
IDENTIFY
#NASAasteroid
NASA
EXPLORI
#NASAasteroid
NASA

1
00:00:47,670 --> 00:00:45,110
the water back

2
00:00:49,190 --> 00:00:47,680
south of the water okay

3
00:00:51,189 --> 00:00:49,200
and then we're going south on the water

4
00:01:34,149 --> 00:00:51,199
tower the first

5
00:02:44,949 --> 00:01:54,630
um

6
00:02:48,830 --> 00:02:46,390
all right so i probably knew i shouldn't

7
00:02:50,949 --> 00:02:48,840
have said we were doing great on time

8
00:02:52,470 --> 00:02:50,959
because this is where everybody won't be

9
00:02:55,110 --> 00:02:52,480
back but we're going to go ahead and

10
00:03:04,309 --> 00:02:55,120
start in a few moments here

11
00:03:06,710 --> 00:03:05,430
scott how do you pronounce your last

12
00:03:20,630 --> 00:03:06,720
name again

13
00:03:20,640 --> 00:03:45,190

uh

14
00:03:48,710 --> 00:03:46,390
okay while we're waiting we'll get

15
00:03:50,789 --> 00:03:48,720
started in just a minute um

16
00:03:54,470 --> 00:03:50,799
just remind folks uh that are out there

17
00:03:57,030 --> 00:03:54,480
in in the virtual world uh that they can

18
00:04:01,830 --> 00:03:57,040
uh post their questions and comments to

19
00:04:05,750 --> 00:04:03,670
and we appreciate

20
00:04:08,149 --> 00:04:05,760
the folks that are participating

21
00:04:10,390 --> 00:04:08,159
from from a remote location and love to

22
00:04:11,990 --> 00:04:10,400
hear your input and comments

23
00:04:14,149 --> 00:04:12,000
either now or during the discussion

24
00:04:16,629 --> 00:04:14,159
period later after the finishing of the

25
00:04:19,110 --> 00:04:16,639
presentations or um tomorrow morning and

26
00:04:20,550 --> 00:04:19,120
again i'll i'll mention this at the end

27
00:04:22,710 --> 00:04:20,560
but we were we're going to have a

28
00:04:24,950 --> 00:04:22,720
session uh we'll have a short discussion

29
00:04:25,909 --> 00:04:24,960
this afternoon and then from 8 a.m to 10

30
00:04:26,950 --> 00:04:25,919
a.m

31
00:04:30,790 --> 00:04:26,960
and

32
00:04:32,230 --> 00:04:30,800
synthesis

33
00:04:33,670 --> 00:04:32,240
period

34
00:04:35,110 --> 00:04:33,680
so with that i think we've got most

35
00:04:38,390 --> 00:04:35,120
people back in the room

36
00:04:40,830 --> 00:04:38,400
our next uh presenter is scott sebcheck

37
00:04:43,110 --> 00:04:40,840
he's the president of prospect

38
00:04:44,629 --> 00:04:43,120

dynamics scott has worked as an engineer

39
00:04:46,710 --> 00:04:44,639
and a program manager missile defense

40
00:04:49,350 --> 00:04:46,720
space launch and aircraft systems for

41
00:05:10,230 --> 00:04:49,360
lockheed martin and united technologies

42
00:05:14,870 --> 00:05:12,950
and just as a note of context coming at

43
00:05:17,430 --> 00:05:14,880
this from the standpoint of prospect

44
00:05:19,350 --> 00:05:17,440
dynamics as a company that's working to

45
00:05:21,670 --> 00:05:19,360
develop technologies to support

46
00:05:23,110 --> 00:05:21,680
uh asteroid mining there's a little bit

47
00:05:25,350 --> 00:05:23,120
of a different mindset that we came into

48
00:05:26,710 --> 00:05:25,360
this with we're looking at technologies

49
00:05:28,790 --> 00:05:26,720
that we're developing that have

50
00:05:30,230 --> 00:05:28,800
applicability in one area and how they

51
00:05:31,909 --> 00:05:30,240
might be applicable

52
00:05:35,749 --> 00:05:31,919
elsewhere planetary defense being one of

53
00:05:39,590 --> 00:05:36,629
so

54
00:05:41,830 --> 00:05:39,600
getting to a new architecture we focused

55
00:05:43,270 --> 00:05:41,840
on three areas scalability flexibility

56
00:05:44,950 --> 00:05:43,280
and cost

57
00:05:46,230 --> 00:05:44,960
for me scalability is significant

58
00:05:48,870 --> 00:05:46,240
because

59
00:05:51,189 --> 00:05:48,880
it means time the more we are able to

60
00:05:55,029 --> 00:05:51,199
scale the system on demand

61
00:05:56,150 --> 00:05:55,039
the less time we require in order to

62
00:05:57,510 --> 00:05:56,160
bring about the effect that we're

63
00:06:01,189 --> 00:05:57,520

looking for

64
00:06:03,110 --> 00:06:01,199
so the ideal system in this sense would

65
00:06:05,510 --> 00:06:03,120
have all of the equipment all of the

66
00:06:08,230 --> 00:06:05,520
components of the architecture on the

67
00:06:11,029 --> 00:06:08,240
shelf and when a thread is determined be

68
00:06:13,189 --> 00:06:11,039
able to configure to scale the impulse

69
00:06:15,110 --> 00:06:13,199
required or the capabilities required

70
00:06:17,350 --> 00:06:15,120
for the mission

71
00:06:20,070 --> 00:06:17,360
flexibility similarly

72
00:06:22,710 --> 00:06:20,080
is about having options it's about being

73
00:06:24,950 --> 00:06:22,720
able to approach an architecture

74
00:06:27,110 --> 00:06:24,960
not as a point design but without a

75
00:06:29,590 --> 00:06:27,120
priority threat information in

76
00:06:31,749 --> 00:06:29,600
developing a general system that uses 90

77
00:06:33,830 --> 00:06:31,759
to 95 percent of the same equipment

78
00:06:35,909 --> 00:06:33,840
regardless of what you're doing but has

79
00:06:37,830 --> 00:06:35,919
that element of configurability or

80
00:06:40,150 --> 00:06:37,840
flexibility that

81
00:06:41,830 --> 00:06:40,160
can allow you to address

82
00:06:44,790 --> 00:06:41,840
potentially a range of different options

83
00:06:47,590 --> 00:06:44,800
or a range of different threats

84
00:06:49,990 --> 00:06:47,600
and finally cost being the third option

85
00:06:52,230 --> 00:06:50,000
like it or not there isn't really a

86
00:06:56,550 --> 00:06:52,240
business case for saving the planet

87
00:06:58,469 --> 00:06:56,560
so that brings us to working within um

88
00:07:00,550 --> 00:06:58,479

funding that is available and funding

89
00:07:02,390 --> 00:07:00,560
that may be available for other related

90
00:07:05,430 --> 00:07:02,400
applications and looking at how do you

91
00:07:07,589 --> 00:07:05,440
leverage that funding to

92
00:07:09,270 --> 00:07:07,599
develop the pieces of the architecture

93
00:07:13,830 --> 00:07:09,280
that would be required

94
00:07:18,390 --> 00:07:15,990
where that led us was

95
00:07:19,270 --> 00:07:18,400
the multiple attached vehicle concept

96
00:07:20,469 --> 00:07:19,280
so

97
00:07:22,390 --> 00:07:20,479
we focus

98
00:07:24,150 --> 00:07:22,400
essentially from the vicinity of the

99
00:07:26,710 --> 00:07:24,160
asteroid on down

100
00:07:28,950 --> 00:07:26,720
in this concept the large vehicle that

101
00:07:30,629 --> 00:07:28,960
is going out to the asteroid serves as a

102
00:07:32,150 --> 00:07:30,639
truck to deliver a fleet of

103
00:07:36,230 --> 00:07:32,160
microsatellites

104
00:07:38,390 --> 00:07:36,240
deploy individually

105
00:07:41,749 --> 00:07:38,400
find a location on the asteroid and

106
00:07:44,950 --> 00:07:41,759
attach to it so you end up with a

107
00:07:47,670 --> 00:07:44,960
essentially a mesh network of satellites

108
00:07:49,909 --> 00:07:47,680
on the surface of the ashtray this

109
00:07:51,270 --> 00:07:49,919
provides you a

110
00:07:53,189 --> 00:07:51,280
ability to

111
00:07:55,189 --> 00:07:53,199
use this distributed

112
00:07:57,189 --> 00:07:55,199
architecture of sensors across the

113
00:07:58,469 --> 00:07:57,199

surface of the asteroid to characterize

114
00:08:00,150 --> 00:07:58,479
and understand

115
00:08:02,629 --> 00:08:00,160
the asteroid more fully than you would

116
00:08:05,670 --> 00:08:02,639
from either remotely or

117
00:08:06,790 --> 00:08:05,680
contacting at a single point

118
00:08:09,029 --> 00:08:06,800
it also

119
00:08:11,430 --> 00:08:09,039
provides you with

120
00:08:12,629 --> 00:08:11,440
the flexibility that i discussed on the

121
00:08:14,950 --> 00:08:12,639
previous slide

122
00:08:17,270 --> 00:08:14,960
so under a reference concept

123
00:08:19,189 --> 00:08:17,280
each one of these vehicles would carry

124
00:08:20,790 --> 00:08:19,199
additional propulsion with it then you

125
00:08:22,790 --> 00:08:20,800
have thrust points covering the surface

126
00:08:24,309 --> 00:08:22,800
of the asterisk and you can use that

127
00:08:25,430 --> 00:08:24,319
thrust in a number of different ways to

128
00:08:27,350 --> 00:08:25,440
bring about

129
00:08:29,749 --> 00:08:27,360
a slow push

130
00:08:31,990 --> 00:08:29,759
or a de-tumble or of various other ways

131
00:08:34,550 --> 00:08:32,000
of affecting the asteroid

132
00:08:36,389 --> 00:08:34,560
you wouldn't have to just bring

133
00:08:38,389 --> 00:08:36,399
propulsion though you could configure

134
00:08:40,070 --> 00:08:38,399
these individual micro satellites such

135
00:08:43,509 --> 00:08:40,080
that they are carrying drilling

136
00:08:45,670 --> 00:08:43,519
equipment or carrying explosives so if

137
00:08:48,949 --> 00:08:45,680
you wanted to look at explosive

138
00:08:50,150 --> 00:08:48,959

fragmentation either in a in a

139
00:08:52,070 --> 00:08:50,160
in a

140
00:08:54,389 --> 00:08:52,080
radical fashion or a more focused

141
00:08:56,550 --> 00:08:54,399
fashion you could potentially bring with

142
00:08:57,990 --> 00:08:56,560
a micro satellites that drill into the

143
00:08:59,990 --> 00:08:58,000
asteroid in different areas

144
00:09:02,870 --> 00:09:00,000
strategically leaking it weakening it

145
00:09:07,829 --> 00:09:05,990
explosives placed at key locations to

146
00:09:09,990 --> 00:09:07,839
detonate that and separate off a large

147
00:09:11,670 --> 00:09:10,000
chunk of the asteroid or a smaller piece

148
00:09:16,230 --> 00:09:11,680
of the yesterday depending on what the

149
00:09:19,590 --> 00:09:17,670
so when looking at this as an

150
00:09:22,150 --> 00:09:19,600
architecture overall

151
00:09:25,030 --> 00:09:22,160
the left side of the screen is is

152
00:09:26,710 --> 00:09:25,040
exactly the same 100 of the time

153
00:09:29,910 --> 00:09:26,720
you have ground communication element a

154
00:09:32,550 --> 00:09:29,920
launch vehicle element and this transit

155
00:09:34,310 --> 00:09:32,560
and deployment vehicle element which

156
00:09:35,910 --> 00:09:34,320
all of these are technologies that

157
00:09:38,550 --> 00:09:35,920
either exist or are currently in

158
00:09:40,310 --> 00:09:38,560
development in the case of the sls

159
00:09:42,710 --> 00:09:40,320
what i would envision in the middle is

160
00:09:44,949 --> 00:09:42,720
that that truck would be

161
00:09:46,949 --> 00:09:44,959
similar to the geosynchronized base

162
00:09:47,910 --> 00:09:46,959
satellites we've been discussing earlier

163
00:09:50,550 --> 00:09:47,920

today

164
00:09:52,790 --> 00:09:50,560
as a baseline concept so technology that

165
00:09:53,990 --> 00:09:52,800
exists being adapted to the purpose of

166
00:09:56,470 --> 00:09:54,000
delivering

167
00:09:59,110 --> 00:09:56,480
multiple

168
00:10:00,230 --> 00:09:59,120
smaller vehicles to the the site of the

169
00:10:01,910 --> 00:10:00,240
asteroid

170
00:10:04,150 --> 00:10:01,920
and that is really one of the key pieces

171
00:10:05,990 --> 00:10:04,160
of scalability within the architecture

172
00:10:08,870 --> 00:10:06,000
because

173
00:10:10,790 --> 00:10:08,880
you don't need to predetermine how many

174
00:10:12,630 --> 00:10:10,800
satellites or microsets you would

175
00:10:15,190 --> 00:10:12,640
necessarily bring with you could build

176
00:10:18,790 --> 00:10:15,200
this in a scalable fashion such that

177
00:10:21,509 --> 00:10:18,800
you bring additional rings or additional

178
00:10:23,509 --> 00:10:21,519
components deployment components for

179
00:10:24,470 --> 00:10:23,519
these vehicles and that really could

180
00:10:26,150 --> 00:10:24,480
scale

181
00:10:27,430 --> 00:10:26,160
to the point of affecting the launch

182
00:10:29,670 --> 00:10:27,440
system as well

183
00:10:31,590 --> 00:10:29,680
if you had a need that the

184
00:10:33,590 --> 00:10:31,600
the hollywood doomsday scenario where

185
00:10:35,590 --> 00:10:33,600
you needed to bring a lot of impulse in

186
00:10:38,230 --> 00:10:35,600
a short period of time

187
00:10:41,269 --> 00:10:38,240
you could scale to the point where you

188
00:10:42,150 --> 00:10:41,279

deliver to orbit to low earth orbit

189
00:10:49,350 --> 00:10:42,160
on

190
00:10:51,030 --> 00:10:49,360
vehicle aboard another launch

191
00:10:52,870 --> 00:10:51,040
rendezvous them in orbit and then your

192
00:10:56,550 --> 00:10:52,880
truck becomes a train

193
00:10:58,150 --> 00:10:56,560
pulling a large number of

194
00:11:00,949 --> 00:10:58,160
micro satellites and their deployment

195
00:11:02,790 --> 00:11:00,959
mechanisms with it the right side of the

196
00:11:04,790 --> 00:11:02,800
screen is about the mission package it's

197
00:11:07,190 --> 00:11:04,800
about what you bring with so that you

198
00:11:08,069 --> 00:11:07,200
can achieve your mission objective on

199
00:11:09,990 --> 00:11:08,079
site

200
00:11:12,470 --> 00:11:10,000
so as i mentioned

201
00:11:14,790 --> 00:11:12,480
the slow push concept would imply that

202
00:11:15,990 --> 00:11:14,800
these are largely propulsive

203
00:11:18,790 --> 00:11:16,000
vehicles that you're bringing with or

204
00:11:19,829 --> 00:11:18,800
have a propulsive payload with them

205
00:11:22,870 --> 00:11:19,839
or

206
00:11:24,949 --> 00:11:22,880
you can bring in a mix you can bring in

207
00:11:26,710 --> 00:11:24,959
components like ground penetrating radar

208
00:11:28,069 --> 00:11:26,720
or other sensors special sensors that

209
00:11:31,509 --> 00:11:28,079
you want to carry with for a better

210
00:11:33,990 --> 00:11:31,519
understanding of the the body

211
00:11:35,750 --> 00:11:34,000
drills explosives as i mentioned or

212
00:11:38,710 --> 00:11:35,760
something like a

213
00:11:40,310 --> 00:11:38,720

a transponder with additional long range

214
00:11:42,389 --> 00:11:40,320
communication so that whatever you're

215
00:11:43,910 --> 00:11:42,399
doing on this asteroid you can then

216
00:11:49,509 --> 00:11:43,920
leave this behind

217
00:11:54,629 --> 00:11:51,990
and i said the left side of that screen

218
00:11:56,710 --> 00:11:54,639
was existing technology or technology

219
00:11:59,269 --> 00:11:56,720
already in development when it comes

220
00:12:00,870 --> 00:11:59,279
down to the micro satellite

221
00:12:02,870 --> 00:12:00,880
the large portion of that is already in

222
00:12:04,150 --> 00:12:02,880
existence as well

223
00:12:05,590 --> 00:12:04,160
the bottom right corner of the screen

224
00:12:07,910 --> 00:12:05,600
don't get hung up on that it would not

225
00:12:11,350 --> 00:12:07,920
look anything like that it's meant to be

226
00:12:13,350 --> 00:12:11,360
a notional concept of of what the

227
00:12:15,829 --> 00:12:13,360
fundamental architecture is

228
00:12:18,470 --> 00:12:15,839
the bulk of the micro satellite vehicle

229
00:12:21,990 --> 00:12:18,480
is just that it's a space vehicle it

230
00:12:23,910 --> 00:12:22,000
contains all of the propulsion coms

231
00:12:24,710 --> 00:12:23,920
data handling everything you need for

232
00:12:26,870 --> 00:12:24,720
that

233
00:12:28,790 --> 00:12:26,880
space vehicle to operate

234
00:12:31,670 --> 00:12:28,800
then there are two other pieces one

235
00:12:33,350 --> 00:12:31,680
since you want to attach to the asteroid

236
00:12:36,389 --> 00:12:33,360
an attachment device

237
00:12:38,230 --> 00:12:36,399
the other a modular payload so you start

238
00:12:39,910 --> 00:12:38,240

with an interface and then you bring

239
00:12:41,590 --> 00:12:39,920
that ability to

240
00:12:43,670 --> 00:12:41,600
bring on a payload

241
00:12:46,310 --> 00:12:43,680
as we discussed for the

242
00:12:48,710 --> 00:12:46,320
various mission packages

243
00:12:53,670 --> 00:12:51,110
way that works out now is the bulk of

244
00:12:55,910 --> 00:12:53,680
that core bus is something that you can

245
00:12:57,110 --> 00:12:55,920
buy online right now between cubesat

246
00:12:58,389 --> 00:12:57,120
technology and micro satellite

247
00:12:59,990 --> 00:12:58,399
technology

248
00:13:01,190 --> 00:13:00,000
the bulk of this vehicle you can put

249
00:13:02,790 --> 00:13:01,200
together today

250
00:13:04,790 --> 00:13:02,800
key pieces remaining in development are

251
00:13:07,670 --> 00:13:04,800
this attach mechanism which is where

252
00:13:10,710 --> 00:13:07,680
we're focusing the integration the

253
00:13:12,230 --> 00:13:10,720
software for coordinating the swarm of

254
00:13:14,629 --> 00:13:12,240
microsatellites and the interaction

255
00:13:16,710 --> 00:13:14,639
between them while on the surface

256
00:13:19,269 --> 00:13:16,720
as well as that payload interface and

257
00:13:21,670 --> 00:13:19,279
the payloads that could be adapted to it

258
00:13:24,389 --> 00:13:21,680
many of those would be to reuse existing

259
00:13:27,190 --> 00:13:24,399
propulsion technologies or existing

260
00:13:34,230 --> 00:13:27,200
other technologies and packaging them

261
00:13:38,629 --> 00:13:36,310
where that gets me to is

262
00:13:40,470 --> 00:13:38,639
the mo the least mature part of this

263
00:13:42,550 --> 00:13:40,480

architecture is something that we could

264
00:13:45,189 --> 00:13:42,560
demonstrate in low earth orbit not go to

265
00:13:47,350 --> 00:13:45,199
an asteroid to demonstrate and that is

266
00:13:49,509 --> 00:13:47,360
the integrated microsatellite with an

267
00:13:53,269 --> 00:13:49,519
attached capability

268
00:13:56,550 --> 00:13:53,279
so how i see this working is launching

269
00:13:58,870 --> 00:13:56,560
maybe a handful of these microsatellites

270
00:14:02,069 --> 00:13:58,880
cubesat class microsatellite into low

271
00:14:03,910 --> 00:14:02,079
earth orbit and then we use the closest

272
00:14:05,750 --> 00:14:03,920
analog in low earth orbit to an asteroid

273
00:14:07,910 --> 00:14:05,760
which would be a piece of space debris

274
00:14:10,150 --> 00:14:07,920
something that's tumbling uncontrolled

275
00:14:12,470 --> 00:14:10,160
not designed to be mated with take these

276
00:14:14,550 --> 00:14:12,480
cubesats demonstrate the ability to find

277
00:14:16,550 --> 00:14:14,560
locations and attach to that

278
00:14:18,790 --> 00:14:16,560
then use that to characterize the motion

279
00:14:20,069 --> 00:14:18,800
of the ashtray or asteroid analog in

280
00:14:22,790 --> 00:14:20,079
this case the

281
00:14:24,790 --> 00:14:22,800
space debris and then affect the orbit

282
00:14:27,269 --> 00:14:24,800
of that space debris

283
00:14:29,189 --> 00:14:27,279
if you are um

284
00:14:31,590 --> 00:14:29,199
if you are altering the orbit you can

285
00:14:35,430 --> 00:14:31,600
think of it as a proof of concept for

286
00:14:38,310 --> 00:14:35,440
for certain capabilities with respect to

287
00:14:40,550 --> 00:14:38,320
on-orbit servicing if you are using this

288
00:14:42,310 --> 00:14:40,560

as a control d orbit of that piece of

289
00:14:45,590 --> 00:14:42,320
space debris not only have you

290
00:14:47,910 --> 00:14:45,600
demonstrated your capabilities for

291
00:14:50,389 --> 00:14:47,920
planetary defense and the attachment

292
00:14:52,710 --> 00:14:50,399
itself but you've also now demonstrated

293
00:14:54,470 --> 00:14:52,720
a rather low cost straightforward

294
00:14:56,310 --> 00:14:54,480
approach to mitigating large pieces of

295
00:14:58,710 --> 00:14:56,320
space debris

296
00:15:00,389 --> 00:14:58,720
so this is the demonstration that really

297
00:15:02,949 --> 00:15:00,399
matures the microattach vehicle

298
00:15:05,430 --> 00:15:02,959
component of this and then if you wanted

299
00:15:07,670 --> 00:15:05,440
to tie back to the arm mission

300
00:15:10,230 --> 00:15:07,680
with something like this the opportunity

301
00:15:12,710 --> 00:15:10,240
there would be to bring along a handful

302
00:15:16,310 --> 00:15:12,720
again of these microsatellites

303
00:15:18,870 --> 00:15:16,320
to deploy onsite at the asteroid and use

304
00:15:20,150 --> 00:15:18,880
them in that asteroid context

305
00:15:22,710 --> 00:15:20,160
in that

306
00:15:25,750 --> 00:15:22,720
that relevant environment to

307
00:15:27,910 --> 00:15:25,760
in place a transponder to

308
00:15:30,230 --> 00:15:27,920
demonstrate the ability to attach

309
00:15:31,829 --> 00:15:30,240
potentially to demonstrate the effect of

310
00:15:33,110 --> 00:15:31,839
drilling or some other concept on the

311
00:15:35,749 --> 00:15:33,120
asteroid

312
00:15:37,269 --> 00:15:35,759
so the focus here is a low earth orbit

313
00:15:39,269 --> 00:15:37,279

demonstration but it does open up the

314
00:15:43,269 --> 00:15:39,279
possibility to a demonstration in

315
00:15:48,150 --> 00:15:45,670
asteroid redirection mission

316
00:15:49,509 --> 00:15:48,160
so going back to those key elements

317
00:15:51,590 --> 00:15:49,519
the

318
00:15:53,430 --> 00:15:51,600
scalability within this system

319
00:15:55,509 --> 00:15:53,440
really comes in two dimensions first the

320
00:15:57,749 --> 00:15:55,519
number of microsatellites as well as the

321
00:16:01,749 --> 00:15:57,759
capability you put in those individual

322
00:16:02,790 --> 00:16:01,759
payloads nothing in this architecture

323
00:16:07,749 --> 00:16:02,800
is

324
00:16:09,189 --> 00:16:07,759
chemical propulsion propulsion payload

325
00:16:10,949 --> 00:16:09,199
and electrical propulsive payload

326
00:16:12,710 --> 00:16:10,959
whatever you want to do you have

327
00:16:14,550 --> 00:16:12,720
opportunities for flexibility within

328
00:16:16,790 --> 00:16:14,560
this architecture

329
00:16:19,990 --> 00:16:16,800
and that buys us time

330
00:16:22,069 --> 00:16:20,000
second flexibility this allows us to

331
00:16:23,670 --> 00:16:22,079
approach the problem of planetary

332
00:16:27,509 --> 00:16:23,680
defense in multiple ways through a slow

333
00:16:29,590 --> 00:16:27,519
push through fragmentation so it spans a

334
00:16:32,069 --> 00:16:29,600
portion of the chart that bong we

335
00:16:34,230 --> 00:16:32,079
presented earlier where depending on the

336
00:16:36,470 --> 00:16:34,240
time you have available you may need to

337
00:16:37,670 --> 00:16:36,480
look at different options and finally

338
00:16:40,230 --> 00:16:37,680

cost

339
00:16:42,230 --> 00:16:40,240
as i went through the bulk of the

340
00:16:44,069 --> 00:16:42,240
technology here is already developed and

341
00:16:46,629 --> 00:16:44,079
we're talking about a repurposing of

342
00:16:49,110 --> 00:16:46,639
technology that's already in existence

343
00:16:50,629 --> 00:16:49,120
also as has been pointed out a little

344
00:16:52,470 --> 00:16:50,639
earlier that there are single point

345
00:16:54,310 --> 00:16:52,480
failures and a lot of the concepts that

346
00:16:56,389 --> 00:16:54,320
have been described

347
00:16:58,310 --> 00:16:56,399
this opens up that tolerance you have a

348
00:17:00,629 --> 00:16:58,320
lot of microsatellites and you could

349
00:17:02,550 --> 00:17:00,639
potentially bring more microsatellites

350
00:17:03,670 --> 00:17:02,560
that you

351
00:17:06,230 --> 00:17:03,680
you need

352
00:17:08,230 --> 00:17:06,240
for the baseline mission and in doing so

353
00:17:10,549 --> 00:17:08,240
you could lower the cost lower than

354
00:17:11,590 --> 00:17:10,559
necessary uh quality standards because

355
00:17:13,829 --> 00:17:11,600
you have

356
00:17:15,750 --> 00:17:13,839
dozens or hundreds of these that most

357
00:17:19,429 --> 00:17:15,760
need to work rather than a single device

