1
00:00:05,749 --> 00:00:04,150
nasa's jet propulsion laboratory

2
00:00:08,390 --> 00:00:05,759
presents

3
00:00:10,470 --> 00:00:08,400
the von carmen lecture a series of talks

4
00:00:13,749 --> 00:00:10,480
by scientists and engineers who are

5
00:00:30,950 --> 00:00:13,759
exploring our planet our solar system

6
00:00:36,229 --> 00:00:33,350
hey good evening ladies and gentlemen

7
00:00:37,910 --> 00:00:36,239
how's everyone tonight

8
00:00:39,510 --> 00:00:37,920
thanks for coming to visit us we really

9
00:00:41,750 --> 00:00:39,520
appreciate your attendance

10
00:00:43,910 --> 00:00:41,760
so over the last 15 years a miniature

11
00:00:45,990 --> 00:00:43,920
revolution in space science has been

12
00:00:47,830 --> 00:00:46,000
underway cubesats

13
00:00:49,910 --> 00:00:47,840

first flown is educational tools the

14
00:00:51,830 --> 00:00:49,920
size of soup cans significant

15
00:00:54,310 --> 00:00:51,840
capabilities have now been developed to

16
00:00:56,470 --> 00:00:54,320
allow these nano spacecraft to travel to

17
00:00:59,029 --> 00:00:56,480
the moon pardon me asteroids and even

18
00:01:00,869 --> 00:00:59,039
mars tonight we'll talk about how nasa

19
00:01:03,189 --> 00:01:00,879
other companies and students are

20
00:01:04,630 --> 00:01:03,199
building and flying small spacecraft and

21
00:01:05,830 --> 00:01:04,640
what types of missions they're

22
00:01:07,670 --> 00:01:05,840
attempting

23
00:01:09,510 --> 00:01:07,680
tonight's guest is a mission architect

24
00:01:12,310 --> 00:01:09,520
at nasa's jet propulsion laboratory in

25
00:01:14,230 --> 00:01:12,320
the planetary mission concept group his

26
00:01:16,789 --> 00:01:14,240
research his current research focuses on

27
00:01:19,109 --> 00:01:16,799
deep space nano spacecraft science and

28
00:01:21,270 --> 00:01:19,119
implementation he is also the principal

29
00:01:23,830 --> 00:01:21,280
investigator on the inspire deep space

30
00:01:26,630 --> 00:01:23,840
cubesats and chief engineer of marco the

31
00:01:28,710 --> 00:01:26,640
first nano spacecraft headed to mars

32
00:01:30,950 --> 00:01:28,720
he also supports robotic and scientific

33
00:01:33,510 --> 00:01:30,960
research in the arctic including a novel

34
00:01:35,190 --> 00:01:33,520
buoyant rover which explores underneath

35
00:01:37,030 --> 00:01:35,200
lake and sea ice

36
00:01:38,789 --> 00:01:37,040
before starting at jpl he served as a

37
00:01:41,749 --> 00:01:38,799
postdoctoral fellow at the japanese

38
00:01:43,749 --> 00:01:41,759

aerospace exploration agency jaxa as a

39
00:01:46,630 --> 00:01:43,759
member of the hayabusa astrodynamics

40
00:01:48,630 --> 00:01:46,640
team and an ikaros mission team member

41
00:01:50,630 --> 00:01:48,640
prior to jaxa he was a postdoctoral

42
00:01:52,950 --> 00:01:50,640
fellow and chief engineer at of the

43
00:01:54,950 --> 00:01:52,960
university of michigan's radio aurora

44
00:01:56,789 --> 00:01:54,960
explorer cubesat project

45
00:01:59,190 --> 00:01:56,799
he received his phd in aerospace

46
00:02:01,350 --> 00:01:59,200
engineering master's degrees in space

47
00:02:03,109 --> 00:02:01,360
systems and aerospace engineering and

48
00:02:04,630 --> 00:02:03,119
bachelor's degrees in aerospace and

49
00:02:06,230 --> 00:02:04,640
electrical engineering all from the

50
00:02:09,029 --> 00:02:06,240
university of michigan

51
00:02:10,710 --> 00:02:09,039
and all that other time he has he scuba

52
00:02:12,869 --> 00:02:10,720
dives as part of the california science

53
00:02:15,430 --> 00:02:12,879
center aquarium dive team

54
00:02:17,910 --> 00:02:15,440
is an adjunct professor at arizona state

55
00:02:20,710 --> 00:02:17,920
university works at space camp in south

56
00:02:23,350 --> 00:02:20,720
korea each summer is an instrument-rated

57
00:02:25,750 --> 00:02:23,360
private pilot and finished the ironman

58
00:02:27,589 --> 00:02:25,760
lake tahoe in 2015.

