> 02:27:10,720

everything up there but there were

3670

02:27:14,389 --> 02:27:13,359

different ways of of structuring how we

3671

02:27:16,710 --> 02:27:14,399

do this

3672

02:27:17,750 --> 02:27:16,720

not necessarily the specifics of what we

3673

02:27:20,230 --> 02:27:17,760

do

3674

02:27:22,309 --> 02:27:20,240

right that i i i thought that came

3675

02:27:25,110 --> 02:27:22,319

through in several of the

3676

02:27:26,870 --> 02:27:25,120

items today any any other comments

3677

02:27:30,070 --> 02:27:26,880

that was a good comment

3678

02:27:31,670 --> 02:27:30,080

go ahead john

3679

02:27:34,309 --> 02:27:31,680

yeah i have one comment that seems a

3680

02:27:36,230 --> 02:27:34,319

little counter almost uh the innovation

3681

02:27:37,990 --> 02:27:36,240

and everything else um that we mentioned

3682

02:27:39,990 --> 02:27:38,000

which is there was a theme throughout

3683

02:27:41,990 --> 02:27:40,000

all the presentations which is that for

3684

02:27:43,510 --> 02:27:42,000

most of the areas it seems like there's

3685

02:27:45,030 --> 02:27:43,520

a broad base where we can leverage

3686

02:27:46,309 --> 02:27:45,040

existing assets capabilities and

3687

02:27:47,990 --> 02:27:46,319

expertise

3688

02:27:50,230 --> 02:27:48,000

and then we won't need to

3689

02:27:51,990 --> 02:27:50,240

rely on lots of technology development

3690

02:27:53,349 --> 02:27:52,000

throughout the overall mission in the

3691

02:27:54,309 --> 02:27:53,359

areas where there is a lot of innovation

3692

02:28:01,110 --> 02:27:54,319

you know that's where they'll be looking

3693

02:28:05,190 --> 02:28:03,910

i'm thinking both of those really fit

3694

02:28:08,630 --> 02:28:05,200

under

3695

02:28:10,950 --> 02:28:08,640

most promising ideas that

3696

02:28:11,830 --> 02:28:10,960

help to reduce

3697

02:28:14,469 --> 02:28:11,840

um

3698

02:28:17,270 --> 02:28:14,479

improve system performance

3699

02:28:19,429 --> 02:28:17,280

and um contribute to affordability both

3700

02:28:22,150 --> 02:28:19,439

of them could show up under that first

3701

02:28:23,830 --> 02:28:22,160

bullet couldn't they

3702

02:28:25,590 --> 02:28:23,840

and and what first quality are you

3703

02:28:27,830 --> 02:28:25,600

talking about the first bulletin

3704

02:28:30,950 --> 02:28:27,840

findings is this turned on can anyone

3705

02:28:30,960 --> 02:28:33,349

okay

3706

02:28:38,309 --> 02:28:36,309

all right any other comments

3707

02:28:41,910 --> 02:28:38,319

all right let's step through

3708

02:28:47,110 --> 02:28:45,110

on in vehicle systems

3709

02:28:48,309 --> 02:28:47,120

we had discussions on key technology

3710

02:28:50,790 --> 02:28:48,319

readiness

3711

02:28:53,670 --> 02:28:50,800

areas solar arrays thrusters power

3712

02:28:56,710 --> 02:28:53,680

processing units

3713

02:28:58,550 --> 02:28:56,720

adaptations of existing spacecraft buses

3714

02:29:00,309 --> 02:28:58,560

uh the balance i don't think i heard

3715

02:29:02,550 --> 02:29:00,319

this so much as we saw in the papers we

3716

02:29:04,230 --> 02:29:02,560

thought but we can talk about whether we

3717

02:29:05,670 --> 02:29:04,240

felt like we did a balance between

3718

02:29:07,830 --> 02:29:05,680

technology development for improved

3719

02:29:09,830 --> 02:29:07,840

mission versus you oh no this one we

3720

02:29:11,270 --> 02:29:09,840

certainly did use of low risk mature

3721

02:29:13,349 --> 02:29:11,280

technologies that was the kind of the

3722

02:29:15,190 --> 02:29:13,359

comment that that john made what i

3723

02:29:15,990 --> 02:29:15,200

didn't hear necessarily was a talk about

3724

02:29:22,710 --> 02:29:16,000

a

3725

02:29:24,790 --> 02:29:22,720

something in them

3726

02:29:26,309 --> 02:29:24,800

and then off uh have alpha amps um

3727

02:29:28,469 --> 02:29:26,319

certainly the plan we have right now is

3728

02:29:31,030 --> 02:29:28,479

to pick some medium level and off-ramp

3729

02:29:32,469 --> 02:29:31,040

if it need be

3730

02:29:34,950 --> 02:29:32,479

as opposed to trying to unramp it

3731

02:29:36,469 --> 02:29:34,960

especially if our target schedule is

3732

02:29:37,349 --> 02:29:36,479

what it is so

3733

02:29:39,190 --> 02:29:37,359

and then

3734

02:29:41,429 --> 02:29:39,200

key risk and development areas

3735

02:29:43,830 --> 02:29:41,439

uh asteroid characterization rendezvous

3736

02:29:46,230 --> 02:29:43,840

and capture system solar arrays high

3737

02:29:47,270 --> 02:29:46,240

power thrusters power processing units

3738

02:29:48,710 --> 02:29:47,280

although

3739

02:29:50,070 --> 02:29:48,720

really we hear talks about that being

3740

02:29:51,830 --> 02:29:50,080

fairly mature so maybe that shouldn't be

3741

02:29:54,710 --> 02:29:51,840

on this list but we can talk about it

3742

02:29:56,389 --> 02:29:54,720

xenon tanks dust and volatiles

3743

02:29:58,150 --> 02:29:56,399

so i'll stop there and just kind of open

3744

02:30:00,150 --> 02:29:58,160

up the discussions on does this

3745

02:30:05,750 --> 02:30:00,160

adequately capture things and and are

3746

02:30:09,910 --> 02:30:07,590

yeah the one thing i think that probably

3747

02:30:12,150 --> 02:30:09,920

needs to be added to that that i heard

3748

02:30:16,550 --> 02:30:12,160

in a number of the presentations is that

3749

02:30:16,560 --> 02:30:19,910

capability for simulation

3750

02:30:24,790 --> 02:30:22,550

and test of many of these systems on the

3751

02:30:26,150 --> 02:30:24,800

ground and lab

3752

02:30:33,910 --> 02:30:26,160

so i think they didn't need to capture

3753

02:30:38,150 --> 02:30:35,190

we'll see if we have that somewhere

3754

02:30:41,990 --> 02:30:38,160

coming up i don't think we do though

3755

02:30:46,790 --> 02:30:44,630

yeah ppus i think we take off

3756

02:30:48,309 --> 02:30:46,800

there was discussion xenon tanks but

3757

02:30:50,710 --> 02:30:48,319

it's really a go design not really a

3758

02:30:51,830 --> 02:30:50,720

technology or a key risk area does

3759

02:30:54,309 --> 02:30:51,840

anybody

3760

02:30:58,230 --> 02:30:56,309

there's still some out there that think

3761

02:31:00,950 --> 02:30:58,240

that we should leave the power

3762

02:31:03,030 --> 02:31:00,960

processing units i think

3763

02:31:05,110 --> 02:31:03,040

okay what it's worth um

3764

02:31:07,429 --> 02:31:05,120

there was at least

3765

02:31:09,510 --> 02:31:07,439

the european talk talked about something

3766

02:31:11,990 --> 02:31:09,520

other than hall thrusters

3767

02:31:12,790 --> 02:31:12,000

and we've seen that a couple of times

3768

02:31:16,950 --> 02:31:12,800

where

3769

02:31:19,429 --> 02:31:16,960

the discussion was uh can we do you know

3770

02:31:20,550 --> 02:31:19,439

other plasma based

3771

02:31:22,309 --> 02:31:20,560

sep

3772

02:31:25,429 --> 02:31:22,319