358
00:17:23,110 --> 00:17:19,439
that has to work perfectly

359
00:17:25,909 --> 00:17:23,120
so benefits both on in terms of

360
00:17:29,669 --> 00:17:28,150
also timeline with the fact that so much

361
00:17:30,789 --> 00:17:29,679
of this technology is already in

362
00:17:32,230 --> 00:17:30,799
existence

363
00:17:34,470 --> 00:17:32,240

the pacing item is really the

364
00:17:36,870 --> 00:17:34,480
development of the attach mechanism and

365
00:17:38,150 --> 00:17:36,880
the demonstration of that capability

366
00:17:41,830 --> 00:17:38,160
everything else

367
00:17:41,840 --> 00:17:45,990
i'd be happy to take any questions

368
00:17:46,000 --> 00:17:51,990
questions

369
00:17:56,950 --> 00:17:54,710
you you said at some point um cubesats

370
00:17:59,750 --> 00:17:56,960
are these actually cubesat size is that

371
00:18:01,590 --> 00:17:59,760
your is that the idea here so that is

372
00:18:02,950 --> 00:18:01,600
something that's as early in the

373
00:18:04,150 --> 00:18:02,960
architecture as we are we have some

374
00:18:06,390 --> 00:18:04,160
flexibility

375
00:18:08,070 --> 00:18:06,400
and what i would envision for the near

376
00:18:10,390 --> 00:18:08,080
term demonstration would be a cubesat

377
00:18:12,470 --> 00:18:10,400
class when we put this up to alter the

378
00:18:14,230 --> 00:18:12,480
trajectory of a

379
00:18:16,310 --> 00:18:14,240
piece of space debris yes i think that

380
00:18:18,070 --> 00:18:16,320
the cubesat class on an asteroid i think

381
00:18:20,070 --> 00:18:18,080
they might be a little bit larger and so

382
00:18:21,510 --> 00:18:20,080
what sort of propulsion would they

383
00:18:22,950 --> 00:18:21,520
actually have

384
00:18:25,510 --> 00:18:22,960
so the

385
00:18:27,190 --> 00:18:25,520
there is nothing that is necessarily

386
00:18:29,350 --> 00:18:27,200
determined at this point each of the

387
00:18:31,669 --> 00:18:29,360
microsatellites themselves would

388
00:18:36,789 --> 00:18:31,679

have a

389
00:18:37,510 --> 00:18:36,799
attitude and divert control system

390
00:18:39,830 --> 00:18:37,520
for

391
00:18:40,950 --> 00:18:39,840
attitude positioning and rendezvous with

392
00:18:42,390 --> 00:18:40,960
the asteroid

393
00:18:44,310 --> 00:18:42,400
since they're being delivered to the

394
00:18:46,950 --> 00:18:44,320
vicinity of the asteroid by the by the

395
00:18:49,029 --> 00:18:46,960
truck by the transit employment vehicle

396
00:18:50,630 --> 00:18:49,039
then you would be bringing a payload

397
00:18:52,950 --> 00:18:50,640
along and

398
00:18:55,029 --> 00:18:52,960
the payload that would bring about the

399
00:18:57,029 --> 00:18:55,039
divert of the asteroid

400
00:18:58,870 --> 00:18:57,039
those are

401
00:19:00,230 --> 00:18:58,880
something that we

402
00:19:01,909 --> 00:19:00,240
can specify in a number of different

403
00:19:03,590 --> 00:19:01,919
ways depending on what you want to do

404
00:19:05,510 --> 00:19:03,600
with it you can bring a propulsive

405
00:19:07,750 --> 00:19:05,520
payload that is chemical

406
00:19:09,350 --> 00:19:07,760
and then potentially your pulsing

407
00:19:11,029 --> 00:19:09,360
as the asteroid rotates you don't bother

408
00:19:13,430 --> 00:19:11,039
with de-tumbling and when

409
00:19:14,950 --> 00:19:13,440
one cubesat is aligned with the vector

410
00:19:17,270 --> 00:19:14,960
you want to push you get pulses when

411
00:19:18,390 --> 00:19:17,280
another one comes by impulses or you

412
00:19:20,630 --> 00:19:18,400
have

413
00:19:22,230 --> 00:19:20,640

a distribution of solar electric

414
00:19:23,830 --> 00:19:22,240
propulsion fluids so this architecture

415
00:19:26,710 --> 00:19:23,840
really allows that flexibility and

416
00:19:29,029 --> 00:19:26,720
doesn't need to answer that question

417
00:19:31,190 --> 00:19:29,039
yeah all that sounds like to me just

418
00:19:32,789 --> 00:19:31,200
i have to say a lot to put in a cubesat

419
00:19:35,669 --> 00:19:32,799
i mean to have it attitude control

420
00:19:37,350 --> 00:19:35,679
system and i mean the payload yeah sure

421
00:19:39,190 --> 00:19:37,360
you have some sort of payload and you

422
00:19:40,950 --> 00:19:39,200
get to specify that but it just seems

423
00:19:42,789 --> 00:19:40,960
like you're talking about

424
00:19:44,230 --> 00:19:42,799
a cubesat that

425
00:19:45,590 --> 00:19:44,240
the ones i've seen are pretty simple

426
00:19:46,870 --> 00:19:45,600
they don't have attitude control or

427
00:19:49,750 --> 00:19:46,880
anything but it's got to get from the

428
00:19:51,430 --> 00:19:49,760
bus to the to the surface of the body

429
00:19:52,390 --> 00:19:51,440
it's got to have some ability to thrust

430
00:19:54,950 --> 00:19:52,400
it's going to have some ability to

431
00:19:56,630 --> 00:19:54,960
control its attitude it's got to have

432
00:19:58,710 --> 00:19:56,640
you know i mean it seems like that's a

433
00:20:00,950 --> 00:19:58,720
lot to put in something there's a lot

434
00:20:02,549 --> 00:20:00,960
going on with 3u cubesats there's quite

435
00:20:06,230 --> 00:20:02,559
a bit of functionality that's being

436
00:20:11,270 --> 00:20:08,549
okay um

437
00:20:12,710 --> 00:20:11,280
something to keep in mind as you uh

438
00:20:14,070 --> 00:20:12,720

if you're going to place multiple of

439
00:20:15,830 --> 00:20:14,080
these

440
00:20:17,909 --> 00:20:15,840
assets on the surface is the thermal

441
00:20:20,549 --> 00:20:17,919
problem you you're going to have

442
00:20:22,070 --> 00:20:20,559
thermal cycling problems as well as very

443
00:20:23,750 --> 00:20:22,080
cold periods that are probably going to

444
00:20:25,590 --> 00:20:23,760
require heat

445
00:20:27,110 --> 00:20:25,600
in some form which is going to require

446
00:20:29,430 --> 00:20:27,120
then some larger

447
00:20:32,710 --> 00:20:29,440
solar arrays depending on the asteroids

448
00:20:34,789 --> 00:20:32,720
distance and so forth also you mentioned

449
00:20:36,870 --> 00:20:34,799
that you're working on developing an

450
00:20:39,590 --> 00:20:36,880
anchoring system can you tell me say

451
00:20:41,590 --> 00:20:39,600
anything about that okay

452
00:20:42,789 --> 00:20:41,600
uh as to the first part of your uh

453
00:20:43,909 --> 00:20:42,799
question

454
00:20:47,909 --> 00:20:43,919
the

455
00:20:50,149 --> 00:20:47,919
scale is each one and working with

456
00:20:51,990 --> 00:20:50,159
multiples is each piece of equipment

457
00:20:53,590 --> 00:20:52,000
doesn't need to carry all of the

458
00:20:56,470 --> 00:20:53,600
functionality there's there's the

459
00:20:58,470 --> 00:20:56,480
benefit of multiple devices so if you

460
00:21:00,789 --> 00:20:58,480
need devices

461
00:21:02,070 --> 00:21:00,799
that if things need to shut down for a

462
00:21:03,750 --> 00:21:02,080
portion if they can only operate in

463
00:21:05,110 --> 00:21:03,760

certain ranges that's fine because

464
00:21:07,190 --> 00:21:05,120
something else is carrying the load

465
00:21:09,510 --> 00:21:07,200
doing the work at that period of time

466
00:21:11,110 --> 00:21:09,520
so by having the broader architecture

467
00:21:13,190 --> 00:21:11,120
you're able to mitigate some of the

468
00:21:15,190 --> 00:21:13,200
concerns but certainly thermal issues a

469
00:21:16,710 --> 00:21:15,200
lot of the other issues you mentioned

470
00:21:20,149 --> 00:21:16,720
have

471
00:21:22,710 --> 00:21:20,159
that's being done now

472
00:21:24,230 --> 00:21:22,720
and would require extension for deep

473
00:21:26,390 --> 00:21:24,240
space operation

474
00:21:29,190 --> 00:21:26,400
but i think they're they're not

475
00:21:30,789 --> 00:21:29,200
insurmountable problems

476
00:21:35,510 --> 00:21:30,799
okay thank you scott

477
00:21:41,350 --> 00:21:39,110
okay our next speaker is bob mueller

478
00:21:43,190 --> 00:21:41,360
he's a senior technologist for advanced

479
00:21:44,549 --> 00:21:43,200
projects development at nasty kennedy

480
00:21:45,909 --> 00:21:44,559
space center

481
00:21:47,669 --> 00:21:45,919
and he is in the engineering and

482
00:21:50,149 --> 00:21:47,679
technology directorate he's also the

483
00:21:55,029 --> 00:21:50,159
co-founder of the ksc granular mechanics

484
00:22:01,190 --> 00:21:59,029
so rob when you whenever you're ready

485
00:22:02,789 --> 00:22:01,200
okay can you hear me

486
00:22:04,549 --> 00:22:02,799
are we live

487
00:22:05,430 --> 00:22:04,559
we're on the internet

488
00:22:08,230 --> 00:22:05,440

okay

489
00:22:10,549 --> 00:22:08,240
let's check

490
00:22:12,390 --> 00:22:10,559
so good afternoon

491
00:22:16,390 --> 00:22:12,400
i'd like to acknowledge

492
00:22:19,909 --> 00:22:16,400
my co-investigators uh dr phil metzger

493
00:22:22,390 --> 00:22:19,919
dr laurent sabil and dr jim montevany

494
00:22:24,390 --> 00:22:22,400
and what we'd like to talk about today

495
00:22:25,110 --> 00:22:24,400
is the utilization of surface material

496
00:22:28,070 --> 00:22:25,120
for

497
00:22:29,669 --> 00:22:28,080
asteroid deflection and by that we mean

498
00:22:34,230 --> 00:22:29,679
regolith

499
00:22:36,390 --> 00:22:34,240
resources that you might find

500
00:22:37,669 --> 00:22:36,400
on a neo or

501
00:22:39,909 --> 00:22:37,679
an ia

502
00:22:40,870 --> 00:22:39,919
and of course we're just talking about

503
00:22:43,909 --> 00:22:40,880
the

504
00:22:45,909 --> 00:22:43,919
neos that are earth crossing so

505
00:22:48,710 --> 00:22:45,919
it's these two classes we're showing

506
00:22:50,630 --> 00:22:48,720
here surrounded by the dotted line

507
00:22:52,950 --> 00:22:50,640
and the premise is

508
00:22:53,830 --> 00:22:52,960
that if you

509
00:22:56,230 --> 00:22:53,840
can

510
00:22:57,669 --> 00:22:56,240
give a delta velocity

511
00:22:59,669 --> 00:22:57,679
to the object

512
00:23:00,630 --> 00:22:59,679
and you can

513
00:23:04,870 --> 00:23:00,640

very

514
00:23:05,669 --> 00:23:04,880
orbit but that small change in orbit is

515
00:23:07,669 --> 00:23:05,679
enough

516
00:23:08,630 --> 00:23:07,679
to miss the earth

517
00:23:09,909 --> 00:23:08,640
so

518
00:23:11,190 --> 00:23:09,919
what we're talking about here

519
00:23:14,230 --> 00:23:11,200
essentially

520
00:23:15,750 --> 00:23:14,240
is providing delta v

521
00:23:17,510 --> 00:23:15,760
and that is provided by an exchange of

522
00:23:20,070 --> 00:23:17,520
momentum with the asteroid via ejection

523
00:23:22,870 --> 00:23:20,080
of surface material of course that has

524
00:23:25,029 --> 00:23:22,880
to happen at appropriate times in

525
00:23:27,270 --> 00:23:25,039
the rotation period

526
00:23:29,270 --> 00:23:27,280
and this just follows the basic

527
00:23:31,029 --> 00:23:29,280
principle of a rocket it's a device that

528
00:23:33,350 --> 00:23:31,039
can apply acceleration to itself a

529
00:23:35,430 --> 00:23:33,360
thrust by expelling part of its mass

530
00:23:37,590 --> 00:23:35,440
with high speed and move due to the

531
00:23:39,590 --> 00:23:37,600
conservation of momentum and then what

532
00:23:41,029 --> 00:23:39,600
we're showing here is is tchilkovsky's

533
00:23:43,830 --> 00:23:41,039
rocket equation

534
00:23:45,669 --> 00:23:43,840
and that's what we used to

535
00:23:47,510 --> 00:23:45,679
do some just very preliminary

536
00:23:49,590 --> 00:23:47,520
calculations to show

537
00:23:51,190 --> 00:23:49,600
uh just we were wondering if this was

538
00:23:53,830 --> 00:23:51,200

feasible or not

539
00:23:56,070 --> 00:23:53,840
and there are two options basically that

540
00:23:58,149 --> 00:23:56,080
we've identified option one

541
00:24:00,070 --> 00:23:58,159
is you eject regolith

542
00:24:04,070 --> 00:24:00,080
so that the mass that you're using is a

543
00:24:06,710 --> 00:24:04,080
regolith or you could eject boulders

544
00:24:07,990 --> 00:24:06,720
and and that would form the exchange of

545
00:24:10,230 --> 00:24:08,000
momentum

546
00:24:12,789 --> 00:24:10,240
there has been previous work on this old

547
00:24:14,870 --> 00:24:12,799
and olds and chernaya

548
00:24:18,070 --> 00:24:14,880
had a niacc phase one

549
00:24:20,630 --> 00:24:18,080
contract from nasa in 2004 where they

550
00:24:23,830 --> 00:24:20,640
looked at a similar kind of idea

551
00:24:25,669 --> 00:24:23,840
also uh dr sebil and dr montevani who

552
00:24:28,310 --> 00:24:25,679
are in our lab

553
00:24:29,990 --> 00:24:28,320
they also received an iac phase one

554
00:24:32,149 --> 00:24:30,000
contract in 2012

555
00:24:34,230 --> 00:24:32,159
and they're about to propose for a phase

556
00:24:35,669 --> 00:24:34,240
two contract and we'd like to roll some

557
00:24:38,630 --> 00:24:35,679
of this thinking into that phase two

558
00:24:39,990 --> 00:24:38,640
proposal and uh take this work a little

559
00:24:40,870 --> 00:24:40,000
bit further

560
00:24:42,950 --> 00:24:40,880
uh

561
00:24:45,110 --> 00:24:42,960
and so the the picture you see on the

562
00:24:46,630 --> 00:24:45,120
right there is is these ejection of

563
00:24:50,070 --> 00:24:46,640

these volatiles

564
00:24:51,669 --> 00:24:50,080
if there are volatiles on these

565
00:24:53,590 --> 00:24:51,679
neos then

566
00:24:55,669 --> 00:24:53,600
if you heat up

567
00:24:57,990 --> 00:24:55,679
the volatiles you can have sublimation

568
00:25:00,390 --> 00:24:58,000
of gases and

569
00:25:03,110 --> 00:25:00,400
focus that through a nozzle and then get

570
00:25:05,669 --> 00:25:03,120
a thrust and then on the other one the

571
00:25:06,710 --> 00:25:05,679
ejection of regolith or boulders that

572
00:25:09,750 --> 00:25:06,720
could be

573
00:25:10,870 --> 00:25:09,760
uh via a mass driver or catapult some

574
00:25:13,590 --> 00:25:10,880
kind of

575
00:25:15,909 --> 00:25:13,600
device to eject the regulars so if you

576
00:25:19,029 --> 00:25:15,919
use that rocket equation

577
00:25:19,990 --> 00:25:19,039
and you you do a this is just a a case

578
00:25:20,870 --> 00:25:20,000
study

579
00:25:22,070 --> 00:25:20,880
uh

580
00:25:24,789 --> 00:25:22,080
it's not

581
00:25:27,110 --> 00:25:24,799
defined exactly what we need we just

582
00:25:29,590 --> 00:25:27,120
did it to get a ballpark figure

583
00:25:31,669 --> 00:25:29,600
we picked a 400 meter diameter object

584
00:25:33,350 --> 00:25:31,679
with various mission durations we said

585
00:25:36,470 --> 00:25:33,360
it had to achieve

586
00:25:38,070 --> 00:25:36,480
delta v of one meter per second which

587
00:25:41,590 --> 00:25:38,080
may be large

588
00:25:43,669 --> 00:25:41,600

we also said that gas solid material

589
00:25:46,149 --> 00:25:43,679
is ejected at a velocity of 32 meters

590
00:25:48,630 --> 00:25:46,159
per second we assumed that the asteroid

591
00:25:50,310 --> 00:25:48,640
has a density of 2 000 kilograms per

592
00:25:52,230 --> 00:25:50,320
meter cube so if you just run the rocket

593
00:25:54,630 --> 00:25:52,240
equation you get this curve here

594
00:25:58,310 --> 00:25:54,640
and it shows you that the

595
00:26:00,470 --> 00:25:58,320
ejected mass rate on the

596
00:26:03,029 --> 00:26:00,480
vertical scale here

597
00:26:05,029 --> 00:26:03,039
it's it's rather high

598
00:26:07,269 --> 00:26:05,039
this this these numbers are the

599
00:26:11,990 --> 00:26:07,279
kilograms per second

600
00:26:14,230 --> 00:26:12,000
so then this becomes sort of asymptotic

601
00:26:15,510 --> 00:26:14,240
asymptotic and so you get to

602
00:26:18,470 --> 00:26:15,520
66

603
00:26:20,470 --> 00:26:18,480
kilograms per second

604
00:26:22,789 --> 00:26:20,480
and that was the kind of metric we were

605
00:26:24,470 --> 00:26:22,799
looking for because in our lab we

606
00:26:26,470 --> 00:26:24,480
specialize in in-situ resource

607
00:26:28,630 --> 00:26:26,480
utilization and specifically in robotic

608
00:26:31,590 --> 00:26:28,640
excavation and so

609
00:26:34,230 --> 00:26:31,600
we we're trying to see is it feasible to

610
00:26:36,950 --> 00:26:34,240
put to send a robotic excavator to an

611
00:26:40,390 --> 00:26:36,960
asteroid with some kind of energy source

612
00:26:42,070 --> 00:26:40,400
and a mass driver and then use the

613
00:26:43,269 --> 00:26:42,080

in-situ material

614
00:26:46,070 --> 00:26:43,279
as a

615
00:26:49,669 --> 00:26:46,080
propel to form an exchange of momentum

616
00:26:51,909 --> 00:26:49,679
and so it turns out that that is

617
00:26:53,830 --> 00:26:51,919
possible

618
00:26:56,630 --> 00:26:53,840
if you look at these numbers

619
00:26:59,909 --> 00:26:56,640
the attractive thing about this concept

620
00:27:02,310 --> 00:26:59,919
versus the other concepts is that the

621
00:27:03,590 --> 00:27:02,320
mass you have to transport from earth to

622
00:27:04,470 --> 00:27:03,600
the asteroid

623
00:27:07,350 --> 00:27:04,480
is

624
00:27:09,750 --> 00:27:07,360
small because the exchange of momentum

625
00:27:12,310 --> 00:27:09,760
is provided with the mass that you find

626
00:27:15,590 --> 00:27:12,320
in situ so that is the attraction of

627
00:27:16,310 --> 00:27:15,600
this concept however the trade-off is

628
00:27:18,549 --> 00:27:16,320
that

629
00:27:21,269 --> 00:27:18,559
even though it's it looks attractive

630
00:27:23,029 --> 00:27:21,279
from a mass transportation and delta v

631
00:27:25,669 --> 00:27:23,039
from earth point of view

632
00:27:28,230 --> 00:27:25,679
there is a level of technology assumed

633
00:27:30,470 --> 00:27:28,240
that we don't have today and would need

634
00:27:32,789 --> 00:27:30,480
to be developed and also there's a level

635
00:27:34,870 --> 00:27:32,799
of reliability if you're really doing

636
00:27:37,590 --> 00:27:34,880
this for planetary defense

637
00:27:40,070 --> 00:27:37,600
would you rely on these robots to

638
00:27:42,070 --> 00:27:40,080

perform this kind of orbital

639
00:27:44,950 --> 00:27:42,080
trajectory change

640
00:27:46,389 --> 00:27:44,960
so uh we think it is possible but it

641
00:27:48,710 --> 00:27:46,399
would require some technology

642
00:27:50,630 --> 00:27:48,720
development so you need a mass driver a

643
00:27:52,230 --> 00:27:50,640
catapult or some kind of other throwing

644
00:27:54,950 --> 00:27:52,240
or pushing device that people have

645
00:27:57,029 --> 00:27:54,960
proposed electrostatic devices

646
00:27:58,950 --> 00:27:57,039
electromagnetic devices all kinds of

647
00:28:00,549 --> 00:27:58,960
things but the key is it has to be low

648
00:28:02,870 --> 00:28:00,559
mass and reliable

649
00:28:05,590 --> 00:28:02,880
mining technology we are developing

650
00:28:07,590 --> 00:28:05,600
robotic excavators today across the

651
00:28:09,909 --> 00:28:07,600
agency and private industry i have a

652
00:28:11,350 --> 00:28:09,919
competition called the robotic mining

653
00:28:12,950 --> 00:28:11,360
competition nasa robotic mining

654
00:28:14,310 --> 00:28:12,960
competition we have 50 universities come

655
00:28:16,470 --> 00:28:14,320
to kennedy space center every year with

656
00:28:17,909 --> 00:28:16,480
a robotic mining machine a dig in a

657
00:28:20,149 --> 00:28:17,919
simulated lunar

658
00:28:22,470 --> 00:28:20,159
regolith of black point one crushed

659
00:28:24,389 --> 00:28:22,480
basalt so we have 50 university teams

660
00:28:25,909 --> 00:28:24,399
every year working on this problem

661
00:28:27,430 --> 00:28:25,919
i think it could be done

662
00:28:29,430 --> 00:28:27,440
now the next thing you need is solar

663
00:28:32,230 --> 00:28:29,440

cells or nuclear plant to provide energy

664
00:28:33,350 --> 00:28:32,240
to the above items and that is a caveat

665
00:28:34,310 --> 00:28:33,360
on this whole thing you do need the

666
00:28:36,230 --> 00:28:34,320
energy

667
00:28:38,630 --> 00:28:36,240
but one other attractive thing about

668
00:28:40,070 --> 00:28:38,640
this is several of the presenters at

669
00:28:43,350 --> 00:28:40,080
this workshop have

670
00:28:45,510 --> 00:28:43,360
said that there's a very large degree of

671
00:28:48,070 --> 00:28:45,520
of uh uncertainty

672
00:28:49,830 --> 00:28:48,080
on what the size of the asteroid is

673
00:28:51,510 --> 00:28:49,840
before you ever get there just because

674
00:28:53,190 --> 00:28:51,520
of the remote sensing technologies we

675
00:28:56,389 --> 00:28:53,200
have so you might get there and you

676
00:28:57,510 --> 00:28:56,399
might it might be much much bigger than

677
00:29:00,310 --> 00:28:57,520
you thought

678
00:29:02,310 --> 00:29:00,320
and so your system has to be flexible

679
00:29:04,870 --> 00:29:02,320
to accommodate that

680
00:29:06,950 --> 00:29:04,880
so with this kind of a system which uses

681
00:29:09,029 --> 00:29:06,960
the in-situ materials

682
00:29:11,269 --> 00:29:09,039
you can do that you can

683
00:29:12,470 --> 00:29:11,279
be flexible in your concept of

684
00:29:15,110 --> 00:29:12,480
operations

685
00:29:17,269 --> 00:29:15,120
and so that's when i talk about control

686
00:29:19,990 --> 00:29:17,279
knobs that's what i mean

687
00:29:21,190 --> 00:29:20,000
is if you have a situation where you

688
00:29:23,990 --> 00:29:21,200

arrive and you don't have what you

689
00:29:26,470 --> 00:29:24,000
expected then you can turn your control

690
00:29:29,430 --> 00:29:26,480
knobs and maybe still solve the problem

691
00:29:31,110 --> 00:29:29,440
and in our studies of this of this

692
00:29:32,389 --> 00:29:31,120
technology we're going to need to look

693
00:29:34,630 --> 00:29:32,399
at all these control knobs and see if

694
00:29:35,750 --> 00:29:34,640
this is possible but so the control

695
00:29:37,830 --> 00:29:35,760
knobs i've listed here and they're

696
00:29:39,669 --> 00:29:37,840
probably some more is you can increase

697
00:29:41,990 --> 00:29:39,679
the ejection velocity then you need less

698
00:29:43,590 --> 00:29:42,000
regolith you can increase the duration

699
00:29:45,830 --> 00:29:43,600
of total ejection then you have less

700
00:29:48,310 --> 00:29:45,840
regulate ejected per day decrease the

701
00:29:50,389 --> 00:29:48,320
period of rotation because you can only

702
00:29:52,549 --> 00:29:50,399
fling it off at a certain point in

703
00:29:55,190 --> 00:29:52,559
rotation to be effective

704
00:29:56,870 --> 00:29:55,200
in either increasing or decreasing the

705
00:29:58,310 --> 00:29:56,880
velocity of your object

706
00:30:00,549 --> 00:29:58,320
and uh

707
00:30:02,230 --> 00:30:00,559
you you might if you require less delta

708
00:30:03,830 --> 00:30:02,240
v we assumed one meter per second delta

709
00:30:05,830 --> 00:30:03,840
v if it takes less than that that's less

710
00:30:07,669 --> 00:30:05,840
regular also the volatiles could be used

711
00:30:09,430 --> 00:30:07,679
if we find volatiles

712
00:30:11,830 --> 00:30:09,440
so some of the negatives are that

713
00:30:14,230 --> 00:30:11,840

excavation is high but not impossible

714
00:30:15,750 --> 00:30:14,240
for robotic excavators

715
00:30:17,750 --> 00:30:15,760
we have to look at this delta v we don't

716
00:30:19,510 --> 00:30:17,760
really understand what what the delta v

717
00:30:21,029 --> 00:30:19,520
is maybe some of you can help us with

718
00:30:22,710 --> 00:30:21,039
that because

719
00:30:24,389 --> 00:30:22,720
there are other people studying that one

720
00:30:25,510 --> 00:30:24,399
interesting idea was

721
00:30:27,110 --> 00:30:25,520
thermal

722
00:30:28,630 --> 00:30:27,120
fracking you know fracking is such a big

723
00:30:31,350 --> 00:30:28,640
subject these days

724