59
00:02:29,110 --> 00:02:27,599
yeah he's not busy at all

60
00:02:39,830 --> 00:02:29,120
ladies and gentlemen please help me

61
00:02:43,830 --> 00:02:41,509
thank you mark and thank you all for

62
00:02:45,910 --> 00:02:43,840
coming tonight to jpl

63
00:02:47,910 --> 00:02:45,920

here at jpl we explore the furthest

64
00:02:49,589 --> 00:02:47,920
ranges of the solar system and yet we

65
00:02:51,509 --> 00:02:49,599
also support activities right here on

66
00:02:53,589 --> 00:02:51,519
earth near earth as well

67
00:02:55,350 --> 00:02:53,599
in fact just above our heads right now

68
00:02:57,670 --> 00:02:55,360
we have the space station overflying the

69
00:03:00,390 --> 00:02:57,680
earth and providing a unique observation

70
00:03:02,710 --> 00:03:00,400
capability one that is unmatched in

71
00:03:04,470 --> 00:03:02,720
terms of its size and its breadth

72
00:03:05,910 --> 00:03:04,480
yet did you know on board the space

73
00:03:07,830 --> 00:03:05,920
station itself

74
00:03:09,990 --> 00:03:07,840
there's actually a spacecraft launcher

75
00:03:12,390 --> 00:03:10,000
on board just on the side of the cable

76
00:03:13,910 --> 00:03:12,400
module provided by the japanese

77
00:03:16,229 --> 00:03:13,920
and if we take a closer look at this

78
00:03:18,630 --> 00:03:16,239
particular launch on here it's not just

79
00:03:20,710 --> 00:03:18,640
one spacecraft coming out it's actually

80
00:03:22,710 --> 00:03:20,720
two small spacecraft

81
00:03:24,229 --> 00:03:22,720
now the small spacecraft that are on

82
00:03:26,550 --> 00:03:24,239
here are really the subject of tonight's

83
00:03:28,710 --> 00:03:26,560
talk and really opening up how we're

84
00:03:30,710 --> 00:03:28,720
exploring the solar system

85
00:03:32,630 --> 00:03:30,720
when we take a closer look at these they

86
00:03:35,110 --> 00:03:32,640
really are quite small

87
00:03:37,270 --> 00:03:35,120
only about 30 centimeters long and about

88
00:03:39,750 --> 00:03:37,280

10 centimeters wide

89
00:03:41,670 --> 00:03:39,760
and this is one of the bigger ones

90
00:03:43,990 --> 00:03:41,680
when you open these up however they

91
00:03:45,830 --> 00:03:44,000
really do expand everything from solar

92
00:03:47,990 --> 00:03:45,840
rays to the up

93
00:03:49,910 --> 00:03:48,000
a telescope on the front end

94
00:03:51,190 --> 00:03:49,920
solar panels and an antenna to talk back

95
00:03:52,789 --> 00:03:51,200
to earth

96
00:03:54,309 --> 00:03:52,799
so every one of the large spacecraft you

97
00:03:56,470 --> 00:03:54,319
see around here are made up of the same

98
00:03:58,070 --> 00:03:56,480
components that we have right here

99
00:03:58,869 --> 00:03:58,080
only in this case we don't launch just

100
00:04:00,789 --> 00:03:58,879
one

101
00:04:02,470 --> 00:04:00,799
but 28 different satellites launched

102
00:04:03,750 --> 00:04:02,480
together to make a constellation around

103
00:04:05,670 --> 00:04:03,760
the earth

104
00:04:08,149 --> 00:04:05,680
far cheaper and far more focused than

105
00:04:09,509 --> 00:04:08,159
what we've done before

106
00:04:10,949 --> 00:04:09,519
when we start digging into some of the

107
00:04:13,190 --> 00:04:10,959
nomenclatures some of the names that we

108
00:04:15,270 --> 00:04:13,200
give some of these different spacecraft

109
00:04:17,189 --> 00:04:15,280
we like to talk about them in terms of

110
00:04:20,550 --> 00:04:17,199
units or u's

111
00:04:22,710 --> 00:04:20,560
a 1u is 10 centimeters on the side 10 by

112
00:04:25,990 --> 00:04:22,720
10 by 10 centimeters and to give you a

113
00:04:27,430 --> 00:04:26,000

sense of scale this is a 1u spacecraft

114
00:04:29,590 --> 00:04:27,440
and it's actually double the size of

115
00:04:31,670 --> 00:04:29,600
some of them that have flown

116
00:04:34,230 --> 00:04:31,680
next to that we have two units about 20

117
00:04:36,710 --> 00:04:34,240
centimeters tall or three units a full

118
00:04:38,150 --> 00:04:36,720
30 centimeters in height but still 10 by

119
00:04:42,550 --> 00:04:38,160
10 on there

120
00:04:44,469 --> 00:04:42,560
in comparison juno is 20 meters wide

121
00:04:46,790 --> 00:04:44,479
and in a little bit more direct case we

122
00:04:49,749 --> 00:04:46,800
talk about soup cans loafs of bread and

123
00:04:53,030 --> 00:04:51,430
this really is about the same size on

124
00:04:54,870 --> 00:04:53,040
here

125
00:04:55,990 --> 00:04:54,880
so these cubesats

126
00:04:57,510 --> 00:04:56,000
look like they don't have a lot of

127
00:04:59,670 --> 00:04:57,520
capability

128
00:05:02,550 --> 00:04:59,680
but over the last years we've really

129
00:05:04,150 --> 00:05:02,560
been developing what they're able to do

130
00:05:05,590 --> 00:05:04,160
now not only are they small but they're

131
00:05:07,189 --> 00:05:05,600
pretty lightweight

132
00:05:09,350 --> 00:05:07,199
so many of the spacecraft that we have

133
00:05:13,029 --> 00:05:09,360
exploring the solar system range from

134
00:05:14,230 --> 00:05:13,039
about 500 kilograms up to over 10 000

135
00:05:16,070 --> 00:05:14,240
kilograms

136
00:05:17,749 --> 00:05:16,080
these are incredibly large spacecraft

137
00:05:20,310 --> 00:05:17,759
and take dedicated launch vehicles to

138
00:05:22,230 --> 00:05:20,320

reach orbit and to explore further

139
00:05:23,590 --> 00:05:22,240
there's a whole class of vehicles though

140
00:05:25,909 --> 00:05:23,600
that are a little bit smaller and we do

141
00:05:27,909 --> 00:05:25,919
call these small spacecraft definitions

142
00:05:30,390 --> 00:05:27,919
vary but somewhere in the 500 kilogram

143
00:05:31,749 --> 00:05:30,400
range and down we have small spacecraft

144
00:05:33,830 --> 00:05:31,759
and within there

145
00:05:35,430 --> 00:05:33,840
picosatellites nanosatellites and

146
00:05:37,110 --> 00:05:35,440
microsatellites

147
00:05:39,350 --> 00:05:37,120
and everybody somewhat comes up with

148
00:05:41,830 --> 00:05:39,360
different definitions here

149
00:05:43,830 --> 00:05:41,840
cubesats fit within this picosatellite

150
00:05:45,749 --> 00:05:43,840
to nanosatellite category on here so

151
00:05:47,270 --> 00:05:45,759
you'll often hear me say nanospacecraft

152
00:05:50,710 --> 00:05:47,280
or nanosatellite

153
00:05:52,310 --> 00:05:50,720
and cubesat along the way as well

154
00:05:53,990 --> 00:05:52,320
but not only are these things small but

155
00:05:55,430 --> 00:05:54,000
they actually enable us to launch many

156
00:05:58,310 --> 00:05:55,440
more of them

157
00:06:00,150 --> 00:05:58,320
so since the year 2000s we've had an

158
00:06:01,830 --> 00:06:00,160
explosion in the number of spacecraft

159
00:06:03,590 --> 00:06:01,840
that have actually been launching

160
00:06:05,830 --> 00:06:03,600
with cubesats alone you can see they

161
00:06:08,150 --> 00:06:05,840
started small at the first invention and

162
00:06:09,430 --> 00:06:08,160
have just exponentially been climbing

163
00:06:11,510 --> 00:06:09,440

in terms of the number of launch

164
00:06:13,990 --> 00:06:11,520
capability launches that we've had and

165
00:06:15,830 --> 00:06:14,000
cubesats deployed on orbit

166
00:06:17,909 --> 00:06:15,840
and it's not only one type of

167
00:06:19,510 --> 00:06:17,919
institution on there but everything from

168
00:06:20,469 --> 00:06:19,520
universities which really developed this

169
00:06:23,430 --> 00:06:20,479
standard

170
00:06:24,950 --> 00:06:23,440
to the military civil and nasa as well

171
00:06:26,230 --> 00:06:24,960
as commercial entities are actually

172
00:06:27,830 --> 00:06:26,240
large launching cubesats and

173
00:06:30,230 --> 00:06:27,840
accomplishing important missions around

174
00:06:32,710 --> 00:06:30,240
this world and now further out from

175
00:06:36,390 --> 00:06:34,710
now the cubesat itself goes back to

176
00:06:38,870 --> 00:06:36,400
these two individuals professor bob

177
00:06:40,950 --> 00:06:38,880
twiggs previously at stanford university

178
00:06:42,950 --> 00:06:40,960
and professor jordy prixswary at cal

179
00:06:44,629 --> 00:06:42,960
poly san luis obispo

180
00:06:46,710 --> 00:06:44,639
they had a fundamental thought near the

181
00:06:49,270 --> 00:06:46,720
end of the 1990s on here

182
00:06:51,670 --> 00:06:49,280
they recognized two important facts

183
00:06:53,189 --> 00:06:51,680
first of all they recognize

184
00:06:54,629 --> 00:06:53,199
that everybody is carrying a satellite

185
00:06:56,629 --> 00:06:54,639
in their pocket

186
00:06:57,590 --> 00:06:56,639
if you look at your typical cell phone a

187
00:06:59,350 --> 00:06:57,600
lot of electronics have been

188
00:07:01,189 --> 00:06:59,360

miniaturized down from the large boxes

189
00:07:02,790 --> 00:07:01,199
of the 1980s to something that we carry

190
00:07:04,230 --> 00:07:02,800
around every day

191
00:07:05,430 --> 00:07:04,240
we have a payload on board in your

192
00:07:07,110 --> 00:07:05,440
camera

193
00:07:08,870 --> 00:07:07,120
power storage in terms of the batteries

194
00:07:10,309 --> 00:07:08,880
that are there we even have a way to

195
00:07:11,749 --> 00:07:10,319
charge those batteries with a connector

196
00:07:13,990 --> 00:07:11,759
on the back end

197
00:07:16,870 --> 00:07:14,000
we communicate whether it be text or

198
00:07:18,390 --> 00:07:16,880
wireless wi-fi or cell phone

199
00:07:20,469 --> 00:07:18,400
and there's a massive computer on the

200
00:07:22,070 --> 00:07:20,479
inside that is now just the size of your

201
00:07:23,510 --> 00:07:22,080
thumb

202
00:07:24,870 --> 00:07:23,520
some way they can actually determine

203
00:07:26,469 --> 00:07:24,880
your attitude whether you use it for a

204
00:07:28,629 --> 00:07:26,479
compass or even your position when you

205
00:07:30,390 --> 00:07:28,639
use the gps in it to determine where you

206
00:07:32,230 --> 00:07:30,400
are and drive down the street

207
00:07:33,110 --> 00:07:32,240
so all of this capability is now in your

208