i think we're we're going to run into a

3773

02:31:27,349 --> 02:31:25,439

technology timeline difficulty with that

3774

02:31:30,389 --> 02:31:27,359

but it was definitely brought up as a

3775

02:31:31,990 --> 02:31:30,399

discussion point that's true um and

3776

02:31:34,309 --> 02:31:32,000

and it has some very interesting

3777

02:31:36,469 --> 02:31:34,319

features but as you said and as they

3778

02:31:37,510 --> 02:31:36,479

pointed out the trl is still

3779

02:31:38,870 --> 02:31:37,520

something that

3780

02:31:40,630 --> 02:31:38,880

makes it challenging but but it's a good

3781

02:31:41,510 --> 02:31:40,640

thing to bring out

3782

02:31:43,510 --> 02:31:41,520

um

3783

02:31:50,309 --> 02:31:43,520

anything else

3784

02:31:58,469 --> 02:31:52,150

would you go to a mic please

3785

02:32:01,910 --> 02:32:00,309

i think one of the key things in the

3786

02:32:03,830 --> 02:32:01,920

vehicle in the sensing systems is we're

3787

02:32:06,230 --> 02:32:03,840

not exactly sure what we're going to go

3788

02:32:09,190 --> 02:32:06,240

and find even if there are precursor

3789

02:32:11,030 --> 02:32:09,200

missions so i think one of the key

3790

02:32:12,870 --> 02:32:11,040

design requirements is that you know

3791

02:32:15,190 --> 02:32:12,880

either the vehicle system or the sensing

3792

02:32:16,950 --> 02:32:15,200

system needs to be very flexible

3793

02:32:17,670 --> 02:32:16,960

to be able to accommodate a large number

3794

02:32:19,429 --> 02:32:17,680

of

3795

02:32:21,590 --> 02:32:19,439

surfaces or other pieces that we're

3796

02:32:23,510 --> 02:32:21,600

going to encounter there

3797

02:32:24,550 --> 02:32:23,520

i think that was one of the key unknowns

3798

02:32:26,550 --> 02:32:24,560

we saw throughout everyone's

3799

02:32:27,990 --> 02:32:26,560

presentation was

3800

02:32:29,830 --> 02:32:28,000

you know how do i

3801

02:32:36,950 --> 02:32:29,840

know what i'm designing for or do i

3802

02:32:42,230 --> 02:32:39,270

one other thing jim yeah i don't know if

3803

02:32:44,550 --> 02:32:42,240

it fits here under vehicle systems or

3804

02:32:46,469 --> 02:32:44,560

someplace else but you know there was

3805

02:32:48,870 --> 02:32:46,479

there's still a lot of open discussion

3806

02:32:50,710 --> 02:32:48,880

about the type of capture mechanism

3807

02:32:51,990 --> 02:32:50,720

whether you're going to go grab regolith

3808

02:32:53,750 --> 02:32:52,000

or whether you're going to pick off a

3809

02:32:55,750 --> 02:32:53,760

rock or whether you're going to grab the

3810

02:32:58,630 --> 02:32:55,760

whole thing and if you are how does that

3811

02:33:00,389 --> 02:32:58,640

work with the dynamics it's not part of

3812

02:33:02,630 --> 02:33:00,399

the sensing system and algorithms and

3813

02:33:04,230 --> 02:33:02,640

it's not part of

3814

02:33:06,070 --> 02:33:04,240

so it could be under vehicle systems

3815

02:33:08,469 --> 02:33:06,080

unless you want to bucket that i think

3816

02:33:10,309 --> 02:33:08,479

we bucketed it under alternate missions

3817

02:33:13,110 --> 02:33:10,319

okay concept of operation

3818

02:33:14,630 --> 02:33:13,120

but but i think a subset of that is just

3819

02:33:16,230 --> 02:33:14,640

how you're going to actually grab

3820

02:33:18,790 --> 02:33:16,240

whatever it is oh yeah that's true

3821

02:33:20,630 --> 02:33:18,800

that's true and actually with that

3822

02:33:22,710 --> 02:33:20,640

there's also there's a lot of discussion

3823

02:33:24,790 --> 02:33:22,720

about precursors i don't know if it goes

3824

02:33:27,110 --> 02:33:24,800

there or alternative missions but it

3825

02:33:29,270 --> 02:33:27,120

seemed um that was a

3826

02:33:30,870 --> 02:33:29,280

yeah let's let's not lose that thought

3827

02:33:32,870 --> 02:33:30,880

um and see if we get there when we get

3828

02:33:33,590 --> 02:33:32,880

to those i think we do but but i'm not

3829

02:33:34,550 --> 02:33:33,600

sure

3830

02:33:36,790 --> 02:33:34,560

um

3831

02:33:39,349 --> 02:33:36,800

especially on the capture system but for

3832

02:33:41,750 --> 02:33:39,359

all vehicle systems being able to vnv it

3833

02:33:44,150 --> 02:33:41,760

on the ground is incredibly important

3834

02:33:45,590 --> 02:33:44,160

and the capture system the whole

3835

02:33:48,309 --> 02:33:45,600

driving

3836

02:33:50,230 --> 02:33:48,319

you know philosophy underlying the the

3837

02:33:52,469 --> 02:33:50,240

reference capture system is the ability

3838

02:33:54,630 --> 02:33:52,479

to vnv it on the ground that's the

3839

02:33:56,150 --> 02:33:54,640

overriding concern okay

3840

02:33:58,230 --> 02:33:56,160

jim one other input too and i don't know

3841

02:33:59,990 --> 02:33:58,240

if it goes here or if you've got it on

3842

02:34:01,990 --> 02:34:00,000

vehicle systems if the the concept of

3843

02:34:03,030 --> 02:34:02,000

designing for reusability extensibility

3844

02:34:04,950 --> 02:34:03,040

long life

3845

02:34:06,710 --> 02:34:04,960

that i don't know we have a you got a

3846

02:34:08,550 --> 02:34:06,720

sensibility category okay man that's

3847

02:34:10,309 --> 02:34:08,560

working um and make sure when we get to

3848

02:34:11,750 --> 02:34:10,319

that uh if we haven't captured it

3849

02:34:13,429 --> 02:34:11,760

adequately

3850

02:34:15,670 --> 02:34:13,439

okay anything else

3851

02:34:19,429 --> 02:34:15,680

go ahead

3852

02:34:26,070 --> 02:34:22,389

two or three uh different presenters

3853

02:34:27,429 --> 02:34:26,080

talked about using microsats as a

3854

02:34:30,389 --> 02:34:27,439

probe

3855

02:34:33,349 --> 02:34:30,399

is that under sensing or

3856

02:34:35,110 --> 02:34:33,359

is that somewhere else because they

3857

02:34:36,230 --> 02:34:35,120

really referred them as

3858

02:34:39,110 --> 02:34:36,240

sensors

3859

02:34:40,230 --> 02:34:39,120

to know more about the target

3860

02:34:42,070 --> 02:34:40,240

uh

3861

02:34:43,510 --> 02:34:42,080

we had thought that like cubesats and

3862

02:34:47,590 --> 02:34:43,520

stuff we were putting it under mission

3863

02:34:50,150 --> 02:34:48,790

anything else and we'll go on to the

3864

02:34:52,710 --> 02:34:50,160

next category

3865

02:34:54,150 --> 02:34:52,720

sensing systems and algorithms

3866

02:34:55,750 --> 02:34:54,160

there's a wide range of sensor

3867

02:34:57,270 --> 02:34:55,760

technologies discussed for various

3868

02:34:58,790 --> 02:34:57,280

mission requirements

3869

02:35:02,630 --> 02:34:58,800

which includes characterization

3870

02:35:03,910 --> 02:35:02,640

rendezvous proximity operations capture

3871

02:35:06,550 --> 02:35:03,920

you know things to think about the

3872

02:35:08,550 --> 02:35:06,560

target size shape range temple dynamics

3873

02:35:10,469 --> 02:35:08,560

shape modeling

