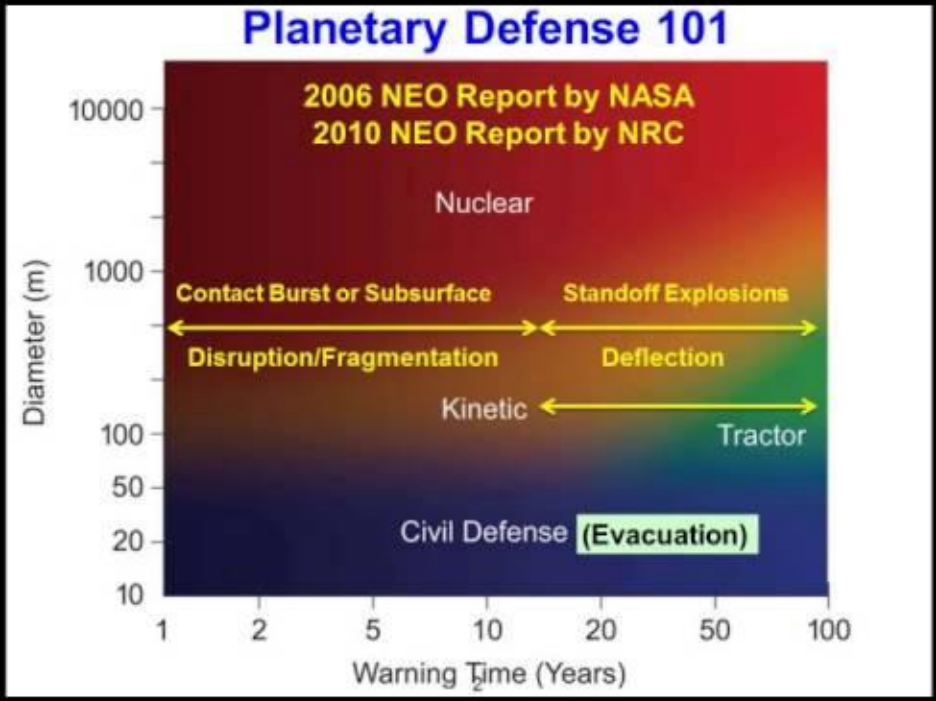
Planetary Defense 101
2006 NEO Report by NASA
2010 NEO Report by NRC
Nuclear
Contact Burst or Subsurface
Standoff Explosions
Disruption/Fragmentation
Deflection
Kinetic
Tractor
Civil Defense
(Evacuation)
Diameter (m)
10000
1000
100
50
20
10
1
2
5
10
20
50
100
Warning Time (Years)