00:07:34,230 --> 00:07:33,120
pocket

209
00:07:37,189 --> 00:07:34,240
imagine what we can do with that

210
00:07:40,070 --> 00:07:37,199
capability when we put it in spacecraft

211
00:07:41,510 --> 00:07:40,080
they also recognize the second thing

212
00:07:44,390 --> 00:07:41,520
no one wants to launch something that's

213
00:07:46,870 --> 00:07:44,400

uncertain but if we can define a box

214
00:07:48,870 --> 00:07:46,880
and isolate what's inside that box from

215
00:07:51,029 --> 00:07:48,880
say a bigger payload on there maybe

216
00:07:52,950 --> 00:07:51,039
they'll let us carry it along the way

217
00:07:55,270 --> 00:07:52,960
in fact many large rockets actually

218
00:07:57,350 --> 00:07:55,280
carry ballast with them they balance out

219
00:07:59,350 --> 00:07:57,360
the spacecraft on there that's riding on

220
00:08:00,469 --> 00:07:59,360
top and this ballast is little more than

221
00:08:03,670 --> 00:08:00,479
dead weight

222
00:08:05,749 --> 00:08:03,680
intelligent let's do something with that

223
00:08:07,110 --> 00:08:05,759
dead weight along the way

224
00:08:10,629 --> 00:08:07,120
to be able to do that they came up with

225
00:08:12,629 --> 00:08:10,639
a dispenser called a pea pod a poly

226
00:08:15,029 --> 00:08:12,639
poly pico satellite orbital deployer on

227
00:08:17,189 --> 00:08:15,039
here that would contain anything inside

228
00:08:19,189 --> 00:08:17,199
there and isolate it from that larger

229
00:08:20,950 --> 00:08:19,199
vehicle it might ride up with

230
00:08:22,230 --> 00:08:20,960
so we made a standard bolt pattern so

231
00:08:23,670 --> 00:08:22,240
you can put it on any number of

232
00:08:25,350 --> 00:08:23,680
different rockets

233
00:08:27,189 --> 00:08:25,360
we made it so that the satellite inside

234
00:08:29,189 --> 00:08:27,199
did not turn on until deployment again

235
00:08:30,790 --> 00:08:29,199
keeping it totally isolated

236
00:08:32,469 --> 00:08:30,800
and we made a very easy way for it to

237
00:08:34,310 --> 00:08:32,479
get away from that bigger rocket just by

238
00:08:35,509 --> 00:08:34,320

pushing it out like a spring really it's

239
00:08:37,829 --> 00:08:35,519
a jack in the box except we have a

240
00:08:39,269 --> 00:08:37,839
satellite on the inside

241
00:08:41,509 --> 00:08:39,279
this simple method along with the

242
00:08:43,670 --> 00:08:41,519
electronics miniaturization opened up

243
00:08:45,590 --> 00:08:43,680
the launch market and made these small

244
00:08:48,070 --> 00:08:45,600
satellites actually able to get to orbit

245
00:08:50,150 --> 00:08:48,080
in a standard way only by following a

246
00:08:53,030 --> 00:08:50,160
six-page specification

247
00:08:54,949 --> 00:08:53,040
very little paperwork along the way

248
00:08:56,470 --> 00:08:54,959
now ula is one of the large launch

249
00:08:57,590 --> 00:08:56,480
providers that's out there united launch

250
00:08:59,190 --> 00:08:57,600
alliance

251
00:09:00,790 --> 00:08:59,200
and they recently published a

252
00:09:02,230 --> 00:09:00,800
specification on what happens in the

253
00:09:04,389 --> 00:09:02,240
cubesat mission

254
00:09:05,829 --> 00:09:04,399
you have a large rocket that's launching

255
00:09:07,829 --> 00:09:05,839
up there and it deploys a primary

256
00:09:09,829 --> 00:09:07,839
payload maybe it's a telescope or an

257
00:09:12,310 --> 00:09:09,839
earth observer along the way

258
00:09:13,590 --> 00:09:12,320
once that's deployed these p-pods

259
00:09:15,269 --> 00:09:13,600
actually spring

260
00:09:17,590 --> 00:09:15,279
forward and push out the small

261
00:09:19,829 --> 00:09:17,600
satellites or cubesats that are in here

262
00:09:21,509 --> 00:09:19,839
each cubesat performs a mission around

263
00:09:23,190 --> 00:09:21,519

the earth and as we were talking about

264
00:09:25,350 --> 00:09:23,200
these one use 10 centimeters by 10

265
00:09:27,350 --> 00:09:25,360
centimeters by 10 centimeters in size

266
00:09:30,150 --> 00:09:27,360
come out to be very very small

267
00:09:33,670 --> 00:09:30,160
and to date ula has actually launched 55

268
00:09:36,310 --> 00:09:33,680
individual small cubesats on board

269
00:09:38,389 --> 00:09:36,320
overall we've launched over 400 cubesats

270
00:09:40,870 --> 00:09:38,399
in the last 15 years each of which is

271
00:09:43,430 --> 00:09:40,880
performing a different mission on there

272
00:09:45,670 --> 00:09:43,440
so what is a cubesat a cubesat is really

273
00:09:47,990 --> 00:09:45,680
a containerized payload

274
00:09:49,910 --> 00:09:48,000
that is conforming to this small simple

275
00:09:51,269 --> 00:09:49,920
standard and this standard has been

276
00:09:53,190 --> 00:09:51,279
pre-approved by all these different

277
00:09:54,710 --> 00:09:53,200
launch vehicles on there as long as you

278
00:09:56,310 --> 00:09:54,720
stay within the standard you can launch

279
00:09:58,230 --> 00:09:56,320
virtually anything

280
00:09:59,509 --> 00:09:58,240
if you start to violate the standard

281
00:10:03,350 --> 00:09:59,519
then you're going to get into the realm

282
00:10:05,509 --> 00:10:03,360
of expense risk or reduce mission

283
00:10:06,790 --> 00:10:05,519
the properties of the cubesats are worth

284
00:10:08,550 --> 00:10:06,800
talking about on here because the

285
00:10:10,949 --> 00:10:08,560
cubesat is only a specification within

286
00:10:12,949 --> 00:10:10,959
this realm of small spacecraft

287
00:10:14,949 --> 00:10:12,959
most cubesats that you see are around

288
00:10:16,710 --> 00:10:14,959

the range of nanospacecraft here

289
00:10:18,630 --> 00:10:16,720
adhering to this cubesat spec and you

290
00:10:21,430 --> 00:10:18,640
can download it yourself it's open

291
00:10:23,030 --> 00:10:21,440
source and widely distributed

292
00:10:24,550 --> 00:10:23,040
they generally have a very focused

293
00:10:26,389 --> 00:10:24,560
mission objective

294
00:10:27,910 --> 00:10:26,399
many spacecraft we have around the earth

295
00:10:29,750 --> 00:10:27,920
are looking at all sorts of different

296
00:10:31,829 --> 00:10:29,760
sensor data returning returning great

297
00:10:34,069 --> 00:10:31,839
amounts of science a cubesat is

298
00:10:35,910 --> 00:10:34,079
typically looking for a single thing

299
00:10:38,550 --> 00:10:35,920
and in conjunction might

300
00:10:39,910 --> 00:10:38,560
create a large number a large amount of

301
00:10:42,230 --> 00:10:39,920
science measurements

302
00:10:44,230 --> 00:10:42,240
but in general it's got a very focused

303
00:10:46,790 --> 00:10:44,240
mission

304
00:10:49,030 --> 00:10:46,800
they're also generally low-cost and this

305
00:10:51,430 --> 00:10:49,040
is extremely attractive we can have

306
00:10:53,030 --> 00:10:51,440
university students heck we now have an

307
00:10:54,389 --> 00:10:53,040
elementary school that is making a

308
00:10:56,230 --> 00:10:54,399
cubesat that will be launched in the

309
00:10:57,829 --> 00:10:56,240
near future on here

310
00:10:59,110 --> 00:10:57,839
and yet at the same time the very fact

311
00:11:01,350 --> 00:10:59,120
that they're low-cost means that they

312
00:11:03,430 --> 00:11:01,360
are attractive to commercial folks to

313
00:11:05,590 --> 00:11:03,440

the military and to institutions such as

314
00:11:07,269 --> 00:11:05,600
jpl

315
00:11:09,990 --> 00:11:07,279
being low-cost it often means that we

316
00:11:11,350 --> 00:11:10,000
can actually accept increased risk

317
00:11:12,870 --> 00:11:11,360
now when we have a very large vehicle

318
00:11:14,630 --> 00:11:12,880
it's very expensive and you don't want

319
00:11:17,190 --> 00:11:14,640
to make more than one of them

320
00:11:19,110 --> 00:11:17,200
if you have something this low in cost

321
00:11:21,190 --> 00:11:19,120
then you can make more and if one fails

322
00:11:22,870 --> 00:11:21,200
you launch another one up there

323
00:11:24,230 --> 00:11:22,880
that is a massive improvement over what

324
00:11:25,590 --> 00:11:24,240
we've done before with our larger

325
00:11:28,230 --> 00:11:25,600
spacecraft

326
00:11:30,710 --> 00:11:28,240
but it does take some looking at with

327
00:11:32,230 --> 00:11:30,720
any mission you have a few trades that

328
00:11:33,829 --> 00:11:32,240
you have to accomplish

329
00:11:35,430 --> 00:11:33,839
you're often trading against the risk

330
00:11:37,590 --> 00:11:35,440
choices and the number of mission

331
00:11:39,430 --> 00:11:37,600
requirements that you have for a given

332
00:11:41,110 --> 00:11:39,440
cost number

333
00:11:43,110 --> 00:11:41,120
a lot of times

334
00:11:44,470 --> 00:11:43,120
scientists like to add requirements they

335
00:11:45,990 --> 00:11:44,480
want to look at one additional thing

336
00:11:46,870 --> 00:11:46,000
they want to add one more instrument on

337
00:11:48,550 --> 00:11:46,880
there

338
00:11:50,150 --> 00:11:48,560

and every time you start to add

339
00:11:53,350 --> 00:11:50,160
additional requirements

340
00:11:54,949 --> 00:11:53,360
it means that you go out of balance

341
00:11:56,550 --> 00:11:54,959
something needs to change in order for

342
00:11:57,990 --> 00:11:56,560
you to accomplish your mission given

343
00:11:59,910 --> 00:11:58,000
those additional requirements and with

344
00:12:01,670 --> 00:11:59,920
cubesats we typically accept additional

345
00:12:04,069 --> 00:12:01,680
risk along the way

346
00:12:05,590 --> 00:12:04,079
so we take this we add the risk and we

347
00:12:07,110 --> 00:12:05,600
actually can get back in balance on

348
00:12:08,949 --> 00:12:07,120
there but that's not the only thing that

349
00:12:11,590 --> 00:12:08,959
we can do

350
00:12:14,470 --> 00:12:11,600
oh this took a little while to make so

351
00:12:16,790 --> 00:12:14,480
we can also uh change the budget we can

352
00:12:17,829 --> 00:12:16,800
add money on there if we add the money

353
00:12:19,430 --> 00:12:17,839
maybe we don't have to add that

354
00:12:21,110 --> 00:12:19,440
additional risk and we can still stay in