3874

02:35:13,110 --> 02:35:10,479

closed loop control with uncooperative

3875

02:35:14,309 --> 02:35:13,120

target tracking relative nav rate

3876

02:35:15,990 --> 02:35:14,319

matching

3877

02:35:17,990 --> 02:35:16,000

considerations for surface and

3878

02:35:20,710 --> 02:35:18,000

subsurface characterization

3879

02:35:22,710 --> 02:35:20,720

uh crater detection tracking asteroid

3880

02:35:25,750 --> 02:35:22,720

structural strength you know depending

3881

02:35:27,910 --> 02:35:25,760

on your your your mission scenario

3882

02:35:30,070 --> 02:35:27,920

sensor technologies include visible ir

3883

02:35:34,070 --> 02:35:30,080

camera lidar laser altimeter

3884

02:35:36,150 --> 02:35:34,080

spectrometry radar tomography and so on

3885

02:35:38,230 --> 02:35:36,160

we had discussions of integrated systems

3886

02:35:39,910 --> 02:35:38,240

and algorithm development and a lot of

3887

02:35:41,990 --> 02:35:39,920

hardware and software adaptation from

3888

02:35:49,030 --> 02:35:42,000

heritage systems and we listed a bunch

3889

02:35:49,040 --> 02:35:53,429

tell the section that heather

3890

02:35:53,439 --> 02:35:59,110

okay we'll go on

3891

02:36:04,150 --> 02:36:01,670

um then the other topic areas that we

3892

02:36:05,830 --> 02:36:04,160

had and then we need to try to think

3893

02:36:08,230 --> 02:36:05,840

about the different business strategies

3894

02:36:10,870 --> 02:36:08,240

one as well but mission enhancements uh

3895

02:36:13,590 --> 02:36:10,880

what we put under there uh was robotic

3896

02:36:15,670 --> 02:36:13,600

manipulators for enhanced asteroid

3897

02:36:17,910 --> 02:36:15,680

characterization dissimilar capture

3898

02:36:19,190 --> 02:36:17,920

techniques or an enabler for pick up a

3899

02:36:21,270 --> 02:36:19,200

rock scenario

3900

02:36:23,110 --> 02:36:21,280

a cubesat class observation and sensor

3901

02:36:26,070 --> 02:36:23,120

spacecraft

3902

02:36:28,150 --> 02:36:26,080

contact excursion probe surface samplers

3903

02:36:29,990 --> 02:36:28,160

and i'm not sure it really kind of got

3904

02:36:31,590 --> 02:36:30,000

talked about here but taking advantage

3905

02:36:34,389 --> 02:36:31,600

of about the three year transition to

3906

02:36:41,830 --> 02:36:34,399

cis lunar space to do further

3907

02:36:45,830 --> 02:36:43,670

okay that's pretty good

3908

02:36:47,830 --> 02:36:45,840

um

3909

02:36:48,710 --> 02:36:47,840

what's that

3910

02:36:50,389 --> 02:36:48,720

yeah

3911

02:36:52,710 --> 02:36:50,399

when you wear everybody out it's easier

3912

02:36:54,469 --> 02:36:52,720

to get through these sort of things

3913

02:36:56,710 --> 02:36:54,479

thank you for all the presenters

3914

02:36:58,389 --> 02:36:56,720

we really want to make sure that we

3915

02:37:00,790 --> 02:36:58,399

captured the mission enhancements that

3916

02:37:04,469 --> 02:37:00,800

were in the paper right so

3917

02:37:06,710 --> 02:37:04,479

if you don't see what you told us

3918

02:37:09,110 --> 02:37:06,720

but we'll go on um and and as need be

3919

02:37:10,710 --> 02:37:09,120

you know you you can contact me uh us

3920

02:37:12,630 --> 02:37:10,720

over the next day or two

3921

02:37:15,349 --> 02:37:12,640

as well as as we finalize this

3922

02:37:16,950 --> 02:37:15,359

extensibility was our next major topic

3923

02:37:18,870 --> 02:37:16,960

we talked about the similarity and needs

3924

02:37:21,110 --> 02:37:18,880

of satellite servicing missions

3925

02:37:23,110 --> 02:37:21,120

potential for commercial applications

3926

02:37:25,510 --> 02:37:23,120

potential reuse as a cargo tug for

3927

02:37:27,510 --> 02:37:25,520

translunar assets planetary defense

3928

02:37:29,349 --> 02:37:27,520

asteroid deflection demonstration space

3929

02:37:31,110 --> 02:37:29,359

debris removal i'm not sure everything

3930

02:37:33,190 --> 02:37:31,120

actually got talked here today as we as

3931

02:37:34,710 --> 02:37:33,200

much as we saw in some of the papers but

3932

02:37:36,309 --> 02:37:34,720

any comments to this section can you

3933

02:37:37,910 --> 02:37:36,319

list some examples of the potential

3934

02:37:39,990 --> 02:37:37,920

commercial applications so we don't lose

3935

02:37:42,309 --> 02:37:40,000

those thoughts um that's a good idea you

3936

02:37:43,910 --> 02:37:42,319

want to um

3937

02:37:46,790 --> 02:37:43,920

isru

3938

02:37:51,670 --> 02:37:46,800

yeah and then the fuel for satellites

3939

02:37:55,750 --> 02:37:54,230

well the maturation of the scp helps

3940

02:37:58,630 --> 02:37:55,760

geo-converge right

3941

02:38:00,469 --> 02:37:58,640

whether it's ppu quad junction cells

3942

02:38:02,469 --> 02:38:00,479

better deployables

3943

02:38:10,389 --> 02:38:02,479

the list goes on spin off and i don't

3944

02:38:10,399 --> 02:38:13,510

is it worth mentioning

3945

02:38:17,349 --> 02:38:16,309

the robotic planetary

3946

02:38:21,190 --> 02:38:17,359

there is an extensibility they're

3947

02:38:27,270 --> 02:38:23,510

robotic science mission

3948

02:38:30,070 --> 02:38:28,389

okay

3949

02:38:33,510 --> 02:38:30,080

uh i don't i didn't see it here but

3950

02:38:35,910 --> 02:38:33,520

under also under extensibility you know

3951
02:38:36,950 --> 02:38:35,920
if there are assets that are brought

3952
02:38:39,270 --> 02:38:36,960
back

3953
02:38:41,590 --> 02:38:39,280
um you know it's not just

3954
02:38:44,550 --> 02:38:41,600
human crude missions from

3955
02:38:46,389 --> 02:38:44,560
nasa that could go there you know other

3956
02:38:48,389 --> 02:38:46,399
nations could go there

3957
02:38:50,389 --> 02:38:48,399
um you know there are

3958
02:38:52,710 --> 02:38:50,399
you know industry could go there

3959
02:38:54,870 --> 02:38:52,720
in other words there's a

3960
02:38:56,870 --> 02:38:54,880
there's clearly some interest in

3961
02:38:58,710 --> 02:38:56,880
expanding the scope of what you do with

3962
02:39:00,309 --> 02:38:58,720
the results

3963
02:39:03,190 --> 02:39:00,319

okay

3964

02:39:05,190 --> 02:39:03,200

and there's also the trade space of do

3965

02:39:07,590 --> 02:39:05,200

you make this modular

3966

02:39:10,630 --> 02:39:07,600

which affects the extendability

3967

02:39:14,790 --> 02:39:10,640

or do you make it one piece and just

3968

02:39:17,590 --> 02:39:14,800

duplicate that for another mission later

3969

02:39:18,950 --> 02:39:17,600

yes did we well we tried to capture that

3970

02:39:20,469 --> 02:39:18,960

in alternate mission scenarios or

3971

02:39:21,510 --> 02:39:20,479

concept really under concept of

3972

02:39:23,910 --> 02:39:21,520

operations

3973

02:39:25,349 --> 02:39:23,920

the last does that get at your point but

3974

02:39:29,349 --> 02:39:25,359

you didn't really say anything about

3975

02:39:34,550 --> 02:39:31,429

do you think it works okay as a concept