1
00:00:02,560 --> 00:00:27,429
um

2
00:00:27,439 --> 00:01:25,109
okay

3
00:01:31,270 --> 00:01:26,950
yes

4
00:01:33,270 --> 00:01:31,280
um probably the best one would be uh hex

5
00:01:35,350 --> 00:01:33,280
do you see a home

6
00:01:37,590 --> 00:01:35,360
access point called s that would be the

7
00:01:40,390 --> 00:01:37,600
one in this room

8
00:02:14,710 --> 00:01:40,400
password is mars or bust

9
00:02:14,720 --> 00:02:43,190
so

10
00:02:43,200 --> 00:02:59,430
oh

11
00:03:02,869 --> 00:03:00,790
okay do you want to bring it up on here

12
00:03:22,350 --> 00:03:02,879
ryan yeah you want me to

13
00:03:22,360 --> 00:03:34,710

oh okay

14
00:03:34,720 --> 00:03:55,030
so yeah i am broadcasting a camera shot

15
00:03:55,040 --> 00:04:15,830
there you are

16
00:04:15,840 --> 00:04:40,950
and wait 10 seconds

17
00:04:40,960 --> 00:05:09,990
good

18
00:05:13,510 --> 00:05:11,830
actually i'll take i'll take this shot

19
00:05:15,749 --> 00:05:13,520
to the scene as i kind of moved it over

20
00:05:16,710 --> 00:05:15,759
a bit but it may depends on where they

21
00:05:20,629 --> 00:05:16,720
sit

22
00:05:22,710 --> 00:05:20,639
table i think it'll be all right

23
00:06:19,029 --> 00:05:22,720
otherwise if you could screw a little

24
00:06:19,039 --> 00:06:58,390
okay here um go

25
00:06:58,400 --> 00:07:02,550
well

26
00:07:02,560 --> 00:07:26,790
it's like going to another planet yeah

27
00:07:26,800 --> 00:07:51,909
away

28
00:07:51,919 --> 00:08:09,029
did you leave the table here

29
00:08:09,039 --> 00:08:28,070
it's

30
00:08:28,080 --> 00:08:31,630
what

31
00:08:31,640 --> 00:08:44,870
is that

32
00:08:44,880 --> 00:08:52,829
move the other

33
00:09:00,389 --> 00:08:54,870
way that's okay we don't need to have

34
00:09:03,910 --> 00:09:01,910
it's just i think it's just right where

35
00:09:05,670 --> 00:09:03,920
that light is

36
00:09:08,630 --> 00:09:05,680
those fan lights but if you bring up the

37
00:09:10,949 --> 00:09:08,640
front ones

38
00:10:16,150 --> 00:09:10,959

oh yeah you can turn those off yeah or

39
00:10:59,509 --> 00:10:26,310
oh

40
00:10:59,519 --> 00:11:41,110
um

41
00:11:41,120 --> 00:12:15,350
did

42
00:12:15,360 --> 00:12:24,069
okay

43
00:12:24,079 --> 00:12:57,990
think

44
00:12:58,000 --> 00:13:08,389
uh

45
00:13:08,399 --> 00:13:47,430
hey brian how are you sir

46
00:13:52,389 --> 00:13:48,470
josh

47
00:14:35,990 --> 00:13:54,389
hi all right i actually looked at your

48
00:15:37,590 --> 00:14:47,269
is

49
00:16:27,749 --> 00:15:40,150
you know because a lot of that you'd

50
00:17:13,510 --> 00:16:49,430
um

51
00:17:13,520 --> 00:17:30,830
right i think that is

52
00:17:30,840 --> 00:18:24,230
inertia yeah

53
00:18:24,240 --> 00:18:31,350
uh

54
00:18:31,360 --> 00:19:08,789
all right

55
00:19:08,799 --> 00:19:54,310
uh

56
00:20:25,909 --> 00:19:56,390
i'm just saying

57
00:20:25,919 --> 00:21:16,230
um

58
00:21:16,240 --> 00:21:19,590
well it's it's all about

59
00:21:19,600 --> 00:21:35,270
it's all about

60
00:21:35,280 --> 00:22:07,990
your arms

61
00:22:08,000 --> 00:22:24,470
oh

62
00:22:24,480 --> 00:23:04,230
so this is

63
00:23:04,240 --> 00:23:33,750

this is

64
00:23:33,760 --> 00:24:02,870
right

65
00:24:02,880 --> 00:44:04,230
how

66
00:44:08,470 --> 00:44:06,550
all right um good afternoon and i'd like

67
00:44:11,270 --> 00:44:08,480
to welcome everybody to the asteroid

68
00:44:12,550 --> 00:44:11,280
deflections demonstration session here

69
00:44:13,750 --> 00:44:12,560
at lpi

70
00:44:16,069 --> 00:44:13,760
um

71
00:44:17,430 --> 00:44:16,079
what i want to do is first of all to

72
00:44:19,670 --> 00:44:17,440
acknowledge

73
00:44:21,829 --> 00:44:19,680
session chairs introduce myself i'm dan

74
00:44:23,910 --> 00:44:21,839
masnick

75
00:44:25,670 --> 00:44:23,920
senior space systems engineer at nasa

76
00:44:27,910 --> 00:44:25,680
langley research center

77
00:44:29,589 --> 00:44:27,920
i was one of the members of the the keck

78
00:44:30,950 --> 00:44:29,599
sponsored study on the asteroid

79
00:44:32,790 --> 00:44:30,960
retrieval mission

80
00:44:34,550 --> 00:44:32,800
and i am currently leading the efforts

81
00:44:36,950 --> 00:44:34,560
for the agency on looking at the

82
00:44:38,950 --> 00:44:36,960
alternate approach for the asteroid

83
00:44:40,069 --> 00:44:38,960
redirect robotic mission

84
00:44:42,309 --> 00:44:40,079
um

85
00:44:45,030 --> 00:44:42,319
my my session co-chair

86
00:44:46,550 --> 00:44:45,040
pat troutman is not present today he had

87
00:44:49,190 --> 00:44:46,560
some family matters that he had to tend

88
00:44:52,150 --> 00:44:49,200

to he will be joining us virtually um

89
00:44:54,950 --> 00:44:52,160
and pat he leads strategic systems

90
00:44:56,309 --> 00:44:54,960
analysis activities for heomd

91
00:44:57,990 --> 00:44:56,319
back at langley

92
00:44:59,349 --> 00:44:58,000
the human exploration operations mission

93
00:45:02,829 --> 00:44:59,359
directorate

94
00:45:05,510 --> 00:45:02,839
um to my left is paul abel who is

95
00:45:07,430 --> 00:45:05,520
ably providing cover for me and i

96
00:45:09,030 --> 00:45:07,440
appreciate his help

97
00:45:10,630 --> 00:45:09,040
paul serves as the in the astro

98
00:45:12,790 --> 00:45:10,640
materials research and exploration

99
00:45:13,990 --> 00:45:12,800
science directorate at nasa johnson

100
00:45:16,829 --> 00:45:14,000
space center

101
00:45:18,950 --> 00:45:16,839
and is a leader in small body planetary

102
00:45:21,349 --> 00:45:18,960
science um

103
00:45:24,990 --> 00:45:21,359
so i'll mention again for the folks

104
00:45:28,710 --> 00:45:25,000
online uh you know you can go to

105
00:45:30,470 --> 00:45:28,720
www.nasa.gov asteroid workshop

106
00:45:32,470 --> 00:45:30,480
and you can join in the discussion and

107
00:45:34,150 --> 00:45:32,480
send questions to

108
00:45:37,109 --> 00:45:34,160
on twitter at

109
00:45:40,309 --> 00:45:37,119
protect planet

110
00:45:41,750 --> 00:45:40,319
what i'd like to do is

111
00:45:43,270 --> 00:45:41,760
first of all just kind of give a little

112
00:45:46,069 --> 00:45:43,280
bit of background on this session so

113
00:45:49,190 --> 00:45:46,079

next slide please

114
00:45:51,670 --> 00:45:49,200
um so the purpose of this session is to

115
00:45:53,910 --> 00:45:51,680
look at deflection techniques

116
00:45:55,190 --> 00:45:53,920
that could be applied

117
00:45:56,870 --> 00:45:55,200
to

118
00:45:59,510 --> 00:45:56,880
bodies or objects that are large enough

119
00:46:00,390 --> 00:45:59,520
to provide or to result in a significant

120
00:46:02,470 --> 00:46:00,400
damage

121
00:46:03,829 --> 00:46:02,480
if they were to impact the earth

122
00:46:05,270 --> 00:46:03,839
roughly we're talking about something in

123
00:46:07,510 --> 00:46:05,280
the 100 meter

124
00:46:09,349 --> 00:46:07,520
or larger size

125
00:46:12,309 --> 00:46:09,359
and the rfi call

126
00:46:14,230 --> 00:46:12,319
was was looking at demonstrations

127
00:46:15,670 --> 00:46:14,240
in very in these various areas that are

128
00:46:17,910 --> 00:46:15,680
up here

129
00:46:19,990 --> 00:46:17,920
but not necessarily limited to those so

130
00:46:23,990 --> 00:46:20,000
that's what came out in the rfi

131
00:46:26,550 --> 00:46:24,000
um looking at slow push uh techniques

132
00:46:27,910 --> 00:46:26,560
um in particular one of those that was

133
00:46:28,950 --> 00:46:27,920
called out was a gravity tractor

134
00:46:29,910 --> 00:46:28,960
technique

135
00:46:34,630 --> 00:46:29,920
um

136
00:46:36,309 --> 00:46:34,640
investigations that are useful to

137
00:46:39,109 --> 00:46:36,319
planetary defense

138
00:46:39,750 --> 00:46:39,119

uh the use of deployables from the arv

139
00:46:43,990 --> 00:46:39,760
to

140
00:46:46,069 --> 00:46:44,000
again using

141
00:46:48,150 --> 00:46:46,079
for example a standalone transponder for

142
00:46:50,230 --> 00:46:48,160
continually tracking things like that so

143
00:46:53,670 --> 00:46:50,240
everything from the actual

144
00:46:56,630 --> 00:46:53,680
devices that would invoke or impart the

145
00:46:58,309 --> 00:46:56,640
delta v on the object to secondary

146
00:46:59,670 --> 00:46:58,319
supporting

147
00:47:01,670 --> 00:46:59,680
equipment

148
00:47:03,750 --> 00:47:01,680
um

149
00:47:07,109 --> 00:47:03,760
let me just say you know we've

150
00:47:08,710 --> 00:47:07,119
kind of echoing off chris moore's uh

151
00:47:10,069 --> 00:47:08,720
comments from last night you know we

152
00:47:12,390 --> 00:47:10,079
we've spent four and a half billion

153
00:47:14,230 --> 00:47:12,400
years here as a planet

154
00:47:16,630 --> 00:47:14,240
kind of sucking up asteroids and comets

155
00:47:18,390 --> 00:47:16,640
and and taking the shots and uh what's

156
00:47:21,030 --> 00:47:18,400
interesting now is we're finally

157
00:47:22,870 --> 00:47:21,040
starting to talk about how we could

158
00:47:24,630 --> 00:47:22,880
kind of come back at them a little bit

159
00:47:26,390 --> 00:47:24,640
here and prevent them from doing that in

160
00:47:27,670 --> 00:47:26,400
the future i think that's really

161
00:47:29,750 --> 00:47:27,680
exciting

162
00:47:31,349 --> 00:47:29,760
and i think that's a an important part

163
00:47:33,510 --> 00:47:31,359

potentially important part of this

164
00:47:36,829 --> 00:47:33,520
mission

165
00:47:41,030 --> 00:47:36,839
so the next next slide

166
00:47:43,510 --> 00:47:41,040
um we went through we had 92 uh

167
00:47:47,430 --> 00:47:43,520
responses in in this session

168
00:47:49,510 --> 00:47:47,440
um and we've selected 13 uh responses in

169
00:47:52,390 --> 00:47:49,520
the categories below they're basically

170
00:47:53,670 --> 00:47:52,400
kind of grouped into seven basic areas

171
00:47:55,829 --> 00:47:53,680
um

172
00:47:57,589 --> 00:47:55,839
this was you know repositioning a small

173
00:47:59,430 --> 00:47:57,599
asteroid or portion of an asteroid to

174
00:48:01,270 --> 00:47:59,440
impact a larger asteroid kind of the

175
00:48:03,109 --> 00:48:01,280
cosmic billiards approach

176
00:48:04,230 --> 00:48:03,119
um and we'll hear a couple presentations

177
00:48:05,190 --> 00:48:04,240
on that

178
00:48:06,390 --> 00:48:05,200
um

179
00:48:09,109 --> 00:48:06,400
you know we're we're already

180
00:48:10,950 --> 00:48:09,119
demonstrating moving uh a large class of

181
00:48:12,309 --> 00:48:10,960
mass but this potentially is a great

182
00:48:14,150 --> 00:48:12,319
planetary defense technique in the

183
00:48:14,950 --> 00:48:14,160
future that we looked at

184
00:48:17,430 --> 00:48:14,960
um

185
00:48:19,990 --> 00:48:17,440
using the the high efficiency engine

186
00:48:21,670 --> 00:48:20,000
trust to push a rotating asteroid while

187
00:48:24,230 --> 00:48:21,680
using the posing thrust to hold relative

188
00:48:25,829 --> 00:48:24,240

positions ion beam deflection approach

189
00:48:27,109 --> 00:48:25,839
we're going to hear some talks about

190
00:48:29,990 --> 00:48:27,119
that

191
00:48:31,990 --> 00:48:30,000
kinetic impactor is still a viable

192
00:48:33,510 --> 00:48:32,000
approach

193
00:48:34,710 --> 00:48:33,520
maybe the most viable depending on

194
00:48:36,150 --> 00:48:34,720
warning time and we'll hear a couple

195
00:48:37,750 --> 00:48:36,160
thoughts about that

196
00:48:39,910 --> 00:48:37,760
um one of the

197
00:48:41,829 --> 00:48:39,920
the areas that's been talked about quite

198
00:48:44,309 --> 00:48:41,839
a bit is this enhanced gravity

199
00:48:46,549 --> 00:48:44,319
tractoring with local mass augmentation

200
00:48:48,309 --> 00:48:46,559
um and we'll get about that we've also

201
00:48:50,710 --> 00:48:48,319
looked at using the sun's energy to

202
00:48:52,870 --> 00:48:50,720
vaporize the material uh

203
00:48:55,910 --> 00:48:52,880
and also looking at swarms of small

204
00:48:57,190 --> 00:48:55,920
satellites uh to attach and de-spoon

205
00:48:58,790 --> 00:48:57,200
and redirect

206
00:49:00,549 --> 00:48:58,800
and finally we had an area seven that

207
00:49:02,150 --> 00:49:00,559
looked at technologies and approaches

208
00:49:06,150 --> 00:49:02,160
that are applicable across the entire

209
00:49:10,230 --> 00:49:07,670
you know our different non-deflection

210
00:49:11,750 --> 00:49:10,240
topics that are related

211
00:49:14,309 --> 00:49:11,760
so just quickly i'm going to go through

212
00:49:17,030 --> 00:49:14,319
the agenda and the little logistics here

213
00:49:19,589 --> 00:49:17,040

next slide please um

214
00:49:21,829 --> 00:49:19,599
we're basically going to uh

215
00:49:23,670 --> 00:49:21,839
have a first series of presentations

216
00:49:25,270 --> 00:49:23,680
going to the next i won't i won't go

217
00:49:26,950 --> 00:49:25,280
through them all we'll take a short

218
00:49:28,790 --> 00:49:26,960
break and the way we've got it

219
00:49:32,630 --> 00:49:28,800
structured since we we've revamped the

220
00:49:33,829 --> 00:49:32,640
schedule here for this um uh

221
00:49:36,069 --> 00:49:33,839
the extended

222
00:49:37,829 --> 00:49:36,079
portions of the the workshop is we've

223
00:49:39,750 --> 00:49:37,839
got two hours set aside for tomorrow

224
00:49:41,109 --> 00:49:39,760
morning from eight to ten over in the

225
00:49:42,549 --> 00:49:41,119
berkner room

226
00:49:43,910 --> 00:49:42,559
and um we're gonna have a short

227
00:49:47,750 --> 00:49:43,920
discussion

228
00:49:49,589 --> 00:49:47,760
synthesis this afternoon

229
00:49:50,950 --> 00:49:49,599
based on what we've heard today i'll in

230
00:49:52,630 --> 00:49:50,960
the morning i'll have some slides that

231
00:49:55,109 --> 00:49:52,640
we'll kind of

232
00:49:56,870 --> 00:49:55,119
massage and discuss in further in real

233
00:49:59,109 --> 00:49:56,880
time in preparation for the plenary

234
00:50:02,950 --> 00:49:59,119
session uh at ten o'clock

235
00:50:05,030 --> 00:50:02,960
uh tomorrow so i hope folks can can join

236
00:50:07,190 --> 00:50:05,040
if you can't uh join tomorrow morning at

237
00:50:08,230 --> 00:50:07,200
eight um certainly we'll have we'll have

238
00:50:10,069 --> 00:50:08,240

about

239
00:50:12,630 --> 00:50:10,079
roughly 25 minutes to discuss things

240
00:50:14,069 --> 00:50:12,640
this afternoon before before we have to

241
00:50:14,870 --> 00:50:14,079
return

242
00:50:16,309 --> 00:50:14,880
um

243
00:50:18,950 --> 00:50:16,319
what i'm going to do is i've asked each

244
00:50:21,030 --> 00:50:18,960
of the presenters to

245
00:50:21,990 --> 00:50:21,040
keep their talks to approximately 13

246
00:50:25,030 --> 00:50:22,000
minutes

247
00:50:26,710 --> 00:50:25,040
answers

248
00:50:28,870 --> 00:50:26,720
after each presentation which is a

249
00:50:30,390 --> 00:50:28,880
little bit of a change uh

250
00:50:32,230 --> 00:50:30,400
from the last time

251
00:50:34,549 --> 00:50:32,240
um i think that'll flow better we're

252
00:50:36,309 --> 00:50:34,559
gonna stay on time if we get a little

253
00:50:38,470 --> 00:50:36,319
bit ahead like we did for the capture

254
00:50:39,910 --> 00:50:38,480
session this morning we'll take a brief

255
00:50:41,829 --> 00:50:39,920
break just so if folks are coming in to

256
00:50:43,670 --> 00:50:41,839
hear a particular talk we can be as

257
00:50:44,549 --> 00:50:43,680
close to time as possible

258
00:50:46,069 --> 00:50:44,559
um

259
00:50:48,870 --> 00:50:46,079
we've got several folks that will be

260
00:50:50,309 --> 00:50:48,880
presenting uh virtually and we'll

261
00:50:52,549 --> 00:50:50,319
cue them in

262
00:50:55,349 --> 00:50:52,559
and for the virtual presenters

263
00:50:57,589 --> 00:50:55,359

there'll be a time uh clock that they

264
00:50:59,349 --> 00:50:57,599
can see for everybody in the room

265
00:51:02,390 --> 00:50:59,359
we'll give you a three minute warning so

266
00:51:04,950 --> 00:51:02,400
at 10 minutes um i'll hold up a three

267
00:51:06,390 --> 00:51:04,960
and uh and we'll go from there

268
00:51:07,829 --> 00:51:06,400
so

269
00:51:08,950 --> 00:51:07,839
i think we've actually got a couple

270
00:51:10,870 --> 00:51:08,960
minutes

271
00:51:12,390 --> 00:51:10,880
in order to stay on time

272
00:51:13,510 --> 00:51:12,400
um

273
00:51:15,349 --> 00:51:13,520
i think if there's anything else i

274
00:51:17,190 --> 00:51:15,359
wanted to say oh

275
00:51:18,470 --> 00:51:17,200
i guess to fill in you know i can say

276
00:51:20,150 --> 00:51:18,480
from the

277
00:51:22,309 --> 00:51:20,160
the um

278
00:51:23,750 --> 00:51:22,319
the responses that were provided you

279
00:51:25,670 --> 00:51:23,760
know we had the guidance of of the

280
00:51:27,349 --> 00:51:25,680
relevance the impact the maturity and

281
00:51:29,430 --> 00:51:27,359
the affordability

282
00:51:31,910 --> 00:51:29,440
um you know some of that's kind of in

283
00:51:34,630 --> 00:51:31,920
the eye of the beholder some of these uh

284
00:51:37,670 --> 00:51:34,640
concepts will probably add some cost

285
00:51:39,109 --> 00:51:37,680
uh to the asteroid redirect robotic

286
00:51:40,870 --> 00:51:39,119
mission

287
00:51:43,270 --> 00:51:40,880
but we wanted to hear the ideas and see

288
00:51:46,549 --> 00:51:43,280

how how we could incorporate those some

289
00:51:47,270 --> 00:51:46,559
of the ideas will probably be lower cost

290
00:51:48,630 --> 00:51:47,280
and

291
00:51:51,589 --> 00:51:48,640
obviously some have

292
00:51:53,750 --> 00:51:51,599
more near-term applicability

293
00:51:55,589 --> 00:51:53,760
but we tried to try to select those from

294
00:51:57,589 --> 00:51:55,599
the 92 that were

295
00:51:59,589 --> 00:51:57,599
submitted to try to keep in the in the

296
00:52:01,270 --> 00:51:59,599
near term technology development

297
00:52:03,349 --> 00:52:01,280
something that we could fly if we had

298
00:52:05,910 --> 00:52:03,359
the proper funding

299
00:52:09,910 --> 00:52:07,670
so with that why don't we go ahead and

300
00:52:13,030 --> 00:52:09,920
get started we're pretty much on time

301
00:52:15,430 --> 00:52:13,040
um our first presenter is uh

302
00:52:17,270 --> 00:52:15,440
mike ellspermann he's actually filling

303
00:52:19,270 --> 00:52:17,280
in for david smith who was on the agenda

304
00:52:20,870 --> 00:52:19,280
originally

305
00:52:22,549 --> 00:52:20,880
mike is a director of space science and

306
00:52:24,630 --> 00:52:22,559
advanced space utilization for boeing

307
00:52:25,910 --> 00:52:24,640
phantomworks organization uh he's

308
00:52:27,270 --> 00:52:25,920
chartered to develop and mature

309
00:52:28,870 --> 00:52:27,280
innovative space technologies and

310
00:52:30,710 --> 00:52:28,880
capabilities create new space market

311
00:52:33,349 --> 00:52:30,720
opportunities and enable business

312
00:52:37,510 --> 00:52:33,359
creation and growth

313
00:52:47,349 --> 00:52:37,520

so i'll hand it over to mike and welcome

314
00:52:47,359 --> 00:53:02,710
uh

315
00:53:06,150 --> 00:53:03,829
um

316
00:53:09,109 --> 00:53:06,160
the basic concept that we explored

317
00:53:40,470 --> 00:53:09,119
with this response was can a large uh

318
00:54:10,390 --> 00:53:58,069
um

319
00:54:14,230 --> 00:54:12,790
so a little bit on the effort

320
00:54:16,150 --> 00:54:14,240
concept

321
00:54:18,790 --> 00:54:16,160
for the first point rfi

322
00:54:20,309 --> 00:54:18,800
we proposed a

323
00:54:22,549 --> 00:54:20,319
commercial spacecraft derivative as the

324
00:54:26,630 --> 00:54:22,559
point of the part before the redirection

325
00:54:30,630 --> 00:54:27,990
uh the one in particular that we looked

326
00:54:32,870 --> 00:54:30,640
at was the 702 mp which is medium power

327
00:54:34,230 --> 00:54:32,880
um hey mike let me sorry real quick

328
00:54:36,870 --> 00:54:34,240
they're apparently having trouble

329
00:54:39,829 --> 00:54:36,880
hearing you online try that now is that

330
00:54:41,270 --> 00:54:39,839
better

331
00:54:42,390 --> 00:54:41,280
i can speak softer now i guess okay

332
00:54:43,190 --> 00:54:42,400
there you go that's better okay i'm

333
00:54:44,069 --> 00:54:43,200
sorry

334
00:54:46,390 --> 00:54:44,079
um

335
00:54:47,910 --> 00:54:46,400
the the armed vehicle that we developed

336
00:54:50,630 --> 00:54:47,920
uh designed for for the first part of

337
00:54:52,230 --> 00:54:50,640
the rfi response was based on the 702 mp

338
00:54:53,670 --> 00:54:52,240

uh roughly we came up with a design it

339
00:54:55,829 --> 00:54:53,680
weighed about fourteen thousand seven

340
00:54:57,750 --> 00:54:55,839
hundred kilograms a roughly ten thousand

341
00:54:59,190 --> 00:54:57,760
kilograms xenon propellant load based on

342
00:55:01,190 --> 00:54:59,200
the assumptions at the time of about a

343
00:55:03,910 --> 00:55:01,200
thousand metric ton asteroid

344
00:55:06,309 --> 00:55:03,920
uh also working with the jpl design team

345
00:55:08,150 --> 00:55:06,319
at the time the concept we came up with

346
00:55:11,829 --> 00:55:08,160
the lro injection delta v was about 60

347
00:55:16,069 --> 00:55:14,390
subsequent to that

348
00:55:22,950 --> 00:55:16,079
dave talked with some of the folks on

349
00:55:26,950 --> 00:55:24,789
not sure what it is today but that's the

350
00:55:29,109 --> 00:55:26,960
assumption we use for this and also the

351
00:55:30,309 --> 00:55:29,119
the research we got refined such as the

352
00:55:31,030 --> 00:55:30,319
health of the requirements we're less

353
00:55:32,230 --> 00:55:31,040
than

354
00:55:34,230 --> 00:55:32,240
just doing iteration i think it's going

355
00:55:36,150 --> 00:55:34,240
to get more

356
00:55:38,870 --> 00:55:36,160
so a lot less so the spacecraft overall

357
00:55:40,950 --> 00:55:38,880
size came down around six metric tons

358
00:55:42,390 --> 00:55:40,960
so the question that we've that we posed

359
00:55:43,750 --> 00:55:42,400
is can you do an effective demonstrate

360
00:55:47,270 --> 00:55:43,760
deflection demonstration with a six

361
00:55:49,829 --> 00:55:47,280
metric ton asteroid redirect vehicle

362
00:55:51,990 --> 00:55:49,839
um so

363
00:55:52,950 --> 00:55:52,000

uh some of the the four methods that

364
00:55:54,390 --> 00:55:52,960
we've talked about we've kind of

365
00:55:57,430 --> 00:55:54,400
eliminated two

366
00:55:59,030 --> 00:55:57,440
the direct push once again the capture

367
00:56:01,109 --> 00:55:59,040
mission really accomplishes that so we

368
00:56:02,950 --> 00:56:01,119
didn't look at doing any mods to that

369
00:56:04,870 --> 00:56:02,960
the kinetic impactor method

370
00:56:06,789 --> 00:56:04,880
uh that would require some additional

371
00:56:08,309 --> 00:56:06,799
hardware and this kind of we thought it

372
00:56:10,309 --> 00:56:08,319
was a harder implementation so for our

373
00:56:11,670 --> 00:56:10,319
first pass we focused on ion beam

374
00:56:13,990 --> 00:56:11,680
shepherding and the gravity tractor

375
00:56:15,270 --> 00:56:14,000
approaches so for the

376
00:56:16,710 --> 00:56:15,280
the ep thrusters that are being

377
00:56:18,710 --> 00:56:16,720
considered for the mission we've shown a

378
00:56:19,910 --> 00:56:18,720
couple here from our friends at music

379
00:56:21,990 --> 00:56:19,920
and aerojet

380
00:56:23,589 --> 00:56:22,000
um we've been working with them closely

381
00:56:24,950 --> 00:56:23,599
for quite some time on solar electric

382
00:56:26,950 --> 00:56:24,960
health and demonstration missions and

383
00:56:28,710 --> 00:56:26,960
other technology development activities

384
00:56:30,309 --> 00:56:28,720
uh busek has a they currently have two

385
00:56:33,030 --> 00:56:30,319
thrusters of eight kilowatts and 20

386
00:56:34,870 --> 00:56:33,040
kilowatts that are mid prl level play

387
00:56:36,069 --> 00:56:34,880
some still work to do on those uh but

388
00:56:38,309 --> 00:56:36,079

they are beginning to develop a 10

389
00:56:39,670 --> 00:56:38,319
kilowatt thruster that's

390
00:56:40,950 --> 00:56:39,680
right off the eight kilowatt thruster

391
00:56:42,789 --> 00:56:40,960
they have uh

392
00:56:44,630 --> 00:56:42,799
currently and then aerojet has a 12

393
00:56:46,150 --> 00:56:44,640
kilowatt thruster with the performance

394
00:56:48,150 --> 00:56:46,160
specs there

395
00:56:49,510 --> 00:56:48,160
so there are some some relatively mature

396
00:56:50,789 --> 00:56:49,520
technologies in terms of high power

397
00:56:52,470 --> 00:56:50,799
thrusters that will be useful for the

398
00:56:54,069 --> 00:56:52,480
redirect mission these would also be

399
00:56:56,630 --> 00:56:54,079
used for the iron beam shepherding

400
00:56:57,990 --> 00:56:56,640
activity where you would actually

401
00:57:04,150 --> 00:56:58,000
blast the asteroid if you low with the

402
00:57:06,230 --> 00:57:05,270
so

403
00:57:07,510 --> 00:57:06,240
dave

404
00:57:09,589 --> 00:57:07,520
in his work went out and did some

405
00:57:12,069 --> 00:57:09,599
research and found some very i guess

406
00:57:13,589 --> 00:57:12,079
recent papers by a gentleman in claudio

407
00:57:15,190 --> 00:57:13,599
bombordelli

408
00:57:16,549 --> 00:57:15,200
who has done extensive work it looks

409
00:57:18,789 --> 00:57:16,559
like to come up with an analytical

410
00:57:21,030 --> 00:57:18,799
approach to determine the effectiveness

411
00:57:22,789 --> 00:57:21,040
of both the ion beam shepherding and the

412
00:57:24,870 --> 00:57:22,799
gravity tracker methods and gives a

413
00:57:26,710 --> 00:57:24,880

relative comparison of them as a

414
00:57:28,789 --> 00:57:26,720
function of

415
00:57:30,950 --> 00:57:28,799
the effectiveness of each uh

416
00:57:32,870 --> 00:57:30,960
technique uh in terms of maneuvering and

417
00:57:35,030 --> 00:57:32,880
making the asteroid deflect

418
00:57:35,990 --> 00:57:35,040
so his chart there shows for his his

419
00:57:37,510 --> 00:57:36,000
initial

420
00:57:39,190 --> 00:57:37,520
data line he assumed a spacecraft that

421
00:57:41,430 --> 00:57:39,200
had an inverse specific power of five

422
00:57:43,030 --> 00:57:41,440
kilo kilograms per kilowatt

423
00:57:44,630 --> 00:57:43,040
um that's for probably a very

424
00:57:46,390 --> 00:57:44,640
lightweight custom spacecraft that

425
00:57:47,829 --> 00:57:46,400
generates a lot of power

426
00:57:49,589 --> 00:57:47,839
for the point of departure for our

427
00:57:51,190 --> 00:57:49,599
vehicle we're around 20 kilogram

428
00:57:52,630 --> 00:57:51,200
kilograms per kilowatt so it's not quite

429
00:57:54,710 --> 00:57:52,640
as efficient

430
00:57:55,910 --> 00:57:54,720
but since you still have a lot of power

431
00:57:58,069 --> 00:57:55,920
and you have a lot of height you have a

432
00:58:00,309 --> 00:57:58,079
lot of mass relatively speaking we think

433
00:58:02,630 --> 00:58:00,319
it would be a good platform to explore

434
00:58:05,030 --> 00:58:02,640
doing these demonstration missions uh

435
00:58:07,589 --> 00:58:05,040
in in tandem with one another

436
00:58:08,950 --> 00:58:07,599
um so we assumed a delta time to do the

437
00:58:09,910 --> 00:58:08,960
deflection demonstration for about two

438
00:58:11,270 --> 00:58:09,920

years

439
00:58:12,630 --> 00:58:11,280
for the ibs

440
00:58:14,789 --> 00:58:12,640
demonstration you're about two asteroid

441
00:58:16,549 --> 00:58:14,799
diameters hovering away from the target

442
00:58:17,829 --> 00:58:16,559
and for the gravity tractor on this

443
00:58:21,030 --> 00:58:17,839
bomber daily it's in one and a half

444
00:58:25,589 --> 00:58:24,390
so for the ion beam shepherding

445
00:58:28,230 --> 00:58:25,599
technique

446
00:58:29,589 --> 00:58:28,240
uh bombardelli uh created this curve or

447
00:58:32,390 --> 00:58:29,599
these set of curves as a function of the

448
00:58:33,750 --> 00:58:32,400
spacecraft mass his work assumed 150

449
00:58:36,950 --> 00:58:33,760
metric ton

450
00:58:38,870 --> 00:58:36,960
150 150 meter diameter asteroid

451
00:58:40,789 --> 00:58:38,880
so in our analysis we were assuming that

452
00:58:42,309 --> 00:58:40,799
we'd be doing the demonstration on 2009

453
00:58:43,750 --> 00:58:42,319
bd which was the notional target at the

454
00:58:45,910 --> 00:58:43,760
time which is much smaller i think it's

455
00:58:47,349 --> 00:58:45,920
on the order of 10 10 meters in diameter

456
00:58:48,870 --> 00:58:47,359
soon

457
00:58:51,430 --> 00:58:48,880
so our spacecraft fits on the curve

458
00:58:53,510 --> 00:58:51,440
where the red dot is so you can see that

459
00:58:55,829 --> 00:58:53,520
uh and what these represent is for for a

460
00:58:57,990 --> 00:58:55,839
given mass of a spacecraft for a given

461
00:59:00,710 --> 00:58:58,000
force the amount of time it would take

462
00:59:02,549 --> 00:59:00,720
to move the asteroid out of its office

463
00:59:04,710 --> 00:59:02,559

trajectory by about a distance of two

464
00:59:06,230 --> 00:59:04,720
earth radii

465
00:59:08,150 --> 00:59:06,240
and massive ibs is the mass of the

466
00:59:10,150 --> 00:59:08,160
spacecraft obviously lower mass

467
00:59:12,230 --> 00:59:10,160
spacecrafts uh according to the

468
00:59:13,510 --> 00:59:12,240
analytical approach that bombardely

469
00:59:16,390 --> 00:59:13,520
produced here is that they're more

470
00:59:18,950 --> 00:59:16,400
efficient at the same specific power so

471
00:59:21,109 --> 00:59:18,960
ours our inverse specific power for the

472
00:59:22,870 --> 00:59:21,119
the boeing arv is a little bit higher so

473
00:59:24,789 --> 00:59:22,880
it's not going to be quite as efficient

474
00:59:26,390 --> 00:59:24,799
however we think that for in about two

475
00:59:29,109 --> 00:59:26,400
years you could probably

476
00:59:30,950 --> 00:59:29,119
get maybe a 3000 kilometer deflection by

477
00:59:32,309 --> 00:59:30,960
using the ion beam shepherding method

478
00:59:33,990 --> 00:59:32,319
with one of the thrusters that we show

479
00:59:36,150 --> 00:59:34,000
so you wouldn't get the full two two

480
00:59:37,670 --> 00:59:36,160
earth radii deflection that bombardelli

481
00:59:39,109 --> 00:59:37,680
would assume but you could probably

482
00:59:43,750 --> 00:59:39,119
measure that

483
00:59:50,230 --> 00:59:47,670
so for the gravity tractor application

484
00:59:52,870 --> 00:59:50,240
we think that even with a six metric ton

485
00:59:54,870 --> 00:59:52,880
spacecraft for uh in interacting with an

486
00:59:57,270 --> 00:59:54,880
asteroid about the size of 2009bd you

487
00:59:58,470 --> 00:59:57,280
could see also a significant trajectory

488
01:00:01,030 --> 00:59:58,480

deflection

489
01:00:03,030 --> 01:00:01,040
for the the curve shown here this is a

490
01:00:05,670 --> 01:00:03,040
function of the the mass of the

491
01:00:07,109 --> 01:00:05,680
spacecraft uh as and and for different

492
01:00:08,069 --> 01:00:07,119
forcing functions different forces

493
01:00:10,870 --> 01:00:08,079
applied

494
01:00:12,309 --> 01:00:10,880
um our asteroid redirect vehicle kind of

495
01:00:13,670 --> 01:00:12,319
corresponds over on the left hand side

496
01:00:15,270 --> 01:00:13,680
there

497
01:00:16,710 --> 01:00:15,280
once again assuming one and a half

498
01:00:19,030 --> 01:00:16,720
diameter asteroid diameter hover

499
01:00:20,630 --> 01:00:19,040
distance a deflection force based on

500
01:00:22,549 --> 01:00:20,640
gravity alone of about point one newton

501
01:00:24,309 --> 01:00:22,559
over a period of time about six months

502
01:00:26,470 --> 01:00:24,319
we think it would uh become calculated

503
01:00:28,549 --> 01:00:26,480
we can give you about a 1.25 meter per

504
01:00:30,870 --> 01:00:28,559
second change in velocity which should

505
01:00:32,630 --> 01:00:30,880
be measurable by conventional doppler

506
01:00:33,990 --> 01:00:32,640
tracking methods

507
01:00:36,069 --> 01:00:34,000
obviously a larger spacecraft would

508
01:00:37,910 --> 01:00:36,079
probably have a higher more efficient uh

509
01:00:39,349 --> 01:00:37,920
you have a larger deflection

510
01:00:42,309 --> 01:00:39,359
also assume once again this data is

511
01:00:44,230 --> 01:00:42,319
based on 150 metric or 150 meter

512
01:00:45,510 --> 01:00:44,240
absolute diameter

513
01:00:47,670 --> 01:00:45,520

we might be able to do better than that

514
01:00:50,150 --> 01:00:47,680
we might be able to do

515
01:00:51,750 --> 01:00:50,160
a more significant change

516
01:00:54,950 --> 01:00:51,760
given the fact that it's a smaller

517
01:00:59,510 --> 01:00:57,670
so in conclusion we think that uh for

518
01:01:01,349 --> 01:00:59,520
the redirect mission spacecraft that we

519
01:01:03,670 --> 01:01:01,359
developed for the response you could do

520
01:01:04,950 --> 01:01:03,680
two deflection demonstrations uh on a

521
01:01:07,109 --> 01:01:04,960
single mission you would do the gravity

522
01:01:08,710 --> 01:01:07,119
tractor first then followed by the ion

523
01:01:11,190 --> 01:01:08,720
beam shepherding

524
01:01:12,789 --> 01:01:11,200
once again the 6.1 metric ton spacecraft

525
01:01:14,870 --> 01:01:12,799
that we're that we're assuming here is

526