355
00:12:22,230 --> 00:12:21,120
balance on there with the same amount of

356
00:12:24,389 --> 00:12:22,240
risk

357
00:12:26,310 --> 00:12:24,399
or we can go to the scientists

358
00:12:27,829 --> 00:12:26,320
and beg and plead and we can actually

359
00:12:30,470 --> 00:12:27,839
reduce the number of requirements that

360
00:12:32,150 --> 00:12:30,480
we have to bring us back into balance

361
00:12:34,470 --> 00:12:32,160
we do this with large emissions all the

362
00:12:36,470 --> 00:12:34,480
time but if we're coming in with a very

363
00:12:38,629 --> 00:12:36,480

small budget on there that means our

364
00:12:40,389 --> 00:12:38,639
mission requirements have to be very low

365
00:12:42,949 --> 00:12:40,399
and we have to accept more risk to

366
00:12:45,110 --> 00:12:42,959
maintain our balance

367
00:12:47,829 --> 00:12:45,120
back in 2003 some of the first cubesats

368
00:12:49,430 --> 00:12:47,839
were actually launched this is psi4 from

369
00:12:51,350 --> 00:12:49,440
university of tokyo

370
00:12:53,990 --> 00:12:51,360
actually 13 years on it is still

371
00:12:56,150 --> 00:12:54,000
returning images from orbit on there

372
00:12:57,829 --> 00:12:56,160
blowing away anybody's expectations the

373
00:12:59,990 --> 00:12:57,839
first thoughts were that we'd only have

374
00:13:02,949 --> 00:13:00,000
a few days on orbit

375
00:13:04,310 --> 00:13:02,959
and canx1 from utis up in canada

376
00:13:06,550 --> 00:13:04,320
they launched together with similar

377
00:13:08,790 --> 00:13:06,560
missions and similar capabilities but

378
00:13:11,750 --> 00:13:08,800
actually psi4 is still operating where

379
00:13:13,430 --> 00:13:11,760
canex1 failed early on

380
00:13:15,030 --> 00:13:13,440
that didn't study me these students that

381
00:13:17,509 --> 00:13:15,040
are up there and they have launched so

382
00:13:18,949 --> 00:13:17,519
many more cubesats since that time

383
00:13:20,790 --> 00:13:18,959
learning themselves increasing the

384
00:13:22,310 --> 00:13:20,800
capability of the lab and have had many

385
00:13:24,310 --> 00:13:22,320
additional successful missions since

386
00:13:27,590 --> 00:13:24,320
that point

387
00:13:28,870 --> 00:13:27,600
later on in the 2000s we had ames come

388
00:13:30,710 --> 00:13:28,880

through with a whole series of different

389
00:13:32,550 --> 00:13:30,720
spacecraft where they actually were

390
00:13:35,110 --> 00:13:32,560
looking at astrobiology everything from

391
00:13:37,590 --> 00:13:35,120
seeing how bacteria survive in low earth

392
00:13:39,509 --> 00:13:37,600
orbit to doing a controlled yeast growth

393
00:13:41,750 --> 00:13:39,519
yeast growth and actually looking at the

394
00:13:43,269 --> 00:13:41,760
survivability and viability of organics

395
00:13:45,910 --> 00:13:43,279
and each mission learned from the

396
00:13:47,350 --> 00:13:45,920
previous creating a very rapid cadence

397
00:13:49,750 --> 00:13:47,360
of scientific knowledge being brought

398
00:13:53,190 --> 00:13:49,760
forward

399
00:13:54,470 --> 00:13:53,200
late in 2008 2009 the national science

400
00:13:55,910 --> 00:13:54,480
foundation became involved in the

401
00:13:57,910 --> 00:13:55,920
cubesat movement

402
00:14:00,550 --> 00:13:57,920
and around that time they said we want

403
00:14:02,550 --> 00:14:00,560
to actually do scientific cubesats no

404
00:14:03,990 --> 00:14:02,560
more will students be the only ones to

405
00:14:06,629 --> 00:14:04,000
create these small vehicles and take

406
00:14:08,389 --> 00:14:06,639
advantage of the launch availability

407
00:14:09,910 --> 00:14:08,399
and this is a particular cubesat that is

408
00:14:11,509 --> 00:14:09,920
very close to my heart as i worked on it

409
00:14:13,670 --> 00:14:11,519
back at the university of michigan known

410
00:14:15,910 --> 00:14:13,680
as the radio aurora explorer that had a

411
00:14:17,990 --> 00:14:15,920
focused mission to look at and

412
00:14:19,509 --> 00:14:18,000
investigate these irregularities in the

413
00:14:21,350 --> 00:14:19,519

upper ionosphere

414
00:14:22,870 --> 00:14:21,360
by passing overhead and having a radar

415
00:14:25,750 --> 00:14:22,880
beam pass up through the irregularity

416
00:14:27,430 --> 00:14:25,760
and be collected by the small spacecraft

417
00:14:29,110 --> 00:14:27,440
too low for the other observers that we

418
00:14:30,790 --> 00:14:29,120
had up in the sky and too focused for

419
00:14:33,189 --> 00:14:30,800
them to really develop a dedicated

420
00:14:34,790 --> 00:14:33,199
mission to it the cubesat fit the bill

421
00:14:36,629 --> 00:14:34,800
and provided a number of scientific

422
00:14:38,710 --> 00:14:36,639
journals that were out there leading to

423
00:14:40,470 --> 00:14:38,720
terese jorgensen to actually say that

424
00:14:42,949 --> 00:14:40,480
this has convincingly proved that small

425
00:14:45,990 --> 00:14:42,959
spacecraft can provide high caliber

426
00:14:47,430 --> 00:14:46,000
measurements and scientific return

427
00:14:49,590 --> 00:14:47,440
now around that same time that the

428
00:14:51,750 --> 00:14:49,600
science value of cubesats was validated

429
00:14:54,389 --> 00:14:51,760
we also had nasa become more involved

430
00:14:56,310 --> 00:14:54,399
with the cubesat launch initiative

431
00:14:58,550 --> 00:14:56,320
this is actually where nasa will provide

432
00:14:59,829 --> 00:14:58,560
free launches to

433
00:15:01,110 --> 00:14:59,839
those coming from educational

434
00:15:03,430 --> 00:15:01,120
institutions

435
00:15:04,949 --> 00:15:03,440
government centers or just nasa centers

436
00:15:06,790 --> 00:15:04,959
overall

437
00:15:08,230 --> 00:15:06,800
it is if you adhere to certain

438
00:15:09,189 --> 00:15:08,240

requirements on there and if you go

439
00:15:10,790 --> 00:15:09,199
through a

440
00:15:13,030 --> 00:15:10,800
application and down select process

441
00:15:14,949 --> 00:15:13,040
along the way to date there's been over

442
00:15:16,870 --> 00:15:14,959
nine launches with many more scheduled

443
00:15:17,829 --> 00:15:16,880
in the near future and this free launch

444
00:15:20,310 --> 00:15:17,839
has brought down the cost of the

445
00:15:22,470 --> 00:15:20,320
cubesats even more either for the

446
00:15:24,069 --> 00:15:22,480
scientific return or for the students

447
00:15:25,670 --> 00:15:24,079
that are getting the educational benefit

448
00:15:26,870 --> 00:15:25,680
out of them

449
00:15:28,790 --> 00:15:26,880
so the launch

450
00:15:31,189 --> 00:15:28,800
program exploded at this point the

451
00:15:33,030 --> 00:15:31,199
falcon 9s from spacex were launching ula

452
00:15:35,750 --> 00:15:33,040
was launching cubesats on there we were

453
00:15:37,670 --> 00:15:35,760
going overseas to the the nepa in russia

454
00:15:39,350 --> 00:15:37,680
and many other people were also

455
00:15:41,430 --> 00:15:39,360
launching cubesats providing a boom in

456
00:15:43,269 --> 00:15:41,440
launch availability

457
00:15:44,230 --> 00:15:43,279
but the cubesats themselves continued to

458
00:15:45,990 --> 00:15:44,240
develop

459
00:15:48,310 --> 00:15:46,000
what started as simple one use that were

460
00:15:51,110 --> 00:15:48,320
only imagers on board have increased

461
00:15:53,110 --> 00:15:51,120
immensely in capability

462
00:15:54,790 --> 00:15:53,120
this is a recent cubesat that's being

463
00:15:57,030 --> 00:15:54,800

put together it's actually the innards

464
00:15:58,389 --> 00:15:57,040
down below as well as the outer outer

465
00:15:59,829 --> 00:15:58,399
shell built by a company here in

466
00:16:01,030 --> 00:15:59,839
southern california called tyvac

467
00:16:02,949 --> 00:16:01,040
industries

468
00:16:04,150 --> 00:16:02,959
now tyvek is actually going to have two

469
00:16:06,230 --> 00:16:04,160
cubesats

470
00:16:08,870 --> 00:16:06,240
launch independently

471
00:16:11,189 --> 00:16:08,880
find each other on orbit

472
00:16:12,389 --> 00:16:11,199
rendezvous in that same area then dock

473
00:16:15,030 --> 00:16:12,399
together

474
00:16:16,470 --> 00:16:15,040
separate again and do this repeatedly

475
00:16:17,749 --> 00:16:16,480
this is all in the size of a loaf of

476
00:16:19,910 --> 00:16:17,759
bread

477
00:16:21,110 --> 00:16:19,920
that can now maneuver around orbit and

478
00:16:22,710 --> 00:16:21,120
imagine what we can do with this

479
00:16:23,829 --> 00:16:22,720
capability on here

480
00:16:25,910 --> 00:16:23,839
in fact this is one of the test

481
00:16:27,829 --> 00:16:25,920
sequences that they have where the two

482
00:16:29,430 --> 00:16:27,839
satellites actually dock together and

483
00:16:30,949 --> 00:16:29,440
grasp each other

484
00:16:33,030 --> 00:16:30,959
and then these small mechanisms can

485
00:16:34,949 --> 00:16:33,040
actually release again and separate the

486
00:16:36,629 --> 00:16:34,959
two cubesats to the sign they're getting

487
00:16:38,629 --> 00:16:36,639
ready to launch just in the near future

488
00:16:42,470 --> 00:16:38,639

now

489
00:16:45,189 --> 00:16:42,480
actually doing that same or very similar

490
00:16:46,790 --> 00:16:45,199
capability in one and a half use only 15

491
00:16:48,389 --> 00:16:46,800
centimeters high

492
00:16:49,430 --> 00:16:48,399
i ran out of room to put all the

493
00:16:51,350 --> 00:16:49,440
different things that are in the

494
00:16:53,430 --> 00:16:51,360
spacecraft but it includes laser

495
00:16:55,829 --> 00:16:53,440
communications down to earth

496
00:16:58,389 --> 00:16:55,839
multiple cameras on board and a suite of

497
00:16:59,749 --> 00:16:58,399
different sensors a thruster system so

498
00:17:01,189 --> 00:16:59,759
they can actually maneuver around and

499
00:17:02,870 --> 00:17:01,199
orient themselves

500
00:17:05,270 --> 00:17:02,880
and it's all to really study optical

501
00:17:06,870 --> 00:17:05,280
communications and proximity operations

502
00:17:08,630 --> 00:17:06,880
for a low cost