00:30:33,430 --> 00:30:31,360
what if we did thermal fracking

725
00:30:34,789 --> 00:30:33,440
on an asteroid and we broke up large

726
00:30:37,430 --> 00:30:34,799
chunks of it

727
00:30:39,510 --> 00:30:37,440
so uh that because we're talking about

728
00:30:41,750 --> 00:30:39,520
digging small little scoops what if we

729
00:30:44,070 --> 00:30:41,760
broke up large pieces of the asteroid

730
00:30:45,909 --> 00:30:44,080
what if we scored the asteroid

731
00:30:47,590 --> 00:30:45,919
and then broke off a chunk

732
00:30:48,549 --> 00:30:47,600
so there's there's that kind of thinking

733
00:30:50,389 --> 00:30:48,559
too

734
00:30:51,669 --> 00:30:50,399
and we're studying methods for mining

735
00:30:53,510 --> 00:30:51,679
the regolith

736
00:30:55,029 --> 00:30:53,520
so this chart has showed up in many

737
00:30:58,389 --> 00:30:55,039
instantiations

738
00:31:00,549 --> 00:30:58,399

over the last day or two and uh what's

739
00:31:02,870 --> 00:31:00,559
interesting about this is is the spin

740
00:31:05,990 --> 00:31:02,880
rate and how there are no asteroids

741
00:31:07,909 --> 00:31:06,000
above the 2.2

742
00:31:10,310 --> 00:31:07,919
period and so

743
00:31:11,350 --> 00:31:10,320
uh dr laurent sebil came up with this

744
00:31:12,630 --> 00:31:11,360
idea of

745
00:31:14,470 --> 00:31:12,640
uh everybody's been talking about

746
00:31:16,389 --> 00:31:14,480
d-spinning an asteroid what we'd like to

747
00:31:17,430 --> 00:31:16,399
do is spin it up

748
00:31:18,870 --> 00:31:17,440
and so

749
00:31:21,669 --> 00:31:18,880
what we'll do is we'll take the same

750
00:31:24,149 --> 00:31:21,679
technology of regulate ejection or

751
00:31:27,509 --> 00:31:24,159
volatiles sublimation

752
00:31:29,909 --> 00:31:27,519
and you place it in the right spot on

753
00:31:32,549 --> 00:31:29,919
the asteroid and you spin that asteroid

754
00:31:36,149 --> 00:31:32,559
up until it hits that

755
00:31:37,269 --> 00:31:36,159
velocity where in the diagram below it

756
00:31:38,789 --> 00:31:37,279
it actually

757
00:31:40,149 --> 00:31:38,799
disintegrates

758
00:31:42,950 --> 00:31:40,159
and fractures

759
00:31:44,630 --> 00:31:42,960
and so this is a kind of a

760
00:31:45,350 --> 00:31:44,640
inverse thinking

761
00:31:48,310 --> 00:31:45,360
and

762
00:31:50,470 --> 00:31:48,320
but i think it it's worth some study now

763
00:31:53,190 --> 00:31:50,480

there are some negatives in that you

764
00:31:55,909 --> 00:31:53,200
have a debris field now uh which you

765
00:31:58,389 --> 00:31:55,919
can't necessarily predict what size each

766
00:32:00,070 --> 00:31:58,399
chunk will be when it breaks up but in

767
00:32:01,350 --> 00:32:00,080
theory that you could have a good

768
00:32:02,870 --> 00:32:01,360
solution there

769
00:32:05,190 --> 00:32:02,880
and so uh

770
00:32:07,590 --> 00:32:05,200
lauren has run some numbers here

771
00:32:09,110 --> 00:32:07,600
and uh they're shown on the chart but

772
00:32:09,990 --> 00:32:09,120
the basic idea is if you go to this

773
00:32:11,830 --> 00:32:10,000
chart

774
00:32:14,630 --> 00:32:11,840
and if you spin it up then you get into

775
00:32:16,630 --> 00:32:14,640
this place where there are no

776
00:32:18,630 --> 00:32:16,640
asteroids large asteroids because

777
00:32:20,389 --> 00:32:18,640
they've all disintegrated if you're down

778
00:32:21,830 --> 00:32:20,399
in this region then then you can't do it

779
00:32:23,190 --> 00:32:21,840
and you have to use

780
00:32:27,190 --> 00:32:23,200
the other method that i talked about

781
00:32:29,509 --> 00:32:27,200
which is momentum exchange with radar

782
00:32:30,630 --> 00:32:29,519
so in conclusion

783
00:32:32,870 --> 00:32:30,640
our very

784
00:32:34,870 --> 00:32:32,880
quick preliminary look at this

785
00:32:36,710 --> 00:32:34,880
indicates that asteroid deflection is

786
00:32:39,190 --> 00:32:36,720
possible by ejecting in-situ surface

787
00:32:43,669 --> 00:32:39,200
material through propulsion devices and

788
00:32:46,230 --> 00:32:43,679

isru options allow operations changes to

789
00:32:48,310 --> 00:32:46,240
mitigate if the asteroid breaks or into

790
00:32:50,149 --> 00:32:48,320
pieces or if it's larger than expected

791
00:32:52,389 --> 00:32:50,159
there it gives you an operational

792
00:32:54,549 --> 00:32:52,399
flexibility because you have these this

793
00:32:55,830 --> 00:32:54,559
equipment there this robotic equipment

794
00:32:57,750 --> 00:32:55,840
you can change your game plan in the

795
00:32:58,710 --> 00:32:57,760
middle of the game

796
00:33:00,789 --> 00:32:58,720
uh

797
00:33:02,389 --> 00:33:00,799
regular boulder mining mass driver power

798
00:33:04,389 --> 00:33:02,399
equipment must be transported to the

799
00:33:06,549 --> 00:33:04,399
asteroid and operated reliably so that

800
00:33:08,630 --> 00:33:06,559
there's a caveat there that if this

801
00:33:11,110 --> 00:33:08,640
equipment is not reliable then

802
00:33:12,870 --> 00:33:11,120
it's not a good architecture and

803
00:33:14,630 --> 00:33:12,880
increasing the spin rates may cause low

804
00:33:16,789 --> 00:33:14,640
rotators to break apart by rotational

805
00:33:18,230 --> 00:33:16,799
fissure and there are some papers out of

806
00:33:19,669 --> 00:33:18,240
the university of colorado i believe one

807
00:33:20,789 --> 00:33:19,679
of the authors might even be in the room

808
00:33:23,430 --> 00:33:20,799
here

809
00:33:25,110 --> 00:33:23,440
that talk about rotational fissure and

810
00:33:29,029 --> 00:33:25,120
have studied this at the university of

811
00:33:30,630 --> 00:33:29,039
colorado so it's a valid concept

812
00:33:32,149 --> 00:33:30,640
and that's all i have thanks for your

813
00:33:34,230 --> 00:33:32,159

attention

814
00:33:37,590 --> 00:33:34,240
thank you do we have any questions in

815
00:33:42,950 --> 00:33:38,789
any

816
00:33:47,029 --> 00:33:44,710
just just real quick rob just maybe a

817
00:33:49,190 --> 00:33:47,039
comment i mean is

818
00:33:51,110 --> 00:33:49,200
spinning up an asteroid to

819
00:33:53,509 --> 00:33:51,120
fission it um

820
00:33:55,430 --> 00:33:53,519
the question is does it just reaccrete

821
00:33:56,710 --> 00:33:55,440
when you're done so you know there's i

822
00:33:59,029 --> 00:33:56,720
think there's a lot more detail if you

823
00:34:00,310 --> 00:33:59,039
want to think of that as a

824
00:34:02,310 --> 00:34:00,320
uh

825
00:34:04,789 --> 00:34:02,320
an approach um because you got to

826
00:34:07,110 --> 00:34:04,799
maintain that spinning beyond

827
00:34:09,349 --> 00:34:07,120
beyond that fission point so just just a

828
00:34:12,149 --> 00:34:09,359
comment

829
00:34:14,869 --> 00:34:12,159
yeah it's it's just this idea of going

830
00:34:16,470 --> 00:34:14,879
the opposite way sure and maybe doing

831
00:34:18,149 --> 00:34:16,480
something with that we haven't put a

832
00:34:20,230 --> 00:34:18,159
whole lot of thought into it

833
00:34:29,589 --> 00:34:20,240
but uh we're at the brainstorming level

834
00:34:34,389 --> 00:34:32,149
all right our next speaker is um is rob

835
00:34:36,230 --> 00:34:34,399
adams uh dr adams has 18 years of

836
00:34:37,990 --> 00:34:36,240
experience in space program conducting

837
00:34:40,149 --> 00:34:38,000
studies in advanced propulsion planetary

838
00:34:42,069 --> 00:34:40,159

defense against asteroids

839
00:34:43,510 --> 00:34:42,079
and mission design and he's from

840
00:34:48,790 --> 00:34:43,520
marshall space flight center where he's

841
00:34:51,990 --> 00:34:50,790
so welcome rob and as soon as you're

842
00:34:54,950 --> 00:34:52,000
mic'd up

843
00:34:56,389 --> 00:34:54,960
true parking start thanks

844
00:34:58,390 --> 00:34:56,399
thanks dan

845
00:35:01,589 --> 00:34:58,400
okay so today i'm going to talk about

846
00:35:03,109 --> 00:35:01,599
the solar collector option um so just in

847
00:35:05,030 --> 00:35:03,119
case you guys aren't familiar with the

848
00:35:07,270 --> 00:35:05,040
idea uh here's a diagram of it right

849
00:35:09,190 --> 00:35:07,280
here an old sketch that i uh did about a

850
00:35:11,190 --> 00:35:09,200
decade ago actually uh the solar

851
00:35:13,670 --> 00:35:11,200
collector is actually an offshoot of the

852
00:35:14,630 --> 00:35:13,680
solar sail the solar sail suffers in

853
00:35:16,710 --> 00:35:14,640
that

854
00:35:18,870 --> 00:35:16,720
the the sail has to face the sun to be

855
00:35:21,510 --> 00:35:18,880
illuminated but if it does then the

856
00:35:23,349 --> 00:35:21,520
thrust vector uh from the momentum

857
00:35:25,030 --> 00:35:23,359
exchange of the photon bouncing off the

858
00:35:27,190 --> 00:35:25,040
solar cell makes the cell want to go

859
00:35:28,870 --> 00:35:27,200
radially out which is actually not very

860
00:35:30,150 --> 00:35:28,880
helpful when you're trying to change

861
00:35:32,470 --> 00:35:30,160
your trajectory you tend to want to

862
00:35:35,430 --> 00:35:32,480
accelerate along your flight vector so

863
00:35:36,230 --> 00:35:35,440

you tend to fly your solar sail angled

864
00:35:38,470 --> 00:35:36,240
uh

865
00:35:40,390 --> 00:35:38,480
relative to the sun so

866
00:35:41,990 --> 00:35:40,400
somebody a while ago proposed well hey

867
00:35:45,750 --> 00:35:42,000
why don't we do a solar collector where

868
00:35:48,150 --> 00:35:45,760
we shape the the sail into a parabolic

869
00:35:50,950 --> 00:35:48,160
dish and have a secondary collector and

870
00:35:54,630 --> 00:35:50,960
so now we still get that radial force

871
00:35:56,790 --> 00:35:54,640
from the sun but we also get uh this uh

872
00:35:59,349 --> 00:35:56,800
tangential component and so we can get a

873
00:36:00,630 --> 00:35:59,359
better uh direction of force and be able

874
00:36:01,829 --> 00:36:00,640
to use solar collector to go where we

875
00:36:04,230 --> 00:36:01,839
want to go

876
00:36:06,230 --> 00:36:04,240
uh the problem with that is is that uh

877
00:36:08,550 --> 00:36:06,240
in doing this we reduce the total

878
00:36:09,990 --> 00:36:08,560
effective area being uh illuminated by

879
00:36:12,310 --> 00:36:10,000
the sun because we're not you know a

880
00:36:14,870 --> 00:36:12,320
flat shape anymore now we're a parabola

881
00:36:17,190 --> 00:36:14,880
and so this concept kind of fell out of

882
00:36:18,950 --> 00:36:17,200
vogue in terms of just a straight

883
00:36:21,030 --> 00:36:18,960
propulsion device

884
00:36:23,750 --> 00:36:21,040
however it kind of came back

885
00:36:26,390 --> 00:36:23,760
back in 94 if you will

886
00:36:29,190 --> 00:36:26,400
by milos presenting it as a way to

887
00:36:31,990 --> 00:36:29,200
maneuver asteroids and so there are a

888
00:36:34,390 --> 00:36:32,000

lot of operational uh uh capabilities

889
00:36:36,550 --> 00:36:34,400
here that uh that i think are unique i

890
00:36:38,150 --> 00:36:36,560
mean we don't have to touch the asteroid

891
00:36:41,670 --> 00:36:38,160
we're able to handle an asteroid

892
00:36:44,150 --> 00:36:41,680
tumbling on multiple uh

893
00:36:46,069 --> 00:36:44,160
vectors if you will uh

894
00:36:49,030 --> 00:36:46,079
we can uh

895
00:36:51,670 --> 00:36:49,040
use the system to actually uh maneuver

896
00:36:53,910 --> 00:36:51,680
ourselves to the asteroid and station

897
00:36:55,670 --> 00:36:53,920
keep while we're there as well uh here

898
00:36:57,910 --> 00:36:55,680
milos has a

899
00:36:59,430 --> 00:36:57,920
mellow has a station keeping propulsion

900
00:37:01,349 --> 00:36:59,440
system but but really that's not

901
00:37:03,990 --> 00:37:01,359
necessary you can just use the solar

902
00:37:05,750 --> 00:37:04,000
cell itself and have

903
00:37:07,270 --> 00:37:05,760
times where you're illuminating the

904
00:37:09,190 --> 00:37:07,280
asteroids in times where you're

905
00:37:11,910 --> 00:37:09,200
maneuvering back into position to

906
00:37:12,950 --> 00:37:11,920
eliminate the asteroid again so lots of

907
00:37:15,670 --> 00:37:12,960
uh

908
00:37:16,710 --> 00:37:15,680
positive operational concepts of course

909
00:37:18,630 --> 00:37:16,720
uh

910
00:37:20,870 --> 00:37:18,640
from the earlier talk about

911
00:37:23,430 --> 00:37:20,880
messing up the crust we're going to

912
00:37:25,829 --> 00:37:23,440
crust up a great deal after this

913
00:37:28,710 --> 00:37:25,839

so uh um you know you can't have

914
00:37:30,230 --> 00:37:28,720
everything uh but um

915
00:37:31,829 --> 00:37:30,240
you know so the question is is well how

916
00:37:34,230 --> 00:37:31,839
effective is it in actually pushing

917
00:37:36,950 --> 00:37:34,240
asteroid around and so this uh rask

918
00:37:39,109 --> 00:37:36,960
study so this was a rask was run out of

919
00:37:41,510 --> 00:37:39,119
langley back in the uh

920
00:37:43,510 --> 00:37:41,520
early last decade and dan and i had

921
00:37:44,390 --> 00:37:43,520
sister projects and this is the one that

922
00:37:47,670 --> 00:37:44,400
i was

923
00:37:49,990 --> 00:37:47,680
leading here and so this one here

924
00:37:52,069 --> 00:37:50,000
we were looking at you know a large

925
00:37:54,470 --> 00:37:52,079
variety of asteroids at this point we

926
00:37:57,109 --> 00:37:54,480
had not retired the one kilometer risk

927
00:37:59,589 --> 00:37:57,119
it was back in 2002 so we were actually

928
00:38:01,109 --> 00:37:59,599
considering very large as well as very

929
00:38:03,589 --> 00:38:01,119
small asteroids

930
00:38:05,349 --> 00:38:03,599
now for the the mission of you know

931
00:38:07,589 --> 00:38:05,359
defending the earth and all that we

932
00:38:10,310 --> 00:38:07,599
generally need to produce about you know

933
00:38:12,310 --> 00:38:10,320
somewhere in this category right here uh

934
00:38:16,069 --> 00:38:12,320
0.1 to 0.01

935
00:38:17,670 --> 00:38:16,079
of meters per second to uh to push an

936
00:38:20,069 --> 00:38:17,680
asteroid out of the way assuming we have

937
00:38:23,030 --> 00:38:20,079
about at least two years of lead time

938
00:38:24,790 --> 00:38:23,040

so with that you can see that the um the

939
00:38:28,870 --> 00:38:24,800
solar collector or this solar collector

940
00:38:30,310 --> 00:38:28,880
that was a 100 meters in diameter was uh

941
00:38:33,589 --> 00:38:30,320
you know

942
00:38:35,430 --> 00:38:33,599
barely effective at one kilometer i mean

943
00:38:37,430 --> 00:38:35,440
you would have to illuminate you know if

944
00:38:39,430 --> 00:38:37,440
you needed the lower end of the delta v

945
00:38:41,109 --> 00:38:39,440
you would need about a 100 days of

946
00:38:43,349 --> 00:38:41,119
illumination which you know it doesn't

947
00:38:45,030 --> 00:38:43,359
sound too tough here but boy when you

948
00:38:47,589 --> 00:38:45,040
get out here and you need that uh you

949
00:38:49,990 --> 00:38:47,599
know 10 centimeters of uh or uh i'm

950
00:38:51,990 --> 00:38:50,000
sorry a hundred centimeters of

951
00:38:54,310 --> 00:38:52,000
of delta v and you've got to operate for

952
00:38:56,069 --> 00:38:54,320
three years continuously that's that's

953
00:38:57,829 --> 00:38:56,079
starting to get hard to swallow

954
00:38:59,990 --> 00:38:57,839
um the other mission that's important

955
00:39:01,910 --> 00:39:00,000
that we should talk about here is right

956
00:39:03,750 --> 00:39:01,920
in this range right here where we're

957
00:39:06,069 --> 00:39:03,760
trying to produce you know that 500

958
00:39:07,510 --> 00:39:06,079
meters to a thousand uh meters per

959
00:39:09,910 --> 00:39:07,520
second where we're going to do the

960
00:39:12,390 --> 00:39:09,920
asteroid redirect mission taking that 10

961
00:39:14,550 --> 00:39:12,400
meter uh asteroid and pushing it around

962
00:39:16,950 --> 00:39:14,560
solar system and sticking it in its own

963
00:39:18,870 --> 00:39:16,960

slot here uh in the earth immune system

964
00:39:20,550 --> 00:39:18,880
and so you know again here you can see

965
00:39:22,310 --> 00:39:20,560
that our uh

966
00:39:25,109 --> 00:39:22,320
our uh uh

967
00:39:27,750 --> 00:39:25,119
you know our concept can handle you know

968
00:39:30,069 --> 00:39:27,760
that 10 meter uh asteroid very well with

969
00:39:32,790 --> 00:39:30,079
a couple orders of magnitude to spare

970
00:39:34,710 --> 00:39:32,800
now the model here was a very early

971
00:39:37,190 --> 00:39:34,720
model and we were assuming we were

972
00:39:40,150 --> 00:39:37,200
designing the system so that it operated

973
00:39:41,190 --> 00:39:40,160
uh mainly around uh the 500 nanometers

974
00:39:43,349 --> 00:39:41,200
that

975
00:39:45,670 --> 00:39:43,359
is the the center line of the the solar

976
00:39:47,750 --> 00:39:45,680
spectra and we were assuming pretty much

977
00:39:49,349 --> 00:39:47,760
everything made it to the uh the

978
00:39:51,109 --> 00:39:49,359
asteroid that's that's a pretty

979
00:39:53,270 --> 00:39:51,119
aggressive assumption so

980
00:39:56,150 --> 00:39:53,280
uh but my point here is is that we could

981
00:39:58,790 --> 00:39:56,160
accept one to two orders of magnitude of

982
00:40:01,430 --> 00:39:58,800
of uh operational inefficiencies so we

983
00:40:03,030 --> 00:40:01,440
could go down to ten percent efficiency

984
00:40:04,950 --> 00:40:03,040
instead of a hundred percent and still

985
00:40:07,910 --> 00:40:04,960
be able to do that um

986
00:40:11,109 --> 00:40:07,920
that uh redrug mission and we could

987
00:40:13,270 --> 00:40:11,119
still handle asteroids in the uh you

988
00:40:14,710 --> 00:40:13,280

know not up to a

989
00:40:17,670 --> 00:40:14,720
kilometer but you know definitely

990
00:40:19,990 --> 00:40:17,680
hundreds of meters uh to do a planetary

991
00:40:22,790 --> 00:40:20,000
defense

992
00:40:24,870 --> 00:40:22,800
okay so a few years later we took on

993
00:40:26,230 --> 00:40:24,880
another project and here we were looking

994
00:40:29,109 --> 00:40:26,240
at using the

995
00:40:31,190 --> 00:40:29,119
uh solar collector as one of several

996
00:40:34,069 --> 00:40:31,200
options uh that would be launched on the

997
00:40:35,829 --> 00:40:34,079
aries 5 vehicle so that's a predecessor

998
00:40:37,670 --> 00:40:35,839
to the sls here

999
00:40:39,750 --> 00:40:37,680
and so we came up with this uh mission

1000
00:40:41,670 --> 00:40:39,760
concept where we had this locked

1001
00:40:44,710 --> 00:40:41,680
hydrogen kickstage that would kick us

1002
00:40:46,309 --> 00:40:44,720
into uh uh you know out of earth's orbit

1003
00:40:48,069 --> 00:40:46,319
and it turned out this thing ended up

1004
00:40:49,349 --> 00:40:48,079
being almost identical to a centaur

1005
00:40:50,870 --> 00:40:49,359
upper stage

1006
00:40:52,630 --> 00:40:50,880
in terms of mass and

1007
00:40:54,550 --> 00:40:52,640
performance requirements we had this

1008
00:40:57,190 --> 00:40:54,560
cradle system here and then we could put

1009
00:41:00,230 --> 00:40:57,200
six bullets is what we called it and uh

1010
00:41:02,390 --> 00:41:00,240
we had a kinetic interceptor a nuclear

1011
00:41:05,030 --> 00:41:02,400
interceptor and the solar collector

1012
00:41:07,109 --> 00:41:05,040
option all hanging off of this cradle

1013
00:41:08,630 --> 00:41:07,119

and so each one of these uh bullets if

1014
00:41:11,030 --> 00:41:08,640
you will you know would detach from the

1015
00:41:13,349 --> 00:41:11,040
cradle the cradle would continue to fly

1016
00:41:15,750 --> 00:41:13,359
towards the target asteroid uh and then

1017
00:41:17,990 --> 00:41:15,760
the bullets would accelerate you know

1018
00:41:19,910 --> 00:41:18,000
for the nuclear or the kinetic option or

1019
00:41:21,030 --> 00:41:19,920
deploy for the solar option and start to

1020
00:41:22,710 --> 00:41:21,040
operate

1021
00:41:25,349 --> 00:41:22,720
on the asteroid

1022
00:41:27,510 --> 00:41:25,359
and so here is the solar collector in

1023
00:41:29,190 --> 00:41:27,520
its inflated state and so you know this

1024
00:41:31,109 --> 00:41:29,200
is a little bit better drawing than my

1025
00:41:33,829 --> 00:41:31,119
hand drawing before here we were looking

1026
00:41:35,670 --> 00:41:33,839
at 50 meter solar collectors and you can

1027
00:41:37,910 --> 00:41:35,680
kind of get a idea for the dimensions of

1028
00:41:39,349 --> 00:41:37,920
the solar collector versus the

1029
00:41:41,270 --> 00:41:39,359
secondary mirror

1030
00:41:43,190 --> 00:41:41,280
also we

1031
00:41:45,030 --> 00:41:43,200
controlled our solar collector with tip

1032
00:41:47,190 --> 00:41:45,040
veins that also doubled as our avionics

1033
00:41:48,710 --> 00:41:47,200
suite so you can imagine these as highly

1034
00:41:51,510 --> 00:41:48,720
reflective

1035
00:41:53,349 --> 00:41:51,520
uh on one side but solar arrays on the

1036
00:41:55,349 --> 00:41:53,359
other and each one of these were

1037
00:41:59,670 --> 00:41:55,359
independent avionics modules that could

1038
00:42:02,550 --> 00:41:59,680

run a solar collector independently

1039
00:42:04,150 --> 00:42:02,560
so uh i think i kind of said all this uh

1040
00:42:06,230 --> 00:42:04,160
you know one of the big concerns we had

1041
00:42:07,829 --> 00:42:06,240
back in 2007 when we did the study was

1042
00:42:10,309 --> 00:42:07,839
trying to figure out how to unfold and

1043
00:42:11,430 --> 00:42:10,319
fold something more complex than a solar

1044
00:42:13,349 --> 00:42:11,440
cell but

1045
00:42:16,710 --> 00:42:13,359
after two days of listening to people

1046
00:42:19,510 --> 00:42:16,720
talk today uh about uh you know uh

1047
00:42:20,870 --> 00:42:19,520
unfolding inflatable claws and whatnot i

1048
00:42:22,150 --> 00:42:20,880
feel a lot better

1049
00:42:25,510 --> 00:42:22,160
um

1050
00:42:27,109 --> 00:42:25,520
one of the uh the major design issues is

1051
00:42:28,950 --> 00:42:27,119
a secondary collector you can imagine

1052
00:42:29,829 --> 00:42:28,960
the amount of power that's that's being

1053
00:42:32,069 --> 00:42:29,839
focused

1054
00:42:33,510 --> 00:42:32,079
onto the secondary and so what we have

1055
00:42:35,510 --> 00:42:33,520
to achieve here is a very high

1056
00:42:37,430 --> 00:42:35,520
reflectivity on the front

1057
00:42:39,670 --> 00:42:37,440
uh so that we can limit the heat

1058
00:42:42,150 --> 00:42:39,680
absorption of that secondary and then we

1059
00:42:44,390 --> 00:42:42,160
have to you know use a fairly i wouldn't

1060
00:42:46,950 --> 00:42:44,400
say exotic but we're having to use a an

1061
00:42:48,309 --> 00:42:46,960
advanced heat pipe rejection system to

1062
00:42:50,390 --> 00:42:48,319
keep it

1063
00:42:52,950 --> 00:42:50,400

cooled on the back now we can always

1064
00:42:55,430 --> 00:42:52,960
alleviate this problem by making the

1065
00:42:56,470 --> 00:42:55,440
mirror bigger but of course that reduces

1066
00:42:59,990 --> 00:42:56,480
our

1067
00:43:01,270 --> 00:43:00,000
asteroid

1068
00:43:02,950 --> 00:43:01,280
and then i've already mentioned the uh

1069
00:43:05,430 --> 00:43:02,960
the tip veins

1070
00:43:07,030 --> 00:43:05,440
okay so our mass breakout is shown here

1071
00:43:09,670 --> 00:43:07,040
and like i said each one of our bullets

1072
00:43:11,910 --> 00:43:09,680
we targeted at 1500 uh uh

1073
00:43:13,510 --> 00:43:11,920
kilograms and so you can you can see

1074
00:43:15,910 --> 00:43:13,520
here we have a pretty healthy growth

1075
00:43:18,470 --> 00:43:15,920
margin here and uh

1076
00:43:19,990 --> 00:43:18,480
our you know sale aerial density which

1077