01:01:16,710 --> 01:01:14,880
based on a uh would give the deflection

527
01:01:18,309 --> 01:01:16,720
to the 2009 bd target once again we're

528
01:01:20,470 --> 01:01:18,319
not sure where we're going to go or

529
01:01:23,109 --> 01:01:20,480
there's some uncertainty on the 2009 bd

530
01:01:25,109 --> 01:01:23,119
mass as well

531
01:01:26,230 --> 01:01:25,119
the propellant load for the deflection

532
01:01:29,030 --> 01:01:26,240
mission would be enough to do the iron

533
01:01:30,630 --> 01:01:29,040
beam shepherding demonstration um

534
01:01:32,230 --> 01:01:30,640
with that small of a spacecraft though

535
01:01:34,230 --> 01:01:32,240
you probably couldn't do the deflection

536
01:01:35,270 --> 01:01:34,240
demonstrations and the redirect mission

537
01:01:39,430 --> 01:01:35,280
on the same

538
01:01:40,950 --> 01:01:39,440

go up to the full-size spacecraft to the

539
01:01:42,870 --> 01:01:40,960
to the full 10 000 kilogram per pound

540
01:01:44,150 --> 01:01:42,880
load if you wanted to load it up full

541
01:01:45,190 --> 01:01:44,160
and you wanted to take the extra time

542
01:01:46,710 --> 01:01:45,200
required to do it you could probably

543
01:01:48,390 --> 01:01:46,720
demonstrate those techniques and still

544
01:01:51,510 --> 01:01:48,400
do the redirect mission bring the target

545
01:01:52,549 --> 01:01:51,520
back to a lunar retrograde orbit as well

546
01:01:53,910 --> 01:01:52,559
so we think this would be two good

547
01:01:55,750 --> 01:01:53,920
demonstrations to put on the mission for

548
01:01:58,390 --> 01:01:55,760
sure

549
01:01:59,430 --> 01:01:58,400
okay that's it all right thanks mike

550
01:02:00,950 --> 01:01:59,440
um

551
01:02:03,589 --> 01:02:00,960
we've got we've got about four minutes

552
01:02:06,390 --> 01:02:03,599
for questions so

553
01:02:08,390 --> 01:02:06,400
let me focus that we'd like to sure

554
01:02:14,870 --> 01:02:08,400
grab a microphone just so everybody can

555
01:02:17,670 --> 01:02:16,390
so i apologize if i was supposed to

556
01:02:18,789 --> 01:02:17,680
figure this out from one of the graphs

557
01:02:20,390 --> 01:02:18,799
you showed i was having a little bit of

558
01:02:22,549 --> 01:02:20,400
trouble figuring out the dimensions but

559
01:02:25,190 --> 01:02:22,559
can you talk a little bit about the

560
01:02:27,750 --> 01:02:25,200
efficiency of the impulse departed

561
01:02:29,670 --> 01:02:27,760
imparted on the asteroid given that the

562
01:02:31,510 --> 01:02:29,680
beam of ions coming out of the thruster

563
01:02:33,750 --> 01:02:31,520

diverges quite a bit yeah i think in

564
01:02:34,870 --> 01:02:33,760
bombardily's paper he assumed a 74

565
01:02:36,950 --> 01:02:34,880
efficiency

566
01:02:38,789 --> 01:02:36,960
if you did some work on

567
01:02:40,150 --> 01:02:38,799
on being able to reduce the dispersion

568
01:02:41,750 --> 01:02:40,160
angle on the thruster and get it more

569
01:02:42,549 --> 01:02:41,760
focused i'm sure you'd have a you have

570
01:02:47,349 --> 01:02:42,559
more

571
01:02:48,870 --> 01:02:47,359
asteroid but he took into account and in

572
01:02:50,309 --> 01:02:48,880
the curves there that you're going to

573
01:02:51,589 --> 01:02:50,319
have some type of a beam diffusion

574
01:02:54,789 --> 01:02:51,599
that's not going to be absolutely you

575
01:02:57,029 --> 01:02:54,799
know all imparted on the asteroid

576
01:02:58,470 --> 01:02:57,039
does that make makes sense

577
01:03:00,069 --> 01:02:58,480
yeah i'm i'm

578
01:03:01,670 --> 01:03:00,079
mentally processing that seems a lot

579
01:03:03,029 --> 01:03:01,680
higher efficiency than i would have

580
01:03:03,990 --> 01:03:03,039
guessed but i guess that's probably

581
01:03:06,069 --> 01:03:04,000
because

582
01:03:07,670 --> 01:03:06,079
even though the beam diverges a lot that

583
01:03:09,829 --> 01:03:07,680
there's a lot more particles in the

584
01:03:11,670 --> 01:03:09,839
center of the beam than in the

585
01:03:13,750 --> 01:03:11,680
outside i don't know

586
01:03:14,950 --> 01:03:13,760
that out of my college range i'll i can

587
01:03:16,309 --> 01:03:14,960
check it for you i can tell you what i

588
01:03:17,750 --> 01:03:16,319

would love to do is i can give you a

589
01:03:18,470 --> 01:03:17,760
reference to mamadelli's paper that

590
01:03:20,150 --> 01:03:18,480
might

591
01:03:21,910 --> 01:03:20,160
provide that to everybody

592
01:03:23,190 --> 01:03:21,920
yeah i think that's what basically the

593
01:03:24,309 --> 01:03:23,200
case is there is

594
01:03:25,750 --> 01:03:24,319
there's

595
01:03:27,750 --> 01:03:25,760
it's the distribution so you're getting

596
01:03:29,109 --> 01:03:27,760
that yeah

597
01:03:30,309 --> 01:03:29,119
and you know you could also vary the

598
01:03:31,670 --> 01:03:30,319
hovering distance too if you wanted to

599
01:03:33,270 --> 01:03:31,680
get closer but then you've got to worry

600
01:03:36,630 --> 01:03:33,280
about and maybe blow back on the

601
01:03:41,109 --> 01:03:39,829
um do other folks have questions

602
01:03:41,910 --> 01:03:41,119
and actually john brophy just stepped in

603
01:03:44,069 --> 01:03:41,920
the room you might have been able to

604
01:03:45,510 --> 01:03:44,079
answer that question in terms of

605
01:03:48,549 --> 01:03:45,520
efficiency

606
01:03:50,230 --> 01:03:48,559
timing is everything done

607
01:03:51,750 --> 01:03:50,240
just say yes yes

608
01:03:53,510 --> 01:03:51,760
there you go

609
01:03:55,910 --> 01:03:53,520
so i had a question about the rotation

610
01:03:56,870 --> 01:03:55,920
of this aster of the of the target

611
01:03:58,870 --> 01:03:56,880
you're talking about putting a

612
01:03:59,990 --> 01:03:58,880
spacecraft that's going to be what was

613
01:04:01,670 --> 01:04:00,000

it advice

614
01:04:03,349 --> 01:04:01,680
two meters right a couple diameters

615
01:04:05,109 --> 01:04:03,359
asteroid diameter diameter okay so if

616
01:04:07,109 --> 01:04:05,119
it's a 10 meter sp

617
01:04:09,270 --> 01:04:07,119
10 meter asteroid you might be 20 meters

618
01:04:10,829 --> 01:04:09,280
away hopefully yeah right for and that's

619
01:04:13,750 --> 01:04:10,839
true for the for the

620
01:04:15,829 --> 01:04:13,760
um uh the gravity tractor grabbing

621
01:04:17,270 --> 01:04:15,839
factor was two diameters and the ion

622
01:04:20,470 --> 01:04:17,280
beam shepherding is about a diameter and

623
01:04:22,230 --> 01:04:20,480
a half a little closer now

624
01:04:23,750 --> 01:04:22,240
you said it all the way around yeah

625
01:04:26,150 --> 01:04:23,760
but i mean it's okay so that that sets

626
01:04:28,390 --> 01:04:26,160
the skill so you're not that close but

627
01:04:30,950 --> 01:04:28,400
it still seems like some of your thrust

628
01:04:33,510 --> 01:04:30,960
might be going into rotating the body or

629
01:04:36,390 --> 01:04:33,520
you know despainting it as opposed to

630
01:04:38,150 --> 01:04:36,400
just a you know net thrust and i just

631
01:04:39,589 --> 01:04:38,160
wonder if that might have

632
01:04:41,270 --> 01:04:39,599
that's a good that's a good question i

633
01:04:43,109 --> 01:04:41,280
don't think we considered the effect on

634
01:04:44,630 --> 01:04:43,119
the rotation of that because they're not

635
01:04:46,549 --> 01:04:44,640
spheres right they're going to look like

636
01:04:48,710 --> 01:04:46,559
they're potatoes or something yeah

637
01:04:50,230 --> 01:04:48,720
um so you could easily be spinning it or

638
01:04:52,230 --> 01:04:50,240

unspinning it or whatever that's that's

639
01:04:53,349 --> 01:04:52,240
a good point in the the first pass

640
01:04:54,870 --> 01:04:53,359
analysis here we didn't look at the

641
01:04:56,230 --> 01:04:54,880
effect on rotation i think we assumed

642
01:04:57,430 --> 01:04:56,240
that you were just going to have you

643
01:05:00,549 --> 01:04:57,440
know all the ions were going to impart

644
01:05:01,990 --> 01:05:00,559
all that momentum on the on the asteroid

645
01:05:04,230 --> 01:05:02,000
assuming it was flat not moving not

646
01:05:05,190 --> 01:05:04,240
rotating so maybe some less efficiency

647
01:05:16,549 --> 01:05:05,200
yeah i think you're going to lose some

648
01:05:21,670 --> 01:05:19,910
um anything else in the room

649
01:05:24,069 --> 01:05:21,680
i guess um maybe i'll i'll ask a

650
01:05:26,390 --> 01:05:24,079
question in terms of uh

651
01:05:28,470 --> 01:05:26,400
you focused all this on the smaller

652
01:05:30,390 --> 01:05:28,480
target did you didn't look at any of the

653
01:05:31,589 --> 01:05:30,400
larger you know

654
01:05:33,430 --> 01:05:31,599
no but see some other other

655
01:05:35,190 --> 01:05:33,440
presentations that did it yeah so so if

656
01:05:36,549 --> 01:05:35,200
you're going to go and do that so this i

657
01:05:38,470 --> 01:05:36,559
think we you know if the boulder

658
01:05:39,349 --> 01:05:38,480
plucking technique is where we actually

659
01:05:40,549 --> 01:05:39,359
go

660
01:05:42,150 --> 01:05:40,559
you could probably you could still do a

661
01:05:44,470 --> 01:05:42,160
deflection demonstration it might be

662
01:05:46,710 --> 01:05:44,480
harder to determine the actual

663
01:05:49,430 --> 01:05:46,720

effect of the techniques on the larger

664
01:05:50,950 --> 01:05:49,440
asteroid once again if it's much bigger

665
01:05:52,630 --> 01:05:50,960
that's just a function of you know the

666
01:05:53,670 --> 01:05:52,640
way you would really see the the change

667
01:05:54,630 --> 01:05:53,680
in trajectory would be the amount of

668
01:05:56,309 --> 01:05:54,640
time that you're actually doing the

669
01:05:57,829 --> 01:05:56,319
deflection demonstration i think the

670
01:06:00,150 --> 01:05:57,839
mass it would take more time to see a

671
01:06:01,910 --> 01:06:00,160
discernible change in the trajectory

672
01:06:05,029 --> 01:06:01,920
okay

673
01:06:08,150 --> 01:06:05,039
all right well thanks um

674
01:06:10,390 --> 01:06:08,160
we're just uh a minute or two ahead here

675
01:06:11,670 --> 01:06:10,400
um

676
01:06:13,029 --> 01:06:11,680
dan i can't seem to get that to go to

677
01:06:28,549 --> 01:06:13,039
there i can't get to go to the next

678
01:06:33,829 --> 01:06:31,270
okay so just a reminder for the we only

679
01:06:36,630 --> 01:06:33,839
have one mic so for speakers as soon as

680
01:06:39,430 --> 01:06:36,640
you're done with the questions please uh

681
01:06:41,910 --> 01:06:39,440
get mic'd up and we'll continue

682
01:06:43,109 --> 01:06:41,920
uh so our next uh talk is by howard

683
01:06:45,190 --> 01:06:43,119
eller

684
01:06:47,349 --> 01:06:45,200
he is the chief system engineer at

685
01:06:49,270 --> 01:06:47,359
northrop grumman aerospace systems

686
01:06:50,950 --> 01:06:49,280
he's in the space system division

687
01:06:52,309 --> 01:06:50,960
he brings over 30 years of experience in

688
01:06:54,710 --> 01:06:52,319

system and mission engineering to the

689
01:06:56,789 --> 01:06:54,720
development of space system concepts

690
01:06:58,150 --> 01:06:56,799
spacecraft designs and associated

691
01:07:00,549 --> 01:06:58,160
technologies

692
01:07:03,029 --> 01:07:00,559
and over to you okay

693
01:07:05,430 --> 01:07:03,039
uh we took uh seriously the

694
01:07:07,750 --> 01:07:05,440
the approach that we wanted the redirect

695
01:07:10,230 --> 01:07:07,760
mission and the deflection mission to

696
01:07:12,390 --> 01:07:10,240
use the same basic set of hardware

697
01:07:16,230 --> 01:07:12,400
and i am briefing this for james uh

698
01:07:18,470 --> 01:07:16,240
james munger so uh i'm a stand-in so

699
01:07:20,870 --> 01:07:18,480
uh we this is uh three separate

700
01:07:22,789 --> 01:07:20,880
briefings one we did the last time on

701
01:07:24,630 --> 01:07:22,799
the integrated uh sensing system i have

702
01:07:26,549 --> 01:07:24,640
a single chart that kind of summarizes

703
01:07:28,470 --> 01:07:26,559
some of those conclusions

704
01:07:30,069 --> 01:07:28,480
uh the middle one shows uh the

705
01:07:31,829 --> 01:07:30,079
configuration

706
01:07:34,710 --> 01:07:31,839
of the vehicle that we're talking about

707
01:07:36,870 --> 01:07:34,720
here and this is the one that we briefed

708
01:07:39,829 --> 01:07:36,880
at the last one which basically just

709
01:07:42,870 --> 01:07:39,839
adds the capture uh apertures the

710
01:07:45,349 --> 01:07:42,880
astromesh derived astral capture we

711
01:07:50,150 --> 01:07:48,470
this shows you know our basic approach a

712
01:07:51,750 --> 01:07:50,160
single suite

713
01:07:55,349 --> 01:07:51,760

of

714
01:07:58,950 --> 01:07:55,359
sensors that would give us long range

715
01:08:00,950 --> 01:07:58,960
sensing we get the ability to understand

716
01:08:02,630 --> 01:08:00,960
the makeup of the vehicle and then as we

717
01:08:03,750 --> 01:08:02,640
come in closer as we said at the last

718
01:08:05,990 --> 01:08:03,760
briefing

719
01:08:07,910 --> 01:08:06,000
understand the rotational dynamics and

720
01:08:10,789 --> 01:08:07,920
then a detailed understanding of the

721
01:08:11,589 --> 01:08:10,799
configuration all of that focusing again

722
01:08:14,470 --> 01:08:11,599
on

723
01:08:18,070 --> 01:08:14,480
uh knowing where and how we're going to

724
01:08:20,309 --> 01:08:18,080
specifically engage the asteroid

725
01:08:22,870 --> 01:08:20,319
now we took seriously all three of the

726
01:08:25,590 --> 01:08:22,880
approaches you know the direct sep

727
01:08:26,870 --> 01:08:25,600
approach is one that the asteroid

728
01:08:29,590 --> 01:08:26,880
redirect

729
01:08:30,390 --> 01:08:29,600
is you know featuring in spades

730
01:08:32,709 --> 01:08:30,400
but

731
01:08:34,229 --> 01:08:32,719
we also along with just like boeing

732
01:08:36,470 --> 01:08:34,239
believe you could use

733
01:08:39,269 --> 01:08:36,480
prior to that you could do it some type

734
01:08:41,269 --> 01:08:39,279
of a gravity tractoring at least demo

735
01:08:42,789 --> 01:08:41,279
uh be difficult to get the measurements

736
01:08:44,709 --> 01:08:42,799
uh that you might want but you could

737
01:08:47,590 --> 01:08:44,719
certainly show the topology and the

738
01:08:52,950 --> 01:08:47,600

layout and then we've looked at the

739
01:08:56,630 --> 01:08:54,390
so there's

740
01:08:57,990 --> 01:08:56,640
of course three approaches

741
01:09:01,189 --> 01:08:58,000
uh

742
01:09:03,110 --> 01:09:01,199
the no contact one is is probably

743
01:09:05,910 --> 01:09:03,120
preferable in terms of you know

744
01:09:07,990 --> 01:09:05,920
simplifying your interaction

745
01:09:10,390 --> 01:09:08,000
we did quite a bit of work looking at

746
01:09:13,110 --> 01:09:10,400
what it would take to center

747
01:09:16,309 --> 01:09:13,120
which is more this to change

748
01:09:18,630 --> 01:09:16,319
the uh the surface properties

749
01:09:20,550 --> 01:09:18,640
and we believe that in the same volume

750
01:09:23,749 --> 01:09:20,560
of the two capture apertures that we

751
01:09:24,870 --> 01:09:23,759
showed we could get up to a 50 meter 250

752
01:09:27,510 --> 01:09:24,880
meter

753
01:09:28,950 --> 01:09:27,520
uh apertures that would focus the sun

754
01:09:31,349 --> 01:09:28,960
and give us

755
01:09:35,430 --> 01:09:31,359
abilities depending on how you focus it

756
01:09:38,630 --> 01:09:35,440
to either center or a blade the surface

757
01:09:40,390 --> 01:09:38,640
so that's a very interesting approach

758
01:09:42,470 --> 01:09:40,400
and we believe it technically can be

759
01:09:44,070 --> 01:09:42,480
done we've looked at it as a way of

760
01:09:46,070 --> 01:09:44,080
mitigating

761
01:09:47,749 --> 01:09:46,080
earth orbit debris and we think that

762
01:09:50,070 --> 01:09:47,759
works actually pretty well now you're

763
01:09:52,070 --> 01:09:50,080

not going to blade the whole asteroid

764
01:09:55,030 --> 01:09:52,080
but you can change the albedo and if you

765
01:09:56,390 --> 01:09:55,040
integrate over a 30 year period of time

766
01:09:58,709 --> 01:09:56,400
you know if you know

767
01:10:02,149 --> 01:09:58,719
significantly ahead of time then that

768
01:10:05,430 --> 01:10:02,159
change in albedo is a very significant

769
01:10:07,510 --> 01:10:05,440
change in delta v now the question is

770
01:10:08,390 --> 01:10:07,520
you know how permanent is your change

771
01:10:09,910 --> 01:10:08,400
and

772
01:10:11,430 --> 01:10:09,920
can you control it

773
01:10:13,430 --> 01:10:11,440
can you project it

774
01:10:15,189 --> 01:10:13,440
but this is one that we would recommend

775
01:10:17,030 --> 01:10:15,199
you know highly looking at

776
01:10:19,030 --> 01:10:17,040
because

777
01:10:21,110 --> 01:10:19,040
you could do both demos the system that

778
01:10:22,390 --> 01:10:21,120
we showed before had two 20 meter

779
01:10:26,070 --> 01:10:22,400
capture

780
01:10:28,390 --> 01:10:26,080
and on the back side of each of those

781
01:10:32,790 --> 01:10:28,400
two astro meshes you could have

782
01:10:35,669 --> 01:10:32,800
a reflective surface with a a variable

783
01:10:36,870 --> 01:10:35,679
uh focus for your you know using the sun

784
01:10:39,510 --> 01:10:36,880
and you can

785
01:10:41,510 --> 01:10:39,520
co-focus both of those so you could both

786
01:10:44,390 --> 01:10:41,520
do the capture and prior to that you

787
01:10:47,030 --> 01:10:44,400
could do this you know demonstration of

788
01:10:48,149 --> 01:10:47,040

changing a small segment of the surface

789
01:10:51,669 --> 01:10:48,159
into

790
01:10:54,870 --> 01:10:51,679
to see what the change in the albedo is

791
01:10:59,830 --> 01:10:57,270
the one the way that our team wanted to

792
01:11:02,149 --> 01:10:59,840
do it is to do some kind of an mli

793
01:11:04,470 --> 01:11:02,159
direct uh deposit now

794
01:11:07,030 --> 01:11:04,480
the vehicle i'm gonna show that this is

795
01:11:08,149 --> 01:11:07,040
what our basic vehicle looks like same

796
01:11:10,470 --> 01:11:08,159
vehicle

797
01:11:12,870 --> 01:11:10,480
we had the two capture

798
01:11:15,830 --> 01:11:12,880
astro capture devices here

799
01:11:18,709 --> 01:11:15,840
for the redirect but we can also install

800
01:11:21,350 --> 01:11:18,719
two arms easily along that

801
01:11:23,910 --> 01:11:21,360
that volume and this can also telescope

802
01:11:26,070 --> 01:11:23,920
if we don't want that much moment arm

803
01:11:27,590 --> 01:11:26,080
so we can also put the centering devices

804
01:11:30,070 --> 01:11:27,600
here so

805
01:11:32,709 --> 01:11:30,080
this would be sort of like a tool rack

806
01:11:35,350 --> 01:11:32,719
where we would put those apertures and

807
01:11:38,550 --> 01:11:35,360
those appendages the role the material

808
01:11:40,950 --> 01:11:38,560
that we would then use to deploy and

809
01:11:43,270 --> 01:11:40,960
change a certain you know amount of the

810
01:11:47,189 --> 01:11:43,280
area of the asteroid so that we would

811
01:11:49,189 --> 01:11:47,199
get the requisite a change in velocity

812
01:11:50,630 --> 01:11:49,199
so this vehicle for those who weren't at

813
01:11:52,630 --> 01:11:50,640

the last one

814
01:11:57,350 --> 01:11:52,640
it's a eagle 3

815
01:11:59,030 --> 01:11:57,360
this is the same a system that jwst uses

816
01:12:01,669 --> 01:11:59,040
there's a whole number of them in our

817
01:12:04,229 --> 01:12:01,679
system it's a production line

818
01:12:06,630 --> 01:12:04,239
so it has a thousand kilograms of buy

819
01:12:08,870 --> 01:12:06,640
prop you know very strong

820
01:12:09,750 --> 01:12:08,880
cmgs if required

821
01:12:11,830 --> 01:12:09,760
and

822
01:12:13,750 --> 01:12:11,840
this is the interface that we envision

823
01:12:16,390 --> 01:12:13,760
if for any direct contact that we would

824
01:12:19,110 --> 01:12:16,400
use it can be custom tailored it can be

825
01:12:21,590 --> 01:12:19,120
made to adjust depending on the surface

826
01:12:23,750 --> 01:12:21,600
properties and it can be instrumented

827
01:12:26,229 --> 01:12:23,760
and have scientific and

828
01:12:28,470 --> 01:12:26,239
use some of jpl's actual capture you

829
01:12:31,430 --> 01:12:28,480
know apertures if required in addition

830
01:12:34,070 --> 01:12:31,440
to the two arms on either side

831
01:12:37,430 --> 01:12:34,080
uh the xenon tanks are probably the long

832
01:12:40,950 --> 01:12:37,440
lead in here so we've looked at boat

833
01:12:44,149 --> 01:12:40,960
worked with both the atk psi

834
01:12:45,910 --> 01:12:44,159
and the dawn tank and both believe they

835
01:12:47,830 --> 01:12:45,920
could provide this in

836
01:12:48,950 --> 01:12:47,840
time to support the demonstration

837
01:12:51,110 --> 01:12:48,960
mission

838
01:12:52,229 --> 01:12:51,120

so this shows two tanks that would could

839
01:12:57,350 --> 01:12:52,239
both be

840
01:13:01,189 --> 01:12:58,950
uh both

841
01:13:03,030 --> 01:13:01,199
you know the solar arrays are

842
01:13:04,790 --> 01:13:03,040
kind of a feature that distinguishes

843
01:13:07,270 --> 01:13:04,800
this and

844
01:13:09,669 --> 01:13:07,280
this is the astromesh system it stows in

845
01:13:11,430 --> 01:13:09,679
a cylinder it deploys

846
01:13:13,030 --> 01:13:11,440
here are seven of them at the time the

847
01:13:15,030 --> 01:13:13,040
paper was submitted now there's an

848
01:13:16,630 --> 01:13:15,040
eighth and there's about to be a ninth

849
01:13:18,709 --> 01:13:16,640
put on orbit

850
01:13:21,510 --> 01:13:18,719
this system as i said then in the last

851
01:13:23,990 --> 01:13:21,520
briefing is very very stiff

852
01:13:26,550 --> 01:13:24,000
uh in in the rf application because it's

853
01:13:27,830 --> 01:13:26,560
so lightweight it's you know multiple

854
01:13:28,630 --> 01:13:27,840
tens of hertz

855
01:13:31,430 --> 01:13:28,640
in

856
01:13:33,189 --> 01:13:31,440
frequency 100

857
01:13:34,630 --> 01:13:33,199
on orbit success

858
01:13:36,950 --> 01:13:34,640
we suspend

859
01:13:38,790 --> 01:13:36,960
uh the solar a material here and you

860
01:13:40,550 --> 01:13:38,800
have a whole set of different surfaces

861
01:13:42,470 --> 01:13:40,560
that you can add you're not limited to

862
01:13:45,110 --> 01:13:42,480
just one you could have solar array on

863
01:13:47,030 --> 01:13:45,120

one side and an rf on the other or you

864
01:13:49,350 --> 01:13:47,040
can actually look through your rf

865
01:13:53,430 --> 01:13:49,360
surface so if you want a high

866
01:13:56,310 --> 01:13:53,440
data rate pipe back to earth you can off

867
01:13:57,910 --> 01:13:56,320
point the solar array and aim at earth

868
01:13:59,669 --> 01:13:57,920
and get both of those functions out of

869
01:14:02,070 --> 01:13:59,679
one aperture

870
01:14:04,310 --> 01:14:02,080
so as we said before two

871
01:14:06,470 --> 01:14:04,320
this is being used on smap and it's a

872
01:14:09,830 --> 01:14:06,480
very high rate of

873
01:14:12,070 --> 01:14:09,840
rotational rate stiff system

874
01:14:14,390 --> 01:14:12,080
so when we look at what it does

875
01:14:17,350 --> 01:14:14,400
for 50 kilowatts

876
01:14:19,110 --> 01:14:17,360
it's uh has a has good uh you know

877
01:14:21,990 --> 01:14:19,120
blanket performance

878
01:14:23,350 --> 01:14:22,000
the astromesh itself for

879
01:14:28,310 --> 01:14:23,360
12

880
01:14:31,030 --> 01:14:28,320
looking at you know three times that for

881
01:14:33,430 --> 01:14:31,040
the solar a material

882
01:14:37,990 --> 01:14:35,830
we make the module solary modules into a

883
01:14:40,070 --> 01:14:38,000
structure that looks like this

884
01:14:43,189 --> 01:14:40,080
and i have this in my

885
01:14:45,590 --> 01:14:43,199
in my panel in my portfolio so i thought

886
01:14:46,790 --> 01:14:45,600
i'd show it so it stows flat the solar

887
01:14:50,070 --> 01:14:46,800
array materials

888
01:14:52,149 --> 01:14:50,080

stows flat inside the

889
01:14:54,390 --> 01:14:52,159
cylindrical structure and then it

890
01:14:57,350 --> 01:14:54,400
deploys just like this

891
01:15:00,310 --> 01:14:57,360
and so you can stow it and there's

892
01:15:01,830 --> 01:15:00,320
uh and deploy it

893
01:15:03,990 --> 01:15:01,840
and so that's uh

894
01:15:05,910 --> 01:15:04,000
that's that material

895
01:15:07,750 --> 01:15:05,920
it's formed in a rhombus to make that

896
01:15:09,189 --> 01:15:07,760
deployment uh very simple and

897
01:15:11,830 --> 01:15:09,199
straightforward

898
01:15:13,430 --> 01:15:11,840
so in summary

899
01:15:16,310 --> 01:15:13,440
you know we believe all three of these

900
01:15:18,390 --> 01:15:16,320
can be demonstrated on one mission they

901
01:15:20,550 --> 01:15:18,400
could be added to the redirect mission

902
01:15:22,790 --> 01:15:20,560
depending on the mission timeline

903
01:15:24,070 --> 01:15:22,800
and you could do a significant

904
01:15:25,990 --> 01:15:24,080
you know this one's already being

905
01:15:28,709 --> 01:15:26,000
covered so you could do albedo

906
01:15:30,709 --> 01:15:28,719
modification using the 20 meter

907
01:15:32,229 --> 01:15:30,719
apertures that were shown at the last

908
01:15:34,630 --> 01:15:32,239
briefing

909
01:15:36,310 --> 01:15:34,640
sep of course is enabling that's the

910
01:15:38,390 --> 01:15:36,320
huge

911
01:15:39,990 --> 01:15:38,400
development here that would enable not

912
01:15:41,830 --> 01:15:40,000
only this mission but

913
01:15:44,550 --> 01:15:41,840

a number of other ones

914
01:15:46,390 --> 01:15:44,560
and we think power is a key one one one

915
01:15:48,390 --> 01:15:46,400
aspect of the power is

916
01:15:50,790 --> 01:15:48,400
you don't want to wrap your solar array

917
01:15:52,950 --> 01:15:50,800
around the asteroid so that's why we

918
01:15:55,990 --> 01:15:52,960
think the three-dimensional trust

919
01:15:58,550 --> 01:15:56,000
is a very good way to go for this

920
01:16:00,310 --> 01:15:58,560
any questions okay

921
01:16:02,390 --> 01:16:00,320
thanks

922
01:16:06,630 --> 01:16:02,400
okay we have time for uh questions

923
01:16:06,640 --> 01:16:10,950
any questions online

924
01:16:14,950 --> 01:16:11,990
okay

925
01:16:17,990 --> 01:16:16,470
chairman jared

926
01:16:20,630 --> 01:16:18,000
um

927
01:16:22,229 --> 01:16:20,640
can you can you tell us if you did any

928
01:16:24,630 --> 01:16:22,239
analysis to look at how much of the

929
01:16:25,990 --> 01:16:24,640
surface um

930
01:16:27,350 --> 01:16:26,000
that you would have to cover and what's

931
01:16:29,910 --> 01:16:27,360
your your

932
01:16:32,070 --> 01:16:29,920
operational concept for

933
01:16:34,870 --> 01:16:32,080
covering the surface with say an mli if

934
01:16:36,229 --> 01:16:34,880
you were to take that approach

935
01:16:39,030 --> 01:16:36,239
let's see we

936
01:16:41,189 --> 01:16:39,040
did have an analyst work that so there's

937
01:16:43,430 --> 01:16:41,199
a spreadsheet solution

938
01:16:46,830 --> 01:16:43,440

um i think we could provide that i don't

939
01:16:50,950 --> 01:16:49,189
we you know we're envisioning this as

940
01:16:52,630 --> 01:16:50,960
more of a demonstration

941
01:16:54,950 --> 01:16:52,640
you'd like to impact you know a

942
01:16:57,030 --> 01:16:54,960
significant fraction

943
01:16:59,830 --> 01:16:57,040
so that then you could verify it over a

944
01:17:03,430 --> 01:16:59,840
number of years to show the change in

945
01:17:04,310 --> 01:17:03,440
the change in velocity and direction

946
01:17:05,830 --> 01:17:04,320
um

947
01:17:06,790 --> 01:17:05,840
so i think we could we could give you

948
01:17:11,830 --> 01:17:06,800
that

949
01:17:13,669 --> 01:17:11,840
have it here okay and then also with the

950
01:17:15,270 --> 01:17:13,679
the solar rays you got 50 kilowatts

951
01:17:17,990 --> 01:17:15,280
that's both

952
01:17:20,310 --> 01:17:18,000
yeah 225 225 just wanted to confirm that

953
01:17:22,470 --> 01:17:20,320
yeah and it's not difficult to increase

954
01:17:24,709 --> 01:17:22,480
the the diameter of that and to get

955
01:17:26,390 --> 01:17:24,719
significantly more up to

956
01:17:28,149 --> 01:17:26,400
you know 100 kilowatts

957
01:17:31,030 --> 01:17:28,159
okay

958
01:17:32,229 --> 01:17:31,040
area goes up dramatically as you

959
01:17:34,790 --> 01:17:32,239
increase your

960
01:17:35,990 --> 01:17:34,800
diameter okay got a question tim okay

961
01:17:38,149 --> 01:17:36,000
yeah um

962
01:17:41,590 --> 01:17:38,159
i mean y'all haven't done an astromesh

963
01:17:42,950 --> 01:17:41,600

solar array yet is that correct in texas

964
01:17:44,870 --> 01:17:42,960
we are

965
01:17:46,790 --> 01:17:44,880
in the process of

966
01:17:48,310 --> 01:17:46,800
doing the trl

967
01:17:51,030 --> 01:17:48,320
five to six

968
01:17:52,310 --> 01:17:51,040
demo building module and looking at

969
01:17:53,750 --> 01:17:52,320
testing

970
01:17:54,950 --> 01:17:53,760
yeah so my question was what's the

971
01:17:57,189 --> 01:17:54,960
process for

972
01:17:59,350 --> 01:17:57,199
for developing that and you kind of

973
01:18:02,630 --> 01:17:59,360
answered that so yeah yeah so there's

974
01:18:05,270 --> 01:18:02,640
going to be a phase two uh there's two

975
01:18:07,669 --> 01:18:05,280
uh two participants in the phase one

976
01:18:11,110 --> 01:18:07,679
working with glenn and so we're looking

977
01:18:14,390 --> 01:18:12,630
getting involved with that and do you

978
01:18:16,790 --> 01:18:14,400
have any idea when that would be space

979
01:18:19,270 --> 01:18:16,800
qualified what's your time frame

980
01:18:22,550 --> 01:18:19,280
well the the requirement is to get to

981
01:18:24,870 --> 01:18:22,560
trl six before the down select

982
01:18:27,030 --> 01:18:24,880
and so we have

983
01:18:30,229 --> 01:18:27,040
an existing

984
01:18:31,830 --> 01:18:30,239
astromesh and so we're in the process of

985
01:18:34,550 --> 01:18:31,840
developing

986
01:18:36,709 --> 01:18:34,560
the internal solar array material

987
01:18:39,430 --> 01:18:36,719
most the other two participants are

988
01:18:40,470 --> 01:18:39,440

mainly doing a module for the dva

989
01:18:44,950 --> 01:18:40,480
material

990
01:18:47,910 --> 01:18:46,310
what would be

991
01:18:49,990 --> 01:18:47,920
there's a question about what what the

992
01:18:51,669 --> 01:18:50,000
efficiency would be

993
01:18:53,669 --> 01:18:51,679
uh the

994
01:18:56,229 --> 01:18:53,679
solar ray efficiency well we're using

995
01:18:57,910 --> 01:18:56,239
standard solar cells and it's

996
01:19:00,229 --> 01:18:57,920
looking at

997
01:19:01,910 --> 01:19:00,239
operating at around 300 volts right but

998
01:19:03,669 --> 01:19:01,920
i mean like the the mass efficiency i

999
01:19:05,270 --> 01:19:03,679
mean it looked like it was like 160

1000
01:19:08,870 --> 01:19:05,280
watts per kilogram or something yeah

1001
01:19:10,550 --> 01:19:08,880
here are the these are the efficiency

1002
01:19:13,510 --> 01:19:10,560
metrics

1003
01:19:13,520 --> 01:19:17,110
yeah

1004
01:19:21,030 --> 01:19:19,510
okay so i i had one question sure no one

1005
01:19:22,390 --> 01:19:21,040
else uh can you

1006
01:19:23,669 --> 01:19:22,400
just maybe you haven't thought about it

1007
01:19:25,270 --> 01:19:23,679
too much tonight if i missed it i

1008
01:19:26,790 --> 01:19:25,280
apologize but uh

1009
01:19:29,750 --> 01:19:26,800
can you go over a little bit about the

1010
01:19:31,510 --> 01:19:29,760
deployment mechanism for the albedo uh

1011
01:19:32,310 --> 01:19:31,520
change have you thought about how you do

1012
01:19:34,709 --> 01:19:32,320
that

1013
01:19:38,149 --> 01:19:34,719

um with an asteroid

1014
01:19:40,070 --> 01:19:38,159
now when you say so what we're

1015
01:19:42,390 --> 01:19:40,080
so there's two approaches

1016
01:19:44,630 --> 01:19:42,400
one of them is we would have either use

1017
01:19:47,189 --> 01:19:44,640
these apertures because once you're

1018
01:19:49,350 --> 01:19:47,199
steady state you only need one aperture

1019
01:19:51,590 --> 01:19:49,360
off point so you could flip the other

1020
01:19:53,270 --> 01:19:51,600
one and have a reflective surface on the

1021
01:19:55,350 --> 01:19:53,280
back side

1022
01:19:57,830 --> 01:19:55,360
that then focuses

1023
01:19:59,590 --> 01:19:57,840
the sun and you're basically turning the

1024
01:20:00,630 --> 01:19:59,600
regolith to glass

1025
01:20:02,550 --> 01:20:00,640
to get a

1026
01:20:05,750 --> 01:20:02,560
that's one approach so okay so it's

1027
01:20:07,350 --> 01:20:05,760
actually a centering so you're centering

1028
01:20:08,950 --> 01:20:07,360
okay so you're actually changing okay

1029
01:20:10,390 --> 01:20:08,960
got it so that's one approach and then

1030
01:20:12,229 --> 01:20:10,400
the other approach

1031
01:20:13,430 --> 01:20:12,239
would be to carry

1032
01:20:15,990 --> 01:20:13,440
and

1033
01:20:18,229 --> 01:20:16,000
we haven't detailed out how you do

1034
01:20:19,110 --> 01:20:18,239
anyone who's done wallpapering of a room

1035
01:20:21,910 --> 01:20:19,120
knows

1036
01:20:23,510 --> 01:20:21,920
you know thin thin film management is a