503
00:17:10,870 --> 00:17:08,640
not necessarily so we can only do it on

504
00:17:12,230 --> 00:17:10,880
cubesats but so that we can take all

505
00:17:14,150 --> 00:17:12,240
this technology and use them on our

506
00:17:16,069 --> 00:17:14,160
larger vehicles as well

507
00:17:17,429 --> 00:17:16,079
bringing down the mass in any individual

508
00:17:19,429 --> 00:17:17,439
instrument means we can bring it down

509
00:17:22,230 --> 00:17:19,439
for every spacecraft that's out there

510
00:17:24,069 --> 00:17:22,240
increasing all of our capability

511
00:17:25,829 --> 00:17:24,079
these guys are launching one or two at a

512
00:17:28,150 --> 00:17:25,839
time and they have several launches per

513
00:17:29,830 --> 00:17:28,160

year but in the commercial sector

514
00:17:31,350 --> 00:17:29,840
there's a whole other type of revolution

515
00:17:33,110 --> 00:17:31,360
going on

516
00:17:35,430 --> 00:17:33,120
planet labs with the flock that you saw

517
00:17:37,190 --> 00:17:35,440
earlier is launching 28 cubesats at the

518
00:17:40,310 --> 00:17:37,200
time from the space station and have

519
00:17:41,990 --> 00:17:40,320
around 130 already on orbit with another

520
00:17:44,789 --> 00:17:42,000
28 sitting on the space station right

521
00:17:46,390 --> 00:17:44,799
now just waiting to deploy

522
00:17:47,909 --> 00:17:46,400
with these different spacecraft on here

523
00:17:49,830 --> 00:17:47,919
they're actually looking to do very

524
00:17:51,270 --> 00:17:49,840
rapid imaging of the earth

525
00:17:52,870 --> 00:17:51,280
and with this rapid imaging though the

526
00:17:54,870 --> 00:17:52,880
resolution is not as good as what you

527
00:17:57,190 --> 00:17:54,880
might see on a larger spacecraft they're

528
00:17:58,710 --> 00:17:57,200
able to get great temporal coverage

529
00:17:59,990 --> 00:17:58,720
imagine being able to look overhead at

530
00:18:01,270 --> 00:18:00,000
all of your competitors out there and

531
00:18:03,669 --> 00:18:01,280
see how many cars are in their parking

532
00:18:04,870 --> 00:18:03,679
lot at any point during the day you'll

533
00:18:06,150 --> 00:18:04,880
actually be able to determine how well

534
00:18:07,830 --> 00:18:06,160
they're doing their business and how

535
00:18:09,510 --> 00:18:07,840
well your marketing might do

536
00:18:11,270 --> 00:18:09,520
or how the agricultural fields are doing

537
00:18:12,710 --> 00:18:11,280
in any given area given storms that are

538
00:18:14,230 --> 00:18:12,720

passing overhead

539
00:18:15,830 --> 00:18:14,240
there's a whole wealth of knowledge that

540
00:18:17,430 --> 00:18:15,840
they're collecting and it is that

541
00:18:19,669 --> 00:18:17,440
knowledge and the data that actually

542
00:18:21,190 --> 00:18:19,679
drives their commercial success

543
00:18:22,630 --> 00:18:21,200
where the cubesats are the tool to get

544
00:18:23,990 --> 00:18:22,640
them there

545
00:18:25,909 --> 00:18:24,000
when you compare these against some of

546
00:18:27,669 --> 00:18:25,919
the larger vehicles that are out there

547
00:18:30,070 --> 00:18:27,679
worldview and landsat that provide many

548
00:18:31,830 --> 00:18:30,080
of the images that we use on google maps

549
00:18:34,390 --> 00:18:31,840
and other such programs are far larger

550
00:18:35,830 --> 00:18:34,400
around two to three thousand kilograms

551
00:18:37,830 --> 00:18:35,840
these cubesats weigh about five

552
00:18:39,270 --> 00:18:37,840
kilograms and we're launching all of

553
00:18:41,510 --> 00:18:39,280
them at the same time to get better

554
00:18:44,310 --> 00:18:41,520
coverage and really the resolution isn't

555
00:18:45,590 --> 00:18:44,320
bad when you're looking across there

556
00:18:47,909 --> 00:18:45,600
but these aren't the only commercial

557
00:18:50,230 --> 00:18:47,919
fellows that are out there in fact while

558
00:18:51,750 --> 00:18:50,240
ula and while spacex have often provided

559
00:18:53,590 --> 00:18:51,760
launch opportunities there's a whole

560
00:18:55,270 --> 00:18:53,600
market that has sprung up around just

561
00:18:57,029 --> 00:18:55,280
interfacing to the vehicle

562
00:18:58,150 --> 00:18:57,039
if you have 28 different spacecraft that

563
00:18:59,909 --> 00:18:58,160

are going to launch together you need

564
00:19:01,590 --> 00:18:59,919
someone dedicated to integrate those

565
00:19:03,110 --> 00:19:01,600
onto your launch vehicle and that's what

566
00:19:04,630 --> 00:19:03,120
space flight industries and several

567
00:19:05,750 --> 00:19:04,640
other companies have done

568
00:19:07,510 --> 00:19:05,760
that you can actually go to their

569
00:19:09,029 --> 00:19:07,520
website and get a quote what will it

570
00:19:11,750 --> 00:19:09,039
take for me to launch my spacecraft to

571
00:19:14,470 --> 00:19:11,760
orbit or beyond

572
00:19:15,590 --> 00:19:14,480
and beyond that there's a host of all

573
00:19:17,750 --> 00:19:15,600
different companies that are out there

574
00:19:19,669 --> 00:19:17,760
and this is only a very small selection

575
00:19:21,110 --> 00:19:19,679
offering cubesat components

576
00:19:22,789 --> 00:19:21,120
if you don't know how to build a cubesat

577
00:19:24,710 --> 00:19:22,799
you can buy the whole thing or you can

578
00:19:26,789 --> 00:19:24,720
buy parts of it you can develop parts in

579
00:19:28,630 --> 00:19:26,799
your lab and integrate them with others

580
00:19:30,789 --> 00:19:28,640
and here at jpl it's this community that

581
00:19:32,710 --> 00:19:30,799
we've partnered with in order to even go

582
00:19:33,990 --> 00:19:32,720
beyond the solar or beyond the planet

583
00:19:37,990 --> 00:19:34,000
earth

584
00:19:39,990 --> 00:19:38,000
expanded beyond what's in only a single

585
00:19:42,470 --> 00:19:40,000
one used spacecraft on here

586
00:19:45,430 --> 00:19:42,480
this is raincube raincube has a half

587
00:19:47,270 --> 00:19:45,440
meter ka band radar active radar that's

588
00:19:48,150 --> 00:19:47,280

on there that expands out once it's on

589
00:19:49,830 --> 00:19:48,160
orbit

590
00:19:51,590 --> 00:19:49,840
because a truism with cubesats is that

591
00:19:53,669 --> 00:19:51,600
you're only a box until you've deployed

592
00:19:56,230 --> 00:19:53,679
from that peapod and then you can expand

593
00:19:58,549 --> 00:19:56,240
into any shape that you actually need to

594
00:20:00,870 --> 00:19:58,559
with two different solar panels on board

595
00:20:01,990 --> 00:20:00,880
active attitude control to steer around

596
00:20:03,830 --> 00:20:02,000
and the

597
00:20:05,590 --> 00:20:03,840
radar system here we're looking at

598
00:20:07,590 --> 00:20:05,600
developing a new technology to look at

599
00:20:08,870 --> 00:20:07,600
the precipitation in the clouds and how

600
00:20:11,750 --> 00:20:08,880
that will affect the weather and other

601
00:20:13,190 --> 00:20:11,760
things here on earth

602
00:20:14,470 --> 00:20:13,200
now that we're able to perform science

603
00:20:16,390 --> 00:20:14,480
here on earth

604
00:20:17,830 --> 00:20:16,400
we all began to question

605
00:20:20,310 --> 00:20:17,840
how could we go throughout the solar

606
00:20:22,710 --> 00:20:20,320
system what else might we discover given

607
00:20:24,789 --> 00:20:22,720
the unique platform that we have

608
00:20:26,549 --> 00:20:24,799
we looked at heliophysics and found that

609
00:20:29,270 --> 00:20:26,559
we could build constellations of 50 or

610
00:20:31,750 --> 00:20:29,280
greater spacecraft to simultaneously map

611
00:20:33,190 --> 00:20:31,760
out the solar winds far away from earth

612
00:20:35,270 --> 00:20:33,200
and be able to better determine and

613
00:20:37,750 --> 00:20:35,280

better predict what happens when these

614
00:20:39,430 --> 00:20:37,760
coronal mass ejections or the

615
00:20:40,630 --> 00:20:39,440
the solar blasts actually come to earth

616
00:20:42,149 --> 00:20:40,640
itself

617
00:20:43,750 --> 00:20:42,159
we've looked at going to comets into

618
00:20:45,350 --> 00:20:43,760
areas that we would never dare send

619
00:20:47,750 --> 00:20:45,360
another larger spacecraft that was more

620
00:20:49,669 --> 00:20:47,760
expensive imagine going down into the

621
00:20:50,950 --> 00:20:49,679
plumes going down to see the comet

622
00:20:52,789 --> 00:20:50,960
surface on there in that dangerous

623
00:20:54,630 --> 00:20:52,799
environment and not worrying if you lost

624
00:20:57,669 --> 00:20:54,640
a couple spacecraft along the way send

625
00:20:59,270 --> 00:20:57,679
in the probes be just like star trek

626
00:21:00,630 --> 00:20:59,280
and we've also looked at novel science

627
00:21:02,390 --> 00:21:00,640
opportunities these are the areas that

628
00:21:04,149 --> 00:21:02,400
we've never been able to before discover

629
00:21:05,990 --> 00:21:04,159
because we didn't have the vantage point

630
00:21:08,070 --> 00:21:06,000
we weren't able to go by

631
00:21:09,190 --> 00:21:08,080
with a single orbiter going by

632
00:21:11,350 --> 00:21:09,200
pluto

633
00:21:13,590 --> 00:21:11,360
with the new horizons probe we had one

634
00:21:15,510 --> 00:21:13,600
glance across the surface

635
00:21:16,950 --> 00:21:15,520
if just before it had gone to pluto we

636
00:21:19,430 --> 00:21:16,960
had separated out multiple small

637
00:21:20,950 --> 00:21:19,440
spacecraft to simultaneously fly by

638
00:21:22,630 --> 00:21:20,960

imagine what we could discover across

639
00:21:24,230 --> 00:21:22,640
the entire surface there

640
00:21:26,149 --> 00:21:24,240
and that's just one body in our solar

641
00:21:27,350 --> 00:21:26,159
system

642
00:21:29,110 --> 00:21:27,360
now the problem with going throughout

643
00:21:31,830 --> 00:21:29,120
the solar system on here is that it's

644
00:21:33,350 --> 00:21:31,840
big and it is really really big

645
00:21:35,750 --> 00:21:33,360
i've defined things here in terms of

646
00:21:37,590 --> 00:21:35,760
astronomical units and an astronomical