3976

02:39:38,469 --> 02:39:34,560

of operations if we add you know into it

3977

02:39:39,349 --> 02:39:38,479

it touched on testing it it tests

3978

02:39:42,309 --> 02:39:39,359

on

3979

02:39:44,150 --> 02:39:42,319

extendability lots of places okay

3980

02:39:47,670 --> 02:39:44,160

all right

3981

02:39:49,030 --> 02:39:47,680

extending on uh the sap comment earlier

3982

02:39:51,110 --> 02:39:49,040

uh you know

3983

02:39:52,950 --> 02:39:51,120

the sap that we're

3984

02:39:55,110 --> 02:39:52,960

trying to push here does an awful lot

3985

02:39:58,710 --> 02:39:55,120

not just for

3986

02:40:01,670 --> 02:39:58,720

advancing the cause for geocom birds but

3987

02:40:04,710 --> 02:40:01,680

for doing things like deep space

3988

02:40:06,550 --> 02:40:04,720

space orbital debris

3989

02:40:09,110 --> 02:40:06,560

satellite servicing

3990

02:40:10,630 --> 02:40:09,120

uh human exploration you know deep space

3991

02:40:13,750 --> 02:40:10,640

human exploration i mean that was one of

3992

02:40:15,349 --> 02:40:13,760

our initial motivations for sdmd doing

3993

02:40:16,630 --> 02:40:15,359

these technology advancements in the

3994

02:40:18,230 --> 02:40:16,640

first place and

3995

02:40:20,710 --> 02:40:18,240

i think we got to make sure we captured

3996

02:40:21,990 --> 02:40:20,720

that yes some of those i felt i thought

3997

02:40:23,990 --> 02:40:22,000

that we were trying to capture with

3998

02:40:26,309 --> 02:40:24,000

these yeah but you kind of you don't i i

3999

02:40:27,830 --> 02:40:26,319

guess what i would do is put under

4000

02:40:31,190 --> 02:40:27,840

extensibility

4001

02:40:33,110 --> 02:40:31,200

scp specific ah okay spell out sap

4002

02:40:34,870 --> 02:40:33,120

specifically yeah okay and because a lot

4003

02:40:36,870 --> 02:40:34,880

of these are connected to us right but

4004

02:40:40,870 --> 02:40:36,880

you're not making the point yep i got it

4005

02:40:44,389 --> 02:40:42,469

well i guess if we're going to talk

4006

02:40:46,469 --> 02:40:44,399

about about that those sorts of

4007

02:40:49,269 --> 02:40:46,479

specifics right if we develop advanced

4008

02:40:50,870 --> 02:40:49,279

robotics for this those robotics

4009

02:40:52,630 --> 02:40:50,880

with humans involved and work in

4010

02:40:55,510 --> 02:40:52,640

conjunction with dba

4011

02:40:59,349 --> 02:40:55,520

right assembly of large observatories

4012

02:41:02,790 --> 02:40:59,359

um assembly of a mars excursion vehicle

4013

02:41:06,309 --> 02:41:04,550

the expansion of humans into the solar

4014

02:41:09,110 --> 02:41:06,319

system with robotics and humans working

4015

02:41:12,230 --> 02:41:10,309

okay

4016

02:41:13,750 --> 02:41:12,240

all right just because when most people

4017

02:41:15,429 --> 02:41:13,760

see satellite servicing they think

4018

02:41:17,910 --> 02:41:15,439

fixing things that are already existing

4019

02:41:20,230 --> 02:41:17,920

there as opposed to building new things

4020

02:41:21,510 --> 02:41:20,240

that can't be built without it

4021

02:41:24,710 --> 02:41:21,520

okay

4022

02:41:30,230 --> 02:41:26,790

james mentioned that the leftover

4023

02:41:31,830 --> 02:41:30,240

material would have value to industry it

4024

02:41:34,230 --> 02:41:31,840

would have much more value to industry

4025

02:41:35,670 --> 02:41:34,240

if it had some say in which rock was

4026

02:41:37,830 --> 02:41:35,680

brought back

4027

02:41:39,590 --> 02:41:37,840

the any rock will do approach

4028

02:41:43,269 --> 02:41:39,600

doesn't guarantee you really that you'll

4029

02:41:44,790 --> 02:41:43,279

have an industrial useful resource

4030

02:41:47,429 --> 02:41:44,800

left over after the

4031

02:41:49,510 --> 02:41:47,439

orion mission okay

4032

02:41:50,870 --> 02:41:49,520

there was a point made earlier that you

4033

02:41:52,550 --> 02:41:50,880

know big rocks are easier to find than

4034

02:41:53,590 --> 02:41:52,560

small rocks

4035

02:41:55,429 --> 02:41:53,600

and that's of course because of the

4036

02:41:56,790 --> 02:41:55,439

inverse square law but what wasn't

4037

02:41:59,269 --> 02:41:56,800

mentioned is that the slope of the

4038

02:42:01,030 --> 02:41:59,279

population curve is minus 2.6 and

4039

02:42:03,670 --> 02:42:01,040

therefore you actually find much more

4040

02:42:05,110 --> 02:42:03,680

small objects than large objects and

4041

02:42:07,510 --> 02:42:05,120

furthermore because of the fourth power

4042

02:42:09,750 --> 02:42:07,520

radar law they're much much more likely

4043

02:42:12,550 --> 02:42:09,760

to be in the radar you know within range

4044

02:42:14,550 --> 02:42:12,560

of our radar systems are sibo and

4045

02:42:16,469 --> 02:42:14,560

goldstone and so

4046

02:42:18,870 --> 02:42:16,479

if you go out just looking for these

4047

02:42:21,110 --> 02:42:18,880

objects you're they're overwhelmingly

4048

02:42:22,469 --> 02:42:21,120

going to find the smaller objects and

4049

02:42:24,870 --> 02:42:22,479

you're going to be able to characterize

4050

02:42:27,269 --> 02:42:24,880

the smaller objects preferentially to

4051

02:42:28,550 --> 02:42:27,279

the larger objects

4052

02:42:30,469 --> 02:42:28,560

okay

4053

02:42:32,790 --> 02:42:30,479

i'm not sure yet how to capture that in

4054

02:42:34,070 --> 02:42:32,800

this thought process but but we'll make

4055

02:42:36,389 --> 02:42:34,080

a note

4056

02:42:39,190 --> 02:42:36,399

okay that would be very helpful

4057

02:42:40,630 --> 02:42:39,200

all right oh just one i guess we didn't

4058

02:42:43,030 --> 02:42:40,640

it was only talked about briefly but in

4059

02:42:44,469 --> 02:42:43,040

terms of extensibility um you have a lot

4060

02:42:46,230 --> 02:42:44,479

of capability up here but you don't talk

4061

02:42:48,070 --> 02:42:46,240

at all about any science capability you

4062

02:42:49,670 --> 02:42:48,080

could imagine using this uh in some

4063

02:42:51,269 --> 02:42:49,680

fashion to do something really

4064

02:42:53,269 --> 02:42:51,279

interesting in terms of bringing a

4065

02:42:55,910 --> 02:42:53,279

telescope to l1 or l2 or something like

4066

02:42:57,590 --> 02:42:55,920

that you could there's a science

4067

02:42:59,190 --> 02:42:57,600

potential here oh that i think you're

4068

02:43:00,870 --> 02:42:59,200

not capturing with developing this kind

4069

02:43:02,309 --> 02:43:00,880

of technology yeah if you want to if you

4070

02:43:03,750 --> 02:43:02,319

want to move something very big to an

4071

02:43:05,349 --> 02:43:03,760

interesting place you have a possibility

4072

02:43:06,790 --> 02:43:05,359

of doing that oh okay so it comes back

4073

02:43:07,990 --> 02:43:06,800

to the like the accept question

4074

02:43:09,830 --> 02:43:08,000

especially

4075

02:43:12,070 --> 02:43:09,840