1037
01:20:25,910 --> 01:20:23,520
huge issue

1038
01:20:27,110 --> 01:20:25,920

and especially doing it autonomously

1039
01:20:29,669 --> 01:20:27,120
because you're not going to tell or

1040
01:20:31,830 --> 01:20:29,679
robotically operate it

1041
01:20:34,390 --> 01:20:31,840
so you know what are schemes of uh

1042
01:20:37,030 --> 01:20:34,400
having you know discs or material and

1043
01:20:38,149 --> 01:20:37,040
flying around or

1044
01:20:41,270 --> 01:20:38,159
basically

1045
01:20:43,750 --> 01:20:41,280
using the arms

1046
01:20:45,030 --> 01:20:43,760
you know pulling the material attaching

1047
01:20:51,669 --> 01:20:45,040
it

1048
01:20:53,590 --> 01:20:51,679
so uh but we

1049
01:20:56,550 --> 01:20:53,600
we haven't put the brain power yet we've

1050
01:20:57,990 --> 01:20:56,560
only you know drawn the box that we fill

1051
01:21:02,070 --> 01:20:58,000
in

1052
01:21:05,270 --> 01:21:02,080
and so the question you know that's

1053
01:21:07,830 --> 01:21:05,280
that's more attractive than paint

1054
01:21:10,149 --> 01:21:07,840
which will degrade with time and might

1055
01:21:11,590 --> 01:21:10,159
not have the longevity and then there's

1056
01:21:15,350 --> 01:21:11,600
a question about whether there's a

1057
01:21:17,350 --> 01:21:15,360
churning on the surface in terms of uh

1058
01:21:19,990 --> 01:21:17,360
you know what happens and so you might

1059
01:21:20,790 --> 01:21:20,000
lose a surface coating

1060
01:21:23,189 --> 01:21:20,800
all right

1061
01:21:24,070 --> 01:21:23,199
and just um just to follow up on that i

1062
01:21:25,990 --> 01:21:24,080
know we're going to have some

1063
01:21:27,910 --> 01:21:26,000

discussions um from some of our our

1064
01:21:29,430 --> 01:21:27,920
presenters on

1065
01:21:31,189 --> 01:21:29,440
basically solar

1066
01:21:33,110 --> 01:21:31,199
ablation when you're doing that

1067
01:21:34,470 --> 01:21:33,120
centering you know just just a comment

1068
01:21:35,430 --> 01:21:34,480
you might want to

1069
01:21:37,510 --> 01:21:35,440
look at

1070
01:21:39,189 --> 01:21:37,520
not only changing the albedo and using

1071
01:21:41,030 --> 01:21:39,199
that effect which is a

1072
01:21:42,709 --> 01:21:41,040
smaller long-term effect but also the

1073
01:21:45,430 --> 01:21:42,719
effect of

1074
01:21:47,830 --> 01:21:45,440
doing that judiciously to provide a

1075
01:21:49,270 --> 01:21:47,840
thrust a blow-off thrust

1076
01:21:52,149 --> 01:21:49,280
and looking at the combined effect of

1077
01:21:55,189 --> 01:21:53,510
so you kind of got a short term in the

1078
01:21:56,790 --> 01:21:55,199
long term but of course if you capture

1079
01:21:57,990 --> 01:21:56,800
the asteroid and bring it back then

1080
01:22:10,550 --> 01:21:58,000
right you don't really have that long

1081
01:22:15,910 --> 01:22:13,669
okay so our next speaker is andy turner

1082
01:22:17,590 --> 01:22:15,920
and andy has been with uh space systems

1083
01:22:19,110 --> 01:22:17,600
ralph for 30 years

1084
01:22:21,990 --> 01:22:19,120
he works in the advanced systems

1085
01:22:23,350 --> 01:22:22,000
primarily on mission analysis and design

1086
01:22:26,070 --> 01:22:23,360
he's worked on mission operations of the

1087
01:22:28,310 --> 01:22:26,080
global star orbit constellation and on

1088
01:22:30,149 --> 01:22:28,320

geosynchronous spacecraft as well as the

1089
01:22:31,030 --> 01:22:30,159
nasa laddie spacecraft that was recently

1090
01:22:31,750 --> 01:22:31,040
launched

1091
01:22:33,270 --> 01:22:31,760
so

1092
01:22:34,950 --> 01:22:33,280
thank you dan

1093
01:22:39,030 --> 01:22:34,960
good afternoon everybody can you hear me

1094
01:22:41,430 --> 01:22:39,040
okay all right

1095
01:22:43,669 --> 01:22:41,440
okay glad to be here

1096
01:22:46,310 --> 01:22:43,679
i'm looking forward to talking about our

1097
01:22:48,629 --> 01:22:46,320
affordable spacecraft which is

1098
01:22:51,270 --> 01:22:48,639
going to be simply a repurposed

1099
01:22:53,030 --> 01:22:51,280
redesigned geosynchronous spacecraft

1100
01:22:53,990 --> 01:22:53,040
just like one of the other speakers talk

1101
01:22:54,709 --> 01:22:54,000
about

1102
01:22:56,709 --> 01:22:54,719
so

1103
01:22:58,550 --> 01:22:56,719
we have a number of diverse asteroid

1104
01:23:00,629 --> 01:22:58,560
deflection techniques we've envisioned

1105
01:23:01,430 --> 01:23:00,639
already and one other thing i should say

1106
01:23:03,350 --> 01:23:01,440
is

1107
01:23:05,270 --> 01:23:03,360
robot arms are an integral part of our

1108
01:23:07,830 --> 01:23:05,280
approach as well because our company is

1109
01:23:09,910 --> 01:23:07,840
owned by mba so we have access to that

1110
01:23:11,990 --> 01:23:09,920
technology as well so it's a nice

1111
01:23:14,310 --> 01:23:12,000
synergy between the high heritage

1112
01:23:16,470 --> 01:23:14,320
spacecraft and the high heritage

1113
01:23:18,310 --> 01:23:16,480

arms and it fits very nicely in with

1114
01:23:20,310 --> 01:23:18,320
what steve stitch talked to us about

1115
01:23:22,870 --> 01:23:20,320
yesterday about trying to collect all

1116
01:23:24,790 --> 01:23:22,880
the high trl items i'll try to play that

1117
01:23:27,430 --> 01:23:24,800
in mind if i go forward

1118
01:23:30,310 --> 01:23:27,440
okay so a general sustained push if that

1119
01:23:31,350 --> 01:23:30,320
is indeed the approach that is the best

1120
01:23:34,149 --> 01:23:31,360
that would be

1121
01:23:36,229 --> 01:23:34,159
set up by arms where we'd have perhaps a

1122
01:23:38,470 --> 01:23:36,239
sort of hand at the end of the arm as

1123
01:23:40,790 --> 01:23:38,480
our my colleague paul fulford talked

1124
01:23:42,470 --> 01:23:40,800
about this morning you could have a hand

1125
01:23:43,910 --> 01:23:42,480
that simply spread the pressure over a

1126
01:23:46,229 --> 01:23:43,920
wide area

1127
01:23:48,070 --> 01:23:46,239
electrostatic tractor technique is

1128
01:23:49,830 --> 01:23:48,080
interesting of course we all know that

1129
01:23:51,830 --> 01:23:49,840
coulomb forces are much stronger than

1130
01:23:54,149 --> 01:23:51,840
gravitational forces so that's an

1131
01:23:56,709 --> 01:23:54,159
interesting approach we'd put one charge

1132
01:24:00,310 --> 01:23:56,719
on the spacecraft another charge on the

1133
01:24:02,390 --> 01:24:00,320
opposite charge on the object and then

1134
01:24:04,470 --> 01:24:02,400
we'd use the coulomb attraction between

1135
01:24:06,470 --> 01:24:04,480
the two of them we do a lot of work on

1136
01:24:07,990 --> 01:24:06,480
spacecraft charging in our normal line

1137
01:24:09,669 --> 01:24:08,000
of business because we have to be

1138
01:24:11,270 --> 01:24:09,679

concerned with differential charging of

1139
01:24:13,910 --> 01:24:11,280
our spacecraft which use tens of

1140
01:24:15,350 --> 01:24:13,920
kilowatts of power so that's an

1141
01:24:17,830 --> 01:24:15,360
approach there

1142
01:24:19,110 --> 01:24:17,840
my own personal favorite is the gravity

1143
01:24:20,550 --> 01:24:19,120
tractor

1144
01:24:22,550 --> 01:24:20,560
technique which

1145
01:24:24,310 --> 01:24:22,560
dan of course worked on must have worked

1146
01:24:26,310 --> 01:24:24,320
on when you were on the kiss the kiss

1147
01:24:27,430 --> 01:24:26,320
study at the tech must have been

1148
01:24:29,110 --> 01:24:27,440
involved in that i think that's an

1149
01:24:30,950 --> 01:24:29,120
ingenious idea

1150
01:24:33,510 --> 01:24:30,960
to me it's appealing partly because it's

1151
01:24:35,910 --> 01:24:33,520
the most independent of the nature of

1152
01:24:38,470 --> 01:24:35,920
the asteroid the asteroid could be a

1153
01:24:40,870 --> 01:24:38,480
sand castle and you could still be able

1154
01:24:42,709 --> 01:24:40,880
to move it gravitationally okay because

1155
01:24:44,709 --> 01:24:42,719
gravity of course acts with gravity is a

1156
01:24:47,669 --> 01:24:44,719
very egalitarian force

1157
01:24:49,990 --> 01:24:47,679
and lastly we have the kinetic impactors

1158
01:24:51,910 --> 01:24:50,000
i didn't mean to skip over augmenting

1159
01:24:53,830 --> 01:24:51,920
our spacecraft mass as a gravity

1160
01:24:55,669 --> 01:24:53,840
multiplier but that i'll be talking

1161
01:24:57,750 --> 01:24:55,679
about a lot in my talk so i don't want

1162
01:24:59,750 --> 01:24:57,760
to talk about too much about it now i'd

1163
01:25:02,070 --> 01:24:59,760

also like to say that we can

1164
01:25:04,629 --> 01:25:02,080
apply the techniques that were discussed

1165
01:25:06,550 --> 01:25:04,639
by the two previous speakers the ion

1166
01:25:08,470 --> 01:25:06,560
cannon we could actually do that if we

1167
01:25:10,390 --> 01:25:08,480
wanted to because we have envisioned

1168
01:25:12,390 --> 01:25:10,400
using eight thrusters the way our

1169
01:25:14,629 --> 01:25:12,400
spacecraft are configured with their

1170
01:25:17,669 --> 01:25:14,639
electric thrusters they all point in one

1171
01:25:19,669 --> 01:25:17,679
direction for orbit raising but we also

1172
01:25:21,430 --> 01:25:19,679
can swing them 90 degrees so they can

1173
01:25:23,430 --> 01:25:21,440
thrust east west when we're into a

1174
01:25:25,669 --> 01:25:23,440
synchronous orbit so we could have the

1175
01:25:27,669 --> 01:25:25,679
east side thrusters perhaps direct

1176
01:25:28,790 --> 01:25:27,679
thrust on the asteroid and the west side

1177
01:25:30,229 --> 01:25:28,800
thrusters

1178
01:25:31,270 --> 01:25:30,239
provide the thrust to move the whole

1179
01:25:33,510 --> 01:25:31,280
system

1180
01:25:35,110 --> 01:25:33,520
so we could adapt that and with the

1181
01:25:37,270 --> 01:25:35,120
robot arms we would be in a good

1182
01:25:39,110 --> 01:25:37,280
position to try wallpapering the

1183
01:25:40,629 --> 01:25:39,120
asteroid if somebody wanted to bring up

1184
01:25:42,550 --> 01:25:40,639
have us bring along something that we

1185
01:25:43,910 --> 01:25:42,560
could wallpaper it with to change its

1186
01:25:46,390 --> 01:25:43,920
albedo

1187
01:25:48,550 --> 01:25:46,400
so six techniques really okay but i'll

1188
01:25:50,629 --> 01:25:48,560

only discuss four here

1189
01:25:52,790 --> 01:25:50,639
so we have a flexible spacecraft system

1190
01:25:54,390 --> 01:25:52,800
design that can handle any type we could

1191
01:25:56,709 --> 01:25:54,400
apply more than one of these techniques

1192
01:25:58,550 --> 01:25:56,719
as the previous speaker disc previous

1193
01:25:59,830 --> 01:25:58,560
speakers discussed we could use ion

1194
01:26:02,229 --> 01:25:59,840
cannon and

1195
01:26:03,830 --> 01:26:02,239
and the gravity tractor both

1196
01:26:05,189 --> 01:26:03,840
i think one thing that's very important

1197
01:26:07,350 --> 01:26:05,199
though is we have to think about the

1198
01:26:08,709 --> 01:26:07,360
person in the street that they have to

1199
01:26:11,350 --> 01:26:08,719
understand the importance of this

1200
01:26:13,189 --> 01:26:11,360
project and so we can report that we

1201
01:26:15,510 --> 01:26:13,199
move this asteroid out there in space

1202
01:26:17,350 --> 01:26:15,520
but the first in the street can't see it

1203
01:26:19,669 --> 01:26:17,360
i like the gravity tractor approach

1204
01:26:22,629 --> 01:26:19,679
because it involves picking up mass

1205
01:26:24,149 --> 01:26:22,639
a large mass i'm envisioning 160 tons

1206
01:26:25,910 --> 01:26:24,159
which is then brought back to earth

1207
01:26:28,070 --> 01:26:25,920
orbit and of course our astronauts when

1208
01:26:30,950 --> 01:26:28,080
they go up there on their orion capsule

1209
01:26:33,270 --> 01:26:30,960
could bring back some kilograms of mass

1210
01:26:35,030 --> 01:26:33,280
i remember as when i was a boy touching

1211
01:26:36,709 --> 01:26:35,040
a piece of a moon rock

1212
01:26:38,149 --> 01:26:36,719
in the smithsonian that was very

1213
01:26:39,750 --> 01:26:38,159

exciting for me i think a lot of the

1214
01:26:41,669 --> 01:26:39,760
people in the street who of course are

1215
01:26:47,030 --> 01:26:41,679
the taxpayers who pay for all this would

1216
01:26:53,669 --> 01:26:49,350
so our spacecraft configuration this is

1217
01:26:56,149 --> 01:26:53,679
a derivation of our of our 1300 bus

1218
01:26:58,310 --> 01:26:56,159
the previous speaker on his slide six

1219
01:27:01,350 --> 01:26:58,320
showed one of our past spacecraft which

1220
01:27:03,030 --> 01:27:01,360
was in b set which was launched in 2004

1221
01:27:04,950 --> 01:27:03,040
and had a harris

1222
01:27:07,189 --> 01:27:04,960
deployed reflector which we made good

1223
01:27:09,110 --> 01:27:07,199
use of that was the first spacecraft we

1224
01:27:11,590 --> 01:27:09,120
ever flew that had electric propulsion

1225
01:27:14,070 --> 01:27:11,600
so for us electric propulsion is here

1226
01:27:16,470 --> 01:27:14,080
already trl9 although we would change

1227
01:27:18,550 --> 01:27:16,480
over to a higher thrust thruster probe

1228
01:27:21,189 --> 01:27:18,560
which is now a trl7 it's going through a

1229
01:27:22,870 --> 01:27:21,199
life test right now it's the spt-140

1230
01:27:24,149 --> 01:27:22,880
which is made over in

1231
01:27:26,390 --> 01:27:24,159
russia

1232
01:27:29,110 --> 01:27:26,400
uh we here have we have a rollout solar

1233
01:27:31,030 --> 01:27:29,120
array 50 kilowatts we already have a

1234
01:27:33,510 --> 01:27:31,040
solar array that's 30 kilowatts that's

1235
01:27:35,590 --> 01:27:33,520
trl9 today so this isn't the big jump

1236
01:27:37,750 --> 01:27:35,600
it's a much smaller jump in power than

1237
01:27:39,350 --> 01:27:37,760
i've seen over the 30 years i've worked

1238
01:27:41,669 --> 01:27:39,360

my company we didn't even do two

1239
01:27:43,750 --> 01:27:41,679
kilowatts on some of the spacecraft when

1240
01:27:46,310 --> 01:27:43,760
i first started we could of course have

1241
01:27:48,550 --> 01:27:46,320
a separable robotic servicing spacecraft

1242
01:27:51,350 --> 01:27:48,560
we've been working on on development of

1243
01:27:53,110 --> 01:27:51,360
that concept for darpa for a number of

1244
01:27:54,390 --> 01:27:53,120
years

1245
01:27:55,990 --> 01:27:54,400
i don't want to spend too much time on

1246
01:27:58,070 --> 01:27:56,000
this we have robotic arms which i'll

1247
01:28:01,270 --> 01:27:58,080
talk about in a minute compatible with

1248
01:28:04,790 --> 01:28:01,280
any launcher so it could be sls falcon

1249
01:28:06,629 --> 01:28:04,800
heavy or atlas 5 heavy perhaps

1250
01:28:08,870 --> 01:28:06,639
40 kilowatts that's an important number

1251
01:28:10,790 --> 01:28:08,880
for electric propulsion that corresponds

1252
01:28:12,470 --> 01:28:10,800
to 2 newtons of thrust which i'll be

1253
01:28:14,950 --> 01:28:12,480
applying in a moment

1254
01:28:16,870 --> 01:28:14,960
and uh this is our versatile flight

1255
01:28:18,310 --> 01:28:16,880
proven bus so that's of course

1256
01:28:20,870 --> 01:28:18,320
trl9

1257
01:28:23,350 --> 01:28:20,880
it we uh just we've launched five buses

1258
01:28:24,950 --> 01:28:23,360
of this sort this year the last one was

1259
01:28:27,270 --> 01:28:24,960
within the last month

1260
01:28:28,870 --> 01:28:27,280
and we that's a standard rate for us

1261
01:28:30,149 --> 01:28:28,880
about five launches a year of our

1262
01:28:32,310 --> 01:28:30,159
spacecraft

1263
01:28:34,629 --> 01:28:32,320

we have about we also work on a firm

1264
01:28:36,149 --> 01:28:34,639
fixed price this is important because it

1265
01:28:38,629 --> 01:28:36,159
fits in with the affordability we're

1266
01:28:40,870 --> 01:28:38,639
very comfortable with firm fix price for

1267
01:28:44,470 --> 01:28:40,880
our products

1268
01:28:47,590 --> 01:28:44,480
okay we also on the on the

1269
01:28:49,910 --> 01:28:47,600
side of the robot arm this is the

1270
01:28:53,110 --> 01:28:49,920
experience here sort of a survey of the

1271
01:28:55,270 --> 01:28:53,120
experience here with various arm usage

1272
01:28:56,629 --> 01:28:55,280
for the space station on mars in two

1273
01:28:58,790 --> 01:28:56,639
cases

1274
01:29:01,030 --> 01:28:58,800
from mda our owner

1275
01:29:02,550 --> 01:29:01,040
and this arm right here is all ready for

1276
01:29:03,669 --> 01:29:02,560
service it's at

1277
01:29:08,950 --> 01:29:03,679
trl

1278
01:29:10,629 --> 01:29:08,960
this is actually at the goddard space

1279
01:29:11,830 --> 01:29:10,639
flight center today could be used on

1280
01:29:13,430 --> 01:29:11,840
this mission

1281
01:29:15,669 --> 01:29:13,440
and we've been working we worked on

1282
01:29:18,790 --> 01:29:15,679
orbital express phase a study i worked

1283
01:29:20,790 --> 01:29:18,800
on that myself for darpa 10 years ago

1284
01:29:22,149 --> 01:29:20,800
and the darpa phoenix

1285
01:29:24,470 --> 01:29:22,159
we're working on that today which

1286
01:29:26,310 --> 01:29:24,480
involves retrieving antennas from

1287
01:29:28,550 --> 01:29:26,320
spacecraft that are in orbit today and

1288
01:29:29,669 --> 01:29:28,560

reusing them in geo

1289
01:29:32,070 --> 01:29:29,679
so

1290
01:29:36,229 --> 01:29:32,080
this is a propellant budget this is

1291
01:29:38,390 --> 01:29:36,239
comes out of my own career many years i

1292
01:29:40,149 --> 01:29:38,400
worked on this at when before i changed

1293
01:29:41,990 --> 01:29:40,159
over to advanced systems i was with our

1294
01:29:44,070 --> 01:29:42,000
mission analysis department one of my

1295
01:29:45,910 --> 01:29:44,080
jobs was doing these propellant budgets

1296
01:29:47,189 --> 01:29:45,920
this is the most fun propellant budget

1297
01:29:49,189 --> 01:29:47,199
i've ever done

1298
01:29:50,709 --> 01:29:49,199
because it's the propellant budget where

1299
01:29:52,790 --> 01:29:50,719
we're actually adding the mass of an

1300
01:29:54,629 --> 01:29:52,800
asteroid to our spacecraft so we start

1301
01:29:57,830 --> 01:29:54,639
with the fourteen thousand five hundred

1302
01:29:59,430 --> 01:29:57,840
kilos at lawrence which is a carry uh is

1303
01:30:01,430 --> 01:29:59,440
a common thing with

1304
01:30:02,629 --> 01:30:01,440
one of the previous speakers

1305
01:30:04,470 --> 01:30:02,639
that's on a

1306
01:30:06,390 --> 01:30:04,480
full-size launch vehicle

1307
01:30:08,550 --> 01:30:06,400
we go through some

1308
01:30:10,709 --> 01:30:08,560
we get into an orbit where we

1309
01:30:12,629 --> 01:30:10,719
loop around the moon which gives us the

1310
01:30:13,910 --> 01:30:12,639
boost to get into uh

1311
01:30:16,149 --> 01:30:13,920
deep space

1312
01:30:18,229 --> 01:30:16,159
and then we have electric propulsion

1313
01:30:19,350 --> 01:30:18,239

augmenting that delta v to get to the

1314
01:30:21,189 --> 01:30:19,360
asteroid

1315
01:30:22,149 --> 01:30:21,199
so as you see the spacecraft mass comes

1316
01:30:23,990 --> 01:30:22,159
down

1317
01:30:26,470 --> 01:30:24,000
a little bit more than a ton

1318
01:30:29,110 --> 01:30:26,480
to reach the asteroid now suddenly the

1319
01:30:31,110 --> 01:30:29,120
spacecraft mass is increasing by 160

1320
01:30:33,590 --> 01:30:31,120
tons that's when we pick up the boulder

1321
01:30:35,990 --> 01:30:33,600
from its surface we have to land on the

1322
01:30:38,229 --> 01:30:36,000
space on the on the big asteroid we're

1323
01:30:40,950 --> 01:30:38,239
going to pick up a rock as the

1324
01:30:43,830 --> 01:30:40,960
alternative approach from from nasa

1325
01:30:45,669 --> 01:30:43,840
langley discusses pick up a rock we're

1326
01:30:48,470 --> 01:30:45,679
going to need to use our biprop system

1327
01:30:50,390 --> 01:30:48,480
to haul the rock away from the asteroid

1328
01:30:52,790 --> 01:30:50,400
because the attractive force between a

1329
01:30:53,990 --> 01:30:52,800
200 meter asteroid which is the size we

1330
01:30:56,790 --> 01:30:54,000
targeted

1331
01:30:58,149 --> 01:30:56,800
uh yesterday uh when i was i was talking

1332
01:31:00,390 --> 01:30:58,159
to

1333
01:31:02,149 --> 01:31:00,400
lindley johnson after his presentation

1334
01:31:04,629 --> 01:31:02,159
he said there were probably about a

1335
01:31:06,629 --> 01:31:04,639
dozen or so 14 or so objects of this

1336
01:31:08,950 --> 01:31:06,639
size in the range it's easy to reach

1337
01:31:10,709 --> 01:31:08,960
from earth and easy to return to earth

1338
01:31:13,189 --> 01:31:10,719

we'd be going to one of those we pick up

1339
01:31:15,270 --> 01:31:13,199
the rock we're going to need more than

1340
01:31:17,750 --> 01:31:15,280
we need seven newtons of force to pull

1341
01:31:19,430 --> 01:31:17,760
this rock away put this boulder away

1342
01:31:21,030 --> 01:31:19,440
from the 200 meter

1343
01:31:22,550 --> 01:31:21,040
object and we're going to use our

1344
01:31:24,229 --> 01:31:22,560
bi-propellant thrusters that's our

1345
01:31:26,229 --> 01:31:24,239
heritage too we've been using those for

1346
01:31:28,149 --> 01:31:26,239
many years 22 newton thrusters i heard

1347
01:31:30,390 --> 01:31:28,159
somebody mention that earlier today you

1348
01:31:32,629 --> 01:31:30,400
have four of them operating together 80

1349
01:31:33,590 --> 01:31:32,639
newtons of thrust no trouble lifting it

1350
01:31:35,030 --> 01:31:33,600
away

1351
01:31:37,750 --> 01:31:35,040
so then we're going to pull off to a

1352
01:31:38,870 --> 01:31:37,760
distance of about 90 meters and at that

1353
01:31:41,910 --> 01:31:38,880
distance

1354
01:31:43,750 --> 01:31:41,920
we are ready to acquire the asteroid at

1355
01:31:45,990 --> 01:31:43,760
that distance what we do is turn on the

1356
01:31:48,950 --> 01:31:46,000
electric thrusters which generate an

1357
01:31:51,189 --> 01:31:48,960
astoundingly large 2 newtons of thrust

1358
01:31:52,070 --> 01:31:51,199
of taking about 40 kilowatts of power to

1359
01:31:54,629 --> 01:31:52,080
do it

1360
01:31:56,550 --> 01:31:54,639
that exactly balances the gravity force

1361
01:31:59,669 --> 01:31:56,560
that's trying to pull our augmented

1362
01:32:01,430 --> 01:31:59,679
spacecraft mass down to the 200 meter

1363
01:32:03,510 --> 01:32:01,440

large asteroids we've got balanced

1364
01:32:05,189 --> 01:32:03,520
forces here we're not approaching it

1365
01:32:07,350 --> 01:32:05,199
it's not approaching us

1366
01:32:09,750 --> 01:32:07,360
but there's thrust on the entire system

1367
01:32:13,270 --> 01:32:09,760
so the asteroid is accelerated

1368
01:32:14,870 --> 01:32:13,280
for this demonstration we said we do

1369
01:32:16,950 --> 01:32:14,880
.001

1370
01:32:19,110 --> 01:32:16,960
meters per second delta v which i recall

1371
01:32:20,070 --> 01:32:19,120
was in the keck study as a demonstration

1372
01:32:21,590 --> 01:32:20,080
number

1373
01:32:23,430 --> 01:32:21,600
with doppler

1374
01:32:25,430 --> 01:32:23,440
measurements we should be able to see a

1375
01:32:27,270 --> 01:32:25,440
velocity change that big it takes about

1376
01:32:29,430 --> 01:32:27,280
two months to do the

1377
01:32:32,470 --> 01:32:29,440
maneuver notice how here the spacecraft

1378
01:32:34,070 --> 01:32:32,480
mass i'm treating it as six million tons

1379
01:32:35,750 --> 01:32:34,080
this is the heaviest spacecraft in

1380
01:32:36,709 --> 01:32:35,760
history

1381
01:32:38,470 --> 01:32:36,719
so

1382
01:32:39,830 --> 01:32:38,480
then of course we have to

1383
01:32:41,990 --> 01:32:39,840
this is the gravity

1384
01:32:44,550 --> 01:32:42,000
tractor operation

1385
01:32:47,910 --> 01:32:44,560
notice i have an efficiency factor 0.7

1386
01:32:50,229 --> 01:32:47,920
there that's because i'm steering the

1387
01:32:52,390 --> 01:32:50,239
thrust away from the asteroid okay so

1388
01:32:54,229 --> 01:32:52,400

i'm getting a cosine loss there

1389
01:32:56,470 --> 01:32:54,239
i actually don't want to let the ion

1390
01:32:57,510 --> 01:32:56,480
thrust touch the spacecraft the asteroid

1391
01:32:58,870 --> 01:32:57,520
at this time because i don't want to

1392
01:33:02,070 --> 01:32:58,880
charge it up

1393
01:33:03,750 --> 01:33:02,080
okay i don't want any impulsive charge

1394
01:33:05,510 --> 01:33:03,760
that's larger than repulsive

1395
01:33:07,910 --> 01:33:05,520
electrostatic charges bigger than the

1396
01:33:09,910 --> 01:33:07,920
attractive gravitational force i'm going

1397
01:33:11,910 --> 01:33:09,920
to use the byprop thrusters to pull away

1398
01:33:14,550 --> 01:33:11,920
from the big asteroid and then i use the

1399
01:33:17,270 --> 01:33:14,560
electric thrusters to bring this 160 ton

1400
01:33:19,430 --> 01:33:17,280
boulder that we acquired

1401
01:33:21,590 --> 01:33:19,440
so we only use about seven percent of

1402
01:33:24,790 --> 01:33:21,600
the total impulse on this mission

1403
01:33:25,830 --> 01:33:24,800
on the gravity tractor

1404
01:33:27,510 --> 01:33:25,840
okay

1405
01:33:29,510 --> 01:33:27,520
so just a little

1406
01:33:31,030 --> 01:33:29,520
cleanup discussion here

1407
01:33:32,470 --> 01:33:31,040
this is these are the numbers i was

1408
01:33:34,149 --> 01:33:32,480
telling you about 2 newtons of

1409
01:33:36,709 --> 01:33:34,159
attractive force between them when we're

1410
01:33:38,870 --> 01:33:36,719
doing the gravitational tractor that

1411
01:33:41,910 --> 01:33:38,880
corresponds to a distance for a 200

1412
01:33:44,149 --> 01:33:41,920
meter asteroid of about 90 meters so

1413
01:33:46,709 --> 01:33:44,159

we're actually about half a diameter

1414
01:33:48,550 --> 01:33:46,719
away about one radius

1415
01:33:49,990 --> 01:33:48,560
that's sort of shown graphically here

1416
01:33:51,910 --> 01:33:50,000
we're physically actually relatively

1417
01:33:54,550 --> 01:33:51,920
close although this distance is still 90

1418
01:33:56,470 --> 01:33:54,560
meters so we can still turn the electric

1419
01:33:58,950 --> 01:33:56,480
propulsion thrust away so it misses the

1420
01:34:00,950 --> 01:33:58,960
asteroid this also helps us stay out of

1421
01:34:02,550 --> 01:34:00,960
the asteroid shadow because if we go

1422
01:34:04,629 --> 01:34:02,560
into the asteroid shadow we're not going

1423
01:34:06,070 --> 01:34:04,639
to get any power to run our thrusters

1424
01:34:08,709 --> 01:34:06,080
very important

1425
01:34:10,310 --> 01:34:08,719
so i have a couple last few points here

1426
01:34:11,910 --> 01:34:10,320
what if it's a

1427
01:34:13,830 --> 01:34:11,920
what if we can't extract the boulder

1428
01:34:16,070 --> 01:34:13,840
well then we're going to push

1429
01:34:18,550 --> 01:34:16,080
on it instead of gravity tractor what if

1430
01:34:21,830 --> 01:34:18,560
it's a rubble pile but it only contains

1431
01:34:23,350 --> 01:34:21,840
sand maybe it's a sand castle we use the

1432
01:34:26,149 --> 01:34:23,360
arms to scoop

1433
01:34:29,030 --> 01:34:26,159
just scoop six tons put it in a bag

1434
01:34:32,790 --> 01:34:29,040
what if 90 meters is too close then we

1435
01:34:34,950 --> 01:34:32,800
we can bias our thruster thrust down

1436
01:34:36,470 --> 01:34:34,960
below two newtons you move off to a

1437
01:34:41,430 --> 01:34:36,480
greater distance and have a smaller

1438
01:34:46,870 --> 01:34:44,310

okay so a little bit of background here

1439
01:34:49,510 --> 01:34:46,880
we have itakawa

1440
01:34:51,669 --> 01:34:49,520
rubble pile different scales of rubble i

1441
01:34:53,109 --> 01:34:51,679
think what we'll really find not a not a

1442
01:34:55,350 --> 01:34:53,119
hunk of sand but just a bunch of

1443
01:34:57,669 --> 01:34:55,360
different pieces of rubble and we'll

1444
01:34:59,990 --> 01:34:57,679
just pick up a piece the boulder that's

1445
01:35:02,470 --> 01:35:00,000
the right size from the bunch if there's

1446
01:35:04,070 --> 01:35:02,480
a slight rotation on the asteroid maybe

1447
01:35:06,550 --> 01:35:04,080
we pick it up from the north or south

1448
01:35:08,310 --> 01:35:06,560
pole of the asteroid to minimize that

1449
01:35:10,709 --> 01:35:08,320
that's why on my propellant budget i

1450
01:35:12,310 --> 01:35:10,719
didn't have a d spin turn one of the

1451
01:35:15,189 --> 01:35:12,320
beautiful things about picking up the

1452
01:35:16,470 --> 01:35:15,199
boulder from a big rock a big asteroid

1453
01:35:18,229 --> 01:35:16,480
it's a rubble pile it's probably going

1454
01:35:21,910 --> 01:35:18,239
to have less than the

1455
01:35:23,990 --> 01:35:21,920
the 2 rpm spin so the d spin is probably

1456
01:35:25,350 --> 01:35:24,000
traded away as a problem

1457
01:35:27,270 --> 01:35:25,360
we do pick up the problem of having to

1458
01:35:30,550 --> 01:35:27,280
lift it off its surface with more thrust

1459
01:35:33,270 --> 01:35:30,560
than the electric thruster can provide

1460
01:35:35,109 --> 01:35:33,280
so uh also look at this large population

1461
01:35:36,310 --> 01:35:35,119
of rubble pile asterisk probably what we

1462
01:35:37,109 --> 01:35:36,320
have

1463
01:35:38,550 --> 01:35:37,119

okay

1464
01:35:43,750 --> 01:35:38,560
thank you thank you andy all right we've

1465
01:35:43,760 --> 01:35:49,189
anybody in the room

1466
01:35:54,149 --> 01:35:52,149
so a hundred meter asteroid

1467
01:35:57,189 --> 01:35:54,159
200 meter asteroid very nice talk by the

1468
01:35:59,430 --> 01:35:57,199
way 200 meter asteroid might be rotating

1469
01:36:00,629 --> 01:35:59,440
at you know every 10 minutes if you're

1470
01:36:02,229 --> 01:36:00,639
unlucky

1471
01:36:03,750 --> 01:36:02,239
and of course you know you probably can

1472
01:36:05,430 --> 01:36:03,760
pick the one you do for a demonstration

1473
01:36:07,350 --> 01:36:05,440
but if you actually had to do this you

1474
01:36:09,430 --> 01:36:07,360
don't get that option you have to go to

1475
01:36:11,189 --> 01:36:09,440
one that you know is the one you want to

1476
01:36:13,189 --> 01:36:11,199
move uh

1477
01:36:15,350 --> 01:36:13,199
what where does rotation sort of break

1478
01:36:17,669 --> 01:36:15,360
this down what's your maximum rotation

1479
01:36:19,669 --> 01:36:17,679
rate you could well like i said if there

1480
01:36:21,750 --> 01:36:19,679
were if there were a large rotation i

1481
01:36:24,229 --> 01:36:21,760
would go to the north to south pole to

1482
01:36:26,149 --> 01:36:24,239
pick the boulder up i think what will

1483
01:36:28,790 --> 01:36:26,159
happen in real life is is if we get near

1484
01:36:30,709 --> 01:36:28,800
the asteroid we start examining boulders

1485
01:36:33,270 --> 01:36:30,719
what will happen is all the scientists

1486
01:36:34,950 --> 01:36:33,280
will be competing among themselves to

1487
01:36:35,990 --> 01:36:34,960
have us pick up the most interesting

1488
01:36:37,669 --> 01:36:36,000

boulder

1489
01:36:39,350 --> 01:36:37,679
and i think one of the trades would be

1490
01:36:41,270 --> 01:36:39,360
what's the latitude of where that

1491
01:36:42,229 --> 01:36:41,280
boulder is on the rotating aspect i

1492
01:36:44,229 --> 01:36:42,239
think a

1493
01:36:46,629 --> 01:36:44,239
high latitude it might make it easier to

1494
01:36:48,709 --> 01:36:46,639
get off if if it was like lodged in once

1495
01:36:49,510 --> 01:36:48,719
you unlodged it it would tend to you

1496
01:36:51,109 --> 01:36:49,520
know

1497
01:36:53,109 --> 01:36:51,119
go away

1498
01:36:55,350 --> 01:36:53,119
i'm counting on the uh the high thrust

1499
01:36:56,870 --> 01:36:55,360
from our the 80 newtons of thrust which

1500
01:36:59,350 --> 01:36:56,880
is more than enough to muscle away a

1501
01:37:01,430 --> 01:36:59,360
very big boulder from the asteroid to

1502
01:37:02,950 --> 01:37:01,440
get us loose i don't think we need a

1503
01:37:04,830 --> 01:37:02,960
need to pick it up from the equator to

1504
01:37:07,510 --> 01:37:04,840
get a higher

1505
01:37:09,590 --> 01:37:07,520
velocity any other questions

1506
01:37:11,590 --> 01:37:09,600
any questions online okay and again

1507
01:37:13,910 --> 01:37:11,600
encourage folks to uh that are online to

1508
01:37:17,030 --> 01:37:13,920
submit your questions um

1509
01:37:19,270 --> 01:37:18,070
okay

1510
01:37:26,709 --> 01:37:19,280
all right well thank you thank you very

1511
01:37:32,390 --> 01:37:30,229
okay our next speaker is uh dr von v is

1512
01:37:34,550 --> 01:37:32,400
the vance kaufman endowed chair

1513
01:37:36,310 --> 01:37:34,560

professor of aerospace engineering

1514
01:37:38,550 --> 01:37:36,320
and the founding director of the

1515
01:37:40,709 --> 01:37:38,560
asteroid reflection research center at

1516
01:37:42,470 --> 01:37:40,719
iowa state university

1517
01:37:44,470 --> 01:37:42,480
his current research

1518
01:37:46,310 --> 01:37:44,480
focuses on the development of space

1519
01:37:49,189 --> 01:37:46,320
technologies for mitigating the impact

1520
01:37:50,629 --> 01:37:49,199
threat of hazardous asteroids dr v

1521
01:37:53,750 --> 01:37:50,639
okay thank you

1522
01:37:56,149 --> 01:37:53,760
actually my talk is not about flight

1523
01:37:58,870 --> 01:37:56,159
demonstration proposal so i'm gonna have

1524
01:38:01,750 --> 01:37:58,880
a overview of many different

1525
01:38:03,830 --> 01:38:01,760