647
00:21:41,669 --> 00:21:37,600
unit is the distance between the earth

648
00:21:44,710 --> 00:21:41,679
and the sun about 150 million kilometers

649
00:21:46,390 --> 00:21:44,720
venus is about 0.8 u out and earth sits

650
00:21:49,590 --> 00:21:46,400
around one a u

651
00:21:51,430 --> 00:21:49,600
when we're headed out to mars or beyond

652
00:21:53,190 --> 00:21:51,440
we often have to travel hundreds of

653
00:21:55,510 --> 00:21:53,200
millions of kilometers to get there and

654
00:21:56,710 --> 00:21:55,520
then we have to talk to this thing

655
00:21:57,909 --> 00:21:56,720
the problem with traveling throughout

656
00:22:00,070 --> 00:21:57,919
the solar system is that we're all

657
00:22:01,510 --> 00:22:00,080
reliant on power in some manner and

658
00:22:02,549 --> 00:22:01,520
generally the power is coming from the

659
00:22:04,070 --> 00:22:02,559
sun

660
00:22:06,149 --> 00:22:04,080
now the problem with power coming from

661
00:22:08,549 --> 00:22:06,159
the sun and light is that it actually

662
00:22:10,390 --> 00:22:08,559
degrades over distance and it's not only

663
00:22:12,390 --> 00:22:10,400

proportional just to the distance from

664
00:22:14,789 --> 00:22:12,400
the sun that you are is proportional to

665
00:22:16,390 --> 00:22:14,799
the distance squared so power drops off

666
00:22:17,750 --> 00:22:16,400
significantly as you head throughout the

667
00:22:20,070 --> 00:22:17,760
solar system

668
00:22:21,590 --> 00:22:20,080
if we were starting at earth we receive

669
00:22:23,430 --> 00:22:21,600
half the power from the sun once we

670
00:22:25,590 --> 00:22:23,440
actually get to mars

671
00:22:27,909 --> 00:22:25,600
now along the way the problem

672
00:22:29,270 --> 00:22:27,919
also occurs in communications

673
00:22:32,149 --> 00:22:29,280
where it gets harder and harder to

674
00:22:33,990 --> 00:22:32,159
communicate as we head farther out

675
00:22:36,310 --> 00:22:34,000
with that line of power we also get

676
00:22:37,669 --> 00:22:36,320
colder there is less thermal energy on

677
00:22:39,350 --> 00:22:37,679
our spacecraft and so we have to deal

678
00:22:40,870 --> 00:22:39,360
with all these challenges

679
00:22:42,710 --> 00:22:40,880
and none of the cubesats that i showed

680
00:22:44,710 --> 00:22:42,720
you before around the earth really have

681
00:22:46,710 --> 00:22:44,720
to deal with this change in power or the

682
00:22:48,870 --> 00:22:46,720
horrid communications the thermal net is

683
00:22:50,230 --> 00:22:48,880
changing on you all the time

684
00:22:52,230 --> 00:22:50,240
so before we could take any of these

685
00:22:54,310 --> 00:22:52,240
cubesats out there we needed to have a

686
00:22:55,990 --> 00:22:54,320
precursor we needed to show that we

687
00:22:57,669 --> 00:22:56,000
could actually develop the technology to

688
00:22:59,830 --> 00:22:57,679

have these miniaturized spacecraft head

689
00:23:02,470 --> 00:22:59,840
further into the solar system

690
00:23:04,070 --> 00:23:02,480
and that is what inspired it

691
00:23:05,990 --> 00:23:04,080
inspire or the interplanetary

692
00:23:07,270 --> 00:23:06,000
nanospacecraft pathfinder in a relevant

693
00:23:10,549 --> 00:23:07,280
environment

694
00:23:11,990 --> 00:23:10,559
it's still nasa we like our acronyms

695
00:23:13,750 --> 00:23:12,000
it was actually a dual spacecraft

696
00:23:16,390 --> 00:23:13,760
mission and it was to leave earth orbit

697
00:23:18,310 --> 00:23:16,400
and head out about 100 1.5 million

698
00:23:19,590 --> 00:23:18,320
kilometers away from earth it's an

699
00:23:21,350 --> 00:23:19,600
important number it's around the sun

700
00:23:23,990 --> 00:23:21,360
earth lagrange point and it's about four

701
00:23:25,830 --> 00:23:24,000
times farther out than the moon itself

702
00:23:28,230 --> 00:23:25,840
now these guys really were just to drift

703
00:23:29,590 --> 00:23:28,240
out to 1.5 million kilometers and keep

704
00:23:31,029 --> 00:23:29,600
going after that

705
00:23:33,110 --> 00:23:31,039
but they were to prove that we could

706
00:23:34,870 --> 00:23:33,120
communicate that we can navigate and

707
00:23:37,110 --> 00:23:34,880
then fundamentally we could survive with

708
00:23:38,710 --> 00:23:37,120
small spacecraft outside of low earth

709
00:23:40,630 --> 00:23:38,720
orbit and if we didn't have the

710
00:23:43,750 --> 00:23:40,640
technology to do so we would actually

711
00:23:46,549 --> 00:23:43,760
develop that technology along the way

712
00:23:49,110 --> 00:23:46,559
so inspire is currently developed excuse

713
00:23:50,710 --> 00:23:49,120

me and is sitting on the shelf and this

714
00:23:52,390 --> 00:23:50,720
is kind of what it looks like

715
00:23:53,990 --> 00:23:52,400
in a 3u container remember about the

716
00:23:56,390 --> 00:23:54,000
size of a loaf of bread

717
00:23:58,070 --> 00:23:56,400
it actually has x-band antennas that we

718
00:24:00,310 --> 00:23:58,080
can communicate back down to the deep

719
00:24:01,190 --> 00:24:00,320
space network and provide data back and

720
00:24:03,270 --> 00:24:01,200
forth

721
00:24:05,190 --> 00:24:03,280
we have a uhf link so we can actually

722
00:24:06,950 --> 00:24:05,200
talk in between the spacecraft and pass

723
00:24:08,390 --> 00:24:06,960
commands just as if we had been

724
00:24:10,390 --> 00:24:08,400
separated from a mother spacecraft

725
00:24:12,230 --> 00:24:10,400
further in the solar system

726
00:24:13,590 --> 00:24:12,240
we crammed a science payload on board

727
00:24:15,990 --> 00:24:13,600
called a magnetometer to look at the

728
00:24:17,990 --> 00:24:16,000
magnetic field and whereas cassini has a

729
00:24:19,750 --> 00:24:18,000
magnetometer sensor that is about the

730
00:24:21,510 --> 00:24:19,760
size of a shoe box

731
00:24:23,029 --> 00:24:21,520
this entire magnetometer is about the

732
00:24:24,789 --> 00:24:23,039
size of my fist

733
00:24:26,870 --> 00:24:24,799
with a sensor that pops out in a small

734
00:24:29,110 --> 00:24:26,880
five centimeter boom

735
00:24:31,350 --> 00:24:29,120
enabling us to look at the solar wind

736
00:24:33,110 --> 00:24:31,360
in the local earth environment

737
00:24:35,510 --> 00:24:33,120
we made an attitude control system and

738
00:24:37,750 --> 00:24:35,520

here we took a risk we actually made the

739
00:24:39,990 --> 00:24:37,760
attitude control system in a 3d printed

740
00:24:41,350 --> 00:24:40,000
part the entire tank

741
00:24:43,510 --> 00:24:41,360
all of the thrusters on there and the

742
00:24:45,350 --> 00:24:43,520
valving and the pipes that go between

743
00:24:46,950 --> 00:24:45,360
them are 3d printed

744
00:24:48,630 --> 00:24:46,960
in fact we found we had more volume

745
00:24:51,510 --> 00:24:48,640
along the way as we were developing our

746
00:24:53,269 --> 00:24:51,520
design and for 800 we actually doubled

747
00:24:56,230 --> 00:24:53,279
the tank size on there just by printing

748
00:24:57,830 --> 00:24:56,240
a new piece and putting it on board

749
00:24:59,190 --> 00:24:57,840
we have a star tracker we worked with a

750
00:25:01,269 --> 00:24:59,200
company to develop that was slightly

751
00:25:03,110 --> 00:25:01,279
smaller than what was otherwise offered

752
00:25:04,789 --> 00:25:03,120
and we had advanced computers that we'd

753
00:25:06,789 --> 00:25:04,799
actually be able to look at will we be

754
00:25:08,630 --> 00:25:06,799
able to survive and can't if we can't

755
00:25:11,590 --> 00:25:08,640
can we reset ourselves in an intelligent

756
00:25:13,590 --> 00:25:11,600
manner such that we can keep going even

757
00:25:15,750 --> 00:25:13,600
though we had commercial non-space

758
00:25:17,510 --> 00:25:15,760
hardened parts there

759
00:25:19,669 --> 00:25:17,520
we developed a system that actually had

760
00:25:21,750 --> 00:25:19,679
the batteries and expert and the solar

761
00:25:24,230 --> 00:25:21,760
panels on board for power and most

762
00:25:25,750 --> 00:25:24,240
importantly we developed the iris x-band

763
00:25:27,190 --> 00:25:25,760

transponder

764
00:25:28,390 --> 00:25:27,200
this is a communication system that

765
00:25:30,870 --> 00:25:28,400
allows us to navigate with the

766
00:25:33,510 --> 00:25:30,880
spacecraft and communicate from data

767
00:25:35,669 --> 00:25:33,520
rates down at 62.5 bits per second far

768
00:25:38,630 --> 00:25:35,679
lower than the early modems all the way

769
00:25:40,390 --> 00:25:38,640
up to 260 kilobit per second around the

770
00:25:41,590 --> 00:25:40,400
speed of some dsl lines that are out

771
00:25:43,190 --> 00:25:41,600
there

772
00:25:44,950 --> 00:25:43,200
so these spacecraft are ready for flight

773
00:25:46,870 --> 00:25:44,960
and are sitting on the shelf now in fact

774
00:25:50,070 --> 00:25:46,880
they had a launch opportunity along the

775
00:25:53,190 --> 00:25:50,080
way but in fact something else stole it

776
00:25:54,870 --> 00:25:53,200
and that was an unfortunate day

777
00:25:58,149 --> 00:25:54,880
several years ago

778
00:25:59,750 --> 00:25:58,159
we proposed uh here at jpl to send a

779
00:26:02,230 --> 00:25:59,760
lander to mars

780
00:26:04,230 --> 00:26:02,240
and this was the insight lander

781
00:26:06,710 --> 00:26:04,240
is currently now to launch in may of

782
00:26:08,630 --> 00:26:06,720
2018 for a landing in

783
00:26:10,710 --> 00:26:08,640
november and was the launch from

784
00:26:12,230 --> 00:26:10,720
vandenberg air force base

785
00:26:13,909 --> 00:26:12,240
i say a little bit of past tense here

786
00:26:15,430 --> 00:26:13,919
because as many of you might know the

787
00:26:17,269 --> 00:26:15,440
insight lander was actually supposed to

788
00:26:19,430 --> 00:26:17,279

launch a month and a half ago

789
00:26:22,630 --> 00:26:19,440
but had some delays with the seismometer

790
00:26:25,110 --> 00:26:22,640
and so it do the planetary alignment we

791
00:26:27,269 --> 00:26:25,120
have to wait 26 more months

792