and it's not just for these sort of

4076
02:43:13,910 --> 02:43:12,080
things but even as a science potential

4077
02:43:15,190 --> 02:43:13,920
for moving things around

4078
02:43:16,950 --> 02:43:15,200
yeah i mean i i don't know what that

4079
02:43:18,550 --> 02:43:16,960
would be but you know we could be

4080
02:43:20,550 --> 02:43:18,560
ambitious right so

4081
02:43:22,950 --> 02:43:20,560
okay thank you anything else in this

4082
02:43:24,469 --> 02:43:22,960
category oh yeah so i have sort of a

4083
02:43:27,349 --> 02:43:24,479
more general question i'm wondering if

4084
02:43:28,790 --> 02:43:27,359
it's within the scope of this uh uh

4085
02:43:30,469 --> 02:43:28,800
summary to try and place some

4086
02:43:32,309 --> 02:43:30,479
prioritization

4087
02:43:33,990 --> 02:43:32,319
on this long list

4088
02:43:36,550 --> 02:43:34,000

that has consensus of this group or

4089

02:43:38,710 --> 02:43:36,560

whether we're just trying to report on

4090

02:43:40,550 --> 02:43:38,720

everything that was covered i'm not sure

4091

02:43:43,110 --> 02:43:40,560

if that is beyond what we're supposed to

4092

02:43:45,429 --> 02:43:43,120

do my guess is is we probably won't get

4093

02:43:47,349 --> 02:43:45,439

there in the next 15 minutes

4094

02:43:48,710 --> 02:43:47,359

um you know it's a good thought and

4095

02:43:50,230 --> 02:43:48,720

maybe what we can do in terms of the

4096

02:43:51,510 --> 02:43:50,240

findings is one of the things you do is

4097

02:43:53,269 --> 02:43:51,520

you take this list and start going

4098

02:43:55,269 --> 02:43:53,279

through a prioritization activity that

4099

02:43:57,349 --> 02:43:55,279

might be the how we can fit it in as as

4100

02:43:59,110 --> 02:43:57,359

part of our you know next steps that

4101
02:44:01,349 --> 02:43:59,120
kind of stuff is we've got a lot of good

4102
02:44:02,230 --> 02:44:01,359
ideas but but one of the next steps is

4103
02:44:03,670 --> 02:44:02,240
to

4104
02:44:05,750 --> 02:44:03,680
sort out which ones

4105
02:44:07,429 --> 02:44:05,760
hey jim yeah i think the way that we

4106
02:44:08,950 --> 02:44:07,439
should handle that i mean i don't

4107
02:44:11,110 --> 02:44:08,960
disagree with it at all i think we need

4108
02:44:13,030 --> 02:44:11,120
to yeah think about that but i think

4109
02:44:15,429 --> 02:44:13,040
that that should be a discussion that we

4110
02:44:19,190 --> 02:44:15,439
have with the wider group sort of the on

4111
02:44:21,750 --> 02:44:19,200
the on wednesday we're all still here um

4112
02:44:23,670 --> 02:44:21,760
that that we could all say well where's

4113
02:44:25,190 --> 02:44:23,680

what is the next step moving forward i

4114

02:44:26,950 --> 02:44:25,200

mean we're not going to just take all

4115

02:44:28,790 --> 02:44:26,960

this data and then send everybody away

4116

02:44:30,550 --> 02:44:28,800

and say okay we're done right i mean

4117

02:44:33,269 --> 02:44:30,560

nasa is going to definitely interact

4118

02:44:35,990 --> 02:44:33,279

with the participants here going forward

4119

02:44:37,429 --> 02:44:36,000

and but we need to establish you know

4120

02:44:38,630 --> 02:44:37,439

what we should do and how we should do

4121

02:44:40,070 --> 02:44:38,640

it and i think that's something that we

4122

02:44:41,110 --> 02:44:40,080

should bring up as a topic for

4123

02:44:42,630 --> 02:44:41,120

discussion

4124

02:44:44,389 --> 02:44:42,640

uh with the

4125

02:44:45,510 --> 02:44:44,399

the broader audience you know we had

4126
02:44:49,190 --> 02:44:45,520
some other

4127
02:44:51,590 --> 02:44:49,200
uh panels that broke off here uh as you

4128
02:44:54,309 --> 02:44:51,600
know apart from us here today

4129
02:44:56,469 --> 02:44:54,319
uh in the parallel sessions and i'm sure

4130
02:44:57,830 --> 02:44:56,479
they brought up the same point yeah okay

4131
02:45:00,790 --> 02:44:57,840
that's a good point

4132
02:45:02,070 --> 02:45:00,800
we'll figure out how to do that

4133
02:45:04,630 --> 02:45:02,080
so we go on to alternate mission

4134
02:45:06,710 --> 02:45:04,640
scenarios concept of operations we kind

4135
02:45:08,790 --> 02:45:06,720
of had the the

4136
02:45:10,950 --> 02:45:08,800
various you know got introduced very

4137
02:45:12,070 --> 02:45:10,960
quickly on to some of the options that

4138
02:45:13,830 --> 02:45:12,080

were out there

4139

02:45:16,550 --> 02:45:13,840

uh the benefits of obtaining multiple

4140

02:45:19,510 --> 02:45:16,560

samples from the robopile asteroid many

4141

02:45:21,590 --> 02:45:19,520

moons um good discussion on many moons

4142

02:45:23,269 --> 02:45:21,600

and the alternatives there and in terms

4143

02:45:25,670 --> 02:45:23,279

of concept of operation a separate

4144

02:45:28,389 --> 02:45:25,680

transporter and capture vehicles

4145

02:45:30,870 --> 02:45:28,399

and trying to factor in modularity um

4146

02:45:33,510 --> 02:45:30,880

comments on this section so as brought

4147

02:45:37,349 --> 02:45:33,520

up earlier the big one is do we do

4148

02:45:38,870 --> 02:45:37,359

precursors or cursors yes right

4149

02:45:40,790 --> 02:45:38,880

or do you

4150

02:45:42,790 --> 02:45:40,800

you know sort of a modification to that

4151
02:45:45,590 --> 02:45:42,800
is do you do a campaign where you go to

4152
02:45:48,309 --> 02:45:45,600
more than one asteroid you know a small

4153
02:45:49,750 --> 02:45:48,319
one and a big one or some combination

4154
02:45:51,110 --> 02:45:49,760
thereof

4155
02:45:52,469 --> 02:45:51,120
um

4156
02:45:54,710 --> 02:45:52,479
okay

4157
02:45:57,750 --> 02:45:54,720
or do you or do you

4158
02:46:00,870 --> 02:45:57,760
use your combination of assets to do

4159
02:46:02,630 --> 02:46:00,880
grab you know a combination of you know

4160
02:46:04,630 --> 02:46:02,640
regolith and

4161
02:46:06,550 --> 02:46:04,640
there's there's a whole

4162
02:46:07,750 --> 02:46:06,560
different approach

4163
02:46:10,790 --> 02:46:07,760

okay

4164

02:46:12,950 --> 02:46:10,800

i'll expand on that one uh so originally

4165

02:46:14,950 --> 02:46:12,960

when john did the first the kick study

4166

02:46:16,230 --> 02:46:14,960

there was a longer period between launch

4167

02:46:18,150 --> 02:46:16,240

and retrieving they had a little more

4168

02:46:20,389 --> 02:46:18,160

time which opened up more targets and

4169

02:46:22,630 --> 02:46:20,399

things like that uh then when we brought

4170

02:46:25,190 --> 02:46:22,640

it into nasa we focused on you know

4171

02:46:26,550 --> 02:46:25,200

meeting certain milestones uh doing it

4172

02:46:28,389 --> 02:46:26,560

all ourselves without working with

4173

02:46:30,070 --> 02:46:28,399

industry to fund it so you know if you

4174

02:46:31,269 --> 02:46:30,080

have these industry partnerships that

4175

02:46:33,190 --> 02:46:31,279

we're talking about where maybe they

4176