options for nasa consideration also

1526
01:38:06,870 --> 01:38:03,840
yield consideration so i'm not going to

1527
01:38:08,870 --> 01:38:06,880
promote any particular concept

1528
01:38:11,430 --> 01:38:08,880
so during the next

1529
01:38:13,350 --> 01:38:11,440
10 minutes

1530
01:38:15,510 --> 01:38:13,360
so this may not be a good place to talk

1531
01:38:20,950 --> 01:38:15,520
about nuclear options so i will minimize

1532
01:38:25,910 --> 01:38:23,669
so i'm gonna just spend about less than

1533
01:38:28,790 --> 01:38:25,920
one minute to have an overview planetary

1534
01:38:31,350 --> 01:38:28,800
depends 101. if i don't go through this

1535
01:38:34,709 --> 01:38:31,360
one there's always confusion about

1536
01:38:35,510 --> 01:38:34,719
deflection disruption warning time

1537
01:38:37,189 --> 01:38:35,520
the

1538
01:38:39,270 --> 01:38:37,199

so many issues so let's have a very

1539
01:38:41,189 --> 01:38:39,280
brief uh review of

1540
01:38:44,629 --> 01:38:41,199
sort of basic concept behind planetary

1541
01:38:48,149 --> 01:38:44,639
defense and what i'm going to state

1542
01:38:51,510 --> 01:38:48,159
today is all about all from 2006 new

1543
01:38:53,510 --> 01:38:51,520
report by nasa as well as 2010 new

1544
01:38:56,470 --> 01:38:53,520
report by nrc

1545
01:38:58,390 --> 01:38:56,480
so basically when we have sufficient

1546
01:39:02,229 --> 01:38:58,400
warning time yes

1547
01:39:04,149 --> 01:39:02,239
deflection is the best choice

1548
01:39:06,709 --> 01:39:04,159
but if you don't have a sufficient

1549
01:39:08,149 --> 01:39:06,719
warning time then deflection is not

1550
01:39:10,390 --> 01:39:08,159
option

1551
01:39:11,510 --> 01:39:10,400
so we do need some other than something

1552
01:39:14,870 --> 01:39:11,520
other than

1553
01:39:15,910 --> 01:39:14,880
gentle deflections then we may have to

1554
01:39:18,790 --> 01:39:15,920
accept

1555
01:39:21,030 --> 01:39:18,800
disruptions or fragmentations but that

1556
01:39:23,750 --> 01:39:21,040
is also quite misleading once we talk

1557
01:39:25,830 --> 01:39:23,760
about disruption of fragmentation we are

1558
01:39:28,229 --> 01:39:25,840
expecting that

1559
01:39:31,990 --> 01:39:28,239
orbital debris will become much much

1560
01:39:34,310 --> 01:39:32,000
larger at least within about 15 days

1561
01:39:36,470 --> 01:39:34,320
after the impact

1562
01:39:37,750 --> 01:39:36,480
so let's agree that

1563
01:39:40,709 --> 01:39:37,760

we do need

1564
01:39:43,750 --> 01:39:40,719
only

1565
01:39:46,070 --> 01:39:43,760
to be able to utilize for every tractor

1566
01:39:47,750 --> 01:39:46,080
as well as kinetic impactor

1567
01:39:49,830 --> 01:39:47,760
but if you don't have a sufficient

1568
01:39:52,390 --> 01:39:49,840
warning time we have to accept that

1569
01:39:55,270 --> 01:39:52,400
other options which is not 100

1570
01:39:57,430 --> 01:39:55,280
perfect solutions but if we have less

1571
01:39:59,430 --> 01:39:57,440
than one percent of impacting mass

1572
01:40:02,629 --> 01:39:59,440
compared to original mass that may not

1573
01:40:04,709 --> 01:40:02,639
be a bad option so

1574
01:40:07,270 --> 01:40:04,719
the second chart on planetary depends as

1575
01:40:08,390 --> 01:40:07,280
i mentioned warning time is the most

1576
01:40:11,430 --> 01:40:08,400
important

1577
01:40:15,590 --> 01:40:11,440
issue or concern from engineering

1578
01:40:18,550 --> 01:40:15,600
science i know there's many faculty body

1579
01:40:21,590 --> 01:40:18,560
researchers from jbl that's your task to

1580
01:40:24,470 --> 01:40:21,600
give us plenty of warning time

1581
01:40:26,790 --> 01:40:24,480
so target size very important mission

1582
01:40:29,910 --> 01:40:26,800
cost is also very important we cannot

1583
01:40:32,550 --> 01:40:29,920
just have afford very heavy vehicles

1584
01:40:33,350 --> 01:40:32,560
which i heard this afternoon

1585
01:40:35,830 --> 01:40:33,360
and

1586
01:40:37,830 --> 01:40:35,840
also uncertainty political concern

1587
01:40:39,430 --> 01:40:37,840
disruption breast deflection those two

1588
01:40:42,070 --> 01:40:39,440

should not be fighting each other they

1589
01:40:43,669 --> 01:40:42,080
are complementing solutions but i have a

1590
01:40:45,189 --> 01:40:43,679
two red dot

1591
01:40:47,750 --> 01:40:45,199
as you remember

1592
01:40:50,229 --> 01:40:47,760
2012 ba14

1593
01:40:52,950 --> 01:40:50,239
and as well as their small small but

1594
01:40:55,510 --> 01:40:52,960
it's a large it's a very oxymoron kind

1595
01:40:58,550 --> 01:40:55,520
it's a small balance the chelyabinsk

1596
01:40:59,430 --> 01:40:58,560
media with almost zero warning so i have

1597
01:41:03,189 --> 01:40:59,440
two

1598
01:41:05,830 --> 01:41:03,199
dots we have to worry about the a14 has

1599
01:41:09,350 --> 01:41:05,840
one year lead time am i right one year

1600
01:41:10,550 --> 01:41:09,360
but we had near miss we were very lucky

1601
01:41:13,270 --> 01:41:10,560
so let's

1602
01:41:15,910 --> 01:41:13,280
even think about case uh civil defense

1603
01:41:17,030 --> 01:41:15,920
evacuation is good solution too so we

1604
01:41:19,270 --> 01:41:17,040
have

1605
01:41:23,510 --> 01:41:19,280
many different options to be used for

1606
01:41:29,350 --> 01:41:26,310
so i'm going to present three

1607
01:41:31,669 --> 01:41:29,360
topics topic one is arv based kinetic

1608
01:41:34,950 --> 01:41:31,679
impactors as well as multiple gravity

1609
01:41:38,390 --> 01:41:34,960
tractor second topic is about the use of

1610
01:41:40,470 --> 01:41:38,400
a nuclear device and third one is

1611
01:41:43,510 --> 01:41:40,480
very special case what if we have only

1612
01:41:46,229 --> 01:41:43,520
one hour warning are we just gonna

1613
01:41:47,750 --> 01:41:46,239

wait

1614
01:41:50,470 --> 01:41:47,760
but we should

1615
01:41:51,270 --> 01:41:50,480
think about that

1616
01:41:53,669 --> 01:41:51,280
so

1617
01:41:57,350 --> 01:41:53,679
here's i'm here to present this

1618
01:42:01,030 --> 01:41:57,360
sort of notional idea to utilize 40

1619
01:42:03,590 --> 01:42:01,040
kilowatt asteroid redirect vehicle

1620
01:42:05,430 --> 01:42:03,600
with capture seven meters seven meter

1621
01:42:08,950 --> 01:42:05,440
doesn't mean exactly seven meter it can

1622
01:42:11,990 --> 01:42:08,960
be five meter seven ten meter range and

1623
01:42:14,550 --> 01:42:12,000
mass will be about five hundred ton

1624
01:42:17,669 --> 01:42:14,560
it can be five hundred or even thousands

1625
01:42:20,870 --> 01:42:17,679
on kinetic impact depending on the mass

1626
01:42:22,470 --> 01:42:20,880
so when i was preparing proposal to nasa

1627
01:42:25,750 --> 01:42:22,480
i think that this was the only thing i

1628
01:42:28,629 --> 01:42:25,760
was able to come out how to utilize

1629
01:42:29,750 --> 01:42:28,639
you know 40 kilowatt good-looking heavy

1630
01:42:32,550 --> 01:42:29,760
vehicle

1631
01:42:34,709 --> 01:42:32,560
so this is the one so idea is

1632
01:42:36,870 --> 01:42:34,719
not mine it has been well known so

1633
01:42:40,229 --> 01:42:36,880
basically once we detect the large

1634
01:42:43,669 --> 01:42:40,239
asteroid then we find a small asteroid

1635
01:42:45,750 --> 01:42:43,679
and guide that 500 kinetic invector to

1636
01:42:49,030 --> 01:42:45,760
have proper

1637
01:42:52,229 --> 01:42:49,040
kinetic impact sounds very fictional

1638
01:42:53,910 --> 01:42:52,239

but this is one option to utilize 40

1639
01:42:55,189 --> 01:42:53,920
kilowatt

1640
01:42:59,189 --> 01:42:55,199
arb

1641
01:43:04,149 --> 01:43:01,189
however

1642
01:43:07,590 --> 01:43:04,159
total energy contained it in this 500

1643
01:43:10,629 --> 01:43:07,600
ton kinetic impact can be replaced by

1644
01:43:12,149 --> 01:43:10,639
say 10 kilo nuclear device which will

1645
01:43:15,270 --> 01:43:12,159
weigh

1646
01:43:17,830 --> 01:43:15,280
say 10 kilogram or even less than 100

1647
01:43:20,470 --> 01:43:17,840
kilograms so we have to think about

1648
01:43:24,070 --> 01:43:20,480
cost comparisons

1649
01:43:25,510 --> 01:43:24,080
how much is it to launch 100 kilogram

1650
01:43:27,270 --> 01:43:25,520
payload

1651
01:43:32,149 --> 01:43:27,280
which can be easily launched by using

1652
01:43:37,430 --> 01:43:34,870
so these are the proposed research topic

1653
01:43:38,390 --> 01:43:37,440
if nasa likes to have this kind of

1654
01:43:40,870 --> 01:43:38,400
application

1655
01:43:43,590 --> 01:43:40,880
this is not a complete solution we have

1656
01:43:45,750 --> 01:43:43,600
to go through optimal search selection

1657
01:43:47,270 --> 01:43:45,760
of small asteroids we don't have a

1658
01:43:49,990 --> 01:43:47,280
database for

1659
01:43:51,510 --> 01:43:50,000
5 meter or 10 meter size we don't know

1660
01:43:54,229 --> 01:43:51,520
we don't know where the air so assuming

1661
01:43:57,030 --> 01:43:54,239
that during the next 10 20 years we have

1662
01:43:59,990 --> 01:43:57,040
a million small asteroids we have a

1663
01:44:02,229 --> 01:44:00,000

database so once we know the 100 meter

1664
01:44:04,790 --> 01:44:02,239
asteroid is appearing somewhere that we

1665
01:44:07,270 --> 01:44:04,800
run our supercomputer to find the best

1666
01:44:09,910 --> 01:44:07,280
trajectory to pick up the smallest one

1667
01:44:12,870 --> 01:44:09,920
and then hopefully those two are

1668
01:44:15,030 --> 01:44:12,880
flying along the same direction then

1669
01:44:17,430 --> 01:44:15,040
that's the optimal solution we may find

1670
01:44:20,229 --> 01:44:17,440
out that kind of optimal solution also

1671
01:44:22,950 --> 01:44:20,239
someone may propose that or we cannot do

1672
01:44:24,709 --> 01:44:22,960
that we have to pre-place many small

1673
01:44:26,950 --> 01:44:24,719
ashtray around the earth that's the

1674
01:44:30,070 --> 01:44:26,960
russian concept

1675
01:44:33,109 --> 01:44:30,080
and another concept is to utilize earth

1676
01:44:36,149 --> 01:44:33,119
gravity on our jupiter the mars gravity

1677
01:44:37,750 --> 01:44:36,159
a system maneuver to get more delta v so

1678
01:44:40,470 --> 01:44:37,760
there are many academic research

1679
01:44:42,229 --> 01:44:40,480
problems which needs to be done and

1680
01:44:44,470 --> 01:44:42,239
please do not expect that someone should

1681
01:44:46,709 --> 01:44:44,480
have done all this research so that i

1682
01:44:49,830 --> 01:44:46,719
can present those no it requires a

1683
01:44:53,350 --> 01:44:51,109
somehow

1684
01:44:55,590 --> 01:44:53,360
that doesn't look good then we have

1685
01:44:58,070 --> 01:44:55,600
another option to utilize

1686
01:45:00,830 --> 01:44:58,080
solar electric propulsion-based gravity

1687
01:45:04,709 --> 01:45:00,840
tractor as we heard this happen many

1688
01:45:07,270 --> 01:45:04,719

times but i didn't realize that we

1689
01:45:10,390 --> 01:45:07,280
currently do have such a high heavy

1690
01:45:13,030 --> 01:45:10,400
heavy satellite with such powerful 50

1691
01:45:17,669 --> 01:45:13,040
kilowatt energy source so whenever nasa

1692
01:45:19,669 --> 01:45:17,679
started gravity tractor in 2008

1693
01:45:22,070 --> 01:45:19,679
nasa thought it's just like a wonton

1694
01:45:24,790 --> 01:45:22,080
class maybe two ton class gravity

1695
01:45:26,229 --> 01:45:24,800
tractor so at that time i don't think

1696
01:45:29,510 --> 01:45:26,239
i've right

1697
01:45:31,830 --> 01:45:29,520
we couldn't we couldn't dream about 20

1698
01:45:32,709 --> 01:45:31,840
ton class gravity tractor it's a brand

1699
01:45:35,750 --> 01:45:32,719
new

1700
01:45:37,270 --> 01:45:35,760
story to me so at that time we have oh

1701
01:45:38,390 --> 01:45:37,280
here is

1702
01:45:40,070 --> 01:45:38,400
simple

1703
01:45:45,109 --> 01:45:40,080
gravity tractor

1704
01:45:47,350 --> 01:45:45,119
and then i have a few okay i'm gonna use

1705
01:45:49,990 --> 01:45:47,360
okay but okay here it is this is the

1706
01:45:51,830 --> 01:45:50,000
gravity tractor basically is or shooting

1707
01:45:53,990 --> 01:45:51,840
this

1708
01:45:55,270 --> 01:45:54,000
but if there's a debris issue then we

1709
01:45:57,590 --> 01:45:55,280
have to tilt

1710
01:46:00,310 --> 01:45:57,600
so that's why the traditional grape

1711
01:46:01,189 --> 01:46:00,320
tractor required will require two tilted

1712
01:46:03,430 --> 01:46:01,199
jet

1713
01:46:05,830 --> 01:46:03,440

so continuously firing there's a basic

1714
01:46:07,910 --> 01:46:05,840
concept so this is one equation we do

1715
01:46:10,149 --> 01:46:07,920
need gravity structure design

1716
01:46:12,390 --> 01:46:10,159
the gravitational pulling force is

1717
01:46:13,430 --> 01:46:12,400
determined by available

1718
01:46:16,870 --> 01:46:13,440
thrust

1719
01:46:19,109 --> 01:46:16,880
by i heard about augmenting boulder i

1720
01:46:22,070 --> 01:46:19,119
have to figure that out how you get a

1721
01:46:23,109 --> 01:46:22,080
better performance but basically given

1722
01:46:25,270 --> 01:46:23,119
design

1723
01:46:28,149 --> 01:46:25,280
gravitational pulling force is

1724
01:46:31,350 --> 01:46:28,159
predetermined by the maximum available

1725
01:46:33,830 --> 01:46:31,360
thrust whether you add more gravity the

1726
01:46:34,950 --> 01:46:33,840
bold or not still that

1727
01:46:37,669 --> 01:46:34,960
will

1728
01:46:39,430 --> 01:46:37,679
need to be adjust that separation

1729
01:46:41,189 --> 01:46:39,440
distance so i will be paying more

1730
01:46:44,470 --> 01:46:41,199
attention your new gravity structure

1731
01:46:45,750 --> 01:46:44,480
design so at that time in 2008

1732
01:46:49,990 --> 01:46:45,760
so

1733
01:46:53,270 --> 01:46:50,000
what if this there's a mole function of

1734
01:46:55,430 --> 01:46:53,280
the single platform so we created

1735
01:46:57,750 --> 01:46:55,440
halo orbit the satellite will be

1736
01:47:00,470 --> 01:46:57,760
orbiting around like this

1737
01:47:02,870 --> 01:47:00,480
using only one engine and in one ob we

1738
01:47:06,709 --> 01:47:02,880

can place couple of depending on the

1739
01:47:09,430 --> 01:47:06,719
orbital radius so it has the redundancy

1740
01:47:11,270 --> 01:47:09,440
the improvements reliability

1741
01:47:14,470 --> 01:47:11,280
issue but still

1742
01:47:17,669 --> 01:47:14,480
it requires more engineering study so

1743
01:47:19,590 --> 01:47:17,679
multiple solar electric proportions

1744
01:47:22,149 --> 01:47:19,600
uh base gravity tractor we don't need

1745
01:47:24,070 --> 01:47:22,159
the arv they just we don't need a bag or

1746
01:47:26,310 --> 01:47:24,080
something like that we just solar

1747
01:47:29,910 --> 01:47:26,320
electric propulsion-based gravity

1748
01:47:31,109 --> 01:47:29,920
tractor in halo orbit with multiple

1749
01:47:34,229 --> 01:47:31,119
formation

1750
01:47:37,189 --> 01:47:34,239
keeping base we will have much better

1751
01:47:38,629 --> 01:47:37,199
efficiency

1752
01:47:41,590 --> 01:47:38,639
a few minutes

1753
01:47:42,870 --> 01:47:41,600
before i talk to uh next topic of

1754
01:47:45,910 --> 01:47:42,880
nuclear

1755
01:47:48,470 --> 01:47:45,920
there's we have to understand that

1756
01:47:51,350 --> 01:47:48,480
once we have heavy gravity tractor

1757
01:47:54,550 --> 01:47:51,360
instead of operating two years as i

1758
01:47:57,990 --> 01:47:54,560
heard from boeing or no drop or maybe 10

1759
01:48:01,510 --> 01:47:58,000
years the best solution is to use

1760
01:48:03,830 --> 01:48:01,520
gravity tractor as a kinetic impactor

1761
01:48:05,590 --> 01:48:03,840
we don't have to wait 10 20 years over

1762
01:48:07,669 --> 01:48:05,600
even two years

1763
01:48:10,070 --> 01:48:07,679

the total delta we

1764
01:48:12,629 --> 01:48:10,080
resulting from the use of gravity

1765
01:48:14,629 --> 01:48:12,639
tractor as a kinetic invector is at

1766
01:48:15,669 --> 01:48:14,639
least 10 times

1767
01:48:18,470 --> 01:48:15,679
better

1768
01:48:20,550 --> 01:48:18,480
but someone may say that oh we cannot

1769
01:48:23,270 --> 01:48:20,560
guide in the right direction there's

1770
01:48:25,270 --> 01:48:23,280
many many different open issues but

1771
01:48:27,590 --> 01:48:25,280
anyway there is a sort of option to be

1772
01:48:30,229 --> 01:48:27,600
considered by yes

1773
01:48:33,270 --> 01:48:30,239
so i basically i complete my original

1774
01:48:35,350 --> 01:48:33,280
presentation of those proposed concept

1775
01:48:38,550 --> 01:48:35,360
of utilizing arv

1776
01:48:40,950 --> 01:48:38,560
as a kinetic impactor or gravity tractor

1777
01:48:44,629 --> 01:48:40,960
or multiple gravity tractor the next

1778
01:48:50,149 --> 01:48:48,070
let's talk about short warning time so

1779
01:48:51,430 --> 01:48:50,159
once we have a sufficient warning time

1780
01:48:53,830 --> 01:48:51,440
no problem

1781
01:48:55,669 --> 01:48:53,840
somehow we can solve the issue but what

1782
01:48:58,550 --> 01:48:55,679
if we don't have sufficient warning time

1783
01:49:01,990 --> 01:48:58,560
deflection is not an option then

1784
01:49:04,070 --> 01:49:02,000
disruptions fragmentation and dispersion

1785
01:49:06,310 --> 01:49:04,080
is the only option other than simply

1786
01:49:12,310 --> 01:49:06,320
waiting or civil defense

1787
01:49:16,470 --> 01:49:13,910
so current this is more like a

1788
01:49:18,629 --> 01:49:16,480

promotional talk so i have

1789
01:49:21,510 --> 01:49:18,639
nasa naya phase one to study being

1790
01:49:23,830 --> 01:49:21,520
funded by nasa and the title is an

1791
01:49:25,510 --> 01:49:23,840
innovative solution to nasa's new impact

1792
01:49:27,270 --> 01:49:25,520
threat mitigation grant challenge we

1793
01:49:29,430 --> 01:49:27,280
nowadays we hear

1794
01:49:32,550 --> 01:49:29,440
about grandchild but it's nothing new

1795
01:49:34,629 --> 01:49:32,560
the grand challenge by nasa on a new

1796
01:49:35,669 --> 01:49:34,639
deflection has been around

1797
01:49:38,070 --> 01:49:35,679
more than

1798
01:49:40,629 --> 01:49:38,080
three or four years

1799
01:49:43,430 --> 01:49:40,639
and brain bobby is my co-eye

1800
01:49:46,950 --> 01:49:43,440
and the task is to develop practically

1801
01:49:49,109 --> 01:49:46,960
viable practically viable low cost

1802
01:49:51,910 --> 01:49:49,119
technically feasible

1803
01:49:54,709 --> 01:49:51,920
blended kinetic impairment penetrates

1804
01:49:56,470 --> 01:49:54,719
sub-surface nuclear explosion concept

1805
01:49:59,270 --> 01:49:56,480
technique method

1806
01:50:01,830 --> 01:49:59,280
for mitigating new impact threat with

1807
01:50:03,750 --> 01:50:01,840
short warning time when deflection is

1808
01:50:05,589 --> 01:50:03,760
not an option

1809
01:50:07,109 --> 01:50:05,599
since and this is basically

1810
01:50:09,430 --> 01:50:07,119
illustrations

1811
01:50:13,270 --> 01:50:09,440
fragmentations

1812
01:50:15,189 --> 01:50:13,280
if we have at least 15 days 15 days

1813
01:50:16,470 --> 01:50:15,199

we will have this kind of orbital

1814
01:50:18,629 --> 01:50:16,480
dispersion

1815
01:50:21,510 --> 01:50:18,639
then the errors will go through that so

1816
01:50:23,270 --> 01:50:21,520
less than probably one percent

1817
01:50:26,229 --> 01:50:23,280
mass will

1818
01:50:29,189 --> 01:50:26,239
be intercepted by this cross section due

1819
01:50:31,589 --> 01:50:29,199
to gravitational pull of this so that is

1820
01:50:34,550 --> 01:50:31,599
result but is an illustration not that

1821
01:50:38,390 --> 01:50:34,560
many but not that big

1822
01:50:39,189 --> 01:50:38,400
so this is a base concept

1823
01:50:40,229 --> 01:50:39,199
being

1824
01:50:41,589 --> 01:50:40,239
studied

1825
01:50:44,070 --> 01:50:41,599
by our group

1826
01:50:45,669 --> 01:50:44,080
and also i just want to emphasize that

1827
01:50:47,830 --> 01:50:45,679
many of you think that even though you

1828
01:50:50,070 --> 01:50:47,840
are against the use of nuclear device

1829
01:50:52,470 --> 01:50:50,080
some many of you think that last option

1830
01:50:55,030 --> 01:50:52,480
yes let's use that but that is not that

1831
01:50:57,510 --> 01:50:55,040
simple for the last minute option the

1832
01:50:59,910 --> 01:50:57,520
arrival velocity will be much larger

1833
01:51:02,470 --> 01:50:59,920
than 10 kilometer or even 20 kilometer

1834
01:51:03,430 --> 01:51:02,480
per second so we cannot afford round the

1835
01:51:05,910 --> 01:51:03,440
view

1836
01:51:08,149 --> 01:51:05,920
so we cannot utilize the nuclear device

1837
01:51:11,910 --> 01:51:08,159
let's assume there is a nuclear war just

1838
01:51:14,390 --> 01:51:11,920

hit penetrate no that doesn't work and

1839
01:51:16,229 --> 01:51:14,400
context surface standoff is much much

1840
01:51:20,149 --> 01:51:16,239
less effective we are wasting all the

1841
01:51:23,830 --> 01:51:20,159
energy so the best solution is penetrate

1842
01:51:26,629 --> 01:51:23,840
have a self-serve explosion but that

1843
01:51:29,189 --> 01:51:26,639
is only possible when the speed is less

1844
01:51:31,189 --> 01:51:29,199
than 300 meter per second so only option

1845
01:51:34,550 --> 01:51:31,199
is

1846
01:51:37,830 --> 01:51:34,560
during before last intercept or impact

1847
01:51:40,229 --> 01:51:37,840
we have to release release the payload

1848
01:51:43,830 --> 01:51:40,239
and then the satellite will make

1849
01:51:46,550 --> 01:51:43,840
kinetic impact make a crater and then

1850
01:51:49,910 --> 01:51:46,560
the payload nuclear payload will have

1851
01:51:53,510 --> 01:51:49,920
explosion under the crate with about one

1852
01:51:56,870 --> 01:51:53,520
or two millisecond delay uh explosions

1853
01:52:01,270 --> 01:51:59,189
start here

1854
01:52:03,510 --> 01:52:01,280
thank you thank you we have time for one

1855
01:52:05,669 --> 01:52:03,520
very quick comment or question please so

1856
01:52:07,910 --> 01:52:05,679
a real quick question um

1857
01:52:09,589 --> 01:52:07,920
in military terms if you have one large

1858
01:52:11,430 --> 01:52:09,599
nuclear weapon it isn't as good as

1859
01:52:13,830 --> 01:52:11,440
having a lot of small ones so you

1860
01:52:15,030 --> 01:52:13,840
increase the the kill potential by

1861
01:52:15,750 --> 01:52:15,040
merving

1862
01:52:17,589 --> 01:52:15,760
so

1863
01:52:19,990 --> 01:52:17,599

i'm assuming that you think you're going

1864
01:52:21,510 --> 01:52:20,000
to get enough material off the face of

1865
01:52:22,709 --> 01:52:21,520
the earth so even though you have many

1866
01:52:25,030 --> 01:52:22,719
many hits

1867
01:52:26,149 --> 01:52:25,040
it's less of an impact is that true

1868
01:52:29,430 --> 01:52:26,159
would it mean

1869
01:52:31,589 --> 01:52:29,440
every impact yeah so if you oh yes

1870
01:52:34,870 --> 01:52:31,599
our computational simulation shows that

1871
01:52:37,830 --> 01:52:34,880
if we have at least two weeks lead time

1872
01:52:39,430 --> 01:52:37,840
okay 300 meter using three kiloton

1873
01:52:41,830 --> 01:52:39,440
device which can be easily launched by

1874
01:52:45,669 --> 01:52:41,840
delta to small launch vehicle

1875
01:52:48,470 --> 01:52:45,679
net mass is less than point one percent

1876
01:52:50,870 --> 01:52:48,480
the degree size already

1877
01:52:53,270 --> 01:52:50,880
okay so most of it misses the earth

1878
01:52:56,149 --> 01:52:53,280
period yes okay and then hopefully our

1879
01:52:58,149 --> 01:52:56,159
atmosphere will protect us

1880
01:53:03,990 --> 01:52:58,159
okay thank you thank you okay thank you

1881
01:53:09,109 --> 01:53:06,790
okay our next presenter is uh dr jeff

1882
01:53:10,629 --> 01:53:09,119
landis is a scientist and he's also a

1883
01:53:11,990 --> 01:53:10,639
science fiction writer he has a degree

1884
01:53:13,109 --> 01:53:12,000
in physics and electrical engineering

1885
01:53:15,430 --> 01:53:13,119
and currently works on developing

1886
01:53:17,589 --> 01:53:15,440
advanced technology for space missions

1887
01:53:21,270 --> 01:53:17,599
at nasa uh

1888
01:53:31,350 --> 01:53:24,229

dr lannis is joining us virtually so are

1889
01:53:31,360 --> 01:53:43,109
okay

1890
01:53:49,589 --> 01:53:45,990
hey jeff are you there can you hear us

1891
01:53:51,990 --> 01:53:49,599
yeah hello do you hear me yes we can

1892
01:53:53,430 --> 01:53:52,000
uh i'm not sure can you hear me now uh

1893
01:53:54,950 --> 01:53:53,440
it's a little bit faint if you could try

1894
01:53:56,870 --> 01:53:54,960
getting maybe a little closer microphone

1895
01:53:59,109 --> 01:53:56,880
we'll adjust the volume here if we can i

1896
01:54:02,070 --> 01:53:59,119
am good can you hear me

1897
01:54:05,510 --> 01:54:03,910
okay i don't think

1898
01:54:09,750 --> 01:54:05,520
are you there can you hear us hi

1899
01:54:11,990 --> 01:54:09,760
actually hello do you hear me yes we can

1900
01:54:13,270 --> 01:54:12,000
i'm not sure can you hear me now uh it's

1901
01:54:14,870 --> 01:54:13,280
a little bit faint if you could try

1902
01:54:16,229 --> 01:54:14,880
getting a little closer

1903
01:54:18,390 --> 01:54:16,239
we'll adjust the volume jeff can you

1904
01:54:20,070 --> 01:54:18,400
close the stream um

1905
01:54:23,270 --> 01:54:20,080
length there so that we're not getting a

1906
01:54:28,070 --> 01:54:24,470
there's there's a

1907
01:54:29,910 --> 01:54:28,080
delay coming through with uh quite a bit

1908
01:54:31,830 --> 01:54:29,920
of delay i think that may have been that

1909
01:54:33,030 --> 01:54:31,840
i was switching between my computer and

1910
01:54:36,390 --> 01:54:33,040
my phone

1911
01:54:37,430 --> 01:54:36,400
but on the assumption that you can hear

1912
01:54:39,990 --> 01:54:37,440
me

1913
01:54:40,870 --> 01:54:40,000

uh even though i cannot hear you

1914
01:54:42,870 --> 01:54:40,880
uh

1915
01:54:46,310 --> 01:54:42,880
i should keep going can you confirm that

1916
01:54:56,870 --> 01:54:47,830
okay

1917
01:54:58,390 --> 01:54:56,880
analysis of whether we can use asteroid

1918
01:55:00,629 --> 01:54:58,400
repositioning

1919
01:55:02,950 --> 01:55:00,639
for planetary defense

1920
01:55:04,950 --> 01:55:02,960
uh and i do need to acknowledge the

1921
01:55:06,550 --> 01:55:04,960
compass team

1922
01:55:08,709 --> 01:55:06,560
in fact i need to acknowledge two

1923
01:55:11,109 --> 01:55:08,719
studies first the study we did for the

1924
01:55:13,350 --> 01:55:11,119
keck institute for space studies

1925
01:55:15,669 --> 01:55:13,360
on asteroid repositioning

1926
01:55:18,709 --> 01:55:15,679
and then we used that for white paper

1927
01:55:20,870 --> 01:55:18,719
submitted to the niacc solicitation

1928
01:55:21,990 --> 01:55:20,880
last spring

1929
01:55:24,470 --> 01:55:22,000
the problem

1930
01:55:27,109 --> 01:55:24,480
which has been already

1931
01:55:29,030 --> 01:55:27,119
quite a bit discussed so i perhaps don't

1932
01:55:32,229 --> 01:55:29,040
need to go into great detail on this is

1933
01:55:35,750 --> 01:55:32,239
that asteroid impacts are responsible

1934
01:55:38,229 --> 01:55:35,760
for mass extinction events including the

1935
01:55:41,350 --> 01:55:38,239
very well-known chick-fil-a event

1936
01:55:43,510 --> 01:55:41,360
uh and the probability of this happening

1937
01:55:46,070 --> 01:55:43,520
in any generation is low

1938
01:55:49,350 --> 01:55:46,080

but the consequences are very high so

1939
01:55:52,070 --> 01:55:49,360
we'd like to find a means to divert

1940
01:55:53,589 --> 01:55:52,080
an asteroid and several such means have

1941
01:55:55,910 --> 01:55:53,599
been discussed

1942
01:55:58,229 --> 01:55:55,920
in the previous talks

1943
01:56:01,430 --> 01:55:58,239
in previous work we've done a study on

1944
01:56:02,950 --> 01:56:01,440
behalf of kiss the tech institute for

1945
01:56:06,390 --> 01:56:02,960
space studies

1946
01:56:08,470 --> 01:56:06,400
of how to design a spacecraft capable of

1947
01:56:10,390 --> 01:56:08,480
moving a small asteroid

1948
01:56:13,350 --> 01:56:10,400
and in that study

1949
01:56:15,350 --> 01:56:13,360
we looked at a small asteroid a seven

1950
01:56:19,350 --> 01:56:15,360
meter class near earth object with a

1951
01:56:21,430 --> 01:56:19,360
mass of perhaps as much as uh 500 000

1952
01:56:23,510 --> 01:56:21,440
kilograms

1953
01:56:26,390 --> 01:56:23,520
so it showed that we could do this

1954
01:56:30,070 --> 01:56:26,400
there's just one of many visualizations

1955
01:56:32,470 --> 01:56:30,080
uh there's been any number of such uh

1956
01:56:35,189 --> 01:56:32,480
visualizations that have been done uh

1957
01:56:37,510 --> 01:56:35,199
since we did that study uh

1958
01:56:40,229 --> 01:56:37,520
oh about two years ago

1959
01:56:42,709 --> 01:56:40,239
uh now but it looks like we can pick up

1960
01:56:44,470 --> 01:56:42,719
an asteroid and move it

1961
01:56:48,950 --> 01:56:44,480
into

1962
01:56:51,350 --> 01:56:48,960
orbit

1963
01:56:53,589 --> 01:56:51,360

either low around the moon or around a

1964
01:56:56,870 --> 01:56:53,599
lagrange point

1965
01:57:00,470 --> 01:56:56,880
well directly relocating an asteroid by

1966
01:57:03,109 --> 01:57:00,480
fcp just takes too long to be a way to

1967
01:57:05,430 --> 01:57:03,119
defend the earth uh unless you have an

1968
01:57:08,310 --> 01:57:05,440
enormous amount of time

1969
01:57:10,790 --> 01:57:08,320
uh but we still think we can use this

1970
01:57:13,830 --> 01:57:10,800
asteroid relocation technology

1971
01:57:15,990 --> 01:57:13,840
uh as a method of protecting earth

1972
01:57:17,270 --> 01:57:16,000
uh in fact this was alluded to in the

1973
01:57:19,990 --> 01:57:17,280
previous talk

1974
01:57:22,709 --> 01:57:20,000
we proposed taking one of these seven to

1975
01:57:25,270 --> 01:57:22,719
ten meter diameter asteroids finding it

1976
01:57:27,750 --> 01:57:25,280
bringing it to a position in halo orbit

1977
01:57:29,430 --> 01:57:27,760
uh perhaps in one of the stable earth

1978
01:57:31,350 --> 01:57:29,440
moon lagrange points

1979
01:57:34,709 --> 01:57:31,360
from this point you can eject the

1980
01:57:36,709 --> 01:57:34,719
asteroid with comparative low delta v

1981
01:57:39,910 --> 01:57:36,719
into an escape trajectory so the

1982
01:57:43,589 --> 01:57:39,920
proposal then is to use such an asteroid

1983
01:57:45,350 --> 01:57:43,599
at the lagrange point uh as a defender

1984
01:57:47,990 --> 01:57:45,360
and here's a little just a graphic

1985
01:57:49,430 --> 01:57:48,000
showing it uh you can take your small

1986
01:57:54,070 --> 01:57:49,440
asteroid

1987
01:57:57,109 --> 01:57:54,080
with solar electric propulsion

1988
01:57:57,990 --> 01:57:57,119

into a translunar payload orbit voice

1989
01:58:00,790 --> 01:57:58,000
kept

1990
01:58:04,149 --> 01:58:00,800
and that will be your defending asteroid

1991
01:58:07,109 --> 01:58:04,159
when you have warning of a larger earth

1992
01:58:09,109 --> 01:58:07,119
crossing object approaching uh

1993
01:58:10,629 --> 01:58:09,119
you can then send your defending

1994
01:58:13,830 --> 01:58:10,639
asteroid out

1995
01:58:16,149 --> 01:58:13,840
uh in order to be a collision as the

1996
01:58:19,510 --> 01:58:16,159
previous talk mentioned uh the hyper

1997
01:58:22,470 --> 01:58:19,520
velocity impact is a very efficient way

1998
01:58:24,870 --> 01:58:22,480
of moving an asteroid with delta v

1999
01:58:26,310 --> 01:58:24,880
so the object essentially is to hit an

2000
01:58:28,709 --> 01:58:26,320
incoming bullet

2001
01:58:30,709 --> 01:58:28,719
with a bullet of your own

2002
01:58:33,510 --> 01:58:30,719
so when it's threatening after it is

2003
01:58:35,350 --> 01:58:33,520
detected the path is calculated and we

2004
01:58:37,589 --> 01:58:35,360
eject the defense asteroid into a

2005
01:58:39,750 --> 01:58:37,599
trajectory to intercept it

2006
01:58:42,470 --> 01:58:39,760
with new mid course correction

2007
01:58:45,109 --> 01:58:42,480
as we learn more about the final

2008
01:58:47,669 --> 01:58:45,119
trajectory of the impact the resulting

2009
01:58:50,229 --> 01:58:47,679
impact will be typically at velocities

2010
01:58:51,189 --> 01:58:50,239
on the scale of about 20 kilometers per

2011
01:58:53,109 --> 01:58:51,199
second

2012
01:58:56,390 --> 01:58:53,119
which transfers momentum

2013
01:58:58,790 --> 01:58:56,400

to the impacting object

2014
01:59:00,390 --> 01:58:58,800
so just showing that this can be done we

2015
01:59:03,109 --> 01:59:00,400
know this can be done because it has

2016
01:59:06,070 --> 01:59:03,119
been done uh here's just a view of the

2017
01:59:08,790 --> 01:59:06,080
deep impact probe which successfully

2018
01:59:11,510 --> 01:59:08,800
impacted uh comet temple 1

2019
01:59:12,790 --> 01:59:11,520
at a high velocity so it shows that the

2020
01:59:14,629 --> 01:59:12,800
navigation

2021
01:59:17,589 --> 01:59:14,639
needed to do this

2022
01:59:18,550 --> 01:59:17,599
is a known thing it's something that we

2023
01:59:20,550 --> 01:59:18,560
can

2024
01:59:23,270 --> 01:59:20,560
do

2025
01:59:25,830 --> 01:59:23,280
a lot of calculations are needed uh how

2026
01:59:27,910 --> 01:59:25,840
large a threat can be addressed how much