00:43:22,550 --> 00:43:20,000
is a performance parameter for solar

1078
00:43:24,710 --> 00:43:22,560
sails works out to be about 25 grams per

1079
00:43:27,109 --> 00:43:24,720
uh square meter which is you know pretty

1080
00:43:28,790 --> 00:43:27,119
conservative we uh uh have already

1081
00:43:30,790 --> 00:43:28,800
achieved better numbers than that with

1082
00:43:33,109 --> 00:43:30,800
the solar sails that are being designed

1083
00:43:36,150 --> 00:43:33,119
today

1084
00:43:37,990 --> 00:43:36,160
so uh this concept here we started

1085
00:43:40,630 --> 00:43:38,000
looking at uh you know making a little

1086
00:43:41,990 --> 00:43:40,640
bit better assumptions on how much power

1087
00:43:43,349 --> 00:43:42,000
was actually going to make it to the

1088
00:43:47,270 --> 00:43:43,359

asteroid and i think

1089
00:43:49,190 --> 00:43:47,280
here we used a 50 power uh uh

1090
00:43:51,109 --> 00:43:49,200
you know from the solar collector to the

1091
00:43:53,589 --> 00:43:51,119
actual asteroid and here we're also

1092
00:43:55,829 --> 00:43:53,599
focusing on asteroids between a 100

1093
00:43:57,349 --> 00:43:55,839
meters and one kilometer and so we were

1094
00:43:58,950 --> 00:43:57,359
able to calculate uh you know

1095
00:44:01,829 --> 00:43:58,960
accelerations i mean we've seen that

1096
00:44:04,630 --> 00:44:01,839
with several presentations today

1097
00:44:06,710 --> 00:44:04,640
at the same time you know this was 2007

1098
00:44:09,670 --> 00:44:06,720
so apophis was the

1099
00:44:12,470 --> 00:44:09,680
poster child for astro planetary defense

1100
00:44:14,790 --> 00:44:12,480
and so we modified apophis's trajectory

1101
00:44:18,470 --> 00:44:14,800
so that it would hit uh the planet in

1102
00:44:19,270 --> 00:44:18,480
2029 just on the computer don't worry

1103
00:44:22,309 --> 00:44:19,280
and

1104
00:44:24,630 --> 00:44:22,319
so we actually uh wrote a trajectory

1105
00:44:26,390 --> 00:44:24,640
program to just kind of

1106
00:44:28,790 --> 00:44:26,400
you know integrate the equations of

1107
00:44:31,109 --> 00:44:28,800
motion and back out what acceleration

1108
00:44:33,510 --> 00:44:31,119
would be required as a function of the

1109
00:44:35,990 --> 00:44:33,520
time before impact

1110
00:44:37,589 --> 00:44:36,000
you know previous studies r's and and a

1111
00:44:39,270 --> 00:44:37,599
number of others have shown accelerating

1112
00:44:42,069 --> 00:44:39,280
or decelerating along the velocity

1113
00:44:45,109 --> 00:44:42,079

vector tends to be the the best way to

1114
00:44:47,190 --> 00:44:45,119
uh perturb an incoming asteroid's orbit

1115
00:44:49,270 --> 00:44:47,200
so uh with this we can we have an

1116
00:44:51,030 --> 00:44:49,280
acceleration versus time before impact

1117
00:44:52,550 --> 00:44:51,040
and we have an acceleration versus

1118
00:44:55,030 --> 00:44:52,560
asteroid diameter so we can kind of

1119
00:44:57,030 --> 00:44:55,040
combine the two here and so for a given

1120
00:45:00,790 --> 00:44:57,040
acceleration we can read

1121
00:45:02,390 --> 00:45:00,800
what diameter uh asteroid we can defend

1122
00:45:05,109 --> 00:45:02,400
against uh

1123
00:45:08,230 --> 00:45:05,119
at uh you know with a given warning time

1124
00:45:09,270 --> 00:45:08,240
and so oh okay and um

1125
00:45:10,390 --> 00:45:09,280
i thought you were stopping for a

1126
00:45:12,309 --> 00:45:10,400
question

1127
00:45:16,790 --> 00:45:12,319
so uh

1128
00:45:18,150 --> 00:45:16,800
definitely showing that uh you know if

1129
00:45:20,710 --> 00:45:18,160
we look at here you know giving

1130
00:45:23,430 --> 00:45:20,720
ourselves one to two years warning time

1131
00:45:24,550 --> 00:45:23,440
you know we can still hit uh asteroids

1132
00:45:27,750 --> 00:45:24,560
at uh

1133
00:45:30,309 --> 00:45:27,760
300 meters and this is remember a 50

1134
00:45:32,470 --> 00:45:30,319
meter uh collector where the last one

1135
00:45:33,430 --> 00:45:32,480
was a hundred so this is one-fourth the

1136
00:45:34,950 --> 00:45:33,440
size

1137
00:45:37,589 --> 00:45:34,960
and uh you know we're still able to

1138
00:45:39,270 --> 00:45:37,599

handle a pretty decent sized asteroid

1139
00:45:40,950 --> 00:45:39,280
and that's assuming one at a time if we

1140
00:45:43,190 --> 00:45:40,960
launch six of them at a time then we've

1141
00:45:44,790 --> 00:45:43,200
got you know six times the capability

1142
00:45:46,230 --> 00:45:44,800
assuming that they can all

1143
00:45:48,470 --> 00:45:46,240
interact with the asteroid or we could

1144
00:45:51,829 --> 00:45:48,480
have them come in one after the other

1145
00:45:53,829 --> 00:45:51,839
after uh one is damaged or otherwise has

1146
00:45:55,109 --> 00:45:53,839
become ineffective we can push that one

1147
00:45:56,790 --> 00:45:55,119
to the side have another one coming

1148
00:45:58,710 --> 00:45:56,800
behind it

1149
00:46:00,870 --> 00:45:58,720
so uh there are several issues that we

1150
00:46:02,790 --> 00:46:00,880
need to address

1151
00:46:05,270 --> 00:46:02,800
one is uh is

1152
00:46:08,710 --> 00:46:05,280
there's a coupling between how close the

1153
00:46:10,470 --> 00:46:08,720
collector has to be to the asteroid

1154
00:46:12,790 --> 00:46:10,480
we want to be close to get as much of

1155
00:46:14,710 --> 00:46:12,800
the the sun's radiant energy onto the

1156
00:46:17,109 --> 00:46:14,720
asteroid but we don't want to be close

1157
00:46:18,870 --> 00:46:17,119
because the objective from the asteroid

1158
00:46:21,750 --> 00:46:18,880
is going to impinge on our secondary and

1159
00:46:23,829 --> 00:46:21,760
our primary so uh

1160
00:46:26,470 --> 00:46:23,839
and and that is not a well understood uh

1161
00:46:28,390 --> 00:46:26,480
mechanism here now we have this solar uh

1162
00:46:30,630 --> 00:46:28,400
thermal facility that

1163
00:46:32,069 --> 00:46:30,640

uh harold's not oh there he is uh harold

1164
00:46:34,069 --> 00:46:32,079
garris and some of the other folks at

1165
00:46:35,750 --> 00:46:34,079
marshall worked on and it's a really

1166
00:46:37,750 --> 00:46:35,760
nice facility and we could you know

1167
00:46:39,270 --> 00:46:37,760
right now put some regolith in this

1168
00:46:41,190 --> 00:46:39,280
vacuum chamber right here and start

1169
00:46:43,430 --> 00:46:41,200
testing you know what our ejector rates

1170
00:46:45,349 --> 00:46:43,440
would be and and get an understanding of

1171
00:46:46,550 --> 00:46:45,359
that uh that

1172
00:46:48,790 --> 00:46:46,560
that problem

1173
00:46:51,349 --> 00:46:48,800
also we need to have a collector that's

1174
00:46:53,589 --> 00:46:51,359
large enough that is uh intense enough

1175
00:46:55,190 --> 00:46:53,599
that we can heat

1176
00:46:57,750 --> 00:46:55,200
parts of the regolith and get it to

1177
00:46:59,990 --> 00:46:57,760
vaporize before all of that heat

1178
00:47:01,670 --> 00:47:00,000
dissipates back into the asteroid now

1179
00:47:03,270 --> 00:47:01,680
here's where a rubble pile actually

1180
00:47:04,710 --> 00:47:03,280
works in our favor

1181
00:47:06,230 --> 00:47:04,720
because you know we would expect that

1182
00:47:08,069 --> 00:47:06,240
much void

1183
00:47:09,829 --> 00:47:08,079
we would have a less of a heat

1184
00:47:11,030 --> 00:47:09,839
dissipation through the asteroid but

1185
00:47:12,630 --> 00:47:11,040
that's something else that would need to

1186
00:47:15,190 --> 00:47:12,640
be uh analyzed

1187
00:47:17,109 --> 00:47:15,200
i'll skip this because i think all day

1188
00:47:19,589 --> 00:47:17,119

we've seen people talk about all the

1189
00:47:21,510 --> 00:47:19,599
experiments on inflatable mechanisms i

1190
00:47:22,950 --> 00:47:21,520
think that's well understood or well

1191
00:47:24,870 --> 00:47:22,960
along its way

1192
00:47:27,349 --> 00:47:24,880
and there's some capabilities at

1193
00:47:29,190 --> 00:47:27,359
marshall and other places where

1194
00:47:31,430 --> 00:47:29,200
this has been done

1195
00:47:34,309 --> 00:47:31,440
and then this is just generally showing

1196
00:47:37,589 --> 00:47:34,319
hey you know uh uh we're up to

1197
00:47:41,030 --> 00:47:37,599
20 meter solar sails that have uh flown

1198
00:47:43,670 --> 00:47:41,040
uh the japanese uh the 10 meter uh uh

1199
00:47:44,950 --> 00:47:43,680
antenna that was flown on 77 uh the

1200
00:47:47,589 --> 00:47:44,960
things that we've done on the ground

1201
00:47:50,150 --> 00:47:47,599
here and then the sun jammer concept is

1202
00:47:52,790 --> 00:47:50,160
uh supposed to be a 38 meter so getting

1203
00:47:55,589 --> 00:47:52,800
to the diameters uh that i'm talking

1204
00:47:57,349 --> 00:47:55,599
about is not unrealistic

1205
00:47:59,190 --> 00:47:57,359
and then a few other things that should

1206
00:48:01,510 --> 00:47:59,200
be addressed is a

1207
00:48:02,790 --> 00:48:01,520
am i out of time all right uh is the

1208
00:48:04,230 --> 00:48:02,800
high heating loads on the mirror i've

1209
00:48:06,390 --> 00:48:04,240
kind of already mentioned that and then

1210
00:48:08,549 --> 00:48:06,400
just doing systems design so there are

1211
00:48:10,470 --> 00:48:08,559
issues to be addressed but in my opinion

1212
00:48:11,750 --> 00:48:10,480
they're all engineering issues and when

1213
00:48:13,349 --> 00:48:11,760

you look at all the operational

1214
00:48:14,870 --> 00:48:13,359
capability that the

1215
00:48:17,349 --> 00:48:14,880
the solar collector gives you you can

1216
00:48:19,190 --> 00:48:17,359
imagine launching dozens of these on one

1217
00:48:20,950 --> 00:48:19,200
heavy lift vehicle and having them float

1218
00:48:23,430 --> 00:48:20,960
around the solar system

1219
00:48:25,030 --> 00:48:23,440
pushing things around and uh and

1220
00:48:26,470 --> 00:48:25,040
generally making things the way we want

1221
00:48:27,589 --> 00:48:26,480
them to be

1222
00:48:31,910 --> 00:48:27,599
so

1223
00:48:31,920 --> 00:48:39,990
for any questions in the audience

1224
00:48:44,950 --> 00:48:42,230
i've seen the movie of the

1225
00:48:46,309 --> 00:48:44,960
solar thing you you know the actual test

1226
00:48:47,670 --> 00:48:46,319
unit you have

1227
00:48:49,430 --> 00:48:47,680
what is the diameter that's about 20

1228
00:48:51,190 --> 00:48:49,440
meters right

1229
00:48:53,510 --> 00:48:51,200
here

1230
00:48:55,270 --> 00:48:53,520
oh 18 feet so 6 meters

1231
00:48:57,190 --> 00:48:55,280
and that does a really nice job of

1232
00:48:58,470 --> 00:48:57,200
vaporizing or melting or whatever things

1233
00:49:01,270 --> 00:48:58,480
that are put at least according to

1234
00:49:03,109 --> 00:49:01,280
movies i saw at the folk at the focus

1235
00:49:03,829 --> 00:49:03,119
there

1236
00:49:05,750 --> 00:49:03,839
so

1237
00:49:07,510 --> 00:49:05,760
that kind of worries me about that one

1238
00:49:09,030 --> 00:49:07,520

this one here yeah yeah i've seen a

1239
00:49:11,990 --> 00:49:09,040
movie of that thing in operation that

1240
00:49:12,950 --> 00:49:12,000
would kind of worry me about uh you know

1241
00:49:14,470 --> 00:49:12,960
um

1242
00:49:17,589 --> 00:49:14,480
putting a uh

1243
00:49:18,950 --> 00:49:17,599
basically a optical flat there right

1244
00:49:20,549 --> 00:49:18,960
like if the reflector is over there i

1245
00:49:22,630 --> 00:49:20,559
have an optical flap to aim it over

1246
00:49:24,309 --> 00:49:22,640
there right so

1247
00:49:25,430 --> 00:49:24,319
you have dust probably coming off the

1248
00:49:27,109 --> 00:49:25,440
surface because they're heating up the

1249
00:49:29,270 --> 00:49:27,119
surface over time that dust is going to

1250
00:49:31,589 --> 00:49:29,280
float over to me it's going to coat this

1251
00:49:33,670 --> 00:49:31,599
optical flat it seems like

1252
00:49:36,390 --> 00:49:33,680
you know it wouldn't take much coating

1253
00:49:38,150 --> 00:49:36,400
to sort of like well and then there is a

1254
00:49:39,430 --> 00:49:38,160
survivability issue but you also have to

1255
00:49:40,870 --> 00:49:39,440
consider that

1256
00:49:44,390 --> 00:49:40,880
you know with that level of intensity

1257
00:49:46,069 --> 00:49:44,400
that dust may never make it to the uh

1258
00:49:48,230 --> 00:49:46,079
well meteorites probably would and they

1259
00:49:49,990 --> 00:49:48,240
would you know put small pits in the

1260
00:49:52,230 --> 00:49:50,000
surface well and that's fine but you

1261
00:49:54,309 --> 00:49:52,240
know we have uh we've considered that

1262
00:49:55,670 --> 00:49:54,319
for solar sails the sail you know

1263
00:49:57,109 --> 00:49:55,680

pictures i've shown haven't shown all

1264
00:49:59,190 --> 00:49:57,119
the rip stops and whatnot that you

1265
00:50:00,790 --> 00:49:59,200
design in there so that when you do get

1266
00:50:02,710 --> 00:50:00,800
a puncture that it stops it's kind of

1267
00:50:04,390 --> 00:50:02,720
like a world war ii when we used to

1268
00:50:07,670 --> 00:50:04,400
drill holes in planes so that we could

1269
00:50:09,829 --> 00:50:07,680
stop the cracks in the aircraft sure

1270
00:50:12,309 --> 00:50:09,839
and the the mirror backing material is

1271
00:50:14,150 --> 00:50:12,319
something very light right the what the

1272
00:50:16,069 --> 00:50:14,160
the actual main mirror there oh yeah

1273
00:50:17,910 --> 00:50:16,079
it's usually mylar with a coated

1274
00:50:19,910 --> 00:50:17,920
aluminum on the front and then you have

1275
00:50:22,069 --> 00:50:19,920
one of several coatings on the back

1276
00:50:23,349 --> 00:50:22,079
that's uh to increase emissivity to kind

1277
00:50:24,710 --> 00:50:23,359
of keep the temperature of the sail down

1278
00:50:26,069 --> 00:50:24,720
yeah so that you could have little holes

1279
00:50:28,230 --> 00:50:26,079
in or meteorites going through or

1280
00:50:30,549 --> 00:50:28,240
whatever would be fine it seems like the

1281
00:50:31,670 --> 00:50:30,559
the flap the secondary is the one that

1282
00:50:33,510 --> 00:50:31,680
would you're all right we're calling the

1283
00:50:35,829 --> 00:50:33,520
flat as a second here yeah uh yeah the

1284
00:50:38,230 --> 00:50:35,839
secondary is is a critical path here

1285
00:50:40,630 --> 00:50:38,240
there's no two ways about it um

1286
00:50:42,069 --> 00:50:40,640
you know if i got three months operation

1287
00:50:43,829 --> 00:50:42,079
you know in front of an asteroid out of

1288
00:50:45,030 --> 00:50:43,839

one of these things i'd be very happy

1289
00:50:46,710 --> 00:50:45,040
and uh

1290
00:50:48,390 --> 00:50:46,720
you know again you know we need to get

1291
00:50:51,030 --> 00:50:48,400
into this facility in my opinion and

1292
00:50:52,790 --> 00:50:51,040
figure out how far away we can stand off

1293
00:50:54,950 --> 00:50:52,800
and you know there's the trade if i

1294
00:50:56,870 --> 00:50:54,960
stand off a kilometer away i might get

1295
00:50:58,309 --> 00:50:56,880
fifty percent of the uh radiant energy

1296
00:51:00,710 --> 00:50:58,319
if i stay in half a kilometer i might

1297
00:51:02,549 --> 00:51:00,720
get eighty percent and figuring out uh

1298
00:51:04,549 --> 00:51:02,559
that so that we can figure out you know

1299
00:51:06,630 --> 00:51:04,559
how much material is incident onto the

1300
00:51:09,109 --> 00:51:06,640
uh the sale we also need to understand

1301
00:51:10,790 --> 00:51:09,119
how what's coming off of you know the

1302
00:51:12,230 --> 00:51:10,800
ejector from the asteroid how that's

1303
00:51:13,510 --> 00:51:12,240
going to be affected by that beam when

1304
00:51:15,030 --> 00:51:13,520
you think about that secondary is kind

1305
00:51:17,109 --> 00:51:15,040
of protecting itself there's a beam

1306
00:51:18,549 --> 00:51:17,119
coming off of it and so those particles

1307
00:51:20,829 --> 00:51:18,559
have to fight their way up that beam to

1308
00:51:22,390 --> 00:51:20,839
get to the uh the

1309
00:51:24,069 --> 00:51:22,400
secondary

1310
00:51:30,630 --> 00:51:24,079
thanks all right thank you

1311
00:51:36,870 --> 00:51:34,870
okay our next talk is by steve chesley

1312
00:51:38,950 --> 00:51:36,880
steve is an expert in asteroid and comet

1313
00:51:40,870 --> 00:51:38,960

orbit determination with nasa's neo

1314
00:51:42,150 --> 00:51:40,880
program office at the jet propulsion

1315
00:51:44,710 --> 00:51:42,160
laboratory

1316
00:51:47,030 --> 00:51:44,720
he is presently a co-investigator on the

1317
00:51:47,910 --> 00:51:47,040
osiris-rex asteroid sample return

1318
00:51:49,270 --> 00:51:47,920
mission

1319
00:51:51,829 --> 00:51:49,280
go ahead steve

1320
00:51:53,109 --> 00:51:51,839
thank you paul

1321
00:51:55,109 --> 00:51:53,119
working

1322
00:51:56,549 --> 00:51:55,119
um

1323
00:51:58,470 --> 00:51:56,559
and we're almost to the end of the day

1324
00:52:00,790 --> 00:51:58,480
one more talk after me

1325
00:52:02,710 --> 00:52:00,800
congratulations this is uh this is a

1326
00:52:05,510 --> 00:52:02,720
sort of a

1327
00:52:07,910 --> 00:52:05,520
schematic or cartoon of the

1328
00:52:09,670 --> 00:52:07,920
of the concept here isis impactor for

1329
00:52:11,030 --> 00:52:09,680
surface and interior science what you

1330
00:52:13,910 --> 00:52:11,040
have here in the background is the

1331
00:52:16,230 --> 00:52:13,920
osiris-rex spacecraft

1332
00:52:17,430 --> 00:52:16,240
uh at the asteroid

1333
00:52:19,349 --> 00:52:17,440
venue which is where it's going to

1334
00:52:20,230 --> 00:52:19,359
collect a sample and bring it back to

1335
00:52:21,190 --> 00:52:20,240
earth

1336
00:52:23,430 --> 00:52:21,200
while

1337
00:52:26,390 --> 00:52:23,440
osiris-rex is at its station after it's

1338
00:52:27,510 --> 00:52:26,400

collected a sample the isis spacecraft

1339
00:52:30,630 --> 00:52:27,520
will come in

1340
00:52:33,670 --> 00:52:30,640
and and impact and that's the asteroid

1341
00:52:39,510 --> 00:52:33,680
deflection experiment as well as a

1342
00:52:43,829 --> 00:52:42,230
so a little more detail the the isis is

1343
00:52:45,030 --> 00:52:43,839
intended to launch as a secondary

1344
00:52:47,030 --> 00:52:45,040
payload

1345
00:52:49,670 --> 00:52:47,040
so

1346
00:52:51,349 --> 00:52:49,680
one of the nice things about this is

1347
00:52:53,430 --> 00:52:51,359
it's a don quijote mission some of you

1348
00:52:54,630 --> 00:52:53,440
may know about except that we don't have

1349
00:52:56,390 --> 00:52:54,640
to pay for the

1350
00:52:58,230 --> 00:52:56,400
observer spacecraft and we don't have to

1351
00:52:59,270 --> 00:52:58,240
pay for a launch vehicle so it's very

1352
00:53:01,750 --> 00:52:59,280
efficient

1353
00:53:03,589 --> 00:53:01,760
indeed it's based on an espa that

1354
00:53:04,870 --> 00:53:03,599
minimizes the impact on the primary

1355
00:53:07,349 --> 00:53:04,880
payload

1356
00:53:10,549 --> 00:53:07,359
after the cruise the impacts the

1357
00:53:13,190 --> 00:53:10,559
asteroid wall for cyprus rex is there

1358
00:53:15,030 --> 00:53:13,200
and in a position to observe but after

1359
00:53:16,870 --> 00:53:15,040
it's collected its sample and safely

1360
00:53:19,510 --> 00:53:16,880
coated in the sample return

1361
00:53:22,630 --> 00:53:20,870
as i mentioned it's going to observe the

1362
00:53:24,390 --> 00:53:22,640
impact from a safe position and after

1363
00:53:26,470 --> 00:53:24,400

the debris clears

1364
00:53:30,230 --> 00:53:26,480
it will go in and collect spectra and

1365
00:53:32,630 --> 00:53:30,240
imagery of the sample site as well as

1366
00:53:35,270 --> 00:53:32,640
measure the asteroid deflection caused

1367
00:53:36,069 --> 00:53:35,280
by the impact

1368
00:53:38,230 --> 00:53:36,079
so

1369
00:53:40,710 --> 00:53:38,240
the conclusion at the beginning here the

1370
00:53:43,030 --> 00:53:40,720
takeaway message is isis would leverage

1371
00:53:44,870 --> 00:53:43,040
significant nasa investments

1372
00:53:47,510 --> 00:53:44,880
in terms of say the primary launch

1373
00:53:49,349 --> 00:53:47,520
vehicle in the osiris-rex spacecraft to

1374
00:53:52,390 --> 00:53:49,359
deliver potential discovery level

1375
00:53:54,630 --> 00:53:52,400
science and provide a first-time

1376
00:53:56,710 --> 00:53:54,640
demonstration of asteroid inflection and

1377
00:53:58,230 --> 00:53:56,720
all this is the tiny cost of a

1378
00:54:00,549 --> 00:53:58,240
stand-alone mission where you have to

1379
00:54:03,030 --> 00:54:00,559
pay for your own observer spacecraft

1380
00:54:05,510 --> 00:54:03,040
and so on

1381
00:54:08,069 --> 00:54:05,520
uh and i think this fits well within the

1382
00:54:10,470 --> 00:54:08,079
nasa asteroid initiative grand challenge

1383
00:54:12,549 --> 00:54:10,480
which talks about finding the asteroids

1384
00:54:15,750 --> 00:54:12,559
and knowing what to do about them this

1385
00:54:17,670 --> 00:54:15,760
is a convergence of technology in terms

1386
00:54:20,309 --> 00:54:17,680
of the deflection and the terminal

1387
00:54:21,270 --> 00:54:20,319
guidance the exploration which i here i

1388
00:54:23,670 --> 00:54:21,280

include

1389
00:54:26,309 --> 00:54:23,680
resource utilization and extraction and

1390
00:54:29,030 --> 00:54:26,319
i think uh the most compelling for me

1391
00:54:30,549 --> 00:54:29,040
is the science uh returns from this

1392
00:54:32,230 --> 00:54:30,559
um

1393
00:54:33,990 --> 00:54:32,240
and let's see so one of the program

1394
00:54:35,670 --> 00:54:34,000
goals i just mentioned is that is the

1395
00:54:37,990 --> 00:54:35,680
mitigation of potentially hazardous

1396
00:54:39,750 --> 00:54:38,000
asteroids

1397
00:54:42,630 --> 00:54:39,760
i'll mention here i'm not sure depending

1398
00:54:43,349 --> 00:54:42,640
on how you read the rfi for this

1399
00:54:48,069 --> 00:54:43,359
if

1400
00:54:51,030 --> 00:54:48,079
deflection or the asteroid initiative is

1401
00:54:53,589 --> 00:54:51,040
a part of the asteroid retrieval mission

1402
00:54:54,549 --> 00:54:53,599
concept or the other way around i take

1403
00:54:59,349 --> 00:54:54,559
the

1404
00:55:01,270 --> 00:54:59,359
is one part of a larger program

1405
00:55:04,230 --> 00:55:01,280
that's exemplified by the asteroid

1406
00:55:07,510 --> 00:55:05,829
so stepping through these three things

1407
00:55:09,430 --> 00:55:07,520
first is the technology demonstration

1408
00:55:10,630 --> 00:55:09,440
the deflection demonstration

1409
00:55:13,589 --> 00:55:10,640
the uh

1410
00:55:15,910 --> 00:55:13,599
nrc in 2010 put out an excellent report

1411
00:55:18,069 --> 00:55:15,920
that called as a first priority for a

1412
00:55:19,829 --> 00:55:18,079
space mission in the mitigation area is

1413
00:55:21,990 --> 00:55:19,839

an experimental test of a kinetic

1414
00:55:23,190 --> 00:55:22,000
impactor along with these

1415
00:55:25,510 --> 00:55:23,200
characterization monitoring and

1416
00:55:27,910 --> 00:55:25,520
verification so this is exactly what

1417
00:55:30,710 --> 00:55:27,920
isis would provide

1418
00:55:32,870 --> 00:55:30,720
in the area of exploration

1419
00:55:35,109 --> 00:55:32,880
we have the strategic knowledge gaps

1420
00:55:37,030 --> 00:55:35,119
that have been put forward as considered

1421
00:55:39,670 --> 00:55:37,040
to be important things to understand

1422
00:55:40,789 --> 00:55:39,680
about these targets before we can go

1423
00:55:43,750 --> 00:55:40,799
put

1424
00:55:46,470 --> 00:55:43,760
humans in the in the environment

1425
00:55:47,910 --> 00:55:46,480
there's broad themes and and isis

1426