02:46:35,750 --> 02:46:33,200
would fund a precursor

4177
02:46:38,710 --> 02:46:35,760
and maybe our particular

4178
02:46:39,990 --> 02:46:38,720
return date wouldn't be 2023 or 2024 it

4179
02:46:41,510 --> 02:46:40,000
might be a little bit out it might open

4180
02:46:43,269 --> 02:46:41,520
up a greater opportunity to leverage

4181
02:46:45,110 --> 02:46:43,279
what james just said do we have a better

4182
02:46:46,550 --> 02:46:45,120
campaign perspective can we partner with

4183
02:46:47,269 --> 02:46:46,560
industry to make this better for all of

4184
02:46:50,790 --> 02:46:47,279
us

4185
02:46:50,800 --> 02:46:55,349
yes yes

4186
02:46:58,870 --> 02:46:57,349
okay good oh okay just in terms of

4187
02:47:00,950 --> 02:46:58,880
precursors i want to expand this

4188
02:47:02,389 --> 02:47:00,960

discussion a little bit and that um i

4189

02:47:04,070 --> 02:47:02,399

know everyone's talking about the tight

4190

02:47:05,590 --> 02:47:04,080

timing and the rest but really one of

4191

02:47:07,670 --> 02:47:05,600

the most important precursors you could

4192

02:47:09,590 --> 02:47:07,680

do is do a survey that looks for near

4193

02:47:11,110 --> 02:47:09,600

earth objects right so here you can span

4194

02:47:12,309 --> 02:47:11,120

the number of objects we had and then

4195

02:47:13,510 --> 02:47:12,319

you have many more options you don't

4196

02:47:16,230 --> 02:47:13,520

know what options we have right now

4197

02:47:17,990 --> 02:47:16,240

right now we have very very few

4198

02:47:19,510 --> 02:47:18,000

options in terms of mission targets and

4199

02:47:21,030 --> 02:47:19,520

the rest and i think that could limit

4200

02:47:22,710 --> 02:47:21,040

that could be the show stopper right so

4201
02:47:24,230 --> 02:47:22,720
you want to avoid the show stoppers so

4202
02:47:26,630 --> 02:47:24,240
that's something i think nasa strongly

4203
02:47:33,110 --> 02:47:26,640
has to consider is some kind of space

4204
02:47:37,750 --> 02:47:35,269
so listening to the talks i sensed a lot

4205
02:47:40,469 --> 02:47:37,760
of interest in resources

4206
02:47:42,469 --> 02:47:40,479
and isru as a driver

4207
02:47:43,750 --> 02:47:42,479
and perhaps that's a way of answering

4208
02:47:46,389 --> 02:47:43,760
the why

4209
02:47:47,750 --> 02:47:46,399
and so a lot of commercial interest

4210
02:47:49,030 --> 02:47:47,760
on

4211
02:47:51,670 --> 02:47:49,040
what you do

4212
02:47:54,070 --> 02:47:51,680
with the asteroid and what is its

4213
02:47:56,309 --> 02:47:54,080

ultimate purpose and i think isru

4214

02:48:03,190 --> 02:47:56,319

should be captured as a potential driver

4215

02:48:08,870 --> 02:48:06,150

i have one comment under extensibility

4216

02:48:10,309 --> 02:48:08,880

if we for example pick up a rock from a

4217

02:48:11,990 --> 02:48:10,319

larger rock

4218

02:48:13,190 --> 02:48:12,000

is the question of should we leave

4219

02:48:15,670 --> 02:48:13,200

something

4220

02:48:18,630 --> 02:48:15,680

behind on the rock the big rock that we

4221

02:48:20,630 --> 02:48:18,640

took the little rock from

4222

02:48:26,550 --> 02:48:20,640

beacon or

4223

02:48:26,560 --> 02:48:30,309

okay thank you

4224

02:48:33,830 --> 02:48:32,230

anything else

4225

02:48:36,710 --> 02:48:33,840

the the other category that was

4226
02:48:39,429 --> 02:48:36,720
suggested that uh in addition to these

4227
02:48:47,670 --> 02:48:39,439
five was different business strategies

4228
02:48:53,269 --> 02:48:49,830
okay

4229
02:48:58,790 --> 02:48:56,630
um now this one's the harder one

4230
02:49:00,710 --> 02:48:58,800
we did the easy one and and this one we

4231
02:49:03,110 --> 02:49:00,720
we struggled with ourselves too so you

4232
02:49:04,950 --> 02:49:03,120
know even more than than summarizing

4233
02:49:06,870 --> 02:49:04,960
what was in the papers is what what are

4234
02:49:08,950 --> 02:49:06,880
findings relative to this initiative

4235
02:49:10,469 --> 02:49:08,960
planning and honestly like i said this

4236
02:49:13,110 --> 02:49:10,479
area in particular we didn't have quite

4237
02:49:15,349 --> 02:49:13,120
the guidance that we do now so but but

4238
02:49:16,550 --> 02:49:15,359

anyways i'll just talk through it and

4239

02:49:18,070 --> 02:49:16,560

the things that we would think would be

4240

02:49:19,750 --> 02:49:18,080

next steps is i think what this is

4241

02:49:21,990 --> 02:49:19,760

really more ordered around

4242

02:49:23,590 --> 02:49:22,000

um

4243

02:49:25,190 --> 02:49:23,600

establish a concise set of mission

4244

02:49:27,510 --> 02:49:25,200

objectives and figures of merit that

4245

02:49:29,269 --> 02:49:27,520

includes extensibility commercialization

4246

02:49:30,870 --> 02:49:29,279

considerations

4247

02:49:31,830 --> 02:49:30,880

perform an assessment of various mission

4248

02:49:33,990 --> 02:49:31,840

concept

4249

02:49:35,990 --> 02:49:34,000

options against these farms including

4250

02:49:38,790 --> 02:49:36,000

weighing technology approach and mission

4251
02:49:40,469 --> 02:49:38,800
enhancement options in doing so

4252
02:49:42,150 --> 02:49:40,479
focus the risk reduction activities

4253
02:49:44,230 --> 02:49:42,160
consistent with the mission concept

4254
02:49:47,590 --> 02:49:44,240
approach and leveraging the inputs and

4255
02:49:49,110 --> 02:49:47,600
consider a follow on our arm workshop

4256
02:49:50,790 --> 02:49:49,120
for sensor technologies that would

4257
02:49:53,670 --> 02:49:50,800
address the potential for integrated

4258
02:49:55,429 --> 02:49:53,680
sensing system that is able to support

4259
02:49:57,590 --> 02:49:55,439
all mission phases and broader nasa

4260
02:49:58,469 --> 02:49:57,600
exploration needs and and like i say we

4261
02:50:00,230 --> 02:49:58,479
really

4262
02:50:02,070 --> 02:50:00,240
you know this was a much more difficult

4263
02:50:03,510 --> 02:50:02,080

thing for us to do when we were talking

4264

02:50:05,190 --> 02:50:03,520

it but

4265

02:50:06,830 --> 02:50:05,200

this is what we have right now we'll

4266

02:50:09,910 --> 02:50:06,840

open the floor

4267

02:50:12,550 --> 02:50:09,920

thoughts just one comment the top one

4268

02:50:14,070 --> 02:50:12,560

would address the cost versus uh

4269

02:50:16,550 --> 02:50:14,080

objectives issue

4270

02:50:18,230 --> 02:50:16,560

some of the launch vehicle issues uh one

4271

02:50:20,469 --> 02:50:18,240

of the launch options could take the

4272

02:50:22,389 --> 02:50:20,479

entire budget and have nothing to launch

4273

02:50:24,630 --> 02:50:22,399

so that would be very helpful to

4274

02:50:29,110 --> 02:50:24,640

understand how much is actually being

4275

02:50:29,120 --> 02:50:41,590

anything else

4276

02:50:44,070 --> 02:50:42,309

uh

4277

02:50:45,910 --> 02:50:44,080

just looking at this list one thing i

4278

02:50:47,030 --> 02:50:45,920

think which could be done i think which