00:26:28,950 --> 00:26:27,279
but when insight is actually ready to go

793
00:26:30,789 --> 00:26:28,960
it will launch from vandenberg in atlas

794
00:26:32,870 --> 00:26:30,799
5 401

795
00:26:34,630 --> 00:26:32,880
head out on a cruise stage and then go

796
00:26:36,470 --> 00:26:34,640
through that terrifying seven minutes

797
00:26:38,870 --> 00:26:36,480
down to the surface of mars

798
00:26:40,630 --> 00:26:38,880
entry descent and landing

799
00:26:42,070 --> 00:26:40,640
along the way

800
00:26:43,669 --> 00:26:42,080
it will be going through cruise about

801
00:26:45,110 --> 00:26:43,679
six and a half months

802
00:26:47,029 --> 00:26:45,120
as it's going out there but once it

803
00:26:48,950 --> 00:26:47,039
reaches the surface we're going to be

804
00:26:51,029 --> 00:26:48,960
looking at mars quakes

805
00:26:52,630 --> 00:26:51,039
we're actually going to be investigating

806
00:26:54,710 --> 00:26:52,640
and using the marsquakes themselves to

807
00:26:56,310 --> 00:26:54,720
ring the planet and look at the interior

808
00:26:58,470 --> 00:26:56,320
of the planet itself based on the

809
00:27:00,070 --> 00:26:58,480
seismometer as well as this mold that

810
00:27:01,350 --> 00:27:00,080
will go down several meters into the

811
00:27:03,990 --> 00:27:01,360
surface

812
00:27:05,350 --> 00:27:04,000
this is an incredibly cool mission here

813
00:27:07,669 --> 00:27:05,360

where we're looking at the internal to

814
00:27:09,830 --> 00:27:07,679
mars but we still have to get there and

815
00:27:11,510 --> 00:27:09,840
as you might know many mars programs in

816
00:27:13,350 --> 00:27:11,520
the past have not made it all the way to

817
00:27:14,870 --> 00:27:13,360
the surface

818
00:27:16,950 --> 00:27:14,880
in order to get around that fact we

819
00:27:18,789 --> 00:27:16,960
established a rule here at jpl we wanted

820
00:27:20,470 --> 00:27:18,799
to learn from any failures that we might

821
00:27:22,230 --> 00:27:20,480
have had in the past

822
00:27:23,990 --> 00:27:22,240
now this means that going through entry

823
00:27:26,549 --> 00:27:24,000
descent and landing we'd like to get

824
00:27:29,350 --> 00:27:26,559
that data back in real time to know did

825
00:27:30,789 --> 00:27:29,360
it survive and how well did it do

826
00:27:32,549 --> 00:27:30,799
right now we have a lot of different

827
00:27:35,669 --> 00:27:32,559
mars orbiters around the planet over

828
00:27:36,870 --> 00:27:35,679
there and typically we obser we collect

829
00:27:39,029 --> 00:27:36,880
all the data with these different

830
00:27:40,470 --> 00:27:39,039
orbiters in preparation for sending it

831
00:27:42,149 --> 00:27:40,480
back to earth

832
00:27:43,190 --> 00:27:42,159
for insight the mars reconnaissance

833
00:27:45,110 --> 00:27:43,200
orbiter would be collecting this

834
00:27:47,269 --> 00:27:45,120
information but it collects it in such a

835
00:27:48,870 --> 00:27:47,279
broadband that it actually has to store

836
00:27:50,870 --> 00:27:48,880
it immediately on board and can't send

837
00:27:52,789 --> 00:27:50,880
it back in real time

838
00:27:54,710 --> 00:27:52,799

on top of that because of orbital

839
00:27:56,950 --> 00:27:54,720
geometry it actually immediately after

840
00:27:58,310 --> 00:27:56,960
edl passes behind the planet

841
00:28:00,830 --> 00:27:58,320
and it's several hours before we'd

842
00:28:04,310 --> 00:28:00,840
actually know if insight's alive or

843
00:28:06,470 --> 00:28:04,320
dead to get around that fact

844
00:28:08,549 --> 00:28:06,480
jpl proposed a new mission

845
00:28:11,029 --> 00:28:08,559
and it's called marco

846
00:28:13,830 --> 00:28:11,039
it's mars cube one and this was two

847
00:28:15,750 --> 00:28:13,840
spacecraft to launch with insight on

848
00:28:17,669 --> 00:28:15,760
that atlas 401

849
00:28:18,950 --> 00:28:17,679
to actually separate only 90 minutes

850
00:28:21,590 --> 00:28:18,960
after launch

851
00:28:23,669 --> 00:28:21,600
and independently cruise to mars over

852
00:28:25,830 --> 00:28:23,679
that six and a half months

853
00:28:27,669 --> 00:28:25,840
to get there on just the right moment

854
00:28:29,510 --> 00:28:27,679
on just the right day

855
00:28:31,029 --> 00:28:29,520
in just the right spot

856
00:28:33,190 --> 00:28:31,039
so that we could collect the data from

857
00:28:35,269 --> 00:28:33,200
insight and relay it back in real time

858
00:28:36,870 --> 00:28:35,279
back to earth

859
00:28:38,789 --> 00:28:36,880
it has to carry out five different

860
00:28:40,389 --> 00:28:38,799
trajectory correction maneuvers

861
00:28:42,149 --> 00:28:40,399
because of planetary protection and the

862
00:28:44,470 --> 00:28:42,159
regulations when we launch we don't aim

863
00:28:46,070 --> 00:28:44,480

for mars in fact we offset from it

864
00:28:48,070 --> 00:28:46,080
so we have to somehow steer ourselves

865
00:28:49,510 --> 00:28:48,080
back to target to get there at just the

866
00:28:51,510 --> 00:28:49,520
right time

867
00:28:53,350 --> 00:28:51,520
and then on that time we're going to fly

868
00:28:56,950 --> 00:28:53,360
by the planet collect the data from

869
00:28:59,669 --> 00:28:56,960
insight and somehow send it 157 million

870
00:29:00,710 --> 00:28:59,679
kilometers back to earth

871
00:29:02,549 --> 00:29:00,720
now we proposed we're going to do this

872
00:29:05,110 --> 00:29:02,559
with a cubesat

873
00:29:07,190 --> 00:29:05,120
most cubesats operate about 300 to 800

874
00:29:09,510 --> 00:29:07,200
kilometers away from earth

875
00:29:11,510 --> 00:29:09,520
so we had a slight challenge here

876
00:29:13,590 --> 00:29:11,520
but the team from inspire and from

877
00:29:15,430 --> 00:29:13,600
others around the lab came together and

878
00:29:16,870 --> 00:29:15,440
we started to develop the marco

879
00:29:19,350 --> 00:29:16,880
spacecraft

880
00:29:20,870 --> 00:29:19,360
and this is a cad rendering of marco the

881
00:29:23,110 --> 00:29:20,880
engineering model is actually sitting

882
00:29:25,350 --> 00:29:23,120
over on the corner of the stage

883
00:29:26,950 --> 00:29:25,360
and that's actually called a 6u in size

884
00:29:28,630 --> 00:29:26,960
it's about the size of a sam's club

885
00:29:30,710 --> 00:29:28,640
cereal box

886
00:29:32,549 --> 00:29:30,720
it's so small actually that the pelican

887
00:29:34,070 --> 00:29:32,559
case that's next to it stores the

888
00:29:36,470 --> 00:29:34,080

spacecraft and you can take it as

889
00:29:38,310 --> 00:29:36,480
carry-on on board

890
00:29:39,830 --> 00:29:38,320
for a smaller spacecraft like the one

891
00:29:43,269 --> 00:29:39,840
use they fit underneath the seat in

892
00:29:46,789 --> 00:29:44,630
so marco needed to be a little bit

893
00:29:48,630 --> 00:29:46,799
larger it needed to take a lot of

894
00:29:50,630 --> 00:29:48,640
capability to get out to mars this is a

895
00:29:52,950 --> 00:29:50,640
significant challenge to get out there

896
00:29:54,630 --> 00:29:52,960
and to relay the data back again

897
00:29:56,630 --> 00:29:54,640
if we take off the front cover of marco

898
00:29:58,470 --> 00:29:56,640
and start to look at the inside

899
00:30:00,950 --> 00:29:58,480
you can see that it is somewhat of a

900
00:30:02,470 --> 00:30:00,960
complicated and more importantly a dense

901
00:30:04,070 --> 00:30:02,480
system

902
00:30:05,909 --> 00:30:04,080
we actually looked at the density of

903
00:30:07,590 --> 00:30:05,919
mark over some of the larger spacecraft

904
00:30:10,789 --> 00:30:07,600
and while most spacecraft have a density

905
00:30:13,190 --> 00:30:10,799
of about 0.7 with respect to water

906
00:30:14,950 --> 00:30:13,200
marco is double that we just crammed

907
00:30:16,310 --> 00:30:14,960
everything we could into this vehicle on

908
00:30:18,149 --> 00:30:16,320
here and it was all to carry out the

909
00:30:19,350 --> 00:30:18,159
mission at hand

910
00:30:21,190 --> 00:30:19,360
if you start at the top you see the

911
00:30:23,510 --> 00:30:21,200
solar rays this is how we are collecting

912
00:30:24,950 --> 00:30:23,520
power along the way and since they

913
00:30:27,669 --> 00:30:24,960

expand out they actually have to be

914
00:30:29,909 --> 00:30:27,679
deployed once we escape from the p-pod

915
00:30:31,830 --> 00:30:29,919
once we get out of that deployment box

916
00:30:33,350 --> 00:30:31,840
on the inside

917
00:30:34,950 --> 00:30:33,360
rocket

918
00:30:37,590 --> 00:30:34,960
we use that power to actually charge

919
00:30:39,510 --> 00:30:37,600
your batteries which are about halfway

920
00:30:42,870 --> 00:30:39,520
up on the right hand side

921
00:30:45,430 --> 00:30:42,880
i can actually point those out on here

922
00:30:47,029 --> 00:30:45,440
so the batteries are stored right here

923
00:30:48,789 --> 00:30:47,039
and all that power from the solar panels

924
00:30:51,269 --> 00:30:48,799
remember it cuts down to about half of

925
00:30:53,110 --> 00:30:51,279
what it was here at earth about 35 watts

926
00:30:55,510 --> 00:30:53,120
here at earth are collected by these and

927
00:30:58,310 --> 00:30:55,520
only 17 watts when you head out to mars

928
00:31:02,549 --> 00:31:00,630
about half the spacecraft is taken up by

929
00:31:04,470 --> 00:31:02,559
the propulsion system

930
00:31:06,230 --> 00:31:04,480
this is a cold gas propulsion system and

931
00:31:08,310 --> 00:31:06,240
by cold gas i mean it's really it's a

932
00:31:09,990 --> 00:31:08,320
refrigerant that's on board and it's a

933
00:31:12,549 --> 00:31:10,000
very special refrigerant that's in here

934
00:31:14,230 --> 00:31:12,559
kind of the same that was in inspire

935
00:31:15,990 --> 00:31:14,240
in this particular one it's known as

936
00:31:18,470 --> 00:31:16,000
r236fa

937
00:31:19,990 --> 00:31:18,480
or fe36 an fe stands for fire

938
00:31:22,549 --> 00:31:20,000

extinguishers

939
00:31:24,710 --> 00:31:22,559
it is actually the halon replacement

940
00:31:26,149 --> 00:31:24,720