00:55:49,990 --> 00:55:47,920
touches

1427
00:55:51,990 --> 00:55:50,000
sometimes more sometimes less on about a

1428
00:55:54,390 --> 00:55:52,000
dozen of these some of these critical

1429
00:55:56,309 --> 00:55:54,400
ideas like geotechnical properties

1430
00:55:58,710 --> 00:55:56,319
of the small body surface the

1431
00:55:59,589 --> 00:55:58,720
particulate environment around the small

1432
00:56:01,910 --> 00:55:59,599
body

1433
00:56:03,430 --> 00:56:01,920
and the local and global structural

1434
00:56:04,710 --> 00:56:03,440
stability these are the kinds of things

1435
00:56:07,510 --> 00:56:04,720
that we want to know before we put

1436
00:56:09,670 --> 00:56:07,520
humans into that environment

1437
00:56:11,589 --> 00:56:09,680
okay the science i think is is maybe

1438
00:56:13,349 --> 00:56:11,599

this is what distinguishes

1439
00:56:14,789 --> 00:56:13,359
this approach and this particular

1440
00:56:17,750 --> 00:56:14,799
demonstration mission too much of what

1441
00:56:19,190 --> 00:56:17,760
we've heard so far today

1442
00:56:20,870 --> 00:56:19,200
isis is going to answer a lot of

1443
00:56:22,230 --> 00:56:20,880
questions about what these things are

1444
00:56:24,309 --> 00:56:22,240
made of

1445
00:56:25,670 --> 00:56:24,319
we're going to watch the impact happen

1446
00:56:27,270 --> 00:56:25,680
and we'll learn

1447
00:56:29,430 --> 00:56:27,280
what what the ash how the asteroid

1448
00:56:31,430 --> 00:56:29,440
responds in the local sense we'll look

1449
00:56:32,230 --> 00:56:31,440
at the objective field itself

1450
00:56:34,150 --> 00:56:32,240
and

1451
00:56:35,829 --> 00:56:34,160
the crater morphology the possible

1452
00:56:38,069 --> 00:56:35,839
release of volatiles from the impact

1453
00:56:40,710 --> 00:56:38,079
site in a more global sense we'll look

1454
00:56:42,870 --> 00:56:40,720
at the trajectory change in the asteroid

1455
00:56:45,349 --> 00:56:42,880
which will tell us about the interior

1456
00:56:46,870 --> 00:56:45,359
mechanics of the body

1457
00:56:47,990 --> 00:56:46,880
we'll look at the rotation changes that

1458
00:56:50,230 --> 00:56:48,000
we induce

1459
00:56:52,870 --> 00:56:50,240
as well as seismic activity that will be

1460
00:56:56,230 --> 00:56:52,880
reflected through the dampening of shock

1461
00:56:58,390 --> 00:56:56,240
waves and say

1462
00:57:00,069 --> 00:56:58,400
landslides and topple boulders and so

1463
00:57:02,950 --> 00:57:00,079

forth because we'll re-image the entire

1464
00:57:04,470 --> 00:57:02,960
asteroid before we desire threshold and

1465
00:57:07,190 --> 00:57:04,480
then after

1466
00:57:09,910 --> 00:57:07,200
so based on what we we observed we can

1467
00:57:10,829 --> 00:57:09,920
now do some analysis to understand more

1468
00:57:16,390 --> 00:57:10,839
about the

1469
00:57:18,390 --> 00:57:16,400
cohesion ferocity of the impact site

1470
00:57:20,309 --> 00:57:18,400
as well as the geology of the subsurface

1471
00:57:25,190 --> 00:57:20,319
basically the crater will allow us to

1472
00:57:28,710 --> 00:57:27,349
all right how are we going to get to

1473
00:57:30,549 --> 00:57:28,720
the asteroid

1474
00:57:32,309 --> 00:57:30,559
well we have uh

1475
00:57:34,630 --> 00:57:32,319
as you can see a list of ways to do it

1476
00:57:36,710 --> 00:57:34,640
we we have been talking and so the the

1477
00:57:38,390 --> 00:57:36,720
original incarnation of this concept was

1478
00:57:40,789 --> 00:57:38,400
to was to get it right on the inside

1479
00:57:43,030 --> 00:57:40,799
mission to mars

1480
00:57:46,150 --> 00:57:43,040
and that's now been bypassed basically

1481
00:57:49,109 --> 00:57:46,160
due to schedule and fiscal constraints

1482
00:57:51,190 --> 00:57:49,119
that this has passed similar osiris-rex

1483
00:57:53,190 --> 00:57:51,200
would have been a great ride

1484
00:57:54,950 --> 00:57:53,200
that's also a little late

1485
00:57:55,910 --> 00:57:54,960
we're a little late for that the insight

1486
00:57:59,190 --> 00:57:55,920
backup

1487
00:58:01,030 --> 00:57:59,200
works but it's unlikely to materialize

1488
00:58:03,829 --> 00:58:01,040

i also mentioned there's the b612

1489
00:58:07,270 --> 00:58:03,839
sentinel project which is a

1490
00:58:10,069 --> 00:58:07,280
sort of a crowdsource crowdfunded

1491
00:58:12,069 --> 00:58:10,079
near-earth asteroid survey mission we

1492
00:58:14,230 --> 00:58:12,079
could use that but

1493
00:58:15,589 --> 00:58:14,240
i think that their past this launch date

1494
00:58:16,789 --> 00:58:15,599
which is the only one of theirs that

1495
00:58:19,910 --> 00:58:16,799
worked

1496
00:58:21,589 --> 00:58:19,920
if anybody knows of of the elv launch to

1497
00:58:23,750 --> 00:58:21,599
mars in 2018

1498
00:58:25,910 --> 00:58:23,760
let us know if you would like to talk to

1499
00:58:28,069 --> 00:58:25,920
those folks we haven't found one but

1500
00:58:30,230 --> 00:58:28,079
that would also work well so as i say

1501
00:58:31,910 --> 00:58:30,240
there's there's a lot of ways to get

1502
00:58:34,230 --> 00:58:31,920
there at the moment what we're looking

1503
00:58:36,470 --> 00:58:34,240
mostly at are the possibility of a geo

1504
00:58:40,069 --> 00:58:36,480
transfer orbit transfer through lunar

1505
00:58:41,589 --> 00:58:40,079
flyby on our way it works quite well

1506
00:58:43,750 --> 00:58:41,599
and we can get some

1507
00:58:45,750 --> 00:58:43,760
nice impact velocities

1508
00:58:47,750 --> 00:58:45,760
we also have the similar opportunity to

1509
00:58:50,150 --> 00:58:47,760
instead of the osiris-rex or in addition

1510
00:58:53,589 --> 00:58:50,160
to the osiris-rex mission we could go to

1511
00:58:55,109 --> 00:58:53,599
the hayabusa2 target 1999 je3 and do the

1512
00:58:58,150 --> 00:58:55,119
same thing and arrive at the time that's

1513
00:58:59,589 --> 00:58:58,160

appropriate for that mission

1514
00:59:01,990 --> 00:58:59,599
other things that are on the table here

1515
00:59:03,910 --> 00:59:02,000
is the sls test launches that have been

1516
00:59:05,589 --> 00:59:03,920
discussed earlier

1517
00:59:06,630 --> 00:59:05,599
these are not espa compatible so they

1518
00:59:09,589 --> 00:59:06,640
don't look like they're very good

1519
00:59:11,270 --> 00:59:09,599
solution dedicated lodge of course you

1520
00:59:13,430 --> 00:59:11,280
start running into cost issues right

1521
00:59:14,549 --> 00:59:13,440
away and it diminishes the efficiency of

1522
00:59:15,990 --> 00:59:14,559
this approach

1523
00:59:17,349 --> 00:59:16,000
so

1524
00:59:18,870 --> 00:59:17,359
this is our main

1525
00:59:21,829 --> 00:59:18,880
focus at the moment

1526
00:59:24,390 --> 00:59:21,839
is the gto transfer

1527
00:59:26,789 --> 00:59:24,400
we have a notional flight system the

1528
00:59:29,430 --> 00:59:26,799
main point here is very simple there's

1529
00:59:31,510 --> 00:59:29,440
no new technology development all of

1530
00:59:34,710 --> 00:59:31,520
these things are off the shelf you see

1531
00:59:37,829 --> 00:59:34,720
there's uh there's the aspar ring that

1532
00:59:39,829 --> 00:59:37,839
imposes no impact on the host payload a

1533
00:59:42,150 --> 00:59:39,839
very modular flight system with the ring

1534
00:59:43,589 --> 00:59:42,160
the tank a prop module avionics module

1535
00:59:45,750 --> 00:59:43,599
some solar panels

1536
00:59:47,829 --> 00:59:45,760
simple there's no science instruments no

1537
00:59:50,710 --> 00:59:47,839
mechanisms no deployments

1538
00:59:52,470 --> 00:59:50,720

pyros no cross-link communication to the

1539
00:59:56,710 --> 00:59:52,480
observer spacecraft

1540
01:00:00,069 --> 00:59:58,150
the other question that comes up often

1541
01:00:02,309 --> 01:00:00,079
is how are we going to hit this thing

1542
01:00:03,910 --> 01:00:02,319
and i think that's

1543
01:00:05,349 --> 01:00:03,920
maybe a surprise to some but we really

1544
01:00:06,390 --> 01:00:05,359
have this problem pretty well licked

1545
01:00:08,309 --> 01:00:06,400
with the

1546
01:00:11,510 --> 01:00:08,319
jpl auto nav technology which was

1547
01:00:12,470 --> 01:00:11,520
already demonstrated on deep impact

1548
01:00:14,630 --> 01:00:12,480
and

1549
01:00:16,069 --> 01:00:14,640
just retuning the targeting parameters

1550
01:00:18,710 --> 01:00:16,079
here's the kind of the approach we have

1551
01:00:21,190 --> 01:00:18,720
notionally a maneuver at one hour out

1552
01:00:22,549 --> 01:00:21,200
and 30 minutes out and and a few minutes

1553
01:00:23,670 --> 01:00:22,559
out would be the three targeting

1554
01:00:26,470 --> 01:00:23,680
maneuvers

1555
01:00:28,789 --> 01:00:26,480
and and you can see here's a 500 meter

1556
01:00:30,789 --> 01:00:28,799
asteroid like bennu and we have no

1557
01:00:32,470 --> 01:00:30,799
problem with

1558
01:00:37,910 --> 01:00:32,480
three sigma hitting very close to the

1559
01:00:42,789 --> 01:00:39,670
one of the reasons osiris-rex is such a

1560
01:00:45,190 --> 01:00:42,799
good candidate for this is that the

1561
01:00:46,950 --> 01:00:45,200
timeline is suitable so the osiris-rex

1562
01:00:49,190 --> 01:00:46,960
nominal mission has a couple of months

1563
01:00:51,270 --> 01:00:49,200

for acquisition and rendezvous about

1564
01:00:53,589 --> 01:00:51,280
nine months from rendezvous to first

1565
01:00:56,230 --> 01:00:53,599
sampling attempts and another six months

1566
01:00:58,549 --> 01:00:56,240
of margin where they may be doing a

1567
01:00:59,510 --> 01:00:58,559
second contingency sampling attempt for

1568
01:01:01,589 --> 01:00:59,520
instance

1569
01:01:03,829 --> 01:01:01,599
there is a possibility

1570
01:01:05,829 --> 01:01:03,839
of a third contingency sampling attempt

1571
01:01:07,589 --> 01:01:05,839
but they have about

1572
01:01:09,510 --> 01:01:07,599
over a year of

1573
01:01:10,390 --> 01:01:09,520
slack time while they wait for their

1574
01:01:12,789 --> 01:01:10,400
injection

1575
01:01:15,910 --> 01:01:12,799
opportunity back to earth and then their

1576
01:01:18,309 --> 01:01:15,920
uh return window opens here and lasts

1577
01:01:19,750 --> 01:01:18,319
for about four months and that's when we

1578
01:01:22,549 --> 01:01:19,760
would come in just as they're getting

1579
01:01:23,829 --> 01:01:22,559
ready to depart and do our do our impact

1580
01:01:25,349 --> 01:01:23,839
and then include the science

1581
01:01:28,870 --> 01:01:25,359
investigation

1582
01:01:31,190 --> 01:01:28,880
here's a notional mission for a

1583
01:01:33,349 --> 01:01:31,200
late 2017 launch that we have a 14

1584
01:01:34,549 --> 01:01:33,359
kilometer per second impact with 600

1585
01:01:36,710 --> 01:01:34,559
kilograms

1586
01:01:40,069 --> 01:01:36,720
that gives you something like 19 tons of

1587
01:01:42,710 --> 01:01:40,079
tnt released in kinetic energy

1588
01:01:44,549 --> 01:01:42,720

so what osiris-rex would be doing during

1589
01:01:46,069 --> 01:01:44,559
this time frame here

1590
01:01:47,589 --> 01:01:46,079
after the impact or even before the

1591
01:01:49,510 --> 01:01:47,599
impact we'd like to go in and get a

1592
01:01:50,950 --> 01:01:49,520
last-minute update on the ephemeris of

1593
01:01:53,190 --> 01:01:50,960
the asteroids so we know what it was

1594
01:01:56,630 --> 01:01:53,200
like before so we have something with

1595
01:01:58,309 --> 01:01:56,640
high fidelity to compare it with after

1596
01:02:00,309 --> 01:01:58,319
it'll go back into image from a safe

1597
01:02:01,589 --> 01:02:00,319
location and monitor this eject as it

1598
01:02:03,349 --> 01:02:01,599
dissipates

1599
01:02:05,109 --> 01:02:03,359
then it'll be the crater reconnaissance

1600
01:02:08,390 --> 01:02:05,119
period which would probably be a few

1601
01:02:10,630 --> 01:02:08,400
slow flybys at low phase angle

1602
01:02:12,870 --> 01:02:10,640
and then the radio science to determine

1603
01:02:14,549 --> 01:02:12,880
the deflection and global remapping of

1604
01:02:19,670 --> 01:02:14,559
the surface to look for these changes

1605
01:02:23,990 --> 01:02:21,910
so one of the first things people say

1606
01:02:26,630 --> 01:02:24,000
especially the osiris-rex people i'm on

1607
01:02:27,990 --> 01:02:26,640
the osiris-rex team by the way so i have

1608
01:02:29,270 --> 01:02:28,000
a vested interest in that mission

1609
01:02:31,750 --> 01:02:29,280
success

1610
01:02:34,549 --> 01:02:31,760
um but their first response is you're

1611
01:02:35,910 --> 01:02:34,559
going to do what at our asteroid

1612
01:02:38,150 --> 01:02:35,920
and

1613
01:02:39,910 --> 01:02:38,160

i i think if you do a careful analysis

1614
01:02:41,829 --> 01:02:39,920
of thoughtful consideration of the the

1615
01:02:43,910 --> 01:02:41,839
risks that are

1616
01:02:45,349 --> 01:02:43,920
introduced to the cyrus recognition

1617
01:02:47,430 --> 01:02:45,359
through this approach

1618
01:02:49,349 --> 01:02:47,440
they're not very severe there's some

1619
01:02:51,750 --> 01:02:49,359
additional proximity operations would be

1620
01:02:53,190 --> 01:02:51,760
required by the osiris-rex spacecraft

1621
01:02:55,750 --> 01:02:53,200
but these are all

1622
01:02:58,150 --> 01:02:55,760
basic things that have been already done

1623
01:03:00,069 --> 01:02:58,160
in the prime mission many many times

1624
01:03:01,670 --> 01:03:00,079
there is a high velocity debris hazard

1625
01:03:04,230 --> 01:03:01,680
in principle but we know where that

1626
01:03:05,190 --> 01:03:04,240
debris is going and we don't stand there

1627
01:03:07,510 --> 01:03:05,200
that's the

1628
01:03:09,430 --> 01:03:07,520
main way to avoid that

1629
01:03:12,069 --> 01:03:09,440
there's also a low velocity degree

1630
01:03:14,390 --> 01:03:12,079
hazard you can't go back in to survey

1631
01:03:16,069 --> 01:03:14,400
the area until it's all been swept clean

1632
01:03:17,270 --> 01:03:16,079
and that happens on the period of two to

1633
01:03:19,190 --> 01:03:17,280
four weeks

1634
01:03:21,430 --> 01:03:19,200
and while that's happening you monitor

1635
01:03:23,510 --> 01:03:21,440
and you survey the area so you know

1636
01:03:25,750 --> 01:03:23,520
what's there and you don't go in until

1637
01:03:27,430 --> 01:03:25,760
it's safe to do so

1638
01:03:29,589 --> 01:03:27,440

there was also some concern i'll mention

1639
01:03:30,710 --> 01:03:29,599
that that osiris-rex could somehow get

1640
01:03:33,109 --> 01:03:30,720
uh

1641
01:03:34,069 --> 01:03:33,119
outside of its injection window and i

1642
01:03:35,990 --> 01:03:34,079
think the

1643
01:03:37,510 --> 01:03:36,000
response to that is that you just make

1644
01:03:39,270 --> 01:03:37,520
sure that your schedule is set up so

1645
01:03:40,710 --> 01:03:39,280
that you go back to earth with your

1646
01:03:43,349 --> 01:03:40,720
precious sample

1647
01:03:45,670 --> 01:03:43,359
when it's time to do so and that's uh

1648
01:03:47,589 --> 01:03:45,680
this is considered secondary or bonus

1649
01:03:49,270 --> 01:03:47,599
science the osiris-rex mission the crime

1650
01:03:51,190 --> 01:03:49,280
science of course is to get that sample

1651
01:03:54,710 --> 01:03:51,200
home

1652
01:03:56,870 --> 01:03:54,720
okay so the conclusions um

1653
01:03:59,270 --> 01:03:56,880
this is a low-cost mission concept that

1654
01:04:01,190 --> 01:03:59,280
addresses strategic goals at nasa and

1655
01:04:02,390 --> 01:04:01,200
provides a potential discovery class

1656
01:04:06,470 --> 01:04:02,400
science

1657
01:04:08,470 --> 01:04:06,480
across a number of asteroid specialties

1658
01:04:09,670 --> 01:04:08,480
the mission would leverage investment in

1659
01:04:12,150 --> 01:04:09,680
existing

1660
01:04:13,349 --> 01:04:12,160
assets and co-manifesting with some

1661
01:04:14,710 --> 01:04:13,359
other launch would

1662
01:04:16,069 --> 01:04:14,720
even further improve the cost

1663
01:04:17,990 --> 01:04:16,079

effectiveness

1664
01:04:20,950 --> 01:04:18,000
i'll close by saying that uh near

1665
01:04:23,589 --> 01:04:20,960
shoemaker which i worked on was nasa's

1666
01:04:26,069 --> 01:04:23,599
only near rendezvous mission to date the

1667
01:04:28,390 --> 01:04:26,079
next one is going to be osiris-rex fully

1668
01:04:30,710 --> 01:04:28,400
a generation later and

1669
01:04:33,430 --> 01:04:30,720
so i think this opportunity

1670
01:04:35,510 --> 01:04:33,440
represents a one engine generation

1671
01:04:39,430 --> 01:04:35,520
chance to have a low-cost

1672
01:04:42,470 --> 01:04:41,349
and what i'll say in the context of the

1673
01:04:46,230 --> 01:04:42,480
arm

1674
01:04:47,270 --> 01:04:46,240
program is that this obviously can be

1675
01:04:48,710 --> 01:04:47,280
redone

1676
01:04:51,750 --> 01:04:48,720
with other missions like i mentioned

1677
01:04:54,549 --> 01:04:51,760
hiabu if you're going to say pick up a

1678
01:04:56,150 --> 01:04:54,559
rock at a larger asteroid after you've

1679
01:04:58,309 --> 01:04:56,160
gotten your rock and you're backed off

1680
01:05:00,549 --> 01:04:58,319
to a safe position then you can have

1681
01:05:01,589 --> 01:05:00,559
your impact or spacecraft come in and

1682
01:05:04,710 --> 01:05:01,599
that

1683
01:05:05,829 --> 01:05:04,720
asteroid retrieval vehicle could return

1684
01:05:08,150 --> 01:05:05,839
survey

1685
01:05:10,230 --> 01:05:08,160
the impact site and you go ahead and

1686
01:05:11,510 --> 01:05:10,240
measure the deflection that was induced

1687
01:05:13,829 --> 01:05:11,520
and so forth

1688
01:05:16,150 --> 01:05:13,839

so i'll stop there yes

1689
01:05:18,870 --> 01:05:16,160
thank you you have any uh questions for

1690
01:05:22,470 --> 01:05:18,880
for steve go ahead yes i'd like to ask

1691
01:05:24,710 --> 01:05:22,480
about the size of this spacecraft

1692
01:05:26,549 --> 01:05:24,720
you know there are many gto launches

1693
01:05:28,950 --> 01:05:26,559
about 20 a year so there certainly are a

1694
01:05:31,430 --> 01:05:28,960
lot of those although a lot of them are

1695
01:05:34,150 --> 01:05:31,440
not atlas did you consider

1696
01:05:36,150 --> 01:05:34,160
a smaller vehicle for two reasons one is

1697
01:05:39,190 --> 01:05:36,160
it might be able to be launched on more

1698
01:05:40,069 --> 01:05:39,200
gto launches on various launch vehicles

1699
01:05:42,069 --> 01:05:40,079
the other

1700
01:05:43,510 --> 01:05:42,079
if you're going to use that technique so

1701
01:05:45,190 --> 01:05:43,520
if you could work with a smaller vehicle

1702
01:05:46,950 --> 01:05:45,200
you'd have more flexibility there but

1703
01:05:48,549 --> 01:05:46,960
you'd also would gain something if you

1704
01:05:50,789 --> 01:05:48,559
had a smaller vehicle when you did the

1705
01:05:52,390 --> 01:05:50,799
impact because it would be

1706
01:05:53,589 --> 01:05:52,400
you would still be in it i suppose it

1707
01:05:55,109 --> 01:05:53,599
would still be a scientifically

1708
01:05:57,829 --> 01:05:55,119
interesting impact but there might be

1709
01:05:58,870 --> 01:05:57,839
less debris thrown out to worry people

1710
01:06:02,870 --> 01:05:58,880
with

1711
01:06:04,710 --> 01:06:02,880
spacecraft that's there one of the the

1712
01:06:06,950 --> 01:06:04,720
key objectives here is to produce a

1713
01:06:09,750 --> 01:06:06,960

measurable deflection that's both for

1714
01:06:12,309 --> 01:06:09,760
for the planetary defense aspect as well

1715
01:06:15,349 --> 01:06:12,319
as the scientific aspect and

1716
01:06:16,789 --> 01:06:15,359
this concept uh as i showed you

1717
01:06:18,630 --> 01:06:16,799
i didn't mention that's about a tenth of

1718
01:06:19,910 --> 01:06:18,640
a millimeter per second which allows us

1719
01:06:20,950 --> 01:06:19,920
to detect

1720
01:06:23,750 --> 01:06:20,960
the

1721
01:06:25,829 --> 01:06:23,760
deflection with about snr 10

1722
01:06:27,910 --> 01:06:25,839
after several after several weeks of

1723
01:06:29,270 --> 01:06:27,920
observing if we get smaller than that

1724
01:06:31,589 --> 01:06:29,280
we're going to start to lose the ability

1725
01:06:33,029 --> 01:06:31,599
to make that detection in terms of gto

1726
01:06:34,230 --> 01:06:33,039
launches

1727
01:06:35,750 --> 01:06:34,240
one of the options that's always

1728
01:06:37,670 --> 01:06:35,760
available if you're trying to get a ride

1729
01:06:38,470 --> 01:06:37,680
is to upgrade the launcher

1730
01:06:41,510 --> 01:06:38,480
to

1731
01:06:44,150 --> 01:06:41,520
spacecraft along with the primary

1732
01:06:49,589 --> 01:06:46,870
steve i've been hearing that spacex is

1733
01:06:53,109 --> 01:06:49,599
looking for a payload for its first deep

1734
01:06:55,349 --> 01:06:53,119
space test of the falcon 9 heavy have

1735
01:06:57,589 --> 01:06:55,359
you talked to them

1736
01:06:59,190 --> 01:06:57,599
no i haven't uh if they're looking for a

1737
01:07:02,309 --> 01:06:59,200
payload we would probably be able to

1738
01:07:04,309 --> 01:07:02,319

stack about 18 of these things

1739
01:07:06,549 --> 01:07:04,319
in the falcon 9 heavy so that could be

1740
01:07:08,390 --> 01:07:06,559
okay too

1741
01:07:10,630 --> 01:07:08,400
maybe we should do that

1742
01:07:12,390 --> 01:07:10,640
uh one really quick comment and then we

1743
01:07:14,230 --> 01:07:12,400
have to move on

1744
01:07:15,589 --> 01:07:14,240
let's see what one real quick i just

1745
01:07:18,069 --> 01:07:15,599
have to ask are you going to be sending

1746
01:07:20,230 --> 01:07:18,079
the video back to earth

1747
01:07:21,750 --> 01:07:20,240
uh the osiris-rex spacecraft will be

1748
01:07:23,670 --> 01:07:21,760
there it'll have the best view there

1749
01:07:25,670 --> 01:07:23,680
won't be any images returned from the

1750
01:07:27,349 --> 01:07:25,680
spacecraft did you have a camera right

1751
01:07:29,670 --> 01:07:27,359
for targeting

1752
01:07:31,589 --> 01:07:29,680
yeah with with not very good data

1753
01:07:32,789 --> 01:07:31,599
data delivery that's not the objective

1754
01:07:35,349 --> 01:07:32,799
we already know what this thing looks

1755
01:07:36,710 --> 01:07:35,359
like and uh the asteroid and we'll have

1756
01:07:38,309 --> 01:07:36,720
the best view from the osiris-rex

1757
01:07:39,750 --> 01:07:38,319
spacecraft

1758
01:07:40,789 --> 01:07:39,760
we won't get the data back unless we

1759
01:07:41,670 --> 01:07:40,799
miss

1760
01:07:47,589 --> 01:07:41,680
all right

1761
01:07:52,230 --> 01:07:49,510
okay so we're at the last uh

1762
01:07:53,430 --> 01:07:52,240
presentation for the day and um

1763
01:07:56,150 --> 01:07:53,440

the presenter will be joining us

1764
01:07:57,750 --> 01:07:56,160
virtually jonathan warble is a senior

1765
01:07:59,750 --> 01:07:57,760
research scientist in the flight systems

1766
01:08:01,750 --> 01:07:59,760
group at honeybee robotics where he

1767
01:08:04,230 --> 01:08:01,760
supports rd efforts and sensors and

1768
01:08:19,669 --> 01:08:04,240
integration systems

1769
01:08:30,229 --> 01:08:22,309
okay all right go ahead yep i can hear

1770
01:08:30,239 --> 01:08:34,630
can you guys hear me

1771
01:08:37,269 --> 01:08:35,430
okay

1772
01:08:39,749 --> 01:08:37,279
looks like i just got confirmation over

1773
01:08:41,749 --> 01:08:39,759
the uh i am

1774
01:08:43,669 --> 01:08:41,759
all right

1775
01:08:44,630 --> 01:08:43,679
so yeah thank you for the introduction

1776
01:08:47,269 --> 01:08:44,640
uh

1777
01:08:49,110 --> 01:08:47,279
today i'll be presenting on honeybee

1778
01:08:50,470 --> 01:08:49,120
robotics technologies that can support