2027
01:59:30,709 --> 01:59:27,920
delta v do you need how much can you

2028
01:59:33,589 --> 01:59:30,719
achieve how big does the defending

2029
01:59:35,589 --> 01:59:33,599
object have to be the bigger it is the

2030
01:59:37,510 --> 01:59:35,599
more impulse you get

2031
01:59:38,870 --> 01:59:37,520
but it obviously takes much longer to

2032
01:59:40,870 --> 01:59:38,880
move into place

2033
01:59:43,589 --> 01:59:40,880
uh so that brings to the question of how

2034
01:59:45,350 --> 01:59:43,599
much advanced warning do we need

2035
01:59:46,709 --> 01:59:45,360
the longer the warning the lower the

2036
01:59:49,109 --> 01:59:46,719
delta v

2037
01:59:51,750 --> 01:59:49,119
and the final question is does the

2038
01:59:53,830 --> 01:59:51,760

impact uh threaten

2039
01:59:55,990 --> 01:59:53,840
threaten to fragment uh the incoming

2040
01:59:58,629 --> 01:59:56,000
object uh and if so does it make the

2041
01:59:59,990 --> 01:59:58,639
problem worse or does it make it better

2042
02:00:02,310 --> 02:00:00,000
well

2043
02:00:03,990 --> 02:00:02,320
there's two different ways that we can

2044
02:00:07,750 --> 02:00:04,000
think about

2045
02:00:09,589 --> 02:00:07,760
uh intercepting an incoming object so

2046
02:00:12,629 --> 02:00:09,599
the incoming object in this picture

2047
02:00:15,270 --> 02:00:12,639
would be in the red trajectory it's in

2048
02:00:16,709 --> 02:00:15,280
an orbit obviously the orbit will cross

2049
02:00:19,350 --> 02:00:16,719
earth's orbit

2050
02:00:22,229 --> 02:00:19,360
every uh every orbit

2051
02:00:24,229 --> 02:00:22,239
uh but only one particular time of

2052
02:00:25,750 --> 02:00:24,239
crossing is the earth going to be in

2053
02:00:27,270 --> 02:00:25,760
position

2054
02:00:30,229 --> 02:00:27,280
that it will be threatened

2055
02:00:31,430 --> 02:00:30,239
so in strategy one you intercept the

2056
02:00:33,589 --> 02:00:31,440
orbit

2057
02:00:35,510 --> 02:00:33,599
when it passes

2058
02:00:37,430 --> 02:00:35,520
uh you intercept the asteroids orbit

2059
02:00:39,350 --> 02:00:37,440
when it passes earth's orbit

2060
02:00:41,669 --> 02:00:39,360
at a first time

2061
02:00:44,310 --> 02:00:41,679
uh even though it's going to actually

2062
02:00:47,430 --> 02:00:44,320
impact the earth on a future path

2063
02:00:50,229 --> 02:00:47,440

so this is a method that allows you to

2064
02:00:51,510 --> 02:00:50,239
do the interception with a little bit

2065
02:00:53,589 --> 02:00:51,520
more

2066
02:00:55,669 --> 02:00:53,599
uh advanced warning

2067
02:00:57,830 --> 02:00:55,679
so the impact will change the phasing of

2068
02:00:59,589 --> 02:00:57,840
the orbit so that it returns when the

2069
02:01:01,910 --> 02:00:59,599
earth isn't there

2070
02:01:04,149 --> 02:01:01,920
so by intercepting well in advance the

2071
02:01:06,310 --> 02:01:04,159
relatively minimal delta v

2072
02:01:08,790 --> 02:01:06,320
is needed

2073
02:01:10,629 --> 02:01:08,800
uh it's worth noting you can intercept

2074
02:01:13,990 --> 02:01:10,639
it at either place it could be either in

2075
02:01:16,550 --> 02:01:14,000
an inbound path or in an outbound path

2076
02:01:19,669 --> 02:01:16,560
however if the asteroid is at high

2077
02:01:22,709 --> 02:01:19,679
inclination if it's at high eccentricity

2078
02:01:24,629 --> 02:01:22,719
uh it may be difficult to reach on the

2079
02:01:26,709 --> 02:01:24,639
outbound path assuming that the

2080
02:01:28,070 --> 02:01:26,719
impacting pass is an inbound

2081
02:01:30,629 --> 02:01:28,080
path

2082
02:01:33,030 --> 02:01:30,639
the alternative is well what if you

2083
02:01:34,550 --> 02:01:33,040
don't have that luxury

2084
02:01:36,950 --> 02:01:34,560
what if the

2085
02:01:39,030 --> 02:01:36,960
asteroid is approaching earth and you

2086
02:01:41,669 --> 02:01:39,040
don't have the ability to

2087
02:01:43,430 --> 02:01:41,679
perturb it uh on a previous path you

2088
02:01:46,229 --> 02:01:43,440

have to perturb it now

2089
02:01:48,070 --> 02:01:46,239
in this case you have a lower

2090
02:01:50,149 --> 02:01:48,080
amount of time

2091
02:01:52,950 --> 02:01:50,159
uh you have a lower amount of distance

2092
02:01:55,910 --> 02:01:52,960
over which uh you can affect this so you

2093
02:01:57,750 --> 02:01:55,920
need to move the defending asteroids

2094
02:02:01,189 --> 02:01:57,760
further away from earth

2095
02:02:04,629 --> 02:02:01,199
in order to give the impacting delta v

2096
02:02:06,070 --> 02:02:04,639
uh a chance to perturb the asteroid's

2097
02:02:08,709 --> 02:02:06,080
motion enough

2098
02:02:10,790 --> 02:02:08,719
to avoid the impact

2099
02:02:12,709 --> 02:02:10,800
so that's a shorter warning it will

2100
02:02:15,270 --> 02:02:12,719
require higher delta v

2101
02:02:16,790 --> 02:02:15,280
so only relatively smaller asteroids can

2102
02:02:18,790 --> 02:02:16,800
be deflected

2103
02:02:22,470 --> 02:02:18,800
if you don't have the

2104
02:02:24,550 --> 02:02:22,480
long amount of of warning

2105
02:02:26,790 --> 02:02:24,560
so how much impulse is produced by

2106
02:02:29,270 --> 02:02:26,800
interception uh there's actually two

2107
02:02:31,109 --> 02:02:29,280
things you get you get momentum of the

2108
02:02:35,270 --> 02:02:31,119
intercepting asteroids

2109
02:02:38,070 --> 02:02:35,280
the asteroid coming in gives the delta v

2110
02:02:39,669 --> 02:02:38,080
comparable in general to the target's

2111
02:02:41,189 --> 02:02:39,679
flyby velocity

2112
02:02:43,589 --> 02:02:41,199
give or take

2113
02:02:46,470 --> 02:02:43,599

however it also produces the reaction

2114
02:02:48,149 --> 02:02:46,480
force the impact produces a large amount

2115
02:02:50,470 --> 02:02:48,159
of ejecta

2116
02:02:52,070 --> 02:02:50,480
uh basically there's a fireball produced

2117
02:02:54,629 --> 02:02:52,080
by the impact that

2118
02:02:56,950 --> 02:02:54,639
ejects the plume of vaporized material

2119
02:02:58,950 --> 02:02:56,960
the vaporized material

2120
02:03:00,950 --> 02:02:58,960
will uh

2121
02:03:01,990 --> 02:03:00,960
will shoot out and produce additional

2122
02:03:04,470 --> 02:03:02,000
delta v

2123
02:03:05,910 --> 02:03:04,480
for a very simplified calculation this

2124
02:03:07,589 --> 02:03:05,920
will depend on

2125
02:03:09,350 --> 02:03:07,599
a number of different parameters

2126
02:03:11,109 --> 02:03:09,360
including how deep the

2127
02:03:13,910 --> 02:03:11,119
uh impact is

2128
02:03:15,990 --> 02:03:13,920
uh but for a simplified case

2129
02:03:18,709 --> 02:03:16,000
you can calculate the reaction impulse

2130
02:03:20,950 --> 02:03:18,719
produces roughly on the order of half

2131
02:03:23,109 --> 02:03:20,960
the incident of momentum but it can be

2132
02:03:24,550 --> 02:03:23,119
much larger or much smaller depending on

2133
02:03:26,470 --> 02:03:24,560
the details

2134
02:03:29,589 --> 02:03:26,480
of the collision

2135
02:03:31,830 --> 02:03:29,599
so if we ignore that reaction impulse uh

2136
02:03:34,310 --> 02:03:31,840
it's easy enough to see that the delta v

2137
02:03:36,390 --> 02:03:34,320
achieved is just the ratio

2138
02:03:40,229 --> 02:03:36,400

of the masses times the relative

2139
02:03:43,830 --> 02:03:41,030
uh

2140
02:03:47,350 --> 02:03:43,840
so putting that into an example if the

2141
02:03:50,149 --> 02:03:47,360
interceptor is a 1000 ton

2142
02:03:52,709 --> 02:03:50,159
uh 8 meter category asteroid we're

2143
02:03:55,270 --> 02:03:52,719
looking at a target that'll be a 500

2144
02:03:58,229 --> 02:03:55,280
meter 200 million tar

2145
02:04:00,390 --> 02:03:58,239
ton asteroid we'd get a delta v of about

2146
02:04:03,109 --> 02:04:00,400
five centimeters a second

2147
02:04:07,350 --> 02:04:03,119
uh at a relatively conservative impact

2148
02:04:12,390 --> 02:04:09,270
so that will shift

2149
02:04:14,950 --> 02:04:12,400
a asteroid position by on the order of 5

2150
02:04:17,430 --> 02:04:14,960
000 kilometers per year and that's

2151
02:04:18,629 --> 02:04:17,440
accounting for the magnitude but not the

2152
02:04:20,310 --> 02:04:18,639
direction

2153
02:04:22,390 --> 02:04:20,320
of the momentum

2154
02:04:24,870 --> 02:04:22,400
with that it would take about two years

2155
02:04:27,350 --> 02:04:24,880
of advanced warning to shift the orbit

2156
02:04:28,629 --> 02:04:27,360
to shift the phasing by about one earth

2157
02:04:30,629 --> 02:04:28,639
diameter

2158
02:04:32,790 --> 02:04:30,639
so that's a

2159
02:04:35,510 --> 02:04:32,800
quick back of the envelope calculation

2160
02:04:37,270 --> 02:04:35,520
of what kind of advanced warning you

2161
02:04:39,750 --> 02:04:37,280
need

2162
02:04:41,910 --> 02:04:39,760
uh so the calculations there basically

2163
02:04:44,470 --> 02:04:41,920

suggest that the technique of using an

2164
02:04:46,790 --> 02:04:44,480
asteroid to intercept an incoming

2165
02:04:49,510 --> 02:04:46,800
asteroid should be feasible it's

2166
02:04:52,870 --> 02:04:49,520
something that will need a

2167
02:04:54,790 --> 02:04:52,880
warning time typically of greater uh

2168
02:04:56,229 --> 02:04:54,800
greater than a year it's not something

2169
02:04:59,750 --> 02:04:56,239
that uh

2170
02:05:02,149 --> 02:04:59,760
with these small asteroids will give you

2171
02:05:04,629 --> 02:05:02,159
a uh

2172
02:05:07,669 --> 02:05:04,639
a fast response but it is

2173
02:05:10,790 --> 02:05:07,679
in fact a reasonable uh a reasonable

2174
02:05:13,990 --> 02:05:10,800
thing to do uh the rest of the

2175
02:05:17,189 --> 02:05:14,000
charts are mostly just uh backup charts

2176
02:05:19,270 --> 02:05:17,199
uh but basically this would be the class

2177
02:05:21,830 --> 02:05:19,280
event of asteroids that you could

2178
02:05:23,270 --> 02:05:21,840
deflect with about two years of warning

2179
02:05:24,950 --> 02:05:23,280
would be a

2180
02:05:27,750 --> 02:05:24,960
a continental

2181
02:05:29,270 --> 02:05:27,760
uh class of impact or not

2182
02:05:31,910 --> 02:05:29,280
a global

2183
02:05:35,030 --> 02:05:31,920
but uh on the other hand the

2184
02:05:37,030 --> 02:05:35,040
very very large ones are extremely

2185
02:05:39,830 --> 02:05:37,040
infrequent so you could

2186
02:05:42,149 --> 02:05:39,840
deflect one of the more frequent but

2187
02:05:43,750 --> 02:05:42,159
still catastrophic

2188
02:05:44,870 --> 02:05:43,760

impactors

2189
02:05:46,790 --> 02:05:44,880
and that

2190
02:05:48,629 --> 02:05:46,800
i think is

2191
02:05:51,030 --> 02:05:48,639
it for the presentation i guess are

2192
02:05:57,669 --> 02:05:51,040
there any questions

2193
02:06:03,030 --> 02:06:00,390
can he hear us

2194
02:06:04,790 --> 02:06:03,040
can you type and we're still not coming

2195
02:06:08,310 --> 02:06:04,800
through

2196
02:06:12,550 --> 02:06:10,870
okay um are there any questions we can

2197
02:06:15,109 --> 02:06:12,560
kind of queue it up here if someone

2198
02:06:18,629 --> 02:06:15,119
wants to ask them a question

2199
02:06:20,470 --> 02:06:18,639
uh yes i can hear you but only uh by the

2200
02:06:24,069 --> 02:06:20,480
technique of turning off my phone and

2201
02:06:25,270 --> 02:06:24,079
turning on my computer and vice versa

2202
02:06:26,629 --> 02:06:25,280
okay so

2203
02:06:28,550 --> 02:06:26,639
and there does seem to be a bit of a

2204
02:06:35,270 --> 02:06:28,560
time lag here

2205
02:06:38,390 --> 02:06:37,510
we don't have any questions here in the

2206
02:06:42,950 --> 02:06:38,400
room

2207
02:06:47,910 --> 02:06:46,069
okay all right um you might get this

2208
02:06:56,950 --> 02:06:47,920
message in a few seconds jeff but thank

2209
02:06:56,960 --> 02:07:00,790
you can see us presentation

2210
02:07:04,709 --> 02:07:02,550
okay

2211
02:07:08,310 --> 02:07:04,719
all right we'll uh we'll move on uh the

2212
02:07:09,750 --> 02:07:08,320
next talk is uh by uh tim

2213
02:07:12,229 --> 02:07:09,760

uh has worked at the jet propulsion

2214
02:07:14,629 --> 02:07:12,239
laboratory okay thank you

2215
02:07:16,870 --> 02:07:14,639
since 1984 recently he has done mission

2216
02:07:18,629 --> 02:07:16,880
design on several proposed missions

2217
02:07:20,790 --> 02:07:18,639
including moonrise

2218
02:07:21,669 --> 02:07:20,800
isis which is discussed uh later in the

2219
02:07:23,510 --> 02:07:21,679
session

2220
02:07:24,830 --> 02:07:23,520
and the asteroid redirect robotic

2221
02:07:29,750 --> 02:07:24,840
mission

2222
02:07:29,760 --> 02:07:35,109
let's see am i controlling this

2223
02:07:35,119 --> 02:07:39,270
okay so then the question is

2224
02:07:43,270 --> 02:07:41,589
okay that works

2225
02:07:44,470 --> 02:07:43,280
okay

2226
02:07:47,990 --> 02:07:44,480
um

2227
02:07:49,510 --> 02:07:48,000
at the time i wrote this i couldn't

2228
02:07:51,830 --> 02:07:49,520
think of any other way that didn't

2229
02:07:54,709 --> 02:07:51,840
involve physical contact but of course

2230
02:07:56,390 --> 02:07:54,719
you know i'm being educated anyway let's

2231
02:07:58,069 --> 02:07:56,400
just say that it's a nice method of not

2232
02:07:59,270 --> 02:07:58,079
having to touch the asteroid very much

2233
02:08:00,629 --> 02:07:59,280
to move it

2234
02:08:02,790 --> 02:08:00,639
um

2235
02:08:04,390 --> 02:08:02,800
so as you've heard before you know the

2236
02:08:06,390 --> 02:08:04,400
gravity tractor and spacecraft weight

2237
02:08:07,830 --> 02:08:06,400
equals it's a that's the connection

2238
02:08:09,510 --> 02:08:07,840

between the

2239
02:08:12,390 --> 02:08:09,520
spacecraft and the asteroid and so that

2240
02:08:14,950 --> 02:08:12,400
limits how much you can pull on it

2241
02:08:17,270 --> 02:08:14,960
you know as we've seen in in various uh

2242
02:08:19,510 --> 02:08:17,280
arv designs it's it's easy to get one to

2243
02:08:21,669 --> 02:08:19,520
two newtons per spacecraft in the two to

2244
02:08:24,149 --> 02:08:21,679
four ton range

2245
02:08:25,830 --> 02:08:24,159
but unfortunately the spacecraft weight

2246
02:08:27,910 --> 02:08:25,840
for

2247
02:08:30,229 --> 02:08:27,920
asteroids under a

2248
02:08:31,750 --> 02:08:30,239
kilometer in diameter is well under a

2249
02:08:33,030 --> 02:08:31,760
newton and so

2250
02:08:37,990 --> 02:08:33,040
most of the

2251
02:08:39,669 --> 02:08:38,000
is not used

2252
02:08:43,109 --> 02:08:39,679
so it's very propellant efficient but

2253
02:08:47,270 --> 02:08:45,669
now the the weight formula if you you

2254
02:08:48,790 --> 02:08:47,280
know assume a spherical asteroid and you

2255
02:08:50,149 --> 02:08:48,800
operate at an altitude of one radius

2256
02:08:52,149 --> 02:08:50,159
which is about the closest you could

2257
02:08:53,750 --> 02:08:52,159
imagine operating with any degree of

2258
02:08:55,830 --> 02:08:53,760
safety at all

2259
02:08:57,750 --> 02:08:55,840
is is this equation here and the only

2260
02:08:59,510 --> 02:08:57,760
free variable once you've picked the

2261
02:09:00,709 --> 02:08:59,520
asteroid or the asteroid has been picked

2262
02:09:02,950 --> 02:09:00,719
for you

2263
02:09:04,629 --> 02:09:02,960

is the spacecraft mass here so that's

2264
02:09:07,510 --> 02:09:04,639
the only way to

2265
02:09:09,270 --> 02:09:07,520
improve the coupling

2266
02:09:10,870 --> 02:09:09,280
now you can't take a bigger mass with

2267
02:09:12,790 --> 02:09:10,880
you beyond

2268
02:09:14,709 --> 02:09:12,800
maybe you could take imagine a 2010

2269
02:09:16,870 --> 02:09:14,719
spacecraft but at some point you can't

2270
02:09:18,709 --> 02:09:16,880
launch it and if you do it takes much

2271
02:09:19,830 --> 02:09:18,719
longer to get there and time is not your

2272
02:09:21,350 --> 02:09:19,840
friend

2273
02:09:23,830 --> 02:09:21,360
so um

2274
02:09:29,589 --> 02:09:23,840
so clearly you know

2275
02:09:33,510 --> 02:09:30,550
okay

2276
02:09:35,589 --> 02:09:33,520
so um i'm not gonna i'm not a mechanical

2277
02:09:37,510 --> 02:09:35,599
systems guy this is brian's problem

2278
02:09:39,189 --> 02:09:37,520
he'll figure it out if we do this but uh

2279
02:09:41,750 --> 02:09:39,199
or somebody like him

2280
02:09:42,950 --> 02:09:41,760
but um i didn't want to talk mainly i

2281
02:09:45,589 --> 02:09:42,960
want to talk about what you could do

2282
02:09:46,629 --> 02:09:45,599
with with an augmented mass but i did

2283
02:09:48,550 --> 02:09:46,639
want to point out that there are at

2284
02:09:49,750 --> 02:09:48,560
least a couple of things i could think

2285
02:09:50,550 --> 02:09:49,760
of and there's probably a bunch of

2286
02:09:52,629 --> 02:09:50,560
others

2287
02:09:55,430 --> 02:09:52,639
of course you can grab a boulder

2288
02:09:57,430 --> 02:09:55,440

like as is being studied there's also

2289
02:10:00,229 --> 02:09:57,440
the brush wheel sampler that we've used

2290
02:10:02,310 --> 02:10:00,239
for sample return mission concepts but

2291
02:10:04,790 --> 02:10:02,320
in principle if you make it bigger it

2292
02:10:08,629 --> 02:10:04,800
just grabs more mass and flings it up

2293
02:10:12,390 --> 02:10:10,149
you know and that doesn't take a huge

2294
02:10:15,669 --> 02:10:12,400
amount of time to i mean it might be

2295
02:10:17,109 --> 02:10:15,679
days but it's not weeks or something

2296
02:10:18,790 --> 02:10:17,119
so in either case i'm going to assume

2297
02:10:22,470 --> 02:10:18,800
that we can get a thousand tons into

2298
02:10:28,550 --> 02:10:24,870
so um you know gravity tractoring

2299
02:10:30,069 --> 02:10:28,560
operations as we've talked about so far

2300
02:10:32,229 --> 02:10:30,079
the uh the center of mass of the

2301
02:10:33,910 --> 02:10:32,239
spacecraft wants to be as close to the

2302
02:10:35,270 --> 02:10:33,920
asteroid as possible but of course

2303
02:10:37,510 --> 02:10:35,280
because of the can

2304
02:10:39,109 --> 02:10:37,520
the thrusters want to be far enough away

2305
02:10:42,790 --> 02:10:39,119
that they don't have to cant very far to

2306
02:10:45,270 --> 02:10:42,800
avoid whacking exhaust into the asteroid

2307
02:10:47,030 --> 02:10:45,280
so these are kind of competing um

2308
02:10:49,109 --> 02:10:47,040
desires

2309
02:10:51,669 --> 02:10:49,119
if you have if you have collected mass

2310
02:10:54,069 --> 02:10:51,679
then it's relatively easy to leave that

2311
02:10:55,669 --> 02:10:54,079
mass on the you know down close to the

2312
02:10:57,589 --> 02:10:55,679
asteroid as it's kind of shown in this

2313
02:10:59,510 --> 02:10:57,599

cartoon

2314
02:11:00,390 --> 02:10:59,520
now um

2315
02:11:06,550 --> 02:11:00,400
for

2316
02:11:08,069 --> 02:11:06,560
want to

2317
02:11:09,669 --> 02:11:08,079
adjust the orbit in the down track

2318
02:11:11,910 --> 02:11:09,679
direction because this generates a

2319
02:11:14,229 --> 02:11:11,920
secular you change the period you get a

2320
02:11:15,990 --> 02:11:14,239
secular down track trend and so you know

2321
02:11:18,149 --> 02:11:16,000
here's another little cartoon that says

2322
02:11:19,910 --> 02:11:18,159
you know we thrusted in gravity tractor

2323
02:11:22,550 --> 02:11:19,920
for a while and then we got this sort of

2324
02:11:24,229 --> 02:11:22,560
linear trend that runs off for infinity

2325
02:11:26,149 --> 02:11:24,239
and of course i'm not showing the once

2326
02:11:27,910 --> 02:11:26,159
per rev signature

2327
02:11:29,750 --> 02:11:27,920
um

2328
02:11:32,470 --> 02:11:29,760
so what

2329
02:11:35,030 --> 02:11:32,480
what can we do with uh so with this sort

2330
02:11:36,470 --> 02:11:35,040
of approach um on a you know real

2331
02:11:39,510 --> 02:11:36,480
asteroid

2332
02:11:42,069 --> 02:11:39,520
well um 2000 sg 344 is kind of a fun

2333
02:11:44,470 --> 02:11:42,079
asteroid it's in a very earth-like orbit

2334
02:11:45,990 --> 02:11:44,480
um you know dan and company did a study

2335
02:11:48,390 --> 02:11:46,000
that said you could get three to seven

2336
02:11:51,109 --> 02:11:48,400
thousand tons back from it in 2028 but

2337
02:11:52,870 --> 02:11:51,119
unfortunately the asteroid is

2338
02:11:54,470 --> 02:11:52,880

several times larger than that you know

2339
02:11:56,470 --> 02:11:54,480
on the range you see ten thousand to

2340
02:11:58,629 --> 02:11:56,480
three hundred thousand tons

2341
02:12:01,030 --> 02:11:58,639
so clearly the whole asteroid is not

2342
02:12:01,910 --> 02:12:01,040
returnable in a arv

2343
02:12:04,069 --> 02:12:01,920
you know

2344
02:12:06,149 --> 02:12:04,079
grabbing it sort of approach

2345
02:12:07,910 --> 02:12:06,159
so let's let's make some mid-range

2346
02:12:12,629 --> 02:12:07,920
assumptions um

2347
02:12:14,709 --> 02:12:12,639
50 50 000 tons of asteroid mass um

2348
02:12:17,430 --> 02:12:14,719
a thousand ton spacecraft mass after

2349
02:12:18,950 --> 02:12:17,440
we've augmented it at the asteroid

2350
02:12:20,390 --> 02:12:18,960
and you know if you do the math you come

2351
02:12:22,149 --> 02:12:20,400
out with almost two millimeters per

2352
02:12:24,149 --> 02:12:22,159
second per day

2353
02:12:25,109 --> 02:12:24,159
you know with cantangle losses and so

2354
02:12:27,430 --> 02:12:25,119
forth

2355
02:12:29,030 --> 02:12:27,440
and so a meter per second only costs 2.4

2356
02:12:31,430 --> 02:12:29,040
tons of xenon so

2357
02:12:33,990 --> 02:12:31,440
clearly several meters per second not 10

2358
02:12:35,750 --> 02:12:34,000
but several can be accomplished you know

2359
02:12:38,069 --> 02:12:35,760
with the sort of spacecraft that we're

2360
02:12:39,830 --> 02:12:38,079
contemplating here

2361
02:12:42,790 --> 02:12:39,840
now an interesting thing is that if you

2362
02:12:44,790 --> 02:12:42,800
start doing this in 2021 and you go for

2363
02:12:47,750 --> 02:12:44,800

do a meter and a quarter per second

2364
02:12:49,990 --> 02:12:47,760
which takes just under two years

2365
02:12:52,790 --> 02:12:50,000
well let me back up a second so the red

2366
02:12:53,589 --> 02:12:52,800
is the trajectory unmodified

2367
02:12:54,550 --> 02:12:53,599
of

2368
02:12:58,470 --> 02:12:54,560
the

2369
02:13:00,229 --> 02:12:58,480
earth kind of three times three four

2370
02:13:03,910 --> 02:13:00,239
times however you want to count it

2371
02:13:05,990 --> 02:13:03,920
if you make this modification of it

2372
02:13:08,390 --> 02:13:06,000
in 2021 or you know a slightly larger

2373
02:13:10,950 --> 02:13:08,400
modification if you start later

2374
02:13:13,430 --> 02:13:10,960
um it's only off by

2375
02:13:16,229 --> 02:13:13,440
650 000 kilometers here on this first

2376
02:13:18,149 --> 02:13:16,239
little green arc that you can see but it

2377
02:13:19,430 --> 02:13:18,159
turns out that that's enough to capture

2378
02:13:21,510 --> 02:13:19,440
it into this

2379
02:13:23,669 --> 02:13:21,520
sort of orbit for 35 years and then

2380
02:13:26,149 --> 02:13:23,679
eventually it wanders off the other side

2381
02:13:28,229 --> 02:13:26,159
now you know that's just when i stopped

2382
02:13:30,950 --> 02:13:28,239
looking i could probably make it last

2383
02:13:33,830 --> 02:13:30,960
here for even longer if i tried

2384
02:13:35,910 --> 02:13:33,840
um but 35 years is you know longer than

2385
02:13:37,510 --> 02:13:35,920
any of us probably care about

2386
02:13:39,830 --> 02:13:37,520
so it's kind of interesting that you

2387
02:13:41,830 --> 02:13:39,840
could for a relatively

2388
02:13:42,950 --> 02:13:41,840

modest effort

2389
02:13:45,430 --> 02:13:42,960
you know

2390
02:13:50,709 --> 02:13:45,440
stick this 50 000 ton mass out there and

2391
02:13:54,229 --> 02:13:52,709
so another another interesting example

2392
02:13:56,470 --> 02:13:54,239
is apophis which of course has the

2393
02:13:58,470 --> 02:13:56,480
keyholes in all this business well you

2394
02:14:00,550 --> 02:13:58,480
know 2029 we're not that worried about

2395
02:14:02,950 --> 02:14:00,560
at the moment right paul are you worried

2396
02:14:05,030 --> 02:14:02,960
about that yes okay so um

2397
02:14:07,589 --> 02:14:05,040
and it's a big it's 10 times bigger than

2398
02:14:10,470 --> 02:14:07,599
sg344

2399
02:14:11,910 --> 02:14:10,480
so um using a slightly different set of

2400
02:14:13,430 --> 02:14:11,920
assumptions because this is actually

2401
02:14:17,030 --> 02:14:13,440
getting to be big enough that you don't

2402
02:14:18,709 --> 02:14:17,040
have to pull up all that much mass

2403
02:14:20,470 --> 02:14:18,719
you you know with the same sort of

2404
02:14:22,629 --> 02:14:20,480
thrust level on the spacecraft you get

2405
02:14:25,910 --> 02:14:22,639
three microns per second per day which

2406
02:14:27,830 --> 02:14:25,920
you know doesn't sound like much but

2407
02:14:30,870 --> 02:14:27,840
if you if you do down track thrusting

2408
02:14:32,790 --> 02:14:30,880
for one revolution of apophis you get

2409
02:14:35,030 --> 02:14:32,800
you know 90 kilometers per row you do

2410
02:14:37,109 --> 02:14:35,040
this for three times it's 270 per rev

2411
02:14:39,270 --> 02:14:37,119
you go 10 years as you see it's starting

2412
02:14:42,709 --> 02:14:39,280
to make a big difference and so

2413
02:14:44,390 --> 02:14:42,719

i guess i guess my point here is that

2414
02:14:46,069 --> 02:14:44,400
you know this is starting to be of order

2415
02:14:47,510 --> 02:14:46,079
the diameter of the earth it's not you

2416
02:14:50,470 --> 02:14:47,520
know i mean obviously it's twice that

2417
02:14:52,550 --> 02:14:50,480
big but you know you you might find that

2418
02:14:54,229 --> 02:14:52,560
there's cases where a couple thousand

2419
02:14:55,910 --> 02:14:54,239
kilometers is enough to get you out of

2420
02:14:57,350 --> 02:14:55,920
trouble it's certainly enough to move it

2421
02:14:59,270 --> 02:14:57,360
around on the surface and maybe you

2422
02:15:00,550 --> 02:14:59,280
could stick it saying i don't know

2423
02:15:03,270 --> 02:15:00,560
i don't really want to go there i guess

2424
02:15:05,030 --> 02:15:03,280
but the point is that that if you

2425
02:15:07,109 --> 02:15:05,040
you know typically gravity tractoring is

2426
02:15:09,109 --> 02:15:07,119
thought of as this is just good for a

2427
02:15:12,069 --> 02:15:09,119
minor trim but if you can augment the

2428
02:15:14,550 --> 02:15:12,079
mess and you have you know some time

2429
02:15:16,069 --> 02:15:14,560
you can actually use this as the primary

2430
02:15:19,990 --> 02:15:16,079
um

2431
02:15:24,390 --> 02:15:22,229
with you know the earth's radius is a as

2432
02:15:26,550 --> 02:15:24,400
an important uh

2433
02:15:29,030 --> 02:15:26,560
parameter

2434
02:15:30,870 --> 02:15:29,040
so um you know in conclusion

2435
02:15:32,709 --> 02:15:30,880
you know mass augmentation makes gravity

2436
02:15:34,830 --> 02:15:32,719
attracting gravity tractoring an

2437
02:15:37,030 --> 02:15:34,840
attractive primary method for moving

2438
02:15:39,350 --> 02:15:37,040

asteroids it uses all the spacecraft

2439
02:15:40,950 --> 02:15:39,360
stress capacity it works on asteroids as

2440
02:15:43,189 --> 02:15:40,960
big as apophis and probably even a

2441
02:15:45,350 --> 02:15:43,199
little bit bigger although really long

2442
02:15:47,109 --> 02:15:45,360
lead times would be necessary

2443
02:15:48,550 --> 02:15:47,119
and of course you don't have to de-spin

2444
02:15:49,830 --> 02:15:48,560
asteroid in fact

2445
02:15:51,430 --> 02:15:49,840
if you're doing this brush wheel

2446
02:15:53,109 --> 02:15:51,440
sampling thing you probably don't want

2447
02:15:55,430 --> 02:15:53,119
to despin the asteroid because you want

2448
02:15:57,350 --> 02:15:55,440
the asteroid to rotate stuff under your

2449
02:15:59,830 --> 02:15:57,360
brush wheel sampler so that you can just

2450
02:16:01,990 --> 02:15:59,840
keep you know grabbing it up but you

2451
02:16:05,510 --> 02:16:02,000
know other methods are impact are

2452
02:16:07,510 --> 02:16:05,520
probably possible um you know and again

2453
02:16:09,990 --> 02:16:07,520
how you would actually augment the mass

2454
02:16:11,830 --> 02:16:10,000
is is an interesting question and and i

2455
02:16:14,470 --> 02:16:11,840
don't know that that neither one of

2456
02:16:16,550 --> 02:16:14,480
these feels like the absolute perfect

2457
02:16:18,069 --> 02:16:16,560
way to do it there's but you know

2458
02:16:19,189 --> 02:16:18,079
something something is probably out

2459
02:16:21,430 --> 02:16:19,199
there

2460
02:16:23,830 --> 02:16:21,440
and then you know like as i show sg 344

2461
02:16:25,910 --> 02:16:23,840
is kind of a special case that uh could

2462
02:16:27,830 --> 02:16:25,920
be an interesting if it was moved in

2463
02:16:29,750 --> 02:16:27,840

this manner it could make a long-term

2464
02:16:32,549 --> 02:16:29,760
interesting target for human missions

2465
02:16:34,549 --> 02:16:32,559
and you know isru

2466
02:16:36,389 --> 02:16:34,559
utilization whatever

2467
02:16:37,190 --> 02:16:36,399
so that's all i had

2468
02:16:38,790 --> 02:16:37,200
great

2469
02:16:41,429 --> 02:16:38,800
thank you tim

2470
02:16:50,629 --> 02:16:41,439
okay do we have uh any questions

2471
02:16:50,639 --> 02:16:57,190
so

2472
02:16:57,200 --> 02:17:02,389
i'm curious about the you know the the

2473
02:17:07,429 --> 02:17:05,669
the if say that this

2474
02:17:09,110 --> 02:17:07,439
the asteroid deflection mission wasn't

2475
02:17:11,830 --> 02:17:09,120
flown

2476
02:17:13,349 --> 02:17:11,840
could this be combined somehow with the

2477
02:17:14,709 --> 02:17:13,359
arm mission

2478
02:17:15,750 --> 02:17:14,719
i mean because it seems like the crucial

2479
02:17:17,270 --> 02:17:15,760
thing is

2480
02:17:20,070 --> 02:17:17,280
you know that you'd want to sort of

2481
02:17:21,190 --> 02:17:20,080
bring up the trl level on is how do you

2482
02:17:22,870 --> 02:17:21,200
actually get the mass from the

2483
02:17:24,389 --> 02:17:22,880
spacecraft from the from the asteroid

2484
02:17:25,910 --> 02:17:24,399
right you know we've done it for the

2485
02:17:27,830 --> 02:17:25,920
moon you know we can speculate for

2486
02:17:29,349 --> 02:17:27,840
asteroids we don't really know and so

2487
02:17:31,589 --> 02:17:29,359
it'd be nice to have a test and so could

2488
02:17:33,429 --> 02:17:31,599

this be like it seems like this

2489
02:17:35,509 --> 02:17:33,439
potentially would be a vote if you

2490
02:17:37,349 --> 02:17:35,519
couldn't do both missions

2491
02:17:39,190 --> 02:17:37,359
having the if you heard this morning

2492
02:17:41,270 --> 02:17:39,200
session you know you pluck something

2493
02:17:43,509 --> 02:17:41,280
from a bigger body it could be combined

2494
02:17:44,950 --> 02:17:43,519
with this it seems like very very nicely

2495
02:17:46,389 --> 02:17:44,960
in other words you could actually say

2496
02:17:47,910 --> 02:17:46,399
yeah we can get stuff from an asteroid

2497
02:17:48,950 --> 02:17:47,920
because we plucked it from some bigger

2498
02:17:50,950 --> 02:17:48,960
body

2499
02:17:53,589 --> 02:17:50,960
you know and brought it back for

2500
02:17:55,429 --> 02:17:53,599
scientific tests we actually did it and

2501
02:17:57,110 --> 02:17:55,439
so i was just sort of wondering what you

2502
02:17:57,990 --> 02:17:57,120
think about that

2503
02:18:00,870 --> 02:17:58,000
well

2504
02:18:03,669 --> 02:18:00,880
yeah i mean the it's not obvious i don't

2505
02:18:05,910 --> 02:18:03,679
think there's any way to combine this

2506
02:18:07,669 --> 02:18:05,920
with bagging the whole asteroid on the

2507
02:18:08,870 --> 02:18:07,679
same mission

2508
02:18:10,230 --> 02:18:08,880
yes

2509
02:18:11,830 --> 02:18:10,240
but you know obviously if you're

2510
02:18:13,270 --> 02:18:11,840
bringing back a small part of it if the

2511
02:18:14,870 --> 02:18:13,280
small part of it is still big enough to

2512
02:18:17,270 --> 02:18:14,880
do gravity tractoring then you can do

2513
02:18:20,309 --> 02:18:17,280

gravity tractoring after you grab

2514
02:18:21,190 --> 02:18:20,319
the smaller part of the asteroid

2515
02:18:22,870 --> 02:18:21,200
so

2516
02:18:23,830 --> 02:18:22,880
on the other hand i guess i would say

2517
02:18:29,669 --> 02:18:23,840
that

2518
02:18:32,389 --> 02:18:29,679
well okay gravity always works right and

2519
02:18:35,190 --> 02:18:32,399
arguably this is not something that

2520
02:18:37,669 --> 02:18:35,200
really needs a ton of demonstration but

2521
02:18:38,389 --> 02:18:37,679
if people are worried about it

2522
02:18:42,950 --> 02:18:38,399
the

2523
02:18:44,629 --> 02:18:42,960
arv is perfectly capable of gravity

2524
02:18:46,950 --> 02:18:44,639
tractoring these little asteroids and

2525
02:18:49,509 --> 02:18:46,960
detecting the results and making and you

2526
02:18:51,750 --> 02:18:49,519
know having a mini mini sigma detection

2527
02:18:53,270 --> 02:18:51,760
of the of the results so i mean we can

2528
02:18:55,589 --> 02:18:53,280
demonstrate gravity tractoring with

2529
02:18:57,429 --> 02:18:55,599
either mission we just can't demonstrate

2530
02:18:59,990 --> 02:18:57,439
gravity tractoring where we moved a

2531
02:19:01,349 --> 02:19:00,000