4279

02:50:47,750 --> 02:50:47,040

i'll put a different way which should be

4280

02:50:50,230 --> 02:50:47,760

done

4281

02:50:51,830 --> 02:50:50,240

is more incorporation of the small body

4282

02:50:53,269 --> 02:50:51,840

science community into all these

4283

02:50:54,630 --> 02:50:53,279

discussions

4284

02:50:56,150 --> 02:50:54,640

for some reason they're not being

4285

02:50:58,630 --> 02:50:56,160

included in any great degree or not

4286

02:51:00,309 --> 02:50:58,640

being invited and yet they have almost

4287

02:51:02,230 --> 02:51:00,319

all the expertise that exists on these

4288

02:51:04,550 --> 02:51:02,240

objects so i think we need to have

4289

02:51:06,469 --> 02:51:04,560

nasa sponsored workshops to discuss

4290

02:51:12,150 --> 02:51:06,479

these things

4291

02:51:16,870 --> 02:51:14,630

well until i heard deep space industries

4292

02:51:18,870 --> 02:51:16,880

talk i would have argued against more is

4293

02:51:20,230 --> 02:51:18,880

better

4294

02:51:22,630 --> 02:51:20,240

but if you guys are going to make fuel

4295

02:51:24,150 --> 02:51:22,640

out of it maybe more is better we are in

4296

02:51:25,110 --> 02:51:24,160

america anyway

4297

02:51:26,630 --> 02:51:25,120

um

4298

02:51:27,670 --> 02:51:26,640

that is our general approach to

4299

02:51:30,150 --> 02:51:27,680

everything

4300

02:51:31,510 --> 02:51:30,160

um but is is enough enough

4301

02:51:33,590 --> 02:51:31,520

i mean if a figure of merit is going to

4302

02:51:35,830 --> 02:51:33,600

be how much mass we bring back that may

4303

02:51:37,510 --> 02:51:35,840

drive a lot of decisions then

4304

02:51:39,590 --> 02:51:37,520

is one ton enough

4305

02:51:41,349 --> 02:51:39,600

if one ton is enough that may mean we

4306

02:51:42,630 --> 02:51:41,359

spend our money elsewhere in the system

4307

02:51:44,469 --> 02:51:42,640

rather than

4308

02:51:47,269 --> 02:51:44,479

you know you know are these guys going

4309

02:51:48,710 --> 02:51:47,279

to build a 15 meter bag or a 10 meter

4310

02:51:51,510 --> 02:51:48,720

bag

4311

02:51:53,830 --> 02:51:51,520

right so

4312

02:51:55,990 --> 02:51:53,840

is more always better if it ends up

4313

02:51:58,070 --> 02:51:56,000

killing the mission because we

4314

02:52:00,550 --> 02:51:58,080

we get ground into the ground on being

4315

02:52:01,990 --> 02:52:00,560

able to get that much then maybe

4316

02:52:05,269 --> 02:52:02,000

maybe we could pick a number that was

4317

02:52:07,590 --> 02:52:05,279

reasonable and that it just isn't uh

4318

02:52:09,190 --> 02:52:07,600

all right that's enough i think the top

4319

02:52:12,309 --> 02:52:09,200

figure of merit should be can you

4320

02:52:15,510 --> 02:52:12,319

sustain this activity

4321

02:52:17,349 --> 02:52:15,520

doing it once is not very interesting

4322

02:52:19,670 --> 02:52:17,359

so that should be the figure of merit is

4323

02:52:21,510 --> 02:52:19,680

it can you continue doing it

4324

02:52:23,670 --> 02:52:21,520

that would argue that the more comes in

4325

02:52:25,269 --> 02:52:23,680

the continuation than the repeatability

4326

02:52:26,790 --> 02:52:25,279

rather in the size of the initial

4327

02:52:28,550 --> 02:52:26,800

mission well then we're talking about

4328

02:52:29,990 --> 02:52:28,560

transferring of the technology to

4329

02:52:32,070 --> 02:52:30,000

private industry who wants to do it

4330

02:52:33,590 --> 02:52:32,080

again and again because

4331

02:52:35,750 --> 02:52:33,600

other than the scientists coming back

4332

02:52:37,750 --> 02:52:35,760

arguing that we need to do it again i

4333

02:52:38,870 --> 02:52:37,760

think this community's only signed up

4334

02:52:40,630 --> 02:52:38,880

for one

4335

02:52:42,630 --> 02:52:40,640

right

4336

02:52:44,950 --> 02:52:42,640

but i don't speak you want to spend that

4337

02:52:46,309 --> 02:52:44,960

much money to do it go ahead

4338

02:52:47,830 --> 02:52:46,319

please do well but it's not just that

4339

02:52:50,309 --> 02:52:47,840

we're spending the money to do lots of

4340

02:52:52,469 --> 02:52:50,319

other things develop the technology

4341

02:52:54,389 --> 02:52:52,479

practice evas do longer distances et

4342

02:52:56,950 --> 02:52:54,399

cetera et cetera so it's not just

4343

02:52:58,790 --> 02:52:56,960

spending all the money for one ton it's

4344

02:52:59,830 --> 02:52:58,800

for all the other things in addition so

4345

02:53:03,429 --> 02:52:59,840

as long as we can transfer the

4346

02:53:04,309 --> 02:53:03,439

technology to you does that satisfy the

4347

02:53:05,910 --> 02:53:04,319

the

4348

02:53:08,870 --> 02:53:05,920

continual stream of getting more and

4349

02:53:13,269 --> 02:53:11,269

what you decide to develop

4350

02:53:14,630 --> 02:53:13,279

if it's only done according to your

4351
02:53:16,870 --> 02:53:14,640
figures of merit

4352
02:53:19,110 --> 02:53:16,880
because you're the only one

4353
02:53:20,550 --> 02:53:19,120
making decisions about the system

4354
02:53:23,269 --> 02:53:20,560
means that the technology that gets

4355
02:53:25,830 --> 02:53:23,279
developed may not be applicable or

4356
02:53:28,389 --> 02:53:25,840
useful to the private sector so

4357
02:53:30,070 --> 02:53:28,399
that's why a cots like approach

4358
02:53:32,070 --> 02:53:30,080
you know where nasa said we want this

4359
02:53:34,070 --> 02:53:32,080
many tons delivered to the space station

4360
02:53:35,670 --> 02:53:34,080
what else you do with the dragon system

4361
02:53:37,429 --> 02:53:35,680
is up to you if you're going to sell it

4362
02:53:38,710 --> 02:53:37,439
back to us that's a different story

4363
02:53:40,469 --> 02:53:38,720

right if you're going to sell back to us

4364

02:53:42,870 --> 02:53:40,479

now we help ourselves by bringing more

4365

02:53:44,950 --> 02:53:42,880

to sis luna's face

4366

02:53:47,110 --> 02:53:44,960

mark did you want to add something well

4367

02:53:49,349 --> 02:53:47,120

i was just going to try to help heather

4368

02:53:51,510 --> 02:53:49,359

turned around and cued me there's more

4369

02:53:53,670 --> 02:53:51,520

than one aspect to extensibility there's

4370

02:53:54,469 --> 02:53:53,680

extensibility of using the asteroid more

4371

02:53:56,710 --> 02:53:54,479

per

4372

02:53:58,309 --> 02:53:56,720

industry things there's extensibility of

4373

02:54:00,230 --> 02:53:58,319

using the technology

4374

02:54:02,230 --> 02:54:00,240

but there's also extensibility that

4375

02:54:04,389 --> 02:54:02,240

steve stitch will talk about in the crew

4376

02:54:06,230 --> 02:54:04,399

session tomorrow of using these

4377

02:54:08,790 --> 02:54:06,240

technologies and systems to accomplish

4378

02:54:10,230 --> 02:54:08,800

missions beyond this lunar missions mars

4379

02:54:11,030 --> 02:54:10,240

missions other things