1779
01:08:52,390 --> 01:08:50,480
uh

1780
01:08:54,070 --> 01:08:52,400
deflection demonstration

1781
01:08:55,430 --> 01:08:54,080
uh as i'm presenting remotely please let

1782
01:08:57,349 --> 01:08:55,440
me know if the audio is coming through

1783
01:08:59,030 --> 01:08:57,359
clearly and uh during my talk please

1784
01:09:01,030 --> 01:08:59,040
relay any questions or injections

1785
01:09:02,390 --> 01:09:01,040
through the im window as i'll have my

1786
01:09:07,829 --> 01:09:02,400
audio off

1787
01:09:11,430 --> 01:09:10,149
all right

1788
01:09:13,269 --> 01:09:11,440

so

1789
01:09:15,590 --> 01:09:13,279
i began i'd like to provide a bit of

1790
01:09:19,030 --> 01:09:15,600
background on honeybee robotics

1791
01:09:20,870 --> 01:09:19,040
founded in 1983 by steve gorban

1792
01:09:23,189 --> 01:09:20,880
chris chapman honeybee robotics

1793
01:09:25,430 --> 01:09:23,199
spacecraft mechanisms corporation is a

1794
01:09:27,110 --> 01:09:25,440
privately owned small business committed

1795
01:09:28,950 --> 01:09:27,120
to developing high reliability

1796
01:09:30,870 --> 01:09:28,960
mechanical and electromechanical

1797
01:09:32,950 --> 01:09:30,880
products for the us government as well

1798
01:09:35,990 --> 01:09:32,960
as for the private aerospace and space

1799
01:09:38,390 --> 01:09:36,000
sectors robotics has offices in pasadena

1800
01:09:40,070 --> 01:09:38,400
california longmont colorado and our

1801
01:09:42,709 --> 01:09:40,080
headquarters in new york

1802
01:09:45,510 --> 01:09:42,719
we're celebrating 30 years of developing

1803
01:09:47,590 --> 01:09:45,520
space systems this is included involved

1804
01:09:49,430 --> 01:09:47,600
in a number of nasa missions

1805
01:09:52,870 --> 01:09:49,440
we developed the rock abrasion tools for

1806
01:09:55,510 --> 01:09:52,880
the 2003 mars exploration rovers 2007

1807
01:09:57,669 --> 01:09:55,520
mars phoenix lander the tega

1808
01:09:59,990 --> 01:09:57,679
dust cover and icy soil acquisition

1809
01:10:01,350 --> 01:10:00,000
device 2011 mars science laboratory we

1810
01:10:04,070 --> 01:10:01,360
delivered the robotic sample

1811
01:10:06,310 --> 01:10:04,080
manipulation system and the dust removal

1812
01:10:08,149 --> 01:10:06,320
tool end effector so we currently have

1813
01:10:09,830 --> 01:10:08,159

six gadgets on mars and have

1814
01:10:12,070 --> 01:10:09,840
successfully completed over 300

1815
01:10:13,750 --> 01:10:12,080
excavations on the martian surface i

1816
01:10:16,149 --> 01:10:13,760
believe this work is helping pave the

1817
01:10:17,750 --> 01:10:16,159
way for human exploration of ours and

1818
01:10:19,430 --> 01:10:17,760
we're open to support both robotic and

1819
01:10:21,910 --> 01:10:19,440
human exploration of asteroids as well

1820
01:10:25,990 --> 01:10:21,920
as deflection of asteroids

1821
01:10:26,000 --> 01:10:29,350
let's see next slide

1822
01:10:33,669 --> 01:10:31,510
at this workshop honey bee robotics is

1823
01:10:35,990 --> 01:10:33,679
presenting in a number of topic areas

1824
01:10:37,750 --> 01:10:36,000
including uh topic to the asteroid

1825
01:10:39,990 --> 01:10:37,760
redirection systems and topic three

1826
01:10:40,950 --> 01:10:40,000
asteroids deflection demonstration topic

1827
01:10:43,110 --> 01:10:40,960
four

1828
01:10:45,430 --> 01:10:43,120
asteroid capture systems and topic five

1829
01:10:47,510 --> 01:10:45,440
crew systems for asteroid exploration

1830
01:10:50,149 --> 01:10:47,520
and we also presented

1831
01:10:51,350 --> 01:10:50,159
briefly on topic 6 partnerships i'm

1832
01:10:53,030 --> 01:10:51,360
going to briefly touch on some of these

1833
01:10:55,110 --> 01:10:53,040
technologies and the other topic areas

1834
01:10:57,350 --> 01:10:55,120
is there's overlap

1835
01:10:59,110 --> 01:10:57,360
in their applications but i'll focus on

1836
01:11:00,630 --> 01:10:59,120
their application to topic three for

1837
01:11:02,630 --> 01:11:00,640
this session asteroid deflection

1838
01:11:04,630 --> 01:11:02,640

demonstration

1839
01:11:06,630 --> 01:11:04,640
so the way we see our technologies they

1840
01:11:09,030 --> 01:11:06,640
enable us to interact with the asteroid

1841
01:11:11,350 --> 01:11:09,040
in different ways uh from helping us to

1842
01:11:14,790 --> 01:11:11,360
uh if you will better see it touch it

1843
01:11:16,390 --> 01:11:14,800
anchor to it etc

1844
01:11:18,310 --> 01:11:16,400
many of the technologies i'll present

1845
01:11:20,550 --> 01:11:18,320
have their primary utility and

1846
01:11:22,870 --> 01:11:20,560
deflection missions missions seeking to

1847
01:11:25,830 --> 01:11:22,880
make physical contact with the asteroid

1848
01:11:28,950 --> 01:11:25,840
so please bear that in mind

1849
01:11:30,310 --> 01:11:28,960
regarding the ability to see it

1850
01:11:32,390 --> 01:11:30,320
honeybees

1851
01:11:34,470 --> 01:11:32,400
developed laser induced breakdown

1852
01:11:36,630 --> 01:11:34,480
spectroscopy libs

1853
01:11:38,630 --> 01:11:36,640
instrumentation as well as 3d lidar the

1854
01:11:40,310 --> 01:11:38,640
former enables acquisition of

1855
01:11:42,870 --> 01:11:40,320
composition information prior to

1856
01:11:45,510 --> 01:11:42,880
engaging the asteroid and the latter

1857
01:11:47,750 --> 01:11:45,520
supports proximity operations

1858
01:11:49,830 --> 01:11:47,760
libs works by using a little vaporized

1859
01:11:52,550 --> 01:11:49,840
and ionized surface material and when

1860
01:11:54,390 --> 01:11:52,560
that plasma puff cools and recombines it

1861
01:11:55,669 --> 01:11:54,400
emits a spectrum representative of its

1862
01:11:57,830 --> 01:11:55,679
composition

1863
01:11:59,270 --> 01:11:57,840

this allows identification of surface

1864
01:12:01,669 --> 01:11:59,280
materials having

1865
01:12:02,470 --> 01:12:01,679
without having to collect them

1866
01:12:06,390 --> 01:12:02,480
and

1867
01:12:07,350 --> 01:12:06,400
version

1868
01:12:09,270 --> 01:12:07,360
which is

1869
01:12:11,350 --> 01:12:09,280
laser-induced breakdown spectroscopy

1870
01:12:13,189 --> 01:12:11,360
done at a long range

1871
01:12:16,790 --> 01:12:13,199
the spacecraft can better characterize

1872
01:12:19,430 --> 01:12:16,800
the asteroid before interacting with it

1873
01:12:21,430 --> 01:12:19,440
the 3d lidar vision system acts much

1874
01:12:23,830 --> 01:12:21,440
like the human vision with its small

1875
01:12:26,070 --> 01:12:23,840
area of high resolution surrounded by a

1876
01:12:27,510 --> 01:12:26,080
large area of low resolution for spatial

1877
01:12:29,510 --> 01:12:27,520
contacts

1878
01:12:31,590 --> 01:12:29,520
this will help for proximity operations

1879
01:12:33,270 --> 01:12:31,600
if the mission includes interfacing with

1880
01:12:37,510 --> 01:12:33,280
the asteroid surface and touching down

1881
01:12:41,270 --> 01:12:39,350
alternatively

1882
01:12:43,110 --> 01:12:41,280
we can impact it and impactrix

1883
01:12:44,709 --> 01:12:43,120
technology will be useful prior to

1884
01:12:45,750 --> 01:12:44,719
engagement with asteroids has been

1885
01:12:47,270 --> 01:12:45,760
discussed

1886
01:12:49,110 --> 01:12:47,280
throughout the

1887
01:12:51,510 --> 01:12:49,120
conference or workshop

1888
01:12:57,110 --> 01:12:51,520

for

1889
01:12:59,110 --> 01:12:57,120
about the material composition but be

1890
01:13:01,270 --> 01:12:59,120
difficult to determine the

1891
01:13:03,110 --> 01:13:01,280
structural strength of the asteroid

1892
01:13:05,750 --> 01:13:03,120
which is very important with physical

1893
01:13:08,470 --> 01:13:05,760
contact being planned or for an

1894
01:13:10,390 --> 01:13:08,480
larger impact or deflection the physical

1895
01:13:12,950 --> 01:13:10,400
properties of asteroid are poorly

1896
01:13:15,189 --> 01:13:12,960
understood are likely poorly understood

1897
01:13:17,750 --> 01:13:15,199
and could range in strength from

1898
01:13:19,430 --> 01:13:17,760
highly competent basal to weak loose

1899
01:13:22,550 --> 01:13:19,440
rubble um

1900
01:13:24,550 --> 01:13:22,560
so the c-cross impact is shown left

1901
01:13:28,070 --> 01:13:24,560
allows setting the composition of the

1902
01:13:29,350 --> 01:13:28,080
asteroid from a distance it utilizes a

1903
01:13:31,030 --> 01:13:29,360
probe launched from an orbiting

1904
01:13:33,590 --> 01:13:31,040
spacecraft to impact the surface and

1905
01:13:35,990 --> 01:13:33,600
collect scientific data

1906
01:13:37,350 --> 01:13:36,000
measuring the forces at and after impact

1907
01:13:38,950 --> 01:13:37,360
to gain knowledge about the asteroids

1908
01:13:41,350 --> 01:13:38,960
and physical properties

1909
01:13:44,070 --> 01:13:41,360
this technology leverages from a similar

1910
01:13:45,990 --> 01:13:44,080
mission that's been demonstrated

1911
01:13:47,669 --> 01:13:46,000
has demonstrated success the lacrosse

1912
01:13:50,070 --> 01:13:47,679
the lunar crater

1913
01:13:52,870 --> 01:13:50,080

observation and sensing satellite the

1914
01:13:55,030 --> 01:13:52,880
raptor probe which was launched from the

1915
01:13:57,110 --> 01:13:55,040
lro lunar reconnaissance orbiter

1916
01:13:58,630 --> 01:13:57,120
spacecraft and successfully gathered

1917
01:14:00,550 --> 01:13:58,640
data about the moon

1918
01:14:03,189 --> 01:14:00,560
a c-cross probe is a smaller instrument

1919
01:14:05,669 --> 01:14:03,199
sphere like less than 10 20 kilograms uh

1920
01:14:07,590 --> 01:14:05,679
them is designed to impact a commodore

1921
01:14:09,030 --> 01:14:07,600
asteroid at about 10 meters per second

1922
01:14:11,990 --> 01:14:09,040
and measure the forces at an after

1923
01:14:14,470 --> 01:14:12,000
impact with a high degree accuracy

1924
01:14:16,870 --> 01:14:14,480
so alternatively to impacting it we

1925
01:14:18,550 --> 01:14:16,880
could just touch it um

1926
01:14:20,310 --> 01:14:18,560
and here the touch and go surface

1927
01:14:21,990 --> 01:14:20,320
sampler which is shown

1928
01:14:24,229 --> 01:14:22,000
uh first figure it was developed by

1929
01:14:27,030 --> 01:14:24,239
honeybee robotics to trill and acquire a

1930
01:14:29,189 --> 01:14:27,040
sample of regolith up to about 50 cc's

1931
01:14:31,270 --> 01:14:29,199
consolidated materials

1932
01:14:32,470 --> 01:14:31,280
with a you know unconfined compressive

1933
01:14:35,669 --> 01:14:32,480
strength of less than about 10

1934
01:14:37,830 --> 01:14:35,679
megapascals while the cutters penetrate

1935
01:14:39,990 --> 01:14:37,840
to a depth of one to four centimeters

1936
01:14:41,350 --> 01:14:40,000
again this is a useful capability if

1937
01:14:42,550 --> 01:14:41,360
physical contact is planned for

1938
01:14:44,310 --> 01:14:42,560

deflection

1939
01:14:46,709 --> 01:14:44,320
physical properties of asteroids again

1940
01:14:48,149 --> 01:14:46,719
will likely be poorly understood and

1941
01:14:49,189 --> 01:14:48,159
could range

1942
01:14:51,189 --> 01:14:49,199
from

1943
01:14:53,189 --> 01:14:51,199
you know loose to well consolidated the

1944
01:14:54,390 --> 01:14:53,199
system is reusable you can store samples

1945
01:14:55,910 --> 01:14:54,400
inside

1946
01:14:58,390 --> 01:14:55,920
individual containers for instance to

1947
01:14:59,430 --> 01:14:58,400
analysis or sample return if the time

1948
01:15:01,270 --> 01:14:59,440
permits

1949
01:15:03,189 --> 01:15:01,280
the touch and go surface sampler

1950
01:15:05,030 --> 01:15:03,199
consists of a high speed sampling head

1951
01:15:07,030 --> 01:15:05,040
attached to the end of a flexible shaft

1952
01:15:09,590 --> 01:15:07,040
as shown in the second figure

1953
01:15:11,669 --> 01:15:09,600
the sampling head rotates its counter

1954
01:15:14,790 --> 01:15:11,679
rotating cutters at a speed of 5000 to

1955
01:15:16,310 --> 01:15:14,800
8000 rpm and consumes about 20 watts of

1956
01:15:18,149 --> 01:15:16,320
30 watts of power

1957
01:15:20,870 --> 01:15:18,159
the mass of the current prototype is

1958
01:15:23,189 --> 01:15:20,880
around 450 grams of volumetric envelope

1959
01:15:26,149 --> 01:15:23,199
of 50 millimeters by 75 millimeters by

1960
01:15:28,229 --> 01:15:26,159
150 millimeters excluding the drill

1961
01:15:29,830 --> 01:15:28,239
a prototype was developed and tested in

1962
01:15:30,790 --> 01:15:29,840
a laboratory ambient environment on

1963
01:15:33,110 --> 01:15:30,800

various

1964
01:15:34,790 --> 01:15:33,120
target materials the tgss was

1965
01:15:39,110 --> 01:15:34,800
demonstrated

1966
01:15:41,430 --> 01:15:39,120
rate of 30 cc's per second

1967
01:15:43,270 --> 01:15:41,440
and consolidated

1968
01:15:45,590 --> 01:15:43,280
in consolidated shock with strength of

1969
01:15:47,910 --> 01:15:45,600
10 megapascals at a rate of about five a

1970
01:15:49,510 --> 01:15:47,920
half of cc per second

1971
01:15:51,430 --> 01:15:49,520
a number of microgravity tests have

1972
01:15:52,950 --> 01:15:51,440
shown that the tgss can sample both

1973
01:15:54,790 --> 01:15:52,960
consolidated and unconsolidated

1974
01:15:56,550 --> 01:15:54,800
materials and includes a

1975
01:15:57,590 --> 01:15:56,560
sample canister changeout system that

1976
01:15:59,270 --> 01:15:57,600
allows

1977
01:16:02,070 --> 01:15:59,280
sampling of multiple sites with minimal

1978
01:16:04,630 --> 01:16:02,080
cross contamination if desired

1979
01:16:06,709 --> 01:16:04,640
in addition you can

1980
01:16:08,709 --> 01:16:06,719
harpoon sample

1981
01:16:10,709 --> 01:16:08,719
surface it's another technology worked

1982
01:16:13,910 --> 01:16:10,719
on for robotic sample acquisition for

1983
01:16:17,910 --> 01:16:16,149
surface of an asteroid and it's the arp

1984
01:16:19,430 --> 01:16:17,920
ar probe

1985
01:16:21,270 --> 01:16:19,440
which would bring a sample back to an

1986
01:16:22,709 --> 01:16:21,280
orbiting spacecraft providing

1987
01:16:25,110 --> 01:16:22,719
composition information before the

1988
01:16:26,790 --> 01:16:25,120

parent craft engages the asteroid

1989
01:16:28,790 --> 01:16:26,800
this our pruning drilling technology

1990
01:16:31,030 --> 01:16:28,800
leads us into one of honeybees

1991
01:16:33,990 --> 01:16:31,040
strengths

1992
01:16:36,149 --> 01:16:34,000
and that is robotic drilling i'll see

1993
01:16:37,510 --> 01:16:36,159
you next slide

1994
01:16:40,229 --> 01:16:37,520
drilling is often the method of choice

1995
01:16:42,390 --> 01:16:40,239
for penetrating hard rock and this may

1996
01:16:44,550 --> 01:16:42,400
be of interest to anchoring an asteroid

1997
01:16:47,669 --> 01:16:44,560
redirection spacecraft the vast majority

1998
01:16:50,790 --> 01:16:47,679
applications drilling employs the

1999
01:16:52,709 --> 01:16:50,800
turning of a hardened bit which requires

2000
01:16:54,709 --> 01:16:52,719
a certain amount of downforce typically

2001
01:16:56,550 --> 01:16:54,719
referred to as weight on bit

2002
01:16:58,630 --> 01:16:56,560
in a low gravity environment weight on

2003
01:17:00,390 --> 01:16:58,640
bit can be severely limited it must be

2004
01:17:02,070 --> 01:17:00,400
provided either by spacecraft thrusters

2005
01:17:04,149 --> 01:17:02,080
or an anchored base for the drill to

2006
01:17:06,310 --> 01:17:04,159
push or rather pull against

2007
01:17:08,229 --> 01:17:06,320
rotary percussive drilling action

2008
01:17:11,910 --> 01:17:08,239
can be employed to circumvent the need

2009
01:17:13,110 --> 01:17:11,920
for prohibitively high weight on bit

2010
01:17:14,630 --> 01:17:13,120
now the

2011
01:17:16,070 --> 01:17:14,640
feasibility of drilling into small

2012
01:17:17,910 --> 01:17:16,080
bodies with low weight and that has been

2013
01:17:19,830 --> 01:17:17,920

demonstrated i talked about this in a

2014
01:17:21,669 --> 01:17:19,840
earlier talk so if anybody's joined me

2015
01:17:23,350 --> 01:17:21,679
from there please uh

2016
01:17:26,790 --> 01:17:23,360
bear with me

2017
01:17:28,550 --> 01:17:26,800
and it's been done using relevant analog

2018
01:17:29,750 --> 01:17:28,560
stand-ins for likely asteroid surface

2019
01:17:31,189 --> 01:17:29,760
materials

2020
01:17:33,510 --> 01:17:31,199
such testing demonstrates that the

2021
01:17:35,430 --> 01:17:33,520
feasibility of drilling into a small

2022
01:17:37,110 --> 01:17:35,440
body with low weight on bit is dependent

2023
01:17:39,350 --> 01:17:37,120
upon the strength of the materials

2024
01:17:41,189 --> 01:17:39,360
comprising the small body

2025
01:17:42,950 --> 01:17:41,199
drilling in

2026
01:17:44,470 --> 01:17:42,960
low strength materials such as plaster

2027
01:17:46,390 --> 01:17:44,480
or limestone is feasible using a

2028
01:17:48,790 --> 01:17:46,400
commercial commercially available drill

2029
01:17:51,030 --> 01:17:48,800
with a 1.6 millimeter diameter bit as

2030
01:17:53,110 --> 01:17:51,040
little as five newton's weight on bit

2031
01:17:55,830 --> 01:17:53,120
plaster and limestone have a

2032
01:17:58,229 --> 01:17:55,840
unconfined compressive strength of about

2033
01:18:01,270 --> 01:17:58,239
eight megapascals and 40 megapascals

2034
01:18:04,229 --> 01:18:01,280
respectively we should be representative

2035
01:18:06,550 --> 01:18:04,239
of a c-type asteroid however higher

2036
01:18:08,550 --> 01:18:06,560
strength materials such as those

2037
01:18:10,550 --> 01:18:08,560
of an s-type asteroid

2038
01:18:12,870 --> 01:18:10,560

cannot be drilled as readily

2039
01:18:15,110 --> 01:18:12,880
with that low down force so for instance

2040
01:18:17,430 --> 01:18:15,120
120 megapascal

2041
01:18:21,270 --> 01:18:17,440
the salt is representative of the upper

2042
01:18:24,709 --> 01:18:23,270
materials and cannot be penetrated with

2043
01:18:26,550 --> 01:18:24,719
that low weight on bit it's not to say

2044
01:18:29,990 --> 01:18:26,560
you can't do it but

2045
01:18:34,870 --> 01:18:32,229
ahead of time and have contingencies if

2046
01:18:38,790 --> 01:18:36,550
wind up with on site is not what you

2047
01:18:41,350 --> 01:18:38,800
expected

2048
01:18:44,310 --> 01:18:41,360
now the next thing is uh we can

2049
01:18:47,030 --> 01:18:44,320
uh inhale it and uh

2050
01:18:48,550 --> 01:18:47,040
and uh spit it out and i'll get to that

2051
01:18:49,830 --> 01:18:48,560
while we're not proposing to vacuum the

2052
01:18:52,149 --> 01:18:49,840
asteroid out of existence this

2053
01:18:53,990 --> 01:18:52,159
technology is presented as part of the

2054
01:18:56,149 --> 01:18:54,000
crew systems and may provide utility for

2055
01:18:57,510 --> 01:18:56,159
a deflection demonstration

2056
01:18:59,669 --> 01:18:57,520
as mentioned in

2057
01:19:01,189 --> 01:18:59,679
talk on utilization of surface materials

2058
01:19:02,790 --> 01:19:01,199
for asteroid deflection it may be

2059
01:19:05,189 --> 01:19:02,800
possible to use the asteroid bulk

2060
01:19:06,870 --> 01:19:05,199
material as a reaction mass

2061
01:19:09,430 --> 01:19:06,880
this system supports collection of loose

2062
01:19:11,350 --> 01:19:09,440
material which can be fed into a mass

2063
01:19:13,270 --> 01:19:11,360

accelerator so shown on the left we rely

2064
01:19:15,350 --> 01:19:13,280
on injecting pressurized gas into the

2065
01:19:17,430 --> 01:19:15,360
top two centimeters of regolith and then

2066
01:19:20,709 --> 01:19:17,440
capture the regolith propelled upwards

2067
01:19:23,830 --> 01:19:20,719
by the escaping gas and do it for two

2068
01:19:25,910 --> 01:19:23,840
the pneumatic approach can be used

2069
01:19:28,070 --> 01:19:25,920
and is ideally suited to obtaining both

2070
01:19:29,030 --> 01:19:28,080
small samples for scientific analysis as

2071
01:19:30,630 --> 01:19:29,040
well as

2072
01:19:33,910 --> 01:19:30,640
bulk sample for

2073
01:19:36,630 --> 01:19:33,920
mining and processing of resources

2074
01:19:39,430 --> 01:19:36,640
gas could be supplied by electrolyzing

2075
01:19:42,229 --> 01:19:39,440
water and oxygen

2076
01:19:46,229 --> 01:19:42,239
for bulk right with mining a potential

2077
01:19:49,750 --> 01:19:47,590
a system that has been initially

2078
01:19:52,470 --> 01:19:49,760
developed for lunar regulator then matic

2079
01:19:55,189 --> 01:19:52,480
regolith miner is simulated

2080
01:19:56,950 --> 01:19:55,199
to a con is similar to a conventional

2081
01:19:59,189 --> 01:19:56,960
vacuum cleaner however instead of

2082
01:20:00,870 --> 01:19:59,199
creating suction at the nozzle mouth a

2083
01:20:02,950 --> 01:20:00,880
compressed gas is injected moving the

2084
01:20:05,270 --> 01:20:02,960
captured soil with it

2085
01:20:06,870 --> 01:20:05,280
and within the nozzle up the tube and

2086
01:20:09,510 --> 01:20:06,880
through the cyclone separator into a

2087
01:20:11,350 --> 01:20:09,520
soil bin uh shown right is the pneumatic

2088
01:20:12,390 --> 01:20:11,360

excavator integrated into the nasa ames

2089
01:20:15,270 --> 01:20:12,400
center

2090
01:20:16,870 --> 01:20:15,280
uh k10 mini platform the system has been

2091
01:20:19,750 --> 01:20:16,880
successfully tested in a three meter

2092
01:20:21,669 --> 01:20:19,760
long bed filled with gt1 soil stimulant

2093
01:20:24,310 --> 01:20:21,679
within a three and a half meter vacuum

2094
01:20:28,790 --> 01:20:26,629
now in addition to inhaling it and

2095
01:20:30,550 --> 01:20:28,800
sitting it out is a way

2096
01:20:32,390 --> 01:20:30,560
to deflect the asteroid

2097
01:20:34,709 --> 01:20:32,400
we can also lasso it

2098
01:20:36,470 --> 01:20:34,719
honeybee has done work in grappling with

2099
01:20:37,669 --> 01:20:36,480
spacecraft in orbit and our lasso

2100
01:20:39,350 --> 01:20:37,679
technology

2101
01:20:41,270 --> 01:20:39,360
can be used either to anchor to

2102
01:20:44,870 --> 01:20:41,280
protrusions on the surface that are part

2103
01:20:46,950 --> 01:20:44,880
of the larger boulder or asteroid itself

2104
01:20:49,110 --> 01:20:46,960
much like slinging a horn when rock

2105
01:20:50,870 --> 01:20:49,120
climbing in this case the technology

2106
01:20:52,629 --> 01:20:50,880
could be used for spacecraft anchoring

2107
01:20:54,950 --> 01:20:52,639
and transfer forces and torques to the

2108
01:20:58,310 --> 01:20:54,960
asteroid itself and shown above is

2109
01:21:00,310 --> 01:20:58,320
basically a lasso hence its namesake

2110
01:21:02,870 --> 01:21:00,320
and it's cinching down on a expansion

2111
01:21:04,229 --> 01:21:02,880
nozzle um and then picking it up in one

2112
01:21:06,709 --> 01:21:04,239
g

2113
01:21:08,870 --> 01:21:06,719

a fairly simple concept but uh if the

2114
01:21:10,390 --> 01:21:08,880
asteroid is expected to present itself

2115
01:21:12,229 --> 01:21:10,400
with the opportunity it could be fairly

2116
01:21:15,750 --> 01:21:12,239
effective

2117
01:21:17,430 --> 01:21:15,760
uh we can also anchor to it

2118
01:21:20,390 --> 01:21:17,440
now honeybee robots has a number of

2119
01:21:22,470 --> 01:21:20,400
technologies that support the ability of

2120
01:21:24,310 --> 01:21:22,480
spacecraft to anchor to the surface in

2121
01:21:26,550 --> 01:21:24,320
this microgravity environment anchoring

2122
01:21:28,390 --> 01:21:26,560
of equipment is crucial allowing it to

2123
01:21:30,390 --> 01:21:28,400
secretly apply weight on bit for

2124
01:21:32,550 --> 01:21:30,400
trillion or lateral forces for d spin

2125
01:21:34,310 --> 01:21:32,560
depending on the count offs honeybee has

2126
01:21:35,910 --> 01:21:34,320
a long history in anchoring and has

2127