large object a long way with the

2532
02:19:03,110 --> 02:19:01,359
reference mission it would have to be to

2533
02:19:04,309 --> 02:19:03,120
grab a boulder or something equivalent

2534
02:19:05,270 --> 02:19:04,319
to that

2535
02:19:07,509 --> 02:19:05,280
so but

2536
02:19:08,709 --> 02:19:07,519
yeah that wasn't quite what i was saying

2537
02:19:10,230 --> 02:19:08,719
i think that the

2538
02:19:12,230 --> 02:19:10,240

there's no physical doubt that the

2539
02:19:14,070 --> 02:19:12,240
gravity tractoring will work this just

2540
02:19:15,190 --> 02:19:14,080
there seems to be no physical reason why

2541
02:19:16,629 --> 02:19:15,200
it wouldn't work it's very simple

2542
02:19:18,709 --> 02:19:16,639
straightforward newton would have

2543
02:19:21,509 --> 02:19:18,719
thought of it yeah

2544
02:19:23,030 --> 02:19:21,519
um it but grabbing the material from the

2545
02:19:23,990 --> 02:19:23,040
using a chain bucket or whatever it was

2546
02:19:25,990 --> 02:19:24,000
you're talking about to grab the

2547
02:19:27,910 --> 02:19:26,000
material from the surface

2548
02:19:29,190 --> 02:19:27,920
that seems less you know i mean

2549
02:19:30,469 --> 02:19:29,200
obviously you can make it work but it

2550
02:19:32,629 --> 02:19:30,479
seems like

2551
02:19:35,669 --> 02:19:32,639
a less secure thing at the current level

2552
02:19:38,629 --> 02:19:35,679
of trl sure but that's worthwhile

2553
02:19:40,150 --> 02:19:38,639
testing if you could sure no that's true

2554
02:19:43,190 --> 02:19:40,160
and i mean

2555
02:19:45,910 --> 02:19:43,200
the the the grab a boulder approach

2556
02:19:46,830 --> 02:19:45,920
in principle would would be a major step

2557
02:19:50,150 --> 02:19:46,840
in that

2558
02:19:51,750 --> 02:19:50,160
direction and you know if that if that

2559
02:19:53,190 --> 02:19:51,760
if that works as expected i don't know

2560
02:19:54,469 --> 02:19:53,200
why you would mess with the brush wheel

2561
02:19:56,309 --> 02:19:54,479
sampler except that you could maybe get

2562
02:19:57,990 --> 02:19:56,319
more mass that way because you're not

2563
02:20:00,550 --> 02:19:58,000

depending on finding a right size

2564
02:20:01,510 --> 02:20:00,560
boulder so that that's kind of the trade

2565
02:20:06,230 --> 02:20:01,520
you know

2566
02:20:07,590 --> 02:20:06,240
way whichever way you're going to grab

2567
02:20:09,750 --> 02:20:07,600
stuff

2568
02:20:11,750 --> 02:20:09,760
you know clearly clearly you would want

2569
02:20:13,349 --> 02:20:11,760
to you probably would have to sneak up

2570
02:20:15,349 --> 02:20:13,359
on grabbing stuff if you were seriously

2571
02:20:17,670 --> 02:20:15,359
going to move this and not make it the

2572
02:20:20,630 --> 02:20:17,680
first mission unless it was just a demo

2573
02:20:26,230 --> 02:20:22,550
do we have any other any other comments

2574
02:20:31,830 --> 02:20:28,309
okay

2575
02:20:33,030 --> 02:20:31,840
here

2576
02:20:35,190 --> 02:20:33,040
um

2577
02:20:37,110 --> 02:20:35,200
kind of outside my threshold here i was

2578
02:20:39,590 --> 02:20:37,120
keeping this minute two minute delta

2579
02:20:42,950 --> 02:20:39,600
here so we got about a minute um

2580
02:20:44,790 --> 02:20:42,960
i'll just echo that you know

2581
02:20:45,990 --> 02:20:44,800
a lot of these presentations dealt with

2582
02:20:47,110 --> 02:20:46,000
a similar

2583
02:20:48,950 --> 02:20:47,120
concept

2584
02:20:50,710 --> 02:20:48,960
but what i what i hoped or what pat and

2585
02:20:52,389 --> 02:20:50,720
i hope we put this session together and

2586
02:20:54,309 --> 02:20:52,399
we chose the rfi responses was that

2587
02:20:56,710 --> 02:20:54,319
there would be nuggets from each of

2588
02:20:58,230 --> 02:20:56,720

those and i'm clearly seeing some some

2589
02:21:00,150 --> 02:20:58,240
thoughts and some ideas that have come

2590
02:21:01,270 --> 02:21:00,160
out that uh we'll talk about more in the

2591
02:21:02,150 --> 02:21:01,280
discussion

2592
02:21:06,389 --> 02:21:02,160
um

2593
02:21:07,429 --> 02:21:06,399
of the presenters approach that that may

2594
02:21:11,590 --> 02:21:07,439
have

2595
02:21:20,469 --> 02:21:11,600
some more uh interest in being looked at

2596
02:21:25,110 --> 02:21:23,110
okay just a general question

2597
02:21:27,429 --> 02:21:25,120
i've heard that the inner solar system

2598
02:21:29,670 --> 02:21:27,439
is non-deterministic the jupiter and

2599
02:21:32,710 --> 02:21:29,680
beyond are deterministic and that we

2600
02:21:35,270 --> 02:21:32,720
have a very poor gravity model for

2601
02:21:37,190 --> 02:21:35,280
the internal solar system so

2602
02:21:39,429 --> 02:21:37,200
you know all this analysis would seem to

2603
02:21:41,670 --> 02:21:39,439
be you know dependent on us knowing

2604
02:21:42,870 --> 02:21:41,680
exactly what a certain deflection is

2605
02:21:44,389 --> 02:21:42,880
going to do

2606
02:21:45,750 --> 02:21:44,399
because you know we all could be making

2607
02:21:47,750 --> 02:21:45,760
things worse

2608
02:21:48,790 --> 02:21:47,760
so somewhere in maybe the final comments

2609
02:21:50,870 --> 02:21:48,800
it could be

2610
02:21:54,389 --> 02:21:50,880
you know a better model of the inner

2611
02:21:56,630 --> 02:21:54,399
solar system would be a corollary to the

2612
02:21:58,389 --> 02:21:56,640
design of this mission okay let's let's

2613
02:22:01,429 --> 02:21:58,399

hold that thought i think

2614
02:22:02,950 --> 02:22:01,439
for example paul chodos can can

2615
02:22:04,790 --> 02:22:02,960
vouch for the fact that we we do know

2616
02:22:07,510 --> 02:22:04,800
the solar system pretty well and uh we

2617
02:22:08,950 --> 02:22:07,520
can predict um with gravitational

2618
02:22:10,309 --> 02:22:08,960
effects if there's non-grav that's

2619
02:22:12,309 --> 02:22:10,319
another issue but

2620
02:22:14,389 --> 02:22:12,319
for for quiescent asteroids we can

2621
02:22:16,070 --> 02:22:14,399
predict uh with sufficient knowledge

2622
02:22:16,950 --> 02:22:16,080
very far into the future

2623
02:22:18,070 --> 02:22:16,960
um

2624
02:22:19,429 --> 02:22:18,080
so we can talk about that more in the

2625
02:22:22,230 --> 02:22:19,439
open discussion

2626
02:22:23,510 --> 02:22:22,240
um but to get us back on on a topic here

2627
02:22:25,270 --> 02:22:23,520
with the presentations our next

2628
02:22:26,150 --> 02:22:25,280
presenter is josh hopkins

2629
02:22:28,150 --> 02:22:26,160
um

2630
02:22:29,910 --> 02:22:28,160
josh is a space exploration architect at

2631
02:22:31,270 --> 02:22:29,920
lockheed martin

2632
02:22:33,830 --> 02:22:31,280
he was the

2633
02:22:35,910 --> 02:22:33,840
editor of the aia's international

2634
02:22:37,750 --> 02:22:35,920
reference guide to space launch systems

2635
02:22:39,990 --> 02:22:37,760
and a technical advisor for the science

2636
02:22:41,510 --> 02:22:40,000
fiction movie the europa report which i

2637
02:22:42,870 --> 02:22:41,520
haven't seen yet i'd like to see so i

2638
02:22:44,870 --> 02:22:42,880

might talk to you about how how do i get

2639
02:22:47,750 --> 02:22:44,880
a copy

2640
02:22:50,389 --> 02:22:47,760
um anyway josh go ahead thank you so i'm

2641
02:22:51,830 --> 02:22:50,399
filling in for darren wade who

2642
02:22:53,349 --> 02:22:51,840
came when we first held this conference

2643
02:22:55,510 --> 02:22:53,359
but wasn't able to come

2644
02:22:58,309 --> 02:22:55,520
this time so any questions that i can't

2645
02:23:00,630 --> 02:22:58,319
answer i'll refer to him

2646
02:23:02,309 --> 02:23:00,640
so we've been talking about uh asteroid

2647
02:23:03,670 --> 02:23:02,319
deflection for a couple of hours now and

2648
02:23:05,190 --> 02:23:03,680
i was struggling to think what i could

2649
02:23:07,030 --> 02:23:05,200
say that hasn't already been said i'm

2650
02:23:09,110 --> 02:23:07,040
going to try to focus on some

2651
02:23:11,349 --> 02:23:09,120
specific aspects that we've been looking

2652
02:23:12,790 --> 02:23:11,359
at but some of this will start to appear

2653
02:23:14,550 --> 02:23:12,800
familiar now that we've had a couple of

2654
02:23:16,950 --> 02:23:14,560
talks on gravity factors

2655
02:23:18,309 --> 02:23:16,960
so we approached this um

2656
02:23:19,670 --> 02:23:18,319
sort of from first principles and

2657
02:23:21,429 --> 02:23:19,680
thought about two things one is the

2658
02:23:23,190 --> 02:23:21,439
question was kind of how do you make arm

2659
02:23:24,790 --> 02:23:23,200
useful as a planetary defense

2660
02:23:25,750 --> 02:23:24,800
demonstration

2661
02:23:27,670 --> 02:23:25,760
and

2662
02:23:29,830 --> 02:23:27,680
the issue is that the small asteroids

2663
02:23:31,830 --> 02:23:29,840

arm is currently scheduled to visit

2664
02:23:33,590 --> 02:23:31,840
really aren't particularly dangerous you

2665
02:23:35,910 --> 02:23:33,600
want to prove that you can deflect a

2666
02:23:37,750 --> 02:23:35,920
dangerously sized asteroid and the

2667
02:23:39,830 --> 02:23:37,760
techniques at least the way that arm is

2668
02:23:41,670 --> 02:23:39,840
currently conceived probably don't scale

2669
02:23:44,309 --> 02:23:41,680
very well so you're probably not going

2670
02:23:45,990 --> 02:23:44,319
to de-spin a really large asteroid

2671
02:23:48,469 --> 02:23:46,000
the size that would be more useful is

2672
02:23:51,110 --> 02:23:48,479
something in the 100 meter range give or

2673
02:23:53,030 --> 02:23:51,120
take say a factor of 3 in

2674
02:23:55,349 --> 02:23:53,040
size which equates to roughly a factor

2675
02:23:57,349 --> 02:23:55,359
of 10 in volume or mass so below

2676
02:23:59,510 --> 02:23:57,359
something like 30 meters those asteroids

2677
02:24:01,750 --> 02:23:59,520
are common but not very dangerous

2678
02:24:03,990 --> 02:24:01,760
above about 300 meters they're dangerous

2679
02:24:05,830 --> 02:24:04,000
but not very common and most of the ones

2680
02:24:08,150 --> 02:24:05,840
say two-thirds of the ones above 300

2681
02:24:09,270 --> 02:24:08,160
meters or so have been discovered

2682
02:24:13,670 --> 02:24:09,280
so

2683
02:24:15,590 --> 02:24:13,680
hundreds of meters diameter is the size

2684
02:24:17,349 --> 02:24:15,600
range we're interested in

2685
02:24:19,270 --> 02:24:17,359
that corresponds to

2686
02:24:20,950 --> 02:24:19,280
something on the order of a million tons

2687
02:24:22,870 --> 02:24:20,960
of asteroids move

2688
02:24:24,150 --> 02:24:22,880

and the deflection we we decided we want

2689
02:24:26,070 --> 02:24:24,160
to achieve is on the order of a

2690
02:24:28,870 --> 02:24:26,080
centimeter per second that came from the

2691
02:24:31,349 --> 02:24:28,880
study of how to deflect asteroid 2011

2692
02:24:33,190 --> 02:24:31,359
ag-5 when it was one of the top items on

2693
02:24:34,950 --> 02:24:33,200
the risk list a couple of years ago

2694
02:24:37,030 --> 02:24:34,960
that's also a big enough number that you

2695
02:24:38,469 --> 02:24:37,040
can measure it so that you can confirm

2696
02:24:40,070 --> 02:24:38,479
that you have actually deflected the

2697
02:24:41,590 --> 02:24:40,080
asteroid

2698
02:24:44,230 --> 02:24:41,600
now there's i think another important

2699
02:24:46,389 --> 02:24:44,240
point about what the question was which

2700
02:24:48,150 --> 02:24:46,399
is that it's not really a question of

2701
02:24:50,150 --> 02:24:48,160
what's the best asteroid deflection

2702
02:24:52,389 --> 02:24:50,160
demonstration you could do it's what can

2703
02:24:54,150 --> 02:24:52,399
you do with the arm mission

2704
02:24:56,309 --> 02:24:54,160
so what we really need to do is figure

2705
02:24:58,070 --> 02:24:56,319
out how we use the spacecraft roughly as

2706
02:25:00,389 --> 02:24:58,080
conceived by arm with the arm mission

2707
02:25:02,950 --> 02:25:00,399
objectives and add on a deflection

2708
02:25:05,670 --> 02:25:02,960
demonstration so things like deflecting

2709
02:25:07,750 --> 02:25:05,680
kinetic impactors while those might be a

2710
02:25:09,670 --> 02:25:07,760
really good way to deflect an asteroid

2711
02:25:13,030 --> 02:25:09,680
it's probably not something we can do

2712
02:25:14,309 --> 02:25:13,040
very well as part of the arm mission

2713
02:25:15,910 --> 02:25:14,319

likewise there are a number of

2714
02:25:18,309 --> 02:25:15,920
techniques that have been talked about

2715
02:25:19,990 --> 02:25:18,319
for potential deflection that

2716
02:25:21,750 --> 02:25:20,000
could be done

2717
02:25:23,190 --> 02:25:21,760
sort of as secondary payloads or

2718
02:25:25,110 --> 02:25:23,200
additional capabilities on the armed

2719
02:25:26,790 --> 02:25:25,120
spacecraft but we are very budget

2720
02:25:28,070 --> 02:25:26,800
constrained on this mission there is

2721
02:25:29,349 --> 02:25:28,080
literally

2722
02:25:31,270 --> 02:25:29,359
no budget

2723
02:25:33,590 --> 02:25:31,280
in the current nasa allocation so

2724
02:25:36,230 --> 02:25:33,600
anything that adds additional systems

2725
02:25:38,309 --> 02:25:36,240
specifically for asteroid deflection on

2726
02:25:40,309 --> 02:25:38,319
top of the arm requirements is

2727
02:25:42,150 --> 02:25:40,319
potentially a deal breaker so we wanted

2728
02:25:44,150 --> 02:25:42,160
to figure out how to do a useful

2729
02:25:46,150 --> 02:25:44,160
demonstration basically with the arm

2730
02:25:48,870 --> 02:25:46,160
spacecraft with as few modifications as

2731
02:25:50,790 --> 02:25:48,880
possible and we got very interested in a

2732
02:25:54,469 --> 02:25:50,800
comment that dan had made in a hallway

2733
02:25:58,630 --> 02:25:57,190
convention or conference on using mass

2734
02:25:59,990 --> 02:25:58,640
augmentation

2735
02:26:03,190 --> 02:26:00,000
so just very briefly this has been

2736
02:26:05,750 --> 02:26:03,200
touched on before the gravity tractor

2737
02:26:08,070 --> 02:26:05,760
uses electric propulsion on a spacecraft

2738
02:26:09,510 --> 02:26:08,080

to tug an asteroid by using the

2739
02:26:11,349 --> 02:26:09,520
gravitational attraction between the

2740
02:26:14,150 --> 02:26:11,359
spacecraft and the asteroid as the tow

2741
02:26:15,830 --> 02:26:14,160
rope now as has been alluded to before

2742
02:26:17,429 --> 02:26:15,840
the biggest problem with this is that

2743
02:26:19,429 --> 02:26:17,439
you're very limited in the force you can

2744
02:26:21,510 --> 02:26:19,439
apply if you're limited to a few tons of

2745
02:26:23,510 --> 02:26:21,520
spacecraft mass i'm not sure anybody

2746
02:26:25,030 --> 02:26:23,520
talked about this numerically so let me

2747
02:26:27,190 --> 02:26:25,040
be more specific if you're moving

2748
02:26:28,309 --> 02:26:27,200
something like a 100 meter class

2749
02:26:30,150 --> 02:26:28,319
asteroid

2750
02:26:32,870 --> 02:26:30,160
with a spacecraft that's something like

2751
02:26:33,750 --> 02:26:32,880
10 tons which is what arm roughly weighs

2752
02:26:36,469 --> 02:26:33,760
you get

2753
02:26:38,230 --> 02:26:36,479
something like 20 millinewtons of of

2754
02:26:40,790 --> 02:26:38,240
force that's the most you can apply it

2755
02:26:42,469 --> 02:26:40,800
depends on you know the radius and the

2756
02:26:44,550 --> 02:26:42,479
size of the spacecraft to put that in

2757
02:26:46,950 --> 02:26:44,560
perspective that's about one percent of

2758
02:26:49,190 --> 02:26:46,960
the maximum thrust that

2759
02:26:51,750 --> 02:26:49,200
the arm spacecraft has so even though we

2760
02:26:54,950 --> 02:26:51,760
think of scp as being low thrust this is

2761
02:26:57,910 --> 02:26:54,960
two orders of magnitude lower than that

2762
02:26:59,910 --> 02:26:57,920
um to put this in a slightly more uh

2763
02:27:02,230 --> 02:26:59,920

intuitive graspable sense let me

2764
02:27:03,830 --> 02:27:02,240
describe this in in more everyday terms

2765
02:27:05,670 --> 02:27:03,840
what we're trying to do is move a chunk

2766
02:27:06,870 --> 02:27:05,680
of rock the size of a large office

2767
02:27:08,870 --> 02:27:06,880
building

2768
02:27:10,230 --> 02:27:08,880
with a spacecraft that looks roughly

2769
02:27:12,389 --> 02:27:10,240
like a

2770
02:27:13,910 --> 02:27:12,399
large wrecker tow truck that used to

2771
02:27:15,990 --> 02:27:13,920
move semis

2772
02:27:17,670 --> 02:27:16,000
pulling on it with a single human hair

2773
02:27:19,910 --> 02:27:17,680
turns out a human hair has about 20

2774
02:27:21,110 --> 02:27:19,920
milligrams of tensile strength

2775
02:27:23,270 --> 02:27:21,120
and in fact

2776
02:27:25,110 --> 02:27:23,280
the the experts in human hair tensile

2777
02:27:27,270 --> 02:27:25,120
strength are the cosmetics industry so

2778
02:27:29,110 --> 02:27:27,280
when i look this up i can tell you that

2779
02:27:30,550 --> 02:27:29,120
this is more like a bleached human hair

2780
02:27:33,270 --> 02:27:30,560
which has slightly lower tensile

2781
02:27:34,469 --> 02:27:33,280
strength because it's been damaged so

2782
02:27:36,309 --> 02:27:34,479
so that gives you a sense of the

2783
02:27:37,830 --> 02:27:36,319
challenge now the good news is this is

2784
02:27:39,590 --> 02:27:37,840
space with no

2785
02:27:42,070 --> 02:27:39,600
aerodynamic drag another limitation so

2786
02:27:43,670 --> 02:27:42,080
given enough time you actually can tow

2787
02:27:45,429 --> 02:27:43,680
an office building size asteroid with a

2788
02:27:47,510 --> 02:27:45,439

human hair but it would sure be nice to

2789
02:27:49,590 --> 02:27:47,520
be able to do it faster

2790
02:27:52,070 --> 02:27:49,600
so as as tim and others have alluded to

2791
02:27:54,790 --> 02:27:52,080
if you can grab material from the

2792
02:27:56,469 --> 02:27:54,800
asteroid you can amplify

2793
02:27:58,710 --> 02:27:56,479
the

2794
02:28:01,990 --> 02:27:58,720
upper limit on your towing capability

2795
02:28:04,150 --> 02:28:02,000
and for something on the order of um a

2796
02:28:05,990 --> 02:28:04,160
thousand ton sample collection which was

2797
02:28:08,630 --> 02:28:06,000
roughly what the armed spacecraft was

2798
02:28:11,349 --> 02:28:08,640
sized for you can get into the few

2799
02:28:12,950 --> 02:28:11,359
newton's range um so that that's roughly

2800
02:28:14,950 --> 02:28:12,960
what the uh

2801
02:28:17,750 --> 02:28:14,960
the uh the arm spacecraft is designed

2802
02:28:20,550 --> 02:28:17,760
for with scp now this still has the

2803
02:28:22,230 --> 02:28:20,560
advantage that you can

2804
02:28:23,750 --> 02:28:22,240
hug the asteroid in pretty much any

2805
02:28:26,150 --> 02:28:23,760
direction you want

2806
02:28:28,469 --> 02:28:26,160
it has the disadvantage that unlike a a

2807
02:28:30,309 --> 02:28:28,479
traditional gravity tractor you do have

2808
02:28:32,790 --> 02:28:30,319
to have a kind of mechanical interaction

2809
02:28:34,950 --> 02:28:32,800
with the asteroids so you care about

2810
02:28:36,870 --> 02:28:34,960
what its surface properties are like and

2811
02:28:39,030 --> 02:28:36,880
whether there is loose material on it in

2812
02:28:40,790 --> 02:28:39,040
fact it requires that there be

2813
02:28:42,389 --> 02:28:40,800

some material that you can pick up so

2814
02:28:45,110 --> 02:28:42,399
this is one of the

2815
02:28:47,910 --> 02:28:45,120
potential limitations

2816
02:28:49,510 --> 02:28:47,920
so how does the math work out

2817
02:28:52,150 --> 02:28:49,520
several people have talked about a kind

2818
02:28:54,389 --> 02:28:52,160
of intuitive gravity tractor where you

2819
02:28:56,469 --> 02:28:54,399
just hover the spacecraft directly over

2820
02:28:57,990 --> 02:28:56,479
the asteroid it turns out that perhaps a

2821
02:29:00,070 --> 02:28:58,000
better way to do this is to actually

2822
02:29:02,469 --> 02:29:00,080
have the spacecraft orbiting the

2823
02:29:03,990 --> 02:29:02,479
asteroid but offset from the center and

2824
02:29:05,590 --> 02:29:04,000
one attraction of that is that if you

2825
02:29:07,670 --> 02:29:05,600
stop thrusting you don't fall down and

2826
02:29:09,270 --> 02:29:07,680
crash into the asteroid you stay in and

2827
02:29:10,070 --> 02:29:09,280
orbit around and i'll show you that in a

2828
02:29:11,990 --> 02:29:10,080
minute

2829
02:29:13,270 --> 02:29:12,000
so in one of these displaced orbits if

2830
02:29:15,270 --> 02:29:13,280
we have

2831
02:29:17,349 --> 02:29:15,280
a thousand ton sample mass that we've

2832
02:29:20,150 --> 02:29:17,359
picked off with a 10 ton spacecraft and

2833
02:29:22,870 --> 02:29:20,160
we have a 100 meter asteroid that's in

2834
02:29:24,309 --> 02:29:22,880
this case on the order of 2 million tons

2835
02:29:26,630 --> 02:29:24,319
the maximum

2836
02:29:29,349 --> 02:29:26,640
thrust you can apply is is about 2

2837
02:29:33,670 --> 02:29:31,429
which is pretty much in line with the

2838
02:29:34,870 --> 02:29:33,680

capabilities of the armed spacecraft

2839
02:29:37,030 --> 02:29:34,880
and

2840
02:29:39,030 --> 02:29:37,040
with the isps typical of hull thrusters

2841
02:29:40,710 --> 02:29:39,040
you need several hundred kilograms of

2842
02:29:42,469 --> 02:29:40,720
propellant and only a few months of

2843
02:29:45,110 --> 02:29:42,479
thrusting to be able to move that

2844
02:29:47,590 --> 02:29:45,120
asteroid by a centimeter per second so

2845
02:29:49,510 --> 02:29:47,600
it's feasible to do this without blowing

2846
02:29:51,990 --> 02:29:49,520
the propellant budget for the mission

2847
02:29:53,670 --> 02:29:52,000
and without adding years to the mission

2848
02:29:55,750 --> 02:29:53,680
duration

2849
02:29:57,670 --> 02:29:55,760
so the theory here would be that if you

2850
02:30:00,389 --> 02:29:57,680
if you decide to do

2851
02:30:01,349 --> 02:30:00,399
an armed demonstration of the pick a

2852
02:30:03,030 --> 02:30:01,359
rock off

2853
02:30:04,710 --> 02:30:03,040
of a large asteroid

2854
02:30:06,389 --> 02:30:04,720
approach then

2855
02:30:07,910 --> 02:30:06,399
you have the option of doing this

2856
02:30:09,429 --> 02:30:07,920
demonstration i'm not trying to pick

2857
02:30:11,190 --> 02:30:09,439
sides in the debate about whether it's

2858
02:30:13,190 --> 02:30:11,200
better to do

2859
02:30:17,190 --> 02:30:13,200
a mission that grabs only a small

2860
02:30:19,110 --> 02:30:17,200
asteroid or to do the demonstration that

2861
02:30:20,790 --> 02:30:19,120
that visits a large asteroid in godzilla

2862
02:30:22,070 --> 02:30:20,800
boulder but if you choose to do the

2863
02:30:24,230 --> 02:30:22,080

ladder you have the option of

2864
02:30:26,790 --> 02:30:24,240
demonstrating a very real

2865
02:30:28,469 --> 02:30:26,800
asteroid deflection capability

2866
02:30:31,429 --> 02:30:28,479
so we put together a little trajectory

2867
02:30:34,150 --> 02:30:33,030
let's see if i can make it play

2868
02:30:35,910 --> 02:30:34,160
there we go

2869
02:30:37,429 --> 02:30:35,920
so this is um

2870
02:30:45,510 --> 02:30:37,439
an asteroid

2871
02:30:49,110 --> 02:30:47,270
there we go so we have our asteroid

2872
02:30:51,270 --> 02:30:49,120
which is moving in the upper left in

2873
02:30:52,469 --> 02:30:51,280
this picture so there's its velocity

2874
02:30:54,630 --> 02:30:52,479
vector and what we want to do is

2875
02:30:55,990 --> 02:30:54,640
basically add to its velocity vector one

2876
02:30:57,510 --> 02:30:56,000
of the easiest ways to change its

2877
02:30:59,429 --> 02:30:57,520
position is to accelerate it in the

2878
02:31:01,750 --> 02:30:59,439
direction it's already going so the

2879
02:31:03,910 --> 02:31:01,760
spacecraft is thrusting you can see our

2880
02:31:06,550 --> 02:31:03,920
feeble attempt to have a picture of a

2881
02:31:08,710 --> 02:31:06,560
ion plume there in the blue line

2882
02:31:10,389 --> 02:31:08,720
that thrust is pushing the asteroid

2883
02:31:12,790 --> 02:31:10,399
orbit ahead of the

2884
02:31:14,710 --> 02:31:12,800
actual asteroid position and that

2885
02:31:16,469 --> 02:31:14,720
imparts an average

2886
02:31:18,870 --> 02:31:16,479
acceleration through gravity to the

2887
02:31:20,550 --> 02:31:18,880
asteroid in the correct direction so we

2888
02:31:22,870 --> 02:31:20,560

simulated this for

2889
02:31:25,270 --> 02:31:22,880
something like 150 days without crashing

2890
02:31:27,429 --> 02:31:25,280
into the asteroid

2891
02:31:30,309 --> 02:31:27,439
we've got the solar arrays pointed at

2892
02:31:31,910 --> 02:31:30,319
the sun the appropriate times

2893
02:31:33,750 --> 02:31:31,920
um and one of the other attractions of

2894
02:31:35,429 --> 02:31:33,760
this approach is that you are allowed to

2895
02:31:37,429 --> 02:31:35,439
point the thrusters actually in the

2896
02:31:39,670 --> 02:31:37,439
direction you want to go and not canting

2897
02:31:41,510 --> 02:31:39,680
them off at a 45 degree angle to avoid

2898
02:31:43,670 --> 02:31:41,520
plumbing the asteroid because you're

2899
02:31:45,270 --> 02:31:43,680
you're not um pointed directly at the

2900
02:31:48,550 --> 02:31:45,280
asteroid now you'll notice that this

2901
02:31:49,910 --> 02:31:48,560
this trajectory is kind of um

2902
02:31:52,070 --> 02:31:49,920
looks sort of random it's a little bit

2903
02:31:53,750 --> 02:31:52,080
loopy that's partly because the asteroid

2904
02:31:55,429 --> 02:31:53,760
has an irregular gravity field but

2905
02:31:57,429 --> 02:31:55,439
mainly because we didn't take the time

2906
02:31:59,349 --> 02:31:57,439
to do a smarter job of designing the

2907
02:32:01,190 --> 02:31:59,359
trajectory in a way that would be more

2908
02:32:03,429 --> 02:32:01,200
stable and here's what happens you'll

2909
02:32:05,750 --> 02:32:03,439
notice we've turned off the plume

2910
02:32:08,230 --> 02:32:05,760
so that that plume went away if you lose

2911
02:32:10,950 --> 02:32:08,240
thrust you go into a stable orbit around

2912
02:32:14,550 --> 02:32:10,960
the asteroid oops start it over again so

2913
02:32:16,389 --> 02:32:14,560

that it doesn't crash into the asteroid

2914
02:32:18,309 --> 02:32:16,399
now one of the other attractions of the

2915
02:32:20,230 --> 02:32:18,319
mass augmentation because you can

2916
02:32:23,590 --> 02:32:20,240
increase the force you can apply by a

2917
02:32:25,830 --> 02:32:23,600
factor of 100 or a thousand is that you

2918
02:32:27,910 --> 02:32:25,840
can either use that amplification to

2919
02:32:30,150 --> 02:32:27,920
move the asteroid a whole lot faster

2920
02:32:32,230 --> 02:32:30,160
or you can use that increased force to

2921
02:32:34,389 --> 02:32:32,240
allow a much greater offset distance

2922
02:32:36,550 --> 02:32:34,399
from the asteroid so

2923
02:32:38,790 --> 02:32:36,560
operating um

2924
02:32:40,710 --> 02:32:38,800
relatively dumb spacecraft around an

2925
02:32:42,230 --> 02:32:40,720
irregular rotating body with a lumpy

2926
02:32:43,830 --> 02:32:42,240
gravitational field

2927
02:32:45,990 --> 02:32:43,840
is sort of nerve-racking if you're

2928
02:32:48,309 --> 02:32:46,000
trying to do it up close being able to

2929
02:32:50,070 --> 02:32:48,319
do it at a greater distance

2930
02:32:52,469 --> 02:32:50,080
may simplify the mission operations and

2931
02:32:54,870 --> 02:32:52,479
reduce risk quite a bit so we laid in a

2932
02:32:57,190 --> 02:32:54,880
kind of a notional timeline for this

2933
02:32:58,630 --> 02:32:57,200
demonstration based on

2934
02:33:01,030 --> 02:32:58,640
the timeline that's being developed

2935
02:33:02,950 --> 02:33:01,040
right now for the osiris-rex mission

2936
02:33:05,429 --> 02:33:02,960
and we concluded that you could probably

2937
02:33:06,870 --> 02:33:05,439
do this demonstration including the part

2938
02:33:10,070 --> 02:33:06,880

about picking up the material off the

2939
02:33:11,510 --> 02:33:10,080
asteroid in a little over a year so it

2940
02:33:16,309 --> 02:33:11,520
should be feasible

2941
02:33:16,319 --> 02:33:22,150
nominal mission plan

2942
02:33:25,510 --> 02:33:23,670
so the next question we wondered was

2943
02:33:28,150 --> 02:33:25,520
well is this a useful demonstration to

2944
02:33:30,389 --> 02:33:28,160
do and in particular how much can you

2945
02:33:31,910 --> 02:33:30,399
scale this up or another way to phrase

2946
02:33:34,790 --> 02:33:31,920
it is what's the biggest asteroid that

2947
02:33:36,870 --> 02:33:34,800
you could move with this approach given

2948
02:33:39,590 --> 02:33:36,880
roughly the design specifications of the

2949
02:33:41,270 --> 02:33:39,600
arm spacecraft which is that you've got

2950
02:33:43,030 --> 02:33:41,280
several tons of propellant you know it

2951
02:33:45,910 --> 02:33:43,040
depends on how much you use getting to

2952
02:33:47,510 --> 02:33:45,920
the asteroid obviously we sort of

2953
02:33:49,190 --> 02:33:47,520
concluded that you could apply a one

2954
02:33:52,070 --> 02:33:49,200
centimeter per second

2955
02:33:54,469 --> 02:33:52,080
delta v to an asteroid up to about 200

2956
02:33:55,270 --> 02:33:54,479
to 350 meters in size

2957
02:33:56,790 --> 02:33:55,280
so

2958
02:33:58,950 --> 02:33:56,800
that's

2959
02:34:00,630 --> 02:33:58,960
not quite the top end of the largest

2960
02:34:03,670 --> 02:34:00,640
possible threatening asteroid but it's

2961
02:34:05,429 --> 02:34:03,680
pretty close now one caveat to this that

2962
02:34:07,990 --> 02:34:05,439
assumes that the asteroid that is

2963
02:34:09,670 --> 02:34:08,000

dangerous is in an orbit which is easy

2964
02:34:11,670 --> 02:34:09,680
enough to get to that you can use any

2965
02:34:12,469 --> 02:34:11,680
rendezvous based technique in the first

2966
02:34:14,870 --> 02:34:12,479
place

2967
02:34:19,750 --> 02:34:14,880
if the threat is an asteroid in a very

2968
02:34:22,630 --> 02:34:21,429
that is uh

2969
02:34:24,710 --> 02:34:22,640
yeah for everybody

2970
02:34:25,750 --> 02:34:24,720
that is uh has a high relative velocity

2971
02:34:27,190 --> 02:34:25,760
relative to the earth then you need an

2972
02:34:28,150 --> 02:34:27,200
intercept technique and this doesn't

2973
02:34:30,230 --> 02:34:28,160
work

2974
02:34:31,830 --> 02:34:30,240
um but at least for asteroids which are

2975
02:34:33,270 --> 02:34:31,840
reasonably accessible it's a it's a

2976
02:34:34,790 --> 02:34:33,280
viable technique and it turns out even

2977
02:34:37,030 --> 02:34:34,800
though the accessible asteroids are a

2978
02:34:38,630 --> 02:34:37,040
small fraction of the total population

2979
02:34:40,790 --> 02:34:38,640
they're a relatively large fraction of

2980
02:34:43,750 --> 02:34:40,800
the risky population precisely because

2981
02:34:45,190 --> 02:34:43,760
they come very close to earth so often

2982
02:34:47,590 --> 02:34:45,200
so with that i will take any questions

2983
02:34:48,870 --> 02:34:47,600
you've got okay

2984
02:34:53,990 --> 02:34:48,880
do we have any questions in the room

2985
02:34:57,270 --> 02:34:55,429
is it the gravitational pull of the

2986
02:34:59,830 --> 02:34:57,280
asteroid that keeps you from moving away

2987
02:35:01,750 --> 02:34:59,840
from it yes okay

2988
02:35:04,150 --> 02:35:01,760

so that's why it sets the limit and it's

2989
02:35:05,670 --> 02:35:04,160
also why the the tow truck analogy is a

2990
02:35:07,830 --> 02:35:05,680
good one if you apply a force that

2991
02:35:09,429 --> 02:35:07,840
exceeds that gravitational force you

2992
02:35:12,710 --> 02:35:09,439
break the rope and you go

2993
02:35:14,469 --> 02:35:12,720
much farther away from the asteroid

2994
02:35:17,349 --> 02:35:14,479
so what is the total thrust of the

2995
02:35:19,510 --> 02:35:17,359
spacecraft in your demonstration now um

2996
02:35:21,349 --> 02:35:19,520
i think we used we attempted to use the

2997
02:35:23,910 --> 02:35:21,359
arm reference design which is something

2998
02:35:25,910 --> 02:35:23,920
like two newtons

2999
02:35:28,630 --> 02:35:25,920
and that's just the scp thrust obviously

3000
02:35:29,750 --> 02:35:28,640
there's chemical thrusters rcs there

3001
02:35:31,750 --> 02:35:29,760
so

3002
02:35:32,950 --> 02:35:31,760
basically it seems like there's a design

3003
02:35:34,469 --> 02:35:32,960
and this is not so much for the

3004
02:35:36,230 --> 02:35:34,479
demonstration mission but it seems like

3005
02:35:39,750 --> 02:35:36,240
there's a design choice when you start

3006
02:35:42,630 --> 02:35:39,760
talking about moving a thousand tons of

3007
02:35:45,110 --> 02:35:42,640
of well what is what what is more likely

3008
02:35:48,070 --> 02:35:45,120
to have problems moving a thousand tons

3009
02:35:50,710 --> 02:35:48,080
of material to get i think is 1.89

3010
02:35:52,469 --> 02:35:50,720
newtons or something like that or just

3011
02:35:54,309 --> 02:35:52,479
putting the spacecraft against the body

3012
02:35:56,150 --> 02:35:54,319
and thrusting it directly to get two

3013
02:35:57,270 --> 02:35:56,160

newtons of thrust

3014
02:35:59,670 --> 02:35:57,280
um

3015
02:36:01,990 --> 02:35:59,680
and so it seems like that needs some

3016
02:36:03,110 --> 02:36:02,000
consideration that it's not obvious to

3017
02:36:04,790 --> 02:36:03,120
me that

3018