4380

02:54:13,110 --> 02:54:11,040

so

4381

02:54:14,630 --> 02:54:13,120

the broader nasa team that that is

4382

02:54:16,630 --> 02:54:14,640

working this is looking at it from

4383

02:54:18,950 --> 02:54:16,640

multiple points of view so

4384

02:54:21,510 --> 02:54:18,960

to be fair this session is on the

4385

02:54:24,309 --> 02:54:21,520

redirect correct

4386

02:54:25,990 --> 02:54:24,319

yes so that's that's the form when we

4387

02:54:28,309 --> 02:54:26,000

talk about extensibility we're talking

4388

02:54:30,630 --> 02:54:28,319

about extensibility of those elements

4389

02:54:31,910 --> 02:54:30,640

correct and that's that's james is right

4390

02:54:34,389 --> 02:54:31,920

that's exactly what i was going to say

4391

02:54:36,389 --> 02:54:34,399

is in this session you focus on those

4392

02:54:37,990 --> 02:54:36,399

asteroid pieces but in other sessions

4393

02:54:39,670 --> 02:54:38,000

the broader nasa team is considering

4394

02:54:41,190 --> 02:54:39,680

other aspects although the selection

4395

02:54:42,630 --> 02:54:41,200

material might

4396

02:54:44,309 --> 02:54:42,640

you know might

4397

02:54:46,150 --> 02:54:44,319

hinder or help

4398

02:54:49,269 --> 02:54:46,160

the future missions

4399

02:54:51,750 --> 02:54:49,279

so there is

4400

02:54:54,309 --> 02:54:51,760

as you address your figures of merit you

4401

02:54:55,990 --> 02:54:54,319

want to look at is there a potential

4402

02:54:57,830 --> 02:54:56,000

follow-on use to this does someone pick

4403

02:54:59,590 --> 02:54:57,840

up this technology and make it available

4404

02:55:00,309 --> 02:54:59,600

to us 10 years later when we next need

4405

02:55:06,150 --> 02:55:00,319

it

4406

02:55:08,469 --> 02:55:06,160

we developed a lot of technology that

4407

02:55:10,070 --> 02:55:08,479

doesn't help us follow on so having that

4408

02:55:11,990 --> 02:55:10,080

transition into the commercial sector

4409

02:55:13,429 --> 02:55:12,000

when we're doing that right now in the

4410

02:55:14,790 --> 02:55:13,439

on the science side we've been building

4411

02:55:17,349 --> 02:55:14,800

a lot of technology for the last 10

4412

02:55:18,950 --> 02:55:17,359

years and if we can't get it to the

4413

02:55:20,550 --> 02:55:18,960

commercial industry

4414

02:55:22,150 --> 02:55:20,560

to sustain it we can't sustain it

4415

02:55:24,550 --> 02:55:22,160

anymore so we're abandoning technology

4416

02:55:26,070 --> 02:55:24,560

that we've been building for a while

4417

02:55:27,349 --> 02:55:26,080

because we haven't thought through the

4418

02:55:28,630 --> 02:55:27,359

what's next

4419

02:55:31,429 --> 02:55:28,640

and didn't have a way to hand it off

4420

02:55:32,550 --> 02:55:31,439

there's two points that i guess i was

4421

02:55:34,070 --> 02:55:32,560

going to bring up

4422

02:55:38,150 --> 02:55:34,080

an example

4423

02:55:40,710 --> 02:55:38,160

of why you need to actually have some

4424

02:55:43,110 --> 02:55:40,720

discussion along this line of

4425

02:55:45,990 --> 02:55:43,120

of technology is even within sub

4426
02:55:48,630 --> 02:55:46,000
technologies sap technologies and let's

4427
02:55:50,309 --> 02:55:48,640
say that we all agree that well we're

4428
02:55:52,230 --> 02:55:50,319
probably going to go down the hall

4429
02:55:53,590 --> 02:55:52,240
thruster route just because that's the

4430
02:55:55,190 --> 02:55:53,600
most mature

4431
02:55:56,870 --> 02:55:55,200
and that we could bring online to do

4432
02:55:58,870 --> 02:55:56,880
this kind of mission in this timeframe

4433
02:56:01,190 --> 02:55:58,880
even if you got consensus about that

4434
02:56:03,349 --> 02:56:01,200
which you wouldn't

4435
02:56:04,230 --> 02:56:03,359
the fact of the matter is if

4436
02:56:12,150 --> 02:56:04,240
the

4437
02:56:15,110 --> 02:56:12,160
goes with 12.5

4438
02:56:17,269 --> 02:56:15,120

kilowatt individual thrusters

4439

02:56:19,750 --> 02:56:17,279

the geocom community would say those are

4440

02:56:22,309 --> 02:56:19,760

useless for our needs they don't want

4441

02:56:24,389 --> 02:56:22,319

that larger thruster so

4442

02:56:26,469 --> 02:56:24,399

transferring technology

4443

02:56:28,950 --> 02:56:26,479

is very dependent on

4444

02:56:30,950 --> 02:56:28,960

what the rest of the community wants and

4445

02:56:33,510 --> 02:56:30,960

we need to make we need to make a point

4446

02:56:35,269 --> 02:56:33,520

that that that has to be discussed and

4447

02:56:36,950 --> 02:56:35,279

acknowledged in some way so that's the

4448

02:56:39,030 --> 02:56:36,960

first point that i wanted to make and i

4449

02:56:40,710 --> 02:56:39,040

think we should try to capture it within

4450

02:56:42,950 --> 02:56:40,720

this this type of discussion that you're

4451
02:56:45,349 --> 02:56:42,960
bringing up on findings

4452
02:56:46,150 --> 02:56:45,359
the second goes back to

4453
02:56:48,950 --> 02:56:46,160
uh

4454
02:56:51,190 --> 02:56:48,960
how we're dealing with

4455
02:56:52,830 --> 02:56:51,200
the business case because the entire

4456
02:56:56,070 --> 02:56:52,840
discussion that you just

4457
02:56:58,150 --> 02:56:56,080
heard cots versus well the government

4458
02:57:00,630 --> 02:56:58,160
goes and does this as a one-off and then

4459
02:57:02,870 --> 02:57:00,640
sends you know and then you know

4460
02:57:04,469 --> 02:57:02,880
says okay now we could we could uh you

4461
02:57:06,870 --> 02:57:04,479
know hand off the technologies to be

4462
02:57:08,870 --> 02:57:06,880
sold back to us that's that's

4463
02:57:11,510 --> 02:57:08,880

you know completely different mindset of

4464

02:57:13,110 --> 02:57:11,520

how we should go about this and

4465

02:57:15,030 --> 02:57:13,120

i think that there's going to be very

4466

02:57:16,469 --> 02:57:15,040

big differences in how partnerships

4467

02:57:17,990 --> 02:57:16,479

occur

4468

02:57:33,670 --> 02:57:18,000

given different scenarios on the

4469

02:57:39,030 --> 02:57:37,750

okay um any la it is for 5 30 so we've

4470

02:57:40,070 --> 02:57:39,040

reached the end of our session but is

4471

02:57:41,269 --> 02:57:40,080

there any other comments you want to

4472

02:57:43,590 --> 02:57:41,279

make on this

4473

02:57:47,349 --> 02:57:45,510

okay any last comments for the session

4474

02:57:49,190 --> 02:57:47,359

hopefully hopefully everybody enjoyed it

4475

02:57:51,670 --> 02:57:49,200

as much as i did

4476

02:57:54,150 --> 02:57:51,680

um well i want to thank everyone

4477

02:57:55,990 --> 02:57:54,160

and thank my colleagues for for

4478

02:57:58,150 --> 02:57:56,000

participation today

4479

02:58:04,710 --> 02:57:58,160

um it was really an excellent session i

4480

02:58:08,710 --> 02:58:07,190

oh and we'll do our best to capture the

4481

02:58:18,790 --> 02:58:08,720

essence of what we've been talking about