01:21:37,350 --> 01:21:35,920
developed a number of approaches

2128
01:21:38,550 --> 01:21:37,360
including hard rock drilling and

2129
01:21:40,790 --> 01:21:38,560
hammering

2130
01:21:43,430 --> 01:21:40,800
for sending anchors with preliminary

2131
01:21:45,270 --> 01:21:43,440
feasibility tests yielding

2132
01:21:46,550 --> 01:21:45,280
positive results now testing was

2133
01:21:48,629 --> 01:21:46,560
performed with a

2134
01:21:50,550 --> 01:21:48,639
3.8 millimeter nail

2135
01:21:52,310 --> 01:21:50,560
a traditional hammer

2136
01:21:55,350 --> 01:21:52,320
as well as an off-the-shelf nail gun and

2137
01:21:58,070 --> 01:21:55,360
that was into 8 megapascal plaster 40

2138
01:22:00,550 --> 01:21:58,080

megapascal limestone and 120 megapascal

2139
01:22:02,149 --> 01:22:00,560
basalt as you'd expect the nail only

2140
01:22:03,830 --> 01:22:02,159
penetrated the

2141
01:22:05,669 --> 01:22:03,840
flap successfully with the other two it

2142
01:22:06,950 --> 01:22:05,679
failed but the nail gun on the other

2143
01:22:09,030 --> 01:22:06,960
hand was powerful enough to drive a

2144
01:22:10,950 --> 01:22:09,040
short nail into all three rock types

2145
01:22:12,790 --> 01:22:10,960
this type of research

2146
01:22:14,149 --> 01:22:12,800
has shown that

2147
01:22:16,310 --> 01:22:14,159
you might be able to anchor fairly

2148
01:22:18,950 --> 01:22:16,320
quickly to the surface of the asteroid

2149
01:22:20,790 --> 01:22:18,960
and it was made possible by honeybees

2150
01:22:23,910 --> 01:22:20,800
test facilities out in pasadena where we

2151
01:22:26,310 --> 01:22:23,920
have a large library of rock samples

2152
01:22:27,830 --> 01:22:26,320
allowing tests of drills and ink drain

2153
01:22:29,430 --> 01:22:27,840
schemes

2154
01:22:31,430 --> 01:22:29,440
honey bee has also worked on fluid

2155
01:22:33,189 --> 01:22:31,440
anchors and that allows anchoring to

2156
01:22:35,030 --> 01:22:33,199
featured surfaces with the benefit that

2157
01:22:36,709 --> 01:22:35,040
the anchor deployment does not exert any

2158
01:22:38,070 --> 01:22:36,719
force that would be

2159
01:22:40,629 --> 01:22:38,080
it would require reaction by the

2160
01:22:42,310 --> 01:22:40,639
spacecraft and the fluid anchor

2161
01:22:44,470 --> 01:22:42,320
approach of wetting fluids such as foam

2162
01:22:46,310 --> 01:22:44,480
cement epoxy et cetera is injected onto

2163
01:22:47,430 --> 01:22:46,320

a surface or under the

2164
01:22:49,510 --> 01:22:47,440
a hollow

2165
01:22:50,550 --> 01:22:49,520
spike on the foot pad

2166
01:22:52,629 --> 01:22:50,560
and

2167
01:22:54,950 --> 01:22:52,639
if applied to the surface the goal of

2168
01:22:57,270 --> 01:22:54,960
the fluid is simply that a fluid anchors

2169
01:22:59,030 --> 01:22:57,280
simply to inject an adhesive cushion

2170
01:23:00,709 --> 01:22:59,040
between the rock and the pad the ground

2171
01:23:02,470 --> 01:23:00,719
pad

2172
01:23:05,189 --> 01:23:02,480
otherwise

2173
01:23:06,629 --> 01:23:05,199
if it's injected into the ground the

2174
01:23:08,390 --> 01:23:06,639
fluid would go deeper into the loose

2175
01:23:10,149 --> 01:23:08,400
gravel or soil allowing the anchor to

2176
01:23:12,550 --> 01:23:10,159
engage larger volume of asteroid

2177
01:23:14,310 --> 01:23:12,560
material forming a composite footing

2178
01:23:16,390 --> 01:23:14,320
glue mixed with the soil

2179
01:23:18,950 --> 01:23:16,400
now the self-opposing multi-mode anchor

2180
01:23:20,550 --> 01:23:18,960
shown in this slide allows payloads and

2181
01:23:23,030 --> 01:23:20,560
equipment to be securely anchored to the

2182
01:23:25,750 --> 01:23:23,040
surface with minimal applied force by

2183
01:23:27,910 --> 01:23:25,760
laterally opposing the angled anchors

2184
01:23:29,590 --> 01:23:27,920
so there's a number of ways

2185
01:23:30,870 --> 01:23:29,600
that we feel we can anchor to the

2186
01:23:33,350 --> 01:23:30,880
surface of a

2187
01:23:36,149 --> 01:23:33,360
asteroid in order to

2188
01:23:37,830 --> 01:23:36,159

transmit forces and torques to it

2189
01:23:39,110 --> 01:23:37,840
so in conclusion i've presented a number

2190
01:23:41,189 --> 01:23:39,120
of technologies that can support an

2191
01:23:42,470 --> 01:23:41,199
asteroid redirection deflection

2192
01:23:44,229 --> 01:23:42,480
demonstration

2193
01:23:46,310 --> 01:23:44,239
principally involving

2194
01:23:48,470 --> 01:23:46,320
physical contact with the asteroid

2195
01:23:50,149 --> 01:23:48,480
now i'd like to open it for questions uh

2196
01:23:52,310 --> 01:23:50,159
and also i encourage you to visit our

2197
01:23:56,629 --> 01:23:52,320
website it's at the bottom of the page

2198
01:24:01,430 --> 01:23:59,669
all right thank you jonathan um

2199
01:24:03,350 --> 01:24:01,440
i'm not sure what the delay is here with

2200
01:24:04,629 --> 01:24:03,360
questions but are there 10 seconds okay

2201
01:24:07,590 --> 01:24:04,639
about 10 seconds does anybody have a

2202
01:24:09,910 --> 01:24:07,600
question for jonathan

2203
01:24:10,790 --> 01:24:09,920
is there any online

2204
01:24:12,709 --> 01:24:10,800
um

2205
01:24:14,390 --> 01:24:12,719
yeah basically jonathan we're

2206
01:24:16,950 --> 01:24:14,400
we don't have any questions here and we

2207
01:24:17,990 --> 01:24:16,960
appreciate uh your participation and the

2208
01:24:20,629 --> 01:24:18,000
information i think there's some

2209
01:24:22,229 --> 01:24:20,639
applicability of these different types

2210
01:24:25,189 --> 01:24:22,239
of devices for

2211
01:24:27,110 --> 01:24:25,199
uh potential demonstration um either

2212
01:24:29,189 --> 01:24:27,120
either as part of a demo uh planetary

2213
01:24:30,629 --> 01:24:29,199

defense or potentially just as a

2214
01:24:37,189 --> 01:24:30,639
prototype

2215
01:24:40,950 --> 01:24:38,070
so

2216
01:24:42,790 --> 01:24:40,960
um i know it's late

2217
01:24:45,030 --> 01:24:42,800
but we've got about

2218
01:24:47,270 --> 01:24:45,040
about 20 minutes um

2219
01:24:48,550 --> 01:24:47,280
before we wrap up the session today

2220
01:24:50,790 --> 01:24:48,560
and

2221
01:24:51,990 --> 01:24:50,800
welcome thank you

2222
01:24:52,790 --> 01:24:52,000
is

2223
01:24:55,910 --> 01:24:52,800
um

2224
01:24:57,350 --> 01:24:55,920
open the floor up uh for for comments

2225
01:24:59,430 --> 01:24:57,360
particularly if folks are not going to

2226
01:25:01,030 --> 01:24:59,440
be here in the morning

2227
01:25:02,310 --> 01:25:01,040
make sure make sure that you if you've

2228
01:25:05,189 --> 01:25:02,320
got something

2229
01:25:06,950 --> 01:25:05,199
that you want to convey and discuss

2230
01:25:08,790 --> 01:25:06,960
i have a few ideas or

2231
01:25:10,390 --> 01:25:08,800
conversation starters for this afternoon

2232
01:25:14,790 --> 01:25:10,400
but um

2233
01:25:14,800 --> 01:25:17,669
don't okay

2234
01:25:21,590 --> 01:25:19,910
quiet quiet okay

2235
01:25:23,990 --> 01:25:21,600
um

2236
01:25:25,430 --> 01:25:24,000
i guess i'll start out is is i think

2237
01:25:27,350 --> 01:25:25,440
there's

2238
01:25:28,870 --> 01:25:27,360

the goal of what we want to provide here

2239
01:25:31,189 --> 01:25:28,880
are some findings and recommendations

2240
01:25:34,070 --> 01:25:31,199
from this session about

2241
01:25:36,070 --> 01:25:34,080
out of the workshop for

2242
01:25:37,750 --> 01:25:36,080
areas that we think as a group

2243
01:25:41,990 --> 01:25:37,760
should go forward

2244
01:25:48,229 --> 01:25:44,229
it basically goes i think into a couple

2245
01:25:51,590 --> 01:25:50,310
different approaches one is is the

2246
01:25:53,189 --> 01:25:51,600
direct

2247
01:25:55,030 --> 01:25:53,199
demonstration of a planetary defense

2248
01:25:57,590 --> 01:25:55,040
technique um

2249
01:25:59,669 --> 01:25:57,600
and that kind of breaks down into

2250
01:26:02,149 --> 01:25:59,679
the least cost

2251
01:26:03,669 --> 01:26:02,159
complexity where we're basically for the

2252
01:26:05,510 --> 01:26:03,679
armed mission

2253
01:26:06,950 --> 01:26:05,520
we're utilizing

2254
01:26:09,110 --> 01:26:06,960
things that we already have that we're

2255
01:26:10,790 --> 01:26:09,120
not adding anything to the mission

2256
01:26:12,870 --> 01:26:10,800
and then we've got these additional

2257
01:26:14,709 --> 01:26:12,880
aspects of things that we can

2258
01:26:16,470 --> 01:26:14,719
we can show

2259
01:26:19,430 --> 01:26:16,480
understanding that there's likely an

2260
01:26:24,229 --> 01:26:19,440
incremental cost unless it's provided

2261
01:26:24,239 --> 01:26:29,669
and then there's a third class of

2262
01:26:35,110 --> 01:26:32,149
experiments demonstrations

2263
01:26:36,950 --> 01:26:35,120

that probably aren't applicable directly

2264
01:26:38,550 --> 01:26:36,960
to this our mission but could be very

2265
01:26:39,510 --> 01:26:38,560
applicable to planetary defense in

2266
01:26:42,070 --> 01:26:39,520
general

2267
01:26:44,870 --> 01:26:42,080
um the one that comes to mind is is the

2268
01:26:46,470 --> 01:26:44,880
the nuclear detonation um

2269
01:26:48,870 --> 01:26:46,480
in any of the approaches that we've

2270
01:26:51,750 --> 01:26:48,880
looked at so far we don't want to do

2271
01:26:52,629 --> 01:26:51,760
anything with respect to nuclear because

2272
01:26:55,270 --> 01:26:52,639
of

2273
01:26:57,590 --> 01:26:55,280
the obvious cost and schedule and other

2274
01:26:59,189 --> 01:26:57,600
implications however there may be the

2275
01:27:02,149 --> 01:26:59,199
opportunity

2276
01:27:04,870 --> 01:27:02,159
in combination i'll give an example

2277
01:27:07,669 --> 01:27:04,880
the kinetic impactor approach

2278
01:27:09,189 --> 01:27:07,679
very similar to osiris-rex and isis

2279
01:27:10,790 --> 01:27:09,199
could be repeated

2280
01:27:12,790 --> 01:27:10,800
for for example for the alternate

2281
01:27:15,110 --> 01:27:12,800
approach of going to a large target

2282
01:27:16,709 --> 01:27:15,120
we go to the reference approach it's

2283
01:27:18,149 --> 01:27:16,719
really not a player because you

2284
01:27:21,350 --> 01:27:18,159
definitely don't want to be impacting

2285
01:27:25,430 --> 01:27:22,390
but

2286
01:27:26,629 --> 01:27:25,440
as part of that kinetic impactor

2287
01:27:28,390 --> 01:27:26,639
longwea's

2288
01:27:30,550 --> 01:27:28,400

hyper velocity impactor you could at

2289
01:27:32,950 --> 01:27:30,560
least test potentially a mechanism on

2290
01:27:35,030 --> 01:27:32,960
that for example for the the boom

2291
01:27:38,070 --> 01:27:35,040
um that would have a dummy payload so

2292
01:27:39,510 --> 01:27:38,080
you could test out the the approach um

2293
01:27:41,430 --> 01:27:39,520
it wouldn't be a demonstration of the

2294
01:27:43,590 --> 01:27:41,440
actual capability but at least a

2295
01:27:48,950 --> 01:27:43,600
demonstration of the uh

2296
01:27:52,470 --> 01:27:51,350
in in the first category that we've

2297
01:27:53,590 --> 01:27:52,480
talked about

2298
01:27:55,510 --> 01:27:53,600
um

2299
01:27:57,590 --> 01:27:55,520
of actually

2300
01:27:58,310 --> 01:27:57,600
a technique that could be implemented on

2301
01:28:02,470 --> 01:27:58,320
the

2302
01:28:04,390 --> 01:28:02,480
mission i think for both approaches

2303
01:28:07,189 --> 01:28:04,400
whether we go to a small one or pick up

2304
01:28:08,790 --> 01:28:07,199
part of a large one is um i think the

2305
01:28:11,510 --> 01:28:08,800
the gravity tractor

2306
01:28:12,629 --> 01:28:11,520
um the ion beam shepherding or ion beam

2307
01:28:14,950 --> 01:28:12,639
deflection

2308
01:28:17,990 --> 01:28:14,960
um are certainly both that i think are

2309
01:28:18,000 --> 01:28:22,149
the uh

2310
01:28:25,990 --> 01:28:24,149
and and i think i think they need to be

2311
01:28:28,390 --> 01:28:26,000
looked at a little bit in more in depth

2312
01:28:30,390 --> 01:28:28,400
to see how how effective they are and

2313
01:28:32,550 --> 01:28:30,400

then what are the um

2314
01:28:33,430 --> 01:28:32,560
uh the pros and cons of each approach

2315
01:28:38,149 --> 01:28:33,440
we've

2316
01:28:39,910 --> 01:28:38,159
the gravity tractor with the enhanced

2317
01:28:40,870 --> 01:28:39,920
mass augmentation

2318
01:28:42,870 --> 01:28:40,880
um

2319
01:28:44,310 --> 01:28:42,880
but there but that's not because we're

2320
01:28:45,990 --> 01:28:44,320
getting a boulder because we're already

2321
01:28:48,950 --> 01:28:46,000
going down to the surface as part of the

2322
01:28:49,669 --> 01:28:48,960
nominal mission um

2323
01:28:54,229 --> 01:28:49,679
so

2324
01:28:56,629 --> 01:28:54,239
incremental risk

2325
01:28:58,149 --> 01:28:56,639
um but certainly the ion beam deflection

2326
01:28:59,830 --> 01:28:58,159
approach could be tested too in that

2327
01:29:00,790 --> 01:28:59,840
manner

2328
01:29:01,910 --> 01:29:00,800
so

2329
01:29:03,750 --> 01:29:01,920
i guess

2330
01:29:04,709 --> 01:29:03,760
you know try to get everybody's comments

2331
01:29:06,709 --> 01:29:04,719
or

2332
01:29:08,310 --> 01:29:06,719
if there's any additional

2333
01:29:10,149 --> 01:29:08,320
feedback on that i have some specific

2334
01:29:12,229 --> 01:29:10,159
questions for the for the presenters

2335
01:29:13,590 --> 01:29:12,239
that might be able to talk about

2336
01:29:15,430 --> 01:29:13,600
um

2337
01:29:17,110 --> 01:29:15,440
and i'll actually turn it over to paul

2338
01:29:19,669 --> 01:29:17,120

to see if he has some comments

2339
01:29:25,110 --> 01:29:21,590
so one of the things i thought that we

2340
01:29:27,669 --> 01:29:25,120
heard some very interesting ideas

2341
01:29:29,590 --> 01:29:27,679
one of the the

2342
01:29:31,830 --> 01:29:29,600
concepts that

2343
01:29:34,950 --> 01:29:31,840
was novel i think or not novel but is a

2344
01:29:39,510 --> 01:29:36,390
of interest that's applicable directly

2345
01:29:41,750 --> 01:29:39,520
to arm of course is the iron iron beam

2346
01:29:43,590 --> 01:29:41,760
i think that's something that that is uh

2347
01:29:44,950 --> 01:29:43,600
people haven't thought as much about i

2348
01:29:45,830 --> 01:29:44,960
think

2349
01:29:47,110 --> 01:29:45,840
we've

2350
01:29:49,110 --> 01:29:47,120
thought a little bit about the gravity

2351
01:29:51,110 --> 01:29:49,120
tractor um it'd be interesting to see

2352
01:29:53,189 --> 01:29:51,120
what the boulder option

2353
01:29:55,030 --> 01:29:53,199
has in terms of the enhancement

2354
01:29:57,990 --> 01:29:55,040
but would also be interesting to explore

2355
01:29:59,750 --> 01:29:58,000
the the aspects of of the ion beam uh

2356
01:30:02,390 --> 01:29:59,760
system and what that does

2357
01:30:04,709 --> 01:30:02,400
uh to to your your target to your

2358
01:30:06,870 --> 01:30:04,719
asteroid

2359
01:30:08,629 --> 01:30:06,880
one of the things that is would be

2360
01:30:10,629 --> 01:30:08,639
interesting to see is what effects do

2361
01:30:12,470 --> 01:30:10,639
you have on the surface uh especially if

2362
01:30:15,189 --> 01:30:12,480
you're talking about coherent versus

2363
01:30:17,189 --> 01:30:15,199

robo-palm nature and things like that um

2364
01:30:18,470 --> 01:30:17,199
maybe their no effects might be minimal

2365
01:30:20,310 --> 01:30:18,480
but it'd be interesting to at least

2366
01:30:23,030 --> 01:30:20,320
explore that

2367
01:30:24,870 --> 01:30:23,040
so there's a what i see out of this

2368
01:30:27,030 --> 01:30:24,880
especially because of its relevant

2369
01:30:28,709 --> 01:30:27,040
forearm is the trade between

2370
01:30:30,390 --> 01:30:28,719
you know what type of demonstrations can

2371
01:30:32,310 --> 01:30:30,400
you do effectively

2372
01:30:34,070 --> 01:30:32,320
given the time that we have

2373
01:30:35,590 --> 01:30:34,080
the budgets that we have the constraints

2374
01:30:38,390 --> 01:30:35,600
we have

2375
01:30:39,590 --> 01:30:38,400
it would be great to include

2376
01:30:40,629 --> 01:30:39,600
all

2377
01:30:42,070 --> 01:30:40,639
of the

2378
01:30:43,830 --> 01:30:42,080
type of deflection

2379
01:30:45,510 --> 01:30:43,840
techniques that we might use

2380
01:30:47,669 --> 01:30:45,520
so for example

2381
01:30:49,030 --> 01:30:47,679
could you

2382
01:30:52,070 --> 01:30:49,040
test a

2383
01:30:53,510 --> 01:30:52,080
tractor

2384
01:30:55,750 --> 01:30:53,520
and at the end of the mission when you

2385
01:30:56,950 --> 01:30:55,760
have your sample you have your whatever

2386
01:30:58,790 --> 01:30:56,960
it is

2387
01:31:02,149 --> 01:30:58,800
especially if you're going to a larger

2388
01:31:04,149 --> 01:31:02,159

target can you do a deflection uh

2389
01:31:06,149 --> 01:31:04,159
demonstration with the kinetic impactor

2390
01:31:08,310 --> 01:31:06,159
alloy isis after the end that would be

2391
01:31:09,270 --> 01:31:08,320
sort of you know my wish list if i was

2392
01:31:10,870 --> 01:31:09,280
you know

2393
01:31:13,030 --> 01:31:10,880
king of the world and be able to do that

2394
01:31:14,390 --> 01:31:13,040
that would be the greatest thing to do

2395
01:31:16,470 --> 01:31:14,400
again we have to keep in mind the

2396
01:31:18,790 --> 01:31:16,480
constraints that we're under so that's

2397
01:31:20,070 --> 01:31:18,800
what i'm interested in um i would be

2398
01:31:21,110 --> 01:31:20,080
interested in getting other people's

2399
01:31:22,629 --> 01:31:21,120
feedback

2400
01:31:25,110 --> 01:31:22,639
on on what type of things they would

2401
01:31:26,550 --> 01:31:25,120
like to see again this this is a idea

2402
01:31:28,310 --> 01:31:26,560
synthesis we'd like to try and get some

2403
01:31:29,830 --> 01:31:28,320
feedback from the community and see what

2404
01:31:31,110 --> 01:31:29,840
we have so

2405
01:31:32,870 --> 01:31:31,120
yeah come on to the microphone and then

2406
01:31:35,110 --> 01:31:32,880
we'll we'll go from there

2407
01:31:37,110 --> 01:31:35,120
so go ahead okay i'll go first

2408
01:31:40,470 --> 01:31:37,120
well one thing i think is important is

2409
01:31:43,350 --> 01:31:40,480
that we can combine these techniques

2410
01:31:46,470 --> 01:31:43,360
and and it we i think we don't want to

2411
01:31:47,910 --> 01:31:46,480
just have one compete against the other

2412
01:31:49,110 --> 01:31:47,920
necessarily but to see if it's a

2413
01:31:52,390 --> 01:31:49,120

combination

2414
01:31:55,030 --> 01:31:52,400
it occurs to me the ion beam concept

2415
01:31:58,629 --> 01:31:55,040
might benefit for example from

2416
01:32:00,470 --> 01:31:58,639
wallpapering the asteroid first

2417
01:32:02,950 --> 01:32:00,480
you could create you could bring along

2418
01:32:04,310 --> 01:32:02,960
your own folded up surface that you put

2419
01:32:06,629 --> 01:32:04,320
on the asteroid that you're going to put

2420
01:32:08,790 --> 01:32:06,639
the ion beam into since we're going to

2421
01:32:12,629 --> 01:32:08,800
be ruining the surface for scientific

2422
01:32:15,350 --> 01:32:12,639
value anyway with the ion beam probably

2423
01:32:17,030 --> 01:32:15,360
wallpapering won't make it any worse

2424
01:32:20,470 --> 01:32:17,040
so that that's kind of the equivalent of

2425
01:32:22,790 --> 01:32:20,480
pick up a rock for ion beam is some sort

2426
01:32:24,950 --> 01:32:22,800
of pre-prepare previous preparation of

2427
01:32:27,030 --> 01:32:24,960
the asteroid to receive the ion beam for

2428
01:32:29,189 --> 01:32:27,040
one thing if you wallpapered it what you

2429
01:32:30,870 --> 01:32:29,199
could do is make it as a round a

2430
01:32:32,790 --> 01:32:30,880
perfectly round

2431
01:32:35,110 --> 01:32:32,800
piece of wallpaper that maybe hangs off

2432
01:32:37,110 --> 01:32:35,120
the side a little bit but is anchored

2433
01:32:38,629 --> 01:32:37,120
somehow so that you have a bigger target

2434
01:32:41,110 --> 01:32:38,639
to shoot into in

2435
01:32:43,270 --> 01:32:41,120
a better shaped one and just a comment

2436
01:32:45,270 --> 01:32:43,280
with that the problem that you encounter

2437
01:32:47,430 --> 01:32:45,280
is because the rotation of it you can't

2438
01:32:50,149 --> 01:32:47,440

just pick one spot um unless you only

2439
01:32:51,590 --> 01:32:50,159
want to demonstrate a very discreet

2440
01:32:53,110 --> 01:32:51,600
point so

2441
01:32:54,709 --> 01:32:53,120
can i respond to that well maybe what

2442
01:32:55,590 --> 01:32:54,719
you do is you wallpaper it all the way

2443
01:32:58,390 --> 01:32:55,600
around

2444
01:33:00,550 --> 01:32:58,400
okay um and you sort of you sort of do a

2445
01:33:02,310 --> 01:33:00,560
really sort of wallpapering job i'd

2446
01:33:03,910 --> 01:33:02,320
probably do if i tried wallpapering

2447
01:33:06,310 --> 01:33:03,920
anything you know

2448
01:33:08,149 --> 01:33:06,320
it would i'd make it nice and round and

2449
01:33:09,669 --> 01:33:08,159
pretty but it wouldn't be my wife would

2450
01:33:11,990 --> 01:33:09,679
would tell me that it's got to be

2451
01:33:14,229 --> 01:33:12,000
re-wallpapered because it it's not lying

2452
01:33:15,669 --> 01:33:14,239
as flat as it should

2453
01:33:17,669 --> 01:33:15,679
uh yeah the comment i have is i might

2454
01:33:20,790 --> 01:33:17,679
take a lot of wallpaper and and trying

2455
01:33:22,629 --> 01:33:20,800
to trying to do that maybe

2456
01:33:24,470 --> 01:33:22,639
the complexity and the extra cost and

2457
01:33:26,550 --> 01:33:24,480
mass and things like that so

2458
01:33:28,790 --> 01:33:26,560
um it's something we'll think about but

2459
01:33:29,830 --> 01:33:28,800
that might be it might be problematic to

2460
01:33:31,669 --> 01:33:29,840
do that

2461
01:33:33,430 --> 01:33:31,679
so i

2462
01:33:34,870 --> 01:33:33,440
listening to all of this it seems to me

2463
01:33:36,550 --> 01:33:34,880

you're going to be forced by events

2464
01:33:37,990 --> 01:33:36,560
likely i i have a feeling that you're

2465
01:33:39,430 --> 01:33:38,000
going to find that

2466
01:33:40,870 --> 01:33:39,440
you know the

2467
01:33:42,229 --> 01:33:40,880
when you get ready to fly the mission

2468
01:33:43,510 --> 01:33:42,239
there's only going to be one or two

2469
01:33:45,030 --> 01:33:43,520
candidates

2470
01:33:47,910 --> 01:33:45,040
there's not going to be like you know

2471
01:33:48,950 --> 01:33:47,920
pick from 10 sort of so it's whether you

2472
01:33:51,350 --> 01:33:48,960
do a

2473
01:33:52,709 --> 01:33:51,360
pick up a rock or bring the whole thing

2474
01:33:55,750 --> 01:33:52,719
back will be dependent on what's

2475
01:33:58,229 --> 01:33:55,760
available when you want to fly right and

2476
01:33:59,910 --> 01:33:58,239
so and then that will determine what

2477
01:34:01,270 --> 01:33:59,920
sort of um

2478
01:34:02,149 --> 01:34:01,280
of um

2479
01:34:04,229 --> 01:34:02,159
you know

2480
01:34:07,510 --> 01:34:04,239
deflection mission you do if it's pick

2481
01:34:08,629 --> 01:34:07,520
up a rock you can do the ion thing

2482
01:34:09,750 --> 01:34:08,639
if it's

2483
01:34:11,030 --> 01:34:09,760
bring the whole thing back you're going

2484
01:34:11,830 --> 01:34:11,040
to have to do the gravity tractor

2485
01:34:13,510 --> 01:34:11,840
because you don't want to ruin the

2486
01:34:15,030 --> 01:34:13,520
surface with the ion

2487
01:34:17,590 --> 01:34:15,040
so i i just have a feeling that'll be

2488
01:34:20,229 --> 01:34:17,600

forced by events and

2489
01:34:23,110 --> 01:34:20,239
well certainly you're the the type of

2490
01:34:25,030 --> 01:34:23,120
target that is available may uh

2491