02:36:06,710 --> 02:36:04,800
you know if you sort of like if you had

3019
02:36:08,070 --> 02:36:06,720
to do this if you're saying you know the

3020
02:36:10,070 --> 02:36:08,080
earth is going to get hit by this thing

3021
02:36:11,670 --> 02:36:10,080
we have so much time we have to do this

3022
02:36:13,030 --> 02:36:11,680
it has to work

3023
02:36:15,190 --> 02:36:13,040
so it's not obvious that moving the

3024
02:36:17,030 --> 02:36:15,200
thousand tons is the safer

3025
02:36:19,750 --> 02:36:17,040
right option there

3026
02:36:21,349 --> 02:36:19,760
i agree it's not obvious what the best

3027
02:36:23,030 --> 02:36:21,359
deflection approach is and it depends a

3028
02:36:24,790 --> 02:36:23,040
great deal on the properties of the

3029
02:36:26,950 --> 02:36:24,800
asteroid that ends up being the

3030
02:36:29,030 --> 02:36:26,960
dangerous one but one of the reasons for

3031
02:36:31,510 --> 02:36:29,040
doing this rather than a direct push is

3032
02:36:34,630 --> 02:36:31,520
that you're not limited in the direction

3033
02:36:37,190 --> 02:36:34,640
you want to push it so if for example

3034
02:36:39,830 --> 02:36:37,200
you are trying to deflect a

3035
02:36:41,910 --> 02:36:39,840
100 meter asteroid that does not have

3036
02:36:43,910 --> 02:36:41,920
principal axis rotation even if it does

3037
02:36:46,230 --> 02:36:43,920
have principal access rotation you

3038
02:36:47,670 --> 02:36:46,240

probably it's difficult to despin it

3039
02:36:50,230 --> 02:36:47,680
right so you may be limited to pushing

3040
02:36:51,670 --> 02:36:50,240
it in a directional line with the poles

3041
02:36:53,590 --> 02:36:51,680
and if it doesn't have principal axis

3042
02:36:55,030 --> 02:36:53,600
rotation then you'd have a problem of

3043
02:36:56,230 --> 02:36:55,040
even getting consistent yeah i

3044
02:36:58,230 --> 02:36:56,240
understand that

3045
02:36:59,349 --> 02:36:58,240
just as an aside and for the record so

3046
02:37:01,030 --> 02:36:59,359
some of these other talks have talked

3047
02:37:03,190 --> 02:37:01,040
about spacecraft with 80 newtons of

3048
02:37:06,070 --> 02:37:03,200
thrust using so electric propulsion and

3049
02:37:07,270 --> 02:37:06,080
so that was that was chemical

3050
02:37:08,950 --> 02:37:07,280
okay

3051
02:37:11,349 --> 02:37:08,960
but still some of them talked about more

3052
02:37:14,150 --> 02:37:11,359
than than that couple of newtons and so

3053
02:37:15,750 --> 02:37:14,160
you you could right yes it's all the

3054
02:37:17,429 --> 02:37:15,760
question of solar cells right you know

3055
02:37:19,510 --> 02:37:17,439
you get very good solar cells you have

3056
02:37:21,590 --> 02:37:19,520
more thrust i mean

3057
02:37:24,550 --> 02:37:21,600
so in other words it scales better it

3058
02:37:26,309 --> 02:37:24,560
seems like then than the moving the mass

3059
02:37:28,150 --> 02:37:26,319
sorry which scales

3060
02:37:28,950 --> 02:37:28,160
putting in bigger solar panels to have

3061
02:37:32,150 --> 02:37:28,960
more

3062
02:37:34,070 --> 02:37:32,160
scales better because we know how to do

3063
02:37:36,150 --> 02:37:34,080

bigger solar panels they're easy to do

3064
02:37:37,670 --> 02:37:36,160
than to say well we'll move to 2 000

3065
02:37:40,309 --> 02:37:37,680
tons you know

3066
02:37:42,150 --> 02:37:40,319
it's not obvious to me that a solar

3067
02:37:45,429 --> 02:37:42,160
array that can provide

3068
02:37:47,830 --> 02:37:45,439
tens of newtons of scp thrust is easy

3069
02:37:48,790 --> 02:37:47,840
when attached to an asteroid

3070
02:37:50,870 --> 02:37:48,800
fair enough

3071
02:37:52,870 --> 02:37:50,880
if for no weather the simplest reason

3072
02:37:54,950 --> 02:37:52,880
it's hard is that it's going to be dark

3073
02:37:56,389 --> 02:37:54,960
half the time which may chords

3074
02:37:57,590 --> 02:37:56,399
coincide with the direction you want to

3075
02:37:58,870 --> 02:37:57,600
push but

3076
02:38:00,630 --> 02:37:58,880
yeah

3077
02:38:02,870 --> 02:38:00,640
i'm not saying it can't be done but it's

3078
02:38:05,830 --> 02:38:02,880
not obvious that it's easy

3079
02:38:13,990 --> 02:38:05,840
any other questions or comments

3080
02:38:19,030 --> 02:38:16,550
our next speaker is uh john brophy uh

3081
02:38:20,630 --> 02:38:19,040
john is a jpl fellow and is a specialist

3082
02:38:22,150 --> 02:38:20,640
in electric propulsion for the jet

3083
02:38:24,870 --> 02:38:22,160
propulsion laboratory and he's been

3084
02:38:26,790 --> 02:38:24,880
there since 1985. he's responsible for

3085
02:38:29,429 --> 02:38:26,800
the iron propulsion system for nasa's

3086
02:38:31,670 --> 02:38:29,439
don mission and has uh recently was a

3087
02:38:33,910 --> 02:38:31,680
co-lead on the keck sponsored asteroid

3088
02:38:35,830 --> 02:38:33,920

retrieval mission feasibility study

3089
02:38:37,030 --> 02:38:35,840
all right thanks um okay so we're going

3090
02:38:38,469 --> 02:38:37,040
to talk about a little bit different

3091
02:38:40,790 --> 02:38:38,479
approach i think you heard about this

3092
02:38:43,110 --> 02:38:40,800
earlier in the session

3093
02:38:45,190 --> 02:38:43,120
which we now call a ion beam deflection

3094
02:38:46,870 --> 02:38:45,200
or ion beam deflector when we originally

3095
02:38:48,630 --> 02:38:46,880
wrote this up we called it push me pull

3096
02:38:50,950 --> 02:38:48,640
you nobody liked that

3097
02:38:52,309 --> 02:38:50,960
so we changed the name but

3098
02:38:53,590 --> 02:38:52,319
there are other names

3099
02:38:57,830 --> 02:38:53,600
this

3100
02:38:58,710 --> 02:38:57,840
concept was from kitamura who looked at

3101
02:38:59,910 --> 02:38:58,720
it for

3102
02:39:01,510 --> 02:38:59,920
dealing with

3103
02:39:02,309 --> 02:39:01,520
orbital debris

3104
02:39:04,230 --> 02:39:02,319
and

3105
02:39:05,910 --> 02:39:04,240
you blast you have a your sep vehicle

3106
02:39:07,590 --> 02:39:05,920
you blast the ion beam into it you don't

3107
02:39:08,950 --> 02:39:07,600
need to grab the thing you don't need to

3108
02:39:10,710 --> 02:39:08,960
de-tumble it

3109
02:39:12,630 --> 02:39:10,720
and but you do need to thrust in the

3110
02:39:15,110 --> 02:39:12,640
opposite direction in order to maintain

3111
02:39:17,349 --> 02:39:15,120
your position relative to the object

3112
02:39:20,150 --> 02:39:17,359
and then bombardelli and company said

3113
02:39:22,389 --> 02:39:20,160

well let's apply this to

3114
02:39:24,389 --> 02:39:22,399
deflecting asteroids so the same idea

3115
02:39:26,070 --> 02:39:24,399
you blast the ion beam into the asteroid

3116
02:39:28,070 --> 02:39:26,080
and thrust in the other direction to

3117
02:39:30,710 --> 02:39:28,080
maintain the position

3118
02:39:33,110 --> 02:39:30,720
the attractive feature of this is that

3119
02:39:35,670 --> 02:39:33,120
now the coupling force that holds you

3120
02:39:38,070 --> 02:39:35,680
relative to the asteroid is entirely

3121
02:39:39,990 --> 02:39:38,080
within your engineering control it

3122
02:39:41,510 --> 02:39:40,000
decouples this from

3123
02:39:43,190 --> 02:39:41,520
the size

3124
02:39:45,990 --> 02:39:43,200
and spin state of the object that you're

3125
02:39:48,150 --> 02:39:46,000
trying to move and so if you scale the

3126
02:39:50,389 --> 02:39:48,160
vehicle to much higher powers you can

3127
02:39:53,030 --> 02:39:50,399
take advantage of all of that

3128
02:39:53,910 --> 02:39:53,040
additional thrust or at least half of it

3129
02:39:55,830 --> 02:39:53,920
um

3130
02:39:57,670 --> 02:39:55,840
and use that to deflect the asteroid the

3131
02:39:59,830 --> 02:39:57,680
other interesting thing is

3132
02:40:02,150 --> 02:39:59,840
uh that the you can think of this

3133
02:40:04,550 --> 02:40:02,160
basically as a kinetic impactor where

3134
02:40:06,870 --> 02:40:04,560
you're impacting it at the at an atomic

3135
02:40:09,270 --> 02:40:06,880
level but with potentially with an

3136
02:40:12,070 --> 02:40:09,280
arm-sized vehicle a few thousand

3137
02:40:14,950 --> 02:40:12,080
kilograms of stuff so it's a kinetic

3138
02:40:17,670 --> 02:40:14,960

impactor with impact velocities of 30

3139
02:40:20,150 --> 02:40:17,680
kilometers per second or more and a few

3140
02:40:22,870 --> 02:40:20,160
thousand kilograms of mass so it's very

3141
02:40:25,190 --> 02:40:22,880
much like the kinetic impactor

3142
02:40:27,590 --> 02:40:25,200
uh so anyway this might push me pull you

3143
02:40:28,389 --> 02:40:27,600
because you're going in both directions

3144
02:40:30,150 --> 02:40:28,399
okay

3145
02:40:31,990 --> 02:40:30,160
so the question is well does it work do

3146
02:40:34,389 --> 02:40:32,000
you really get that force implied

3147
02:40:36,950 --> 02:40:34,399
applied to the asteroid well this

3148
02:40:37,910 --> 02:40:36,960
occurred to people for other reasons

3149
02:40:39,030 --> 02:40:37,920
and

3150
02:40:41,030 --> 02:40:39,040
they take a

3151
02:40:42,950 --> 02:40:41,040
plate here graphite disc and stick it

3152
02:40:43,990 --> 02:40:42,960
into the exhaust plume here of a hull

3153
02:40:49,030 --> 02:40:44,000
thruster

3154
02:40:50,710 --> 02:40:49,040
this is also on a thrust balance and so

3155
02:40:53,110 --> 02:40:50,720
it turns out that those two match to

3156
02:40:55,030 --> 02:40:53,120
within a few percent so we know that if

3157
02:40:57,670 --> 02:40:55,040
you hit the asteroid with the ion beam

3158
02:40:59,110 --> 02:40:57,680
you will indeed impart the right

3159
02:41:00,630 --> 02:40:59,120
thrust to it

3160
02:41:02,630 --> 02:41:00,640
there are some real world effects of

3161
02:41:04,710 --> 02:41:02,640
course some of them

3162
02:41:07,670 --> 02:41:04,720
is that not all the exhaust might hit

3163
02:41:09,110 --> 02:41:07,680

the asteroid but you can control that

3164
02:41:10,790 --> 02:41:09,120
in terms of

3165
02:41:12,469 --> 02:41:10,800
how you engineer the thruster how far

3166
02:41:13,590 --> 02:41:12,479
you are from the asteroid and how big it

3167
02:41:15,349 --> 02:41:13,600
is

3168
02:41:17,349 --> 02:41:15,359
you will sputter the surface of the

3169
02:41:19,030 --> 02:41:17,359
asteroid this is like sand blasting at

3170
02:41:20,550 --> 02:41:19,040
an atomic scale

3171
02:41:22,469 --> 02:41:20,560
but if the spacecraft's far enough away

3172
02:41:25,030 --> 02:41:22,479
from the asteroid it won't affect the

3173
02:41:26,870 --> 02:41:25,040
spacecraft and the amount of impulse you

3174
02:41:28,309 --> 02:41:26,880
get from the sputtered products is

3175
02:41:30,710 --> 02:41:28,319
negligible

3176
02:41:32,710 --> 02:41:30,720
even though it would help you don't get

3177
02:41:34,630 --> 02:41:32,720
a lot of elastic collisions

3178
02:41:37,190 --> 02:41:34,640
uh and you you won't charge up the

3179
02:41:39,910 --> 02:41:37,200
asteroid because the ion

3180
02:41:41,830 --> 02:41:39,920
plume has lots and lots of electrons and

3181
02:41:43,590 --> 02:41:41,840
ions

3182
02:41:45,590 --> 02:41:43,600
um

3183
02:41:47,670 --> 02:41:45,600
uh hull thrusters are really good for

3184
02:41:49,750 --> 02:41:47,680
moving heavy things but it turns out

3185
02:41:52,150 --> 02:41:49,760
gridded ion engines are really ideally

3186
02:41:54,870 --> 02:41:52,160
suited for this ion beam deflector and

3187
02:41:57,590 --> 02:41:54,880
that's because you can make them with

3188
02:42:00,070 --> 02:41:57,600

almost no beam divergence so here's an

3189
02:42:02,630 --> 02:42:00,080
actual photograph of this nexus ion

3190
02:42:05,269 --> 02:42:02,640
engine it's a 20 kilowatt device

3191
02:42:06,950 --> 02:42:05,279
an ion exhaust velocity of 70 kilometers

3192
02:42:07,750 --> 02:42:06,960
per second so now we're talking some

3193
02:42:08,870 --> 02:42:07,760
real

3194
02:42:10,230 --> 02:42:08,880
speeds here

3195
02:42:12,230 --> 02:42:10,240
you can get an idea how big it is this

3196
02:42:16,150 --> 02:42:12,240
is dan gobel here i'm not sure who

3197
02:42:20,389 --> 02:42:18,389
but uh it has flat carbon carbon grids

3198
02:42:22,630 --> 02:42:20,399
which allows you to get this really very

3199
02:42:24,630 --> 02:42:22,640
low beam divergence only of only a few

3200
02:42:27,349 --> 02:42:24,640
degrees

3201
02:42:28,630 --> 02:42:27,359
and uh and it'll last uh for a very long

3202
02:42:30,389 --> 02:42:28,640
time they did test it for over a

3203
02:42:32,950 --> 02:42:30,399
thousand hours but had very low uh

3204
02:42:36,630 --> 02:42:32,960
erosion and uh so 20 kilowatts that's

3205
02:42:37,990 --> 02:42:36,640
like half the arm vehicle power level

3206
02:42:39,590 --> 02:42:38,000
uh so you've heard a lot about these

3207
02:42:42,710 --> 02:42:39,600
things gravity tractor and kinetic

3208
02:42:44,550 --> 02:42:42,720
impactor kinetic impactors typically

3209
02:42:47,429 --> 02:42:44,560
look at impact

3210
02:42:49,349 --> 02:42:47,439
velocities of 5 to 25 kilometers per

3211
02:42:51,030 --> 02:42:49,359
second or so it depends on how you do

3212
02:42:54,710 --> 02:42:51,040
the

3213
02:42:56,630 --> 02:42:54,720

terminal navigation and guidance uh and

3214
02:42:59,030 --> 02:42:56,640
maybe several thousand a few thousand to

3215
02:43:01,510 --> 02:42:59,040
several thousand kilograms

3216
02:43:04,389 --> 02:43:01,520
uh and as uh an earlier talk said with

3217
02:43:06,309 --> 02:43:04,399
just a plain gravity tractor and our 100

3218
02:43:08,469 --> 02:43:06,319
meter asteroid

3219
02:43:11,990 --> 02:43:08,479
you're down you know less than 100

3220
02:43:14,389 --> 02:43:12,000
millinewtons for a 10-ton spacecraft

3221
02:43:17,110 --> 02:43:14,399
if you take the arm-sized vehicle and

3222
02:43:18,870 --> 02:43:17,120
you can deliver 10 tons of

3223
02:43:20,469 --> 02:43:18,880
propellant and spacecraft to the

3224
02:43:23,190 --> 02:43:20,479
asteroid

3225
02:43:25,190 --> 02:43:23,200
6000 kilograms of which is propellant at

3226
02:43:27,030 --> 02:43:25,200
30 kilometers per second as i said

3227
02:43:29,830 --> 02:43:27,040
that's very comparable to a kinetic

3228
02:43:31,429 --> 02:43:29,840
impactor in terms of mass and velocity

3229
02:43:33,269 --> 02:43:31,439
and you can direct it right along the

3230
02:43:36,630 --> 02:43:33,279
velocity vector which is the most

3231
02:43:38,309 --> 02:43:36,640
effective way to deflect it so if we now

3232
02:43:39,590 --> 02:43:38,319
look at how much force can we apply to

3233
02:43:41,030 --> 02:43:39,600
the asteroid as a function of the

3234
02:43:43,510 --> 02:43:41,040
asteroid diameter

3235
02:43:45,269 --> 02:43:43,520
we see that it's basically a straight

3236
02:43:47,190 --> 02:43:45,279
line that is it's independent of the

3237
02:43:49,910 --> 02:43:47,200
asteroid size because it's entirely

3238
02:43:51,429 --> 02:43:49,920

within our engineering control so that's

3239
02:43:54,389 --> 02:43:51,439
that's a nice feature

3240
02:43:55,990 --> 02:43:54,399
and it is

3241
02:43:58,870 --> 02:43:56,000
you know an order of magnitude or more

3242
02:44:01,429 --> 02:43:58,880
greater depending on the asteroid size

3243
02:44:03,750 --> 02:44:01,439
even if you pick up a rock a 20 ton rock

3244
02:44:05,670 --> 02:44:03,760
it still provides significantly higher

3245
02:44:08,710 --> 02:44:05,680
coupling force until you get to really

3246
02:44:10,469 --> 02:44:08,720
big asteroids but if you don't like this

3247
02:44:12,309 --> 02:44:10,479
this thrust level you can just

3248
02:44:13,830 --> 02:44:12,319
re-engineer it

3249
02:44:17,030 --> 02:44:13,840
just but you know go to higher power

3250
02:44:18,630 --> 02:44:17,040
levels higher thrust levels

3251
02:44:21,349 --> 02:44:18,640
the nice the other nice thing is that

3252
02:44:23,269 --> 02:44:21,359
with a very collimated beam

3253
02:44:24,710 --> 02:44:23,279
uh say a five degree

3254
02:44:27,349 --> 02:44:24,720
beam divergence

3255
02:44:30,469 --> 02:44:27,359
if you want to deflect a say an idikawa

3256
02:44:32,710 --> 02:44:30,479
sized asteroid you could be

3257
02:44:34,150 --> 02:44:32,720
a kilometer away from it and all of the

3258
02:44:35,349 --> 02:44:34,160
beam would hit it if it were spherical

3259
02:44:37,190 --> 02:44:35,359
it's not so you're gonna have to be

3260
02:44:39,910 --> 02:44:37,200
closer but if it were spherical you

3261
02:44:40,790 --> 02:44:39,920
could be a kilometer away from this

3262
02:44:42,870 --> 02:44:40,800
um

3263
02:44:44,550 --> 02:44:42,880

so you have a safe distance from the

3264
02:44:46,389 --> 02:44:44,560
asteroid you don't have to worry about

3265
02:44:50,230 --> 02:44:46,399
backsplattered material and we know we

3266
02:44:51,830 --> 02:44:50,240
can build ion thrusters to do that

3267
02:44:53,349 --> 02:44:51,840
so we looked at

3268
02:44:55,670 --> 02:44:53,359
how does this compare to kinetic

3269
02:44:58,630 --> 02:44:55,680
impactors so if we have kinetic impactor

3270
02:44:59,510 --> 02:44:58,640
masses of one to fight to say five tons

3271
02:45:01,830 --> 02:44:59,520
here

3272
02:45:03,510 --> 02:45:01,840
at different impact velocities and

3273
02:45:06,550 --> 02:45:03,520
compare that to

3274
02:45:08,630 --> 02:45:06,560
an ion beam deflector that has five tons

3275
02:45:10,790 --> 02:45:08,640
of propellant delivered to the target

3276
02:45:13,670 --> 02:45:10,800
of which half is impacted on the

3277
02:45:15,590 --> 02:45:13,680
asteroid at these different isps or

3278
02:45:17,429 --> 02:45:15,600
think exhaust velocities you multiply by

3279
02:45:20,230 --> 02:45:17,439
10. and you can see you can get really

3280
02:45:21,910 --> 02:45:20,240
much higher total impulses delivered

3281
02:45:23,750 --> 02:45:21,920
it takes time to do that it doesn't

3282
02:45:25,990 --> 02:45:23,760
happen instantaneously so that's that's

3283
02:45:26,950 --> 02:45:26,000
the trade-off and of course time is the

3284
02:45:28,550 --> 02:45:26,960
key

3285
02:45:30,870 --> 02:45:28,560
you know one of the things that we know

3286
02:45:31,830 --> 02:45:30,880
for sure probably well probably for sure

3287
02:45:34,070 --> 02:45:31,840
also

3288
02:45:35,830 --> 02:45:34,080

that if you have a potentially hazardous

3289
02:45:37,429 --> 02:45:35,840
object you're going to wait as long as

3290
02:45:39,030 --> 02:45:37,439
possible before you do anything about it

3291
02:45:41,670 --> 02:45:39,040
right so the question is

3292
02:45:43,830 --> 02:45:41,680
uh how long can you wait or how what's

3293
02:45:45,910 --> 02:45:43,840
the minimum time you have to get there

3294
02:45:48,950 --> 02:45:45,920
in order to deflect it

3295
02:45:51,429 --> 02:45:48,960
so dan griebo and company looked at this

3296
02:45:52,469 --> 02:45:51,439
asteroid 2011 ag-5 which you just heard

3297
02:45:53,750 --> 02:45:52,479
about

3298
02:45:55,990 --> 02:45:53,760
and looked at how to deflect it with a

3299
02:45:58,150 --> 02:45:56,000
kinetic impactor so we had them redo

3300
02:45:59,349 --> 02:45:58,160
that analysis using this ion beam

3301
02:46:01,670 --> 02:45:59,359
deflector

3302
02:46:03,190 --> 02:46:01,680
they were trying to get 10 earth radii

3303
02:46:06,150 --> 02:46:03,200
deflections on the

3304
02:46:08,309 --> 02:46:06,160
b plane prior to the keyhole passage the

3305
02:46:09,910 --> 02:46:08,319
reason for 10 earth radii was to

3306
02:46:12,630 --> 02:46:09,920
to knock it not only away from that

3307
02:46:14,070 --> 02:46:12,640
keyhole but other potential some other

3308
02:46:16,710 --> 02:46:14,080
keyholes

3309
02:46:19,030 --> 02:46:16,720
uh we could do the same thing uh 10

3310
02:46:21,990 --> 02:46:19,040
earth radii with this

3311
02:46:24,070 --> 02:46:22,000
ion beam deflector at 80 kilowatts in

3312
02:46:25,030 --> 02:46:24,080
3000 seconds it would take four tons of

3313
02:46:26,389 --> 02:46:25,040

xenon

3314
02:46:28,469 --> 02:46:26,399
but it would take

3315
02:46:30,389 --> 02:46:28,479
about one and three quarters years

3316
02:46:32,950 --> 02:46:30,399
instead of about the one year lead time

3317
02:46:35,110 --> 02:46:32,960
that the kinetic impactor did but you

3318
02:46:36,710 --> 02:46:35,120
may not need 10 earth radii if you have

3319
02:46:39,510 --> 02:46:36,720
very precise control of what you're

3320
02:46:41,190 --> 02:46:39,520
doing you might need only a couple

3321
02:46:43,429 --> 02:46:41,200
and a 2 earth radii

3322
02:46:45,269 --> 02:46:43,439
you could now do this at 40 kilowatts

3323
02:46:47,910 --> 02:46:45,279
and it would only take you a couple of

3324
02:46:48,710 --> 02:46:47,920
tons of xenon and maybe a year and a

3325
02:46:53,110 --> 02:46:48,720
half

3326
02:46:54,389 --> 02:46:53,120
lead time once you got to the asteroid

3327
02:46:55,830 --> 02:46:54,399
the other interesting thing that you

3328
02:46:57,830 --> 02:46:55,840
might be able to do with this and i know

3329
02:46:59,190 --> 02:46:57,840
there's a question earlier is that if

3330
02:47:00,870 --> 02:46:59,200
you didn't line up the center of

3331
02:47:01,830 --> 02:47:00,880
pressure with the center of mass of the

3332
02:47:02,950 --> 02:47:01,840
object

3333
02:47:04,710 --> 02:47:02,960
you could

3334
02:47:06,469 --> 02:47:04,720
affect its spin state and if you were

3335
02:47:08,309 --> 02:47:06,479
smart about this you could

3336
02:47:09,990 --> 02:47:08,319
slow down its spin rate so if you go to

3337
02:47:11,590 --> 02:47:10,000
an asteroid that you want to capture

3338
02:47:14,230 --> 02:47:11,600

it's possible

3339
02:47:16,230 --> 02:47:14,240
that you could as andy thomas suggested

3340
02:47:18,710 --> 02:47:16,240
use this approach to

3341
02:47:21,590 --> 02:47:18,720
slow down the spin rate of the asteroid

3342
02:47:23,510 --> 02:47:21,600
making its subsequent capture easier

3343
02:47:26,150 --> 02:47:23,520
and the pressure that this ion beam puts

3344
02:47:28,070 --> 02:47:26,160
on the asteroid is well below the 25

3345
02:47:30,630 --> 02:47:28,080
pascals that you heard about earlier

3346
02:47:32,230 --> 02:47:30,640
from dan shears so you won't it won't

3347
02:47:35,030 --> 02:47:32,240
disrupt the body

3348
02:47:36,710 --> 02:47:35,040
because it's a very gentle activity and

3349
02:47:38,550 --> 02:47:36,720
it takes a

3350
02:47:40,309 --> 02:47:38,560
manageable amount of propellant to do

3351
02:47:43,030 --> 02:47:40,319
this if you even if it's a thousand tons

3352
02:47:43,830 --> 02:47:43,040
spinning at two rpm

3353
02:47:45,510 --> 02:47:43,840
so

3354
02:47:48,790 --> 02:47:45,520
uh

3355
02:47:52,710 --> 02:47:51,030
this is a potentially very attractive

3356
02:47:53,750 --> 02:47:52,720
approach it's like the gravity tractor

3357
02:47:55,670 --> 02:47:53,760
because you don't have to despin the

3358
02:47:57,910 --> 02:47:55,680
object but it's unlike the gravity

3359
02:47:59,670 --> 02:47:57,920
tractor because you get can get a much

3360
02:48:01,510 --> 02:47:59,680
higher coupling force and a coupling

3361
02:48:03,910 --> 02:48:01,520
force that's completely within your

3362
02:48:05,510 --> 02:48:03,920
engineering control

3363
02:48:08,070 --> 02:48:05,520

you could test this as part of the

3364
02:48:09,510 --> 02:48:08,080
baseline asteroid redirect mission

3365
02:48:11,590 --> 02:48:09,520
even if you did nothing you could just

3366
02:48:13,510 --> 02:48:11,600
point the hull thrusters at the asteroid

3367
02:48:16,230 --> 02:48:13,520
and blast into it

3368
02:48:18,309 --> 02:48:16,240
or you could could lend itself to an

3369
02:48:20,710 --> 02:48:18,319
international cooperation where they

3370
02:48:23,030 --> 02:48:20,720
someone provides a gridded ion engine

3371
02:48:27,030 --> 02:48:23,040
with a very low beam divergence

3372
02:48:28,870 --> 02:48:27,040
and do that as part of the demonstration

3373
02:48:31,510 --> 02:48:28,880
the total impulse and trust are as i

3374
02:48:33,190 --> 02:48:31,520
said entirely within our control

3375
02:48:36,070 --> 02:48:33,200
that total impulse is potentially

3376
02:48:38,389 --> 02:48:36,080
competitive with kinetic impactors it

3377
02:48:39,910 --> 02:48:38,399
also saves you on the fact that

3378
02:48:41,110 --> 02:48:39,920
after you're done blasting into this

3379
02:48:42,469 --> 02:48:41,120
thing you still have the spacecraft

3380
02:48:44,389 --> 02:48:42,479
there and you can get a very precise

3381
02:48:46,309 --> 02:48:44,399
measurement of what you've done to the

3382
02:48:47,910 --> 02:48:46,319
spacecraft that you get that as you go

3383
02:48:49,429 --> 02:48:47,920
along

3384
02:48:50,550 --> 02:48:49,439
and we know we can build gridded ion

3385
02:48:52,710 --> 02:48:50,560
engines

3386
02:48:54,550 --> 02:48:52,720
which would have the right power level

3387
02:48:57,349 --> 02:48:54,560
very high exhaust velocities and very

3388
02:49:04,150 --> 02:48:57,359

low beam divergence angles

3389
02:49:10,469 --> 02:49:07,110
okay do we have any uh questions

3390
02:49:15,510 --> 02:49:12,710
i've got one question here john good

3391
02:49:16,950 --> 02:49:15,520
talk um on just a question on

3392
02:49:19,830 --> 02:49:16,960
the chart where you showed the gravity

3393
02:49:21,429 --> 02:49:19,840
tractor the um you showed a log log plot

3394
02:49:23,670 --> 02:49:21,439
and you had a 20-ton boulder if you

3395
02:49:25,429 --> 02:49:23,680
could flip back to that real quick

3396
02:49:27,349 --> 02:49:25,439
yeah that one right there so so

3397
02:49:29,990 --> 02:49:27,359
obviously depending on the mass of the

3398
02:49:32,550 --> 02:49:30,000
rock that you pick up um that keeps

3399
02:49:34,309 --> 02:49:32,560
offsetting that right but my i'm still

3400
02:49:36,710 --> 02:49:34,319
not completely sure i understand that

3401
02:49:39,429 --> 02:49:36,720
inflection point if you could explain

3402
02:49:41,590 --> 02:49:39,439
why the on a log plot that um yeah that

3403
02:49:43,110 --> 02:49:41,600
slope changes yeah so it's not obvious

3404
02:49:44,790 --> 02:49:43,120
because you know like any time you do

3405
02:49:46,469 --> 02:49:44,800
these analysis it's chocked full of

3406
02:49:48,550 --> 02:49:46,479
assumptions right so

3407
02:49:50,389 --> 02:49:48,560
the assumption here was

3408
02:49:52,830 --> 02:49:50,399
uh we are trying to

3409
02:49:55,750 --> 02:49:52,840
make the gravity tractor look

3410
02:49:57,030 --> 02:49:55,760
as as high a coupling force as we could

3411
02:49:59,030 --> 02:49:57,040
so we're trying to get as close to the

3412
02:50:01,190 --> 02:49:59,040
asteroid as possible so we're assuming

3413
02:50:04,309 --> 02:50:01,200

you're counting the thrusters at

3414
02:50:05,830 --> 02:50:04,319
uh 60 degrees to fire past this is not

3415
02:50:08,230 --> 02:50:05,840
an orbiting gravity tractor but just a

3416
02:50:09,269 --> 02:50:08,240
regular this is an offset so once you

3417
02:50:11,590 --> 02:50:09,279
get to

3418
02:50:13,429 --> 02:50:11,600
about this mass

3419
02:50:17,349 --> 02:50:13,439
you're now uh

3420
02:50:18,710 --> 02:50:17,359
exceed the um half of the thrust and so

3421
02:50:20,790 --> 02:50:18,720
you're no longer candidate you're

3422
02:50:23,110 --> 02:50:20,800
counted at lower less than 60 degrees

3423
02:50:25,429 --> 02:50:23,120
and so the amount of thrust

3424
02:50:26,950 --> 02:50:25,439
available to counteract the gravity

3425
02:50:29,349 --> 02:50:26,960
forces goes up so that's that's

3426
02:50:32,469 --> 02:50:29,359
eliminated by going to the halo approach

3427
02:50:33,830 --> 02:50:32,479
yes that would change that okay

3428
02:50:35,429 --> 02:50:33,840
great thanks

3429
02:50:38,309 --> 02:50:35,439
any questions

3430
02:50:39,030 --> 02:50:38,319
actually i had a question for paul abel

3431
02:50:41,349 --> 02:50:39,040
uh

3432
02:50:43,349 --> 02:50:41,359
scientifically um

3433
02:50:46,230 --> 02:50:43,359
bombarding the surface of an asteroid

3434
02:50:47,670 --> 02:50:46,240
with ions would that sort of uh mess

3435
02:50:55,830 --> 02:50:47,680
things up in terms of scientific

3436
02:50:59,190 --> 02:50:58,309
yeah you're just this is a very it's a

3437
02:51:02,389 --> 02:50:59,200
surface

3438
02:51:04,630 --> 02:51:02,399

important part scientifically so you

3439
02:51:07,030 --> 02:51:04,640
ruin the surface

3440
02:51:09,830 --> 02:51:07,040
so with the gravity tractor what's what

3441
02:51:12,309 --> 02:51:09,840
separation were you assuming that the

3442
02:51:13,750 --> 02:51:12,319
spacecraft and the asteroids so with the

3443
02:51:15,670 --> 02:51:13,760
gravity tractor that varies as a

3444
02:51:17,670 --> 02:51:15,680
function of the of the you know the

3445
02:51:19,349 --> 02:51:17,680
asteroid diameter

3446
02:51:20,309 --> 02:51:19,359
so in fact if you look

3447
02:51:22,870 --> 02:51:20,319
here

3448
02:51:25,830 --> 02:51:22,880
so this is the height above the surface

3449
02:51:27,510 --> 02:51:25,840
for the gravity tractor so it varies um

3450
02:51:31,510 --> 02:51:27,520
okay but there's a certain number of

3451
02:51:32,630 --> 02:51:31,520
diameters of the asteroid then you could

3452
02:51:36,389 --> 02:51:32,640
you could re

3453
02:51:40,070 --> 02:51:36,399
would be an interesting number

3454
02:51:44,870 --> 02:51:41,830
yeah and this is the height above the

3455
02:51:49,269 --> 02:51:44,880
surface is assumed spherical asteroids

3456
02:51:53,429 --> 02:51:50,950
that's a good segue into my question you

3457
02:51:55,510 --> 02:51:53,439
assumed a spherical asteroid how much do

3458
02:51:57,110 --> 02:51:55,520
you think the uh

3459
02:52:00,230 --> 02:51:57,120
fact that the asteroid is probably not

3460
02:52:02,870 --> 02:52:00,240
spherical has concavities and such would

3461
02:52:05,269 --> 02:52:02,880
decrease the efficiency of this yeah so

3462
02:52:07,429 --> 02:52:05,279
most likely what that would do is

3463
02:52:08,230 --> 02:52:07,439

uh require you to be closer to it

3464
02:52:10,630 --> 02:52:08,240
because

3465
02:52:12,950 --> 02:52:10,640
the non you know if it has if it's a hot

3466
02:52:15,190 --> 02:52:12,960
dog shape or something you gotta you

3467
02:52:16,710 --> 02:52:15,200
want the ion beam to impinge on the full

3468
02:52:18,630 --> 02:52:16,720
uh you don't want to miss so you got to

3469
02:52:19,590 --> 02:52:18,640
be a little bit closer but the fact that

3470
02:52:22,309 --> 02:52:19,600
it has

3471
02:52:24,309 --> 02:52:22,319
uh you know a non-um

3472
02:52:27,030 --> 02:52:24,319
uniform surface doesn't matter because

3473
02:52:29,670 --> 02:52:27,040
this is a an atomic process so it'll the

3474
02:52:31,510 --> 02:52:29,680
surface roughness is is independent of

3475
02:52:33,830 --> 02:52:31,520
the force that gets applied well but i'm

3476
02:52:39,750 --> 02:52:33,840
thinking

3477
02:52:40,950 --> 02:52:39,760
impinging the concavity

3478
02:52:43,190 --> 02:52:40,960
so that

3479
02:52:44,950 --> 02:52:43,200
there is uh

3480
02:52:47,349 --> 02:52:44,960
you know

3481
02:52:49,670 --> 02:52:47,359
the push isn't all

3482
02:52:51,910 --> 02:52:49,680
normal oh yeah so you know everything on

3483
02:52:53,429 --> 02:52:51,920
an atomic scale looks the same so it

3484
02:52:55,590 --> 02:52:53,439
doesn't um

3485
02:52:57,190 --> 02:52:55,600
you'll when you have unless you bounce

3486
02:52:58,230 --> 02:52:57,200
off you get you got momentum in this way

3487
02:53:00,710 --> 02:52:58,240
and that momentum is going to get

3488
02:53:02,150 --> 02:53:00,720

stopped and so it'll push it back

3489
02:53:04,469 --> 02:53:02,160
you get some sputtered products but

3490
02:53:06,710 --> 02:53:04,479
those come off at such a low velocity it

3491
02:53:08,230 --> 02:53:06,720
won't it would help you but

3492
02:53:13,030 --> 02:53:08,240
it's negligible

3493
02:53:19,030 --> 02:53:14,870
i think it deserves some

3494
02:53:23,590 --> 02:53:21,269
all right any other questions

3495
02:53:28,790 --> 02:53:23,600
nobody online okay all right thank you

3496
02:53:31,750 --> 02:53:30,550
all right so at this point first of all

3497
02:53:34,230 --> 02:53:31,760
i'd like to compliment all the

3498
02:53:36,710 --> 02:53:34,240
presenters on being

3499
02:53:37,910 --> 02:53:36,720
spot on time um

3500
02:53:40,150 --> 02:53:37,920
and probably shouldn't said that till

3501
02:53:41,590 --> 02:53:40,160
we're done but uh

3502
02:53:43,910 --> 02:53:41,600
um but we're gonna take we've got a

3503
02:53:44,790 --> 02:53:43,920
break here for 15 minutes i'm sorry 10

3504
02:53:46,950 --> 02:53:44,800
minutes

3505
02:53:49,910 --> 02:53:46,960
so back at 3 50

3506
02:53:51,349 --> 02:53:49,920
um and we'll have the uh the final final

3507
02:54:32,870 --> 02:53:51,359
four presentations and then the

3508
02:55:07,349 --> 02:54:34,550
that was like two seconds it's like i

3509
02:55:07,359 --> 02:55:43,269
where are you

3510
02:55:43,279 --> 02:56:11,990
okay

3511
02:56:12,000 --> 02:57:32,630
right

3512
02:57:32,640 --> 02:57:53,110
oh

3513
02:57:53,120 --> 02:58:08,790

materials

3514
02:58:08,800 --> 02:58:45,349
now