01:34:27,189 --> 01:34:25,040
may force you into down a path of a

2492
01:34:28,790 --> 01:34:27,199
certain type of technique but i think

2493
01:34:29,910 --> 01:34:28,800
from our point of view it'd be nice

2494
01:34:31,590 --> 01:34:29,920
especially because we're talking about

2495
01:34:33,910 --> 01:34:31,600
asteroid deflection to try and at least

2496
01:34:35,750 --> 01:34:33,920
test multiple techniques

2497
01:34:37,270 --> 01:34:35,760
but you're right that

2498
01:34:38,790 --> 01:34:37,280
it will be

2499
01:34:40,950 --> 01:34:38,800
somewhat target dependent in terms of

2500
01:34:43,270 --> 01:34:40,960
what's available

2501
01:34:45,669 --> 01:34:43,280
in terms of what are the if we go to the

2502
01:34:47,189 --> 01:34:45,679
bigger targets removing a boulder

2503
01:34:48,709 --> 01:34:47,199
or actually finding some of these

2504
01:34:50,310 --> 01:34:48,719
smaller ones to to go after and

2505
01:34:52,390 --> 01:34:50,320
returning the whole thing so your point

2506
01:34:55,109 --> 01:34:52,400
is your point is well taken i think what

2507
01:34:56,629 --> 01:34:55,119
we're trying to do is see what we can

2508
01:34:57,510 --> 01:34:56,639
maximize

2509
01:34:59,990 --> 01:34:57,520
the

2510
01:35:05,590 --> 01:35:00,000
knowledge that we have for

2511
01:35:09,270 --> 01:35:07,430
so there's a there's a lot of things you

2512
01:35:11,270 --> 01:35:09,280
could do base if you integrated all

2513
01:35:12,950 --> 01:35:11,280

these ideas

2514
01:35:15,510 --> 01:35:12,960
you could take and

2515
01:35:17,350 --> 01:35:15,520
see every uh falcon

2516
01:35:20,870 --> 01:35:17,360
heavy that's leaving

2517
01:35:21,830 --> 01:35:20,880
and see its upper stage as a resource

2518
01:35:23,830 --> 01:35:21,840
because

2519
01:35:25,590 --> 01:35:23,840
you're going to get to the same delta v

2520
01:35:27,910 --> 01:35:25,600
that the payload is going to get to with

2521
01:35:29,750 --> 01:35:27,920
that so you might as well just stay uh

2522
01:35:31,830 --> 01:35:29,760
stick on uh stick with it like you do

2523
01:35:35,669 --> 01:35:31,840
with isis or l cross

2524
01:35:37,109 --> 01:35:35,679
and use that mass as part of your uh

2525
01:35:38,310 --> 01:35:37,119
your uh

2526
01:35:41,430 --> 01:35:38,320
you know your

2527
01:35:44,470 --> 01:35:41,440
to uh impact the velocity so anyway you

2528
01:35:45,510 --> 01:35:44,480
could put an ep system into the espa

2529
01:35:48,629 --> 01:35:45,520
base

2530
01:35:50,629 --> 01:35:48,639
vehicle that would be a secondary and

2531
01:35:53,669 --> 01:35:50,639
send that to

2532
01:35:54,870 --> 01:35:53,679
the asteroid to do the gravity

2533
01:35:56,790 --> 01:35:54,880
tracking

2534
01:35:58,470 --> 01:35:56,800
other things that

2535
01:36:01,030 --> 01:35:58,480
you could do is you know nobody

2536
01:36:03,750 --> 01:36:01,040
mentioned solar sailing we had the solar

2537
01:36:06,470 --> 01:36:03,760
concentrator but that concentrator

2538
01:36:09,109 --> 01:36:06,480

if it's attached to the vehicle could be

2539
01:36:10,870 --> 01:36:09,119
a great solar sail and that would impact

2540
01:36:18,149 --> 01:36:10,880
it

2541
01:36:20,229 --> 01:36:18,159
take out all of the rotation you know

2542
01:36:22,070 --> 01:36:20,239
because you know if it's pushed back

2543
01:36:24,950 --> 01:36:22,080
basically becomes like the

2544
01:36:27,350 --> 01:36:24,960
the feathers on an arrow and then if it

2545
01:36:30,950 --> 01:36:27,360
has enough frontal area still then

2546
01:36:32,550 --> 01:36:30,960
then it will alter the asteroid

2547
01:36:34,149 --> 01:36:32,560
you know trajectory

2548
01:36:36,149 --> 01:36:34,159
and that would be almost a passive

2549
01:36:38,950 --> 01:36:36,159
system you just have to get there and

2550
01:36:40,870 --> 01:36:38,960
you know attach it and anchor it yeah

2551
01:36:43,109 --> 01:36:40,880
just anchor it and so you could couple

2552
01:36:44,790 --> 01:36:43,119
that in with an active demonstration

2553
01:36:47,189 --> 01:36:44,800
after the active demonstration has

2554
01:36:49,270 --> 01:36:47,199
exhausted its propellant then this piece

2555
01:36:51,590 --> 01:36:49,280
of it would continue on

2556
01:36:54,470 --> 01:36:51,600
and you could use the

2557
01:36:56,550 --> 01:36:54,480
the falcon heavy's upper stage as as

2558
01:36:57,430 --> 01:36:56,560
sort of your your mass to get it there

2559
01:37:01,350 --> 01:36:57,440
and

2560
01:37:03,030 --> 01:37:01,360
rock from it

2561
01:37:04,629 --> 01:37:03,040
you know it's already at the necessary

2562
01:37:06,310 --> 01:37:04,639
delta v

2563
01:37:07,910 --> 01:37:06,320

so there's a lot of ways you can

2564
01:37:09,830 --> 01:37:07,920
creatively

2565
01:37:11,990 --> 01:37:09,840
integrate a number of elements and try

2566
01:37:13,830 --> 01:37:12,000
to use free things or at least very low

2567
01:37:15,510 --> 01:37:13,840
cost things

2568
01:37:17,590 --> 01:37:15,520
yeah i think that's that's a good

2569
01:37:20,790 --> 01:37:17,600
comment um i think one of the things

2570
01:37:22,550 --> 01:37:20,800
that and it's kind of a question um

2571
01:37:24,390 --> 01:37:22,560
to the solar collector

2572
01:37:26,070 --> 01:37:24,400
uh side of things but it goes to the

2573
01:37:28,229 --> 01:37:26,080
solar sail too i think one of the

2574
01:37:30,070 --> 01:37:28,239
reasons why it probably is

2575
01:37:32,470 --> 01:37:30,080
not been discussed much is

2576
01:37:34,390 --> 01:37:32,480
the the low trl

2577
01:37:36,550 --> 01:37:34,400
that's associated with it

2578
01:37:37,990 --> 01:37:36,560
um we have flown i mean there are some

2579
01:37:39,350 --> 01:37:38,000
that have flown but

2580
01:37:40,870 --> 01:37:39,360
uh

2581
01:37:42,950 --> 01:37:40,880
there's at least a perception that it's

2582
01:37:44,390 --> 01:37:42,960
fairly low low terrell so maybe i'll let

2583
01:37:45,910 --> 01:37:44,400
real quick rob

2584
01:37:48,629 --> 01:37:45,920
respond to that

2585
01:37:50,790 --> 01:37:48,639
well i mean yeah i mean but we've seen

2586
01:37:52,870 --> 01:37:50,800
several solar sails fly

2587
01:37:55,109 --> 01:37:52,880
you know uh we've got the icarus mission

2588
01:37:57,750 --> 01:37:55,119

that the japanese did we've got nana's

2589
01:37:59,750 --> 01:37:57,760
ld and then we've got the the tdm

2590
01:38:01,510 --> 01:37:59,760
mission that should fly next year so

2591
01:38:04,229 --> 01:38:01,520
there's been a lot of a lot of progress

2592
01:38:06,149 --> 01:38:04,239
in this area and i mean you know i i

2593
01:38:07,030 --> 01:38:06,159
don't see it being

2594
01:38:09,270 --> 01:38:07,040
any

2595
01:38:10,390 --> 01:38:09,280
more development than a lot of the

2596
01:38:13,430 --> 01:38:10,400
things that we're talking about with

2597
01:38:14,629 --> 01:38:13,440
capture mechanisms or

2598
01:38:16,790 --> 01:38:14,639
really

2599
01:38:18,950 --> 01:38:16,800
kinetic deflectors you know we've done a

2600
01:38:20,149 --> 01:38:18,960
lot of work on that and and that has a

2601
01:38:22,550 --> 01:38:20,159
lot and

2602
01:38:24,550 --> 01:38:22,560
i i don't see it as being any lower trl

2603
01:38:26,390 --> 01:38:24,560
than any of the other technologies i've

2604
01:38:27,350 --> 01:38:26,400
wondered about solar sail

2605
01:38:29,030 --> 01:38:27,360
um

2606
01:38:31,109 --> 01:38:29,040
with respect to turning into a solar

2607
01:38:32,629 --> 01:38:31,119
collector yeah i just don't see that as

2608
01:38:34,790 --> 01:38:32,639
being that difficult i think there's

2609
01:38:36,629 --> 01:38:34,800
this perception that we have to have a a

2610
01:38:39,109 --> 01:38:36,639
pristine mirror because we're used to

2611
01:38:41,750 --> 01:38:39,119
that on the astro dynamics community and

2612
01:38:42,790 --> 01:38:41,760
what not but but i mean astrophysics i

2613
01:38:44,390 --> 01:38:42,800

should say but

2614
01:38:46,629 --> 01:38:44,400
i mean we don't need a perfect image of

2615
01:38:48,550 --> 01:38:46,639
the sun we need a hot spot to burn

2616
01:38:51,270 --> 01:38:48,560
regular regolith so

2617
01:38:53,510 --> 01:38:51,280
i i just don't see this being that

2618
01:38:56,870 --> 01:38:53,520
difficult and with the recent

2619
01:38:59,270 --> 01:38:56,880
uh accomplishments in inflatables and in

2620
01:39:01,430 --> 01:38:59,280
uh sales i think those are directly

2621
01:39:02,709 --> 01:39:01,440
applicable yeah so that goes to another

2622
01:39:05,030 --> 01:39:02,719
question actually that i have for you

2623
01:39:07,510 --> 01:39:05,040
and then we'll go to you rob is that

2624
01:39:09,510 --> 01:39:07,520
um right now for the reference approach

2625
01:39:10,629 --> 01:39:09,520
there's an inflatable strut and bag

2626
01:39:11,430 --> 01:39:10,639
concept

2627
01:39:13,750 --> 01:39:11,440
and

2628
01:39:16,550 --> 01:39:13,760
but the inflatable is only

2629
01:39:17,669 --> 01:39:16,560
used for a very brief period of time

2630
01:39:20,870 --> 01:39:17,679
it's stowed

2631
01:39:22,870 --> 01:39:20,880
it's deployed upon approach to the

2632
01:39:24,550 --> 01:39:22,880
the target it's captured and then it's

2633
01:39:25,830 --> 01:39:24,560
allowed to deflate

2634
01:39:28,390 --> 01:39:25,840
i think one of the concerns with

2635
01:39:31,510 --> 01:39:28,400
inflatables is their longevity um and

2636
01:39:35,109 --> 01:39:31,520
their their tolerance to micrometeoroids

2637
01:39:36,950 --> 01:39:35,119
um and maintaining that um so

2638
01:39:38,790 --> 01:39:36,960

i think that's something to think about

2639
01:39:40,629 --> 01:39:38,800
well actually we've addressed that i

2640
01:39:43,270 --> 01:39:40,639
didn't go into it in the presentation

2641
01:39:44,629 --> 01:39:43,280
but we used a special material that when

2642
01:39:45,430 --> 01:39:44,639
uh

2643
01:39:47,109 --> 01:39:45,440
yeah

2644
01:39:48,790 --> 01:39:47,119
you know when it's exposed to nitrogen

2645
01:39:50,950 --> 01:39:48,800
and you know that's what we use there

2646
01:39:52,229 --> 01:39:50,960
and also you got to think that

2647
01:39:54,310 --> 01:39:52,239
our

2648
01:39:55,830 --> 01:39:54,320
are inflatable tubes if you will are

2649
01:39:57,510 --> 01:39:55,840
considerably smaller compared to the

2650
01:39:59,990 --> 01:39:57,520
rest of the vehicle than

2651
01:40:02,390 --> 01:40:00,000
with these uh these other uh concepts as

2652
01:40:04,950 --> 01:40:02,400
well so right and this thing rigidizes

2653
01:40:06,629 --> 01:40:04,960
in a matter of hours so yeah it's

2654
01:40:07,430 --> 01:40:06,639
something that should be tested but i

2655
01:40:09,430 --> 01:40:07,440
mean

2656
01:40:11,510 --> 01:40:09,440
it's been used before so

2657
01:40:13,350 --> 01:40:11,520
okay there are ground versions of the

2658
01:40:16,149 --> 01:40:13,360
astro mesh that have never flown that

2659
01:40:20,870 --> 01:40:16,159
could be had for uh

2660
01:40:26,070 --> 01:40:23,750
okay

2661
01:40:27,910 --> 01:40:26,080
yeah um i don't know how you're planning

2662
01:40:30,629 --> 01:40:27,920
on reporting out

2663
01:40:32,870 --> 01:40:30,639

but i think it would be important to

2664
01:40:36,390 --> 01:40:32,880
bend these ideas

2665
01:40:38,550 --> 01:40:36,400
into an asteroid initiative bin

2666
01:40:41,109 --> 01:40:38,560
and a grand challenge bin

2667
01:40:43,350 --> 01:40:41,119
because what i'm hearing is oh that's

2668
01:40:45,109 --> 01:40:43,360
too low trl and that's

2669
01:40:47,109 --> 01:40:45,119
it's not applicable to the asteroid

2670
01:40:50,310 --> 01:40:47,119
mission and i'm afraid a lot of good

2671
01:40:51,750 --> 01:40:50,320
concepts that might be the greater value

2672
01:40:54,550 --> 01:40:51,760
in the long run

2673
01:40:56,470 --> 01:40:54,560
will not get accepted at this workshop

2674
01:41:00,870 --> 01:40:56,480
because of the myopic

2675
01:41:02,870 --> 01:41:00,880
nature of of our society so if we

2676
01:41:05,510 --> 01:41:02,880
bear in mind that the grand challenge is

2677
01:41:06,629 --> 01:41:05,520
really what the president has asked us

2678
01:41:08,550 --> 01:41:06,639
to do

2679
01:41:10,629 --> 01:41:08,560
and the asteroid initiative is just a

2680
01:41:13,109 --> 01:41:10,639
component of the grand challenge like

2681
01:41:15,669 --> 01:41:13,119
like i think was mentioned earlier

2682
01:41:18,070 --> 01:41:15,679
then that with that kind of a thinking

2683
01:41:19,750 --> 01:41:18,080
mindset i think we'll get more out of

2684
01:41:22,390 --> 01:41:19,760
this workshop than

2685
01:41:25,030 --> 01:41:22,400
if we just dump all the

2686
01:41:27,750 --> 01:41:25,040
further out concepts and and don't don't

2687
01:41:31,030 --> 01:41:27,760
document them yeah no i i agree rob but

2688
01:41:33,270 --> 01:41:31,040

the rfi call specifically was for the r

2689
01:41:34,790 --> 01:41:33,280
arv but your point your points well

2690
01:41:36,870 --> 01:41:34,800
taken that when i go to the opening

2691
01:41:38,709 --> 01:41:36,880
ceremonies it's the grand challenge

2692
01:41:40,550 --> 01:41:38,719
that's rolled out not not just the

2693
01:41:41,430 --> 01:41:40,560
asteroid initiative so the message i'm

2694
01:41:43,590 --> 01:41:41,440
getting

2695
01:41:45,590 --> 01:41:43,600
is that the grand challenge is what

2696
01:41:47,270 --> 01:41:45,600
we're pursuing and the asteroid

2697
01:41:48,790 --> 01:41:47,280
initiative is just a component of the

2698
01:41:50,149 --> 01:41:48,800
grand challenge

2699
01:41:51,750 --> 01:41:50,159
well it's actually the other way around

2700
01:41:53,350 --> 01:41:51,760
the asteroid initiative

2701
01:41:55,590 --> 01:41:53,360
that's what i'm asking a challenge with

2702
01:41:57,350 --> 01:41:55,600
the the asteroid redirect mission

2703
01:41:59,189 --> 01:41:57,360
well it's not clear to me and i work for

2704
01:42:01,350 --> 01:41:59,199
nasa so i'm sure the public's very

2705
01:42:02,870 --> 01:42:01,360
confused sure but no your point's well

2706
01:42:05,109 --> 01:42:02,880
taken that we don't want to

2707
01:42:06,629 --> 01:42:05,119
even if some of these ideas don't

2708
01:42:09,350 --> 01:42:06,639
um

2709
01:42:11,750 --> 01:42:09,360
have apple applicability because because

2710
01:42:13,510 --> 01:42:11,760
they're a little bit farther term trl um

2711
01:42:15,750 --> 01:42:13,520
that we shouldn't uh we should make sure

2712
01:42:18,149 --> 01:42:15,760
they're still captured and it may be

2713
01:42:19,510 --> 01:42:18,159

something that that needs to be funded

2714
01:42:21,830 --> 01:42:19,520
thanks

2715
01:42:24,149 --> 01:42:21,840
so i just want to emphasize that

2716
01:42:26,229 --> 01:42:24,159
everybody feel that oh we have all the

2717
01:42:29,109 --> 01:42:26,239
technology even for the kinetic impact

2718
01:42:30,390 --> 01:42:29,119
because we had such a successful deep

2719
01:42:32,790 --> 01:42:30,400
impact mission

2720
01:42:35,189 --> 01:42:32,800
but as some of

2721
01:42:37,990 --> 01:42:35,199
all of you know that this target size

2722
01:42:41,430 --> 01:42:39,830
six kilometer

2723
01:42:45,350 --> 01:42:41,440
we have to worry about

2724
01:42:46,709 --> 01:42:45,360
hitting 50 meter 100 meter 200 meter

2725
01:42:49,270 --> 01:42:46,719
so

2726
01:42:52,950 --> 01:42:49,280
i know jp may claim that oh we can

2727
01:42:55,590 --> 01:42:52,960
easily hit 50 meter 100 meter but i may

2728
01:42:58,629 --> 01:42:55,600
suggest that next logical flight testing

2729
01:43:02,709 --> 01:42:59,830
actually

2730
01:43:04,629 --> 01:43:02,719
being able to hit 50 meter small size

2731
01:43:06,470 --> 01:43:04,639
target yeah i don't know that we have to

2732
01:43:08,629 --> 01:43:06,480
get down to the 50 meters

2733
01:43:10,870 --> 01:43:08,639
that's the smallest uh target we have to

2734
01:43:13,510 --> 01:43:10,880
worry about yeah

2735
01:43:15,350 --> 01:43:13,520
yeah no but i'm not saying 50 meters

2736
01:43:18,470 --> 01:43:15,360
right but

2737
01:43:20,310 --> 01:43:18,480
can we hit the 300 meter target yeah for

2738
01:43:22,149 --> 01:43:20,320

example so we may not need to take the

2739
01:43:23,590 --> 01:43:22,159
technology demonstration all the way

2740
01:43:25,270 --> 01:43:23,600
down to

2741
01:43:27,109 --> 01:43:25,280
50 meters right but if we go from six

2742
01:43:30,870 --> 01:43:27,119
kilometers yeah i will not use a 50

2743
01:43:32,390 --> 01:43:30,880
meter because 99 we will fail right

2744
01:43:34,310 --> 01:43:32,400
so so that that's something that has to

2745
01:43:35,189 --> 01:43:34,320
be looked at as to what is what is the

2746
01:43:36,550 --> 01:43:35,199
uh

2747
01:43:39,510 --> 01:43:36,560
the target range and i don't know if tim

2748
01:43:41,270 --> 01:43:39,520
and steve can well i mean a 600 meter

2749
01:43:43,270 --> 01:43:41,280
asteroid like what steve was talking

2750
01:43:45,350 --> 01:43:43,280
about would be a great target and we're

2751
01:43:46,310 --> 01:43:45,360
confident we could hit it but

2752
01:43:47,990 --> 01:43:46,320
you know

2753
01:43:49,910 --> 01:43:48,000
we should prove it i guess

2754
01:43:51,669 --> 01:43:49,920
right but i guess what's the what's the

2755
01:43:53,189 --> 01:43:51,679
limit the other thing is for instance

2756
01:43:55,189 --> 01:43:53,199
for the isis concept if you have an

2757
01:43:57,590 --> 01:43:55,199
observer spacecraft and you know from

2758
01:43:58,470 --> 01:43:57,600
telemetry what you were aiming for and

2759
01:44:00,470 --> 01:43:58,480
you know

2760
01:44:02,229 --> 01:44:00,480
from the observations what you hit so

2761
01:44:04,870 --> 01:44:02,239
that's the demonstration of whatever

2762
01:44:07,350 --> 01:44:04,880
level you've designed the system to be

2763
01:44:09,990 --> 01:44:07,360

now you can you can get as we know from

2764
01:44:11,669 --> 01:44:10,000
sdi for instance you can get meter scale

2765
01:44:12,470 --> 01:44:11,679
accuracy if that's what you want to pay

2766
01:44:14,470 --> 01:44:12,480
for

2767
01:44:16,070 --> 01:44:14,480
but as in the case of deep impact which

2768
01:44:18,070 --> 01:44:16,080
was tuned for the target that it had to

2769
01:44:19,990 --> 01:44:18,080
hit isis is tuned for the target it has

2770
01:44:23,109 --> 01:44:20,000
to hit and and that's what we do as

2771
01:44:28,390 --> 01:44:23,119
engineers so but we'll know what we hit

2772
01:44:31,830 --> 01:44:29,990
a minute more that we can go tonight and

2773
01:44:34,070 --> 01:44:31,840
then we'll probably do adjourn here

2774
01:44:35,910 --> 01:44:34,080
um just one quick comment there's been

2775
01:44:38,070 --> 01:44:35,920
some question about how well you could

2776
01:44:40,550 --> 01:44:38,080
know when you hit something

2777
01:44:42,149 --> 01:44:40,560
and you know i was originally an od guy

2778
01:44:44,709 --> 01:44:42,159
so you know it

2779
01:44:46,390 --> 01:44:44,719
it is very precise and a useful number

2780
01:44:49,510 --> 01:44:46,400
would be that if you can stick around

2781
01:44:52,070 --> 01:44:49,520
long enough to see 50 meters of

2782
01:44:54,310 --> 01:44:52,080
of displacement from where it was going

2783
01:44:56,709 --> 01:44:54,320
to be that's easily detectable and 10

2784
01:44:59,910 --> 01:44:56,719
meters is probably detectable

2785
01:45:02,390 --> 01:44:59,920
and so you know i mean 50 meters in in a

2786
01:45:05,350 --> 01:45:02,400
month is is a vanishingly small

2787
01:45:07,189 --> 01:45:05,360
you know delta v so

2788
01:45:09,189 --> 01:45:07,199

it's a very very

2789
01:45:11,430 --> 01:45:09,199
small amount that you need and so you

2790
01:45:14,149 --> 01:45:11,440
know this business that you need large

2791
01:45:15,910 --> 01:45:14,159
to see a large deflection is not

2792
01:45:17,830 --> 01:45:15,920
right don't don't get that out of your

2793
01:45:19,990 --> 01:45:17,840
minds if it's just a matter of did we

2794
01:45:21,750 --> 01:45:20,000
move it a little bit you we can see you

2795
01:45:23,030 --> 01:45:21,760
know next to nothing

2796
01:45:25,030 --> 01:45:23,040
okay assuming that's assuming you've got

2797
01:45:28,070 --> 01:45:25,040
somebody there watching now if you don't

2798
01:45:30,950 --> 01:45:28,080
that's a different pattern right sure

2799
01:45:32,229 --> 01:45:30,960
real quick okay okay real quick um i

2800
01:45:33,990 --> 01:45:32,239
want to echo

2801
01:45:35,510 --> 01:45:34,000
bong's comments about the

2802
01:45:37,350 --> 01:45:35,520
uh kinetic deflection you know we're

2803
01:45:40,629 --> 01:45:37,360
talking about low trl i really think all

2804
01:45:41,830 --> 01:45:40,639
our concepts are relatively low um when

2805
01:45:43,750 --> 01:45:41,840
we worked a

2806
01:45:45,430 --> 01:45:43,760
kinetic deflection and we told them what

2807
01:45:47,350 --> 01:45:45,440
delta v's that we were looking for to

2808
01:45:48,950 --> 01:45:47,360
actually deflect something which is

2809
01:45:51,270 --> 01:45:48,960
different than you know a demonstration

2810
01:45:53,270 --> 01:45:51,280
mission and they can go slower but the

2811
01:45:54,470 --> 01:45:53,280
the closure rates i mean when you think

2812
01:45:55,990 --> 01:45:54,480
about it the closure rates if you're

2813
01:45:57,270 --> 01:45:56,000

going if you've got a closure rate of 10

2814
01:45:59,510 --> 01:45:57,280
kilometers a second one second before

2815
01:46:01,510 --> 01:45:59,520
you hit you're 10 kilometers away

2816
01:46:03,109 --> 01:46:01,520
so when i talked to the global missile

2817
01:46:04,950 --> 01:46:03,119
defense folks about closure rates we

2818
01:46:06,790 --> 01:46:04,960
were talking about their eyebrows went

2819
01:46:08,950 --> 01:46:06,800
up and you know they're doing a pretty

2820
01:46:09,990 --> 01:46:08,960
hard mission themselves so

2821
01:46:12,709 --> 01:46:10,000
you know

2822
01:46:13,910 --> 01:46:12,719
these these aren't easy things so

2823
01:46:16,790 --> 01:46:13,920
yeah that's something that has to be

2824
01:46:18,310 --> 01:46:16,800
studied in in greater detail

2825
01:46:19,590 --> 01:46:18,320
so what i'd like first of all i'd like

2826
01:46:21,990 --> 01:46:19,600
to thank everybody for their

2827
01:46:24,310 --> 01:46:22,000
participation today um

2828
01:46:25,830 --> 01:46:24,320
and we will be reconvening at eight

2829
01:46:27,750 --> 01:46:25,840
o'clock in the morning gives everyone a

2830
01:46:29,910 --> 01:46:27,760
chance maybe to think about the day's

2831
01:46:32,229 --> 01:46:29,920
events um i will be pulling together

2832
01:46:34,390 --> 01:46:32,239
some uh some charts that we'll use for

2833
01:46:36,310 --> 01:46:34,400
the plenary session um and we'll kind of

2834
01:46:38,070 --> 01:46:36,320
go over those and further

2835
01:46:39,270 --> 01:46:38,080
address further comments

2836
01:46:40,790 --> 01:46:39,280
and i'll try to take into account

2837
01:46:42,470 --> 01:46:40,800
everybody's discussion today and the

2838
01:46:43,910 --> 01:46:42,480

comments that we've had in this this

2839
01:46:46,790 --> 01:46:43,920
synthesis period

2840
01:46:47,750 --> 01:46:46,800
so again 8 o'clock tomorrow um across

2841
01:46:50,310 --> 01:46:47,760
the way

2842
01:46:53,270 --> 01:46:50,320
and hopefully folks can uh

2843
01:46:54,709 --> 01:46:53,280
can be there and participate further so

2844
01:46:55,750 --> 01:46:54,719
again thank you for your participation

2845
01:47:32,189 --> 01:46:55,760
and have a