fire extinguisher fluid that you'll find

941
00:31:28,149 --> 00:31:26,159
on many commercial fire extinguishers

942
00:31:30,230 --> 00:31:28,159
that are out there right now

943
00:31:31,909 --> 00:31:30,240
if you've seen the movie wall-e we are

944
00:31:35,590 --> 00:31:31,919
wall-e we are spraying a fire

945
00:31:38,549 --> 00:31:37,190
now at the top here to get all this

946
00:31:40,230 --> 00:31:38,559
propellant out we actually have eight

947
00:31:41,430 --> 00:31:40,240
different thrusters

948
00:31:43,669 --> 00:31:41,440
four of those thrusters are for

949
00:31:45,350 --> 00:31:43,679
trajectory control and actually steering

950
00:31:47,110 --> 00:31:45,360
us the right location

951
00:31:49,190 --> 00:31:47,120
four of them are actually for attitude

952
00:31:51,190 --> 00:31:49,200
orientation on there and they're to work

953
00:31:52,870 --> 00:31:51,200
in conjunction with our reaction wheels

954
00:31:56,230 --> 00:31:52,880
which are wheels that spin internally to

955
00:31:58,310 --> 00:31:56,240
the spacecraft and allow us to orient

956
00:31:59,990 --> 00:31:58,320
we also have that all-important bit

957
00:32:02,149 --> 00:32:00,000
remember we're a communications mission

958
00:32:04,310 --> 00:32:02,159
we're relaying data back to earth

959
00:32:05,669 --> 00:32:04,320
and the iris radio here and x-band

960
00:32:06,870 --> 00:32:05,679
transponders actually the second

961
00:32:08,470 --> 00:32:06,880
generation

962
00:32:10,070 --> 00:32:08,480
is the heart of the spacecraft and is

963
00:32:11,350 --> 00:32:10,080

collecting data at eight kilobit per

964
00:32:12,950 --> 00:32:11,360
second in

965
00:32:15,430 --> 00:32:12,960
and is sending that data out again over

966
00:32:17,669 --> 00:32:15,440
x-band at eight kilowatt per second out

967
00:32:20,149 --> 00:32:17,679
down to the madrid station the dsn and

968
00:32:21,669 --> 00:32:20,159
the 70-meter dish

969
00:32:24,310 --> 00:32:21,679
here we have a 30-centimeter tall

970
00:32:25,669 --> 00:32:24,320
spacecraft talking to a 70-meter dish

971
00:32:26,870 --> 00:32:25,679
i would love to get a picture of those

972
00:32:29,190 --> 00:32:26,880
two together on there but it hasn't

973
00:32:31,190 --> 00:32:29,200
happened quite yet

974
00:32:32,710 --> 00:32:31,200
we use amplifiers on here to actually

975
00:32:34,470 --> 00:32:32,720
bring in signal and raise that the

976
00:32:36,630 --> 00:32:34,480
signal level up when we're communicating

977
00:32:38,630 --> 00:32:36,640
to the spacecraft and we use a power

978
00:32:40,549 --> 00:32:38,640
amplifier to send the data out and back

979
00:32:42,470 --> 00:32:40,559
down to earth as well

980
00:32:43,990 --> 00:32:42,480
but we use some very unique antennas in

981
00:32:45,830 --> 00:32:44,000
order to get there

982
00:32:47,430 --> 00:32:45,840
so you notice there's no large parabolic

983
00:32:48,630 --> 00:32:47,440
disc that you might see on voyager or

984
00:32:49,669 --> 00:32:48,640
cassini

985
00:32:51,350 --> 00:32:49,679
we actually use something called a

986
00:32:53,669 --> 00:32:51,360
reflect array and it really helps when

987
00:32:55,509 --> 00:32:53,679
you're trying to fit in a narrow box

988
00:32:57,430 --> 00:32:55,519

where we have a small piece that sticks

989
00:32:58,789 --> 00:32:57,440
up on the top here called the active

990
00:33:00,149 --> 00:32:58,799
feed and this is where the signal is

991
00:33:02,549 --> 00:33:00,159
transmitted

992
00:33:03,509 --> 00:33:02,559
which bounces off this large deployable

993
00:33:07,430 --> 00:33:03,519
panel

994
00:33:09,509 --> 00:33:07,440
all that energy and sends it on a very

995
00:33:11,669 --> 00:33:09,519
narrow beam all that way back to earth

996
00:33:13,830 --> 00:33:11,679
in the 70 meter dish

997
00:33:15,909 --> 00:33:13,840
this thing has to fold in and fit on the

998
00:33:17,669 --> 00:33:15,919
top there because this doesn't exactly

999
00:33:19,990 --> 00:33:17,679
look like a box when we're trying to

1000
00:33:21,590 --> 00:33:20,000
deploy from the peapod

1001
00:33:23,830 --> 00:33:21,600
we have a whole stack of electronics

1002
00:33:25,590 --> 00:33:23,840
over here all of our avionics everything

1003
00:33:27,669 --> 00:33:25,600
from attitude control in those reaction

1004
00:33:29,430 --> 00:33:27,679
wheels a star tracker

1005
00:33:30,789 --> 00:33:29,440
inertial measurement unit basically the

1006
00:33:32,070 --> 00:33:30,799
pieces that you might have in your phone

1007
00:33:33,750 --> 00:33:32,080
are around there

1008
00:33:34,710 --> 00:33:33,760
the computer sits here in the power

1009
00:33:36,070 --> 00:33:34,720
system

1010
00:33:37,990 --> 00:33:36,080
all of the interface boards and the

1011
00:33:40,630 --> 00:33:38,000
harnessing that is throughout here and

1012
00:33:42,070 --> 00:33:40,640
we fit this all in the 60 container

1013
00:33:44,310 --> 00:33:42,080

now we actually ended up having a little

1014
00:33:45,909 --> 00:33:44,320
bit of extra volume so like any good

1015
00:33:48,149 --> 00:33:45,919
engineer or scientist we decided to fill

1016
00:33:50,470 --> 00:33:48,159
it and in this particular case we

1017
00:33:52,549 --> 00:33:50,480
actually put two cameras on board

1018
00:33:54,149 --> 00:33:52,559
one is a very wide field of view camera

1019
00:33:56,710 --> 00:33:54,159
that can capture both the deployment of

1020
00:33:58,389 --> 00:33:56,720
the of the reflector ray as well as look

1021
00:34:00,789 --> 00:33:58,399
back towards earth and see that small

1022
00:34:02,230 --> 00:34:00,799
little dot out there in the sky

1023
00:34:04,149 --> 00:34:02,240
the other one is a narrow field of view

1024
00:34:05,590 --> 00:34:04,159
camera looking downward towards mars so

1025
00:34:07,590 --> 00:34:05,600
that when we fly overhead with this

1026
00:34:09,750 --> 00:34:07,600
small cubesat we're actually able to

1027
00:34:11,270 --> 00:34:09,760
take images of another planet

1028
00:34:13,909 --> 00:34:11,280
just off of something that's sitting

1029
00:34:17,349 --> 00:34:15,190
we do need to collect that data from

1030
00:34:19,270 --> 00:34:17,359
insight and i mentioned that it's uhf so

1031
00:34:21,750 --> 00:34:19,280
on the back we have a deployable antenna

1032
00:34:23,030 --> 00:34:21,760
what's called a loop antenna on here

1033
00:34:25,750 --> 00:34:23,040
and we're collecting this data from

1034
00:34:27,349 --> 00:34:25,760
inside and then sending it on its way

1035
00:34:29,430 --> 00:34:27,359
so we have one antenna that has to point

1036
00:34:31,750 --> 00:34:29,440
at insight we have another antenna that

1037
00:34:33,829 --> 00:34:31,760
has to point towards earth on there and

1038
00:34:35,430 --> 00:34:33,839

we're passing overhead at high speed as

1039
00:34:37,270 --> 00:34:35,440
insight's going from

1040
00:34:39,030 --> 00:34:37,280
kilometers per second down to zero on

1041
00:34:40,470 --> 00:34:39,040
the surface itself

1042
00:34:42,950 --> 00:34:40,480
so there's a lot of pointing challenges

1043
00:34:45,270 --> 00:34:42,960
that we faced along the way

1044
00:34:47,270 --> 00:34:45,280
now also on the back is this bare area

1045
00:34:48,869 --> 00:34:47,280
at the bottom on here and this area is

1046
00:34:50,710 --> 00:34:48,879
actually filled with some stuff in fact

1047
00:34:52,389 --> 00:34:50,720
we came in lightweight compared to what

1048
00:34:53,909 --> 00:34:52,399
we were supposed to be

1049
00:34:55,829 --> 00:34:53,919
we told our launch provider that we'd be

1050
00:34:57,829 --> 00:34:55,839
about 14 kilograms and when we built

1051
00:34:59,270 --> 00:34:57,839
everything up and we assembled it all we

1052
00:35:00,470 --> 00:34:59,280
were too light we were sitting around 12

1053
00:35:05,670 --> 00:35:00,480
kilograms

1054
00:35:07,030 --> 00:35:05,680
sitting on the back of the spacecraft

1055
00:35:09,750 --> 00:35:07,040
that's one and a half of these that i

1056
00:35:11,349 --> 00:35:09,760
could carry along the way as well

1057
00:35:13,510 --> 00:35:11,359
so there's additional room for more

1058
00:35:16,310 --> 00:35:13,520
payload on here should we choose to find

1059
00:35:18,310 --> 00:35:16,320
things or fly things on future missions

1060
00:35:20,069 --> 00:35:18,320
for now though they act kind of like a

1061
00:35:22,069 --> 00:35:20,079
thermal battery and allow us to turn on

1062
00:35:23,430 --> 00:35:22,079
systems on here in a little bit easier

1063
00:35:25,829 --> 00:35:23,440

of a manner

1064
00:35:27,030 --> 00:35:25,839
it turns out when you head out

1065
00:35:29,190 --> 00:35:27,040
towards mars that you actually need a

1066
00:35:31,829 --> 00:35:29,200
pretty powerful radio and the propulsion

1067
00:35:33,910 --> 00:35:31,839
system uses a lot of power as well

1068
00:35:35,430 --> 00:35:33,920
any power that's going into a spacecraft

1069
00:35:37,829 --> 00:35:35,440
is going to turn into heat in some

1070
00:35:39,750 --> 00:35:37,839
manner and while many large spacecraft

1071
00:35:41,910 --> 00:35:39,760
had large radiators and a large surface

1072
00:35:44,230 --> 00:35:41,920
area to dissipate that heat in this

1073
00:35:46,230 --> 00:35:44,240
particular one we have about a hundred

1074
00:35:48,390 --> 00:35:46,240
times more he or a hundred times more

1075
00:35:51,430 --> 00:35:48,400
heat that we have to dissipate for its

1076
00:35:53,030 --> 00:35:51,440
area compared to something like juno

1077
00:35:54,870 --> 00:35:53,040
and so we have radiative panels on the

1078
00:35:57,270 --> 00:35:54,880
back that we're actually expelling heat

1079
00:36:00,870 --> 00:35:57,280
and we use that tungsten to slow down

1080
00:36:02,550 --> 00:36:00,880
how quickly we are warming up

1081
00:36:04,150 --> 00:36:02,560
cad models are nice but you guys want to

1082
00:36:06,390 --> 00:36:04,160
see the actual thing

1083
00:36:07,910 --> 00:36:06,400
so last july we assembled an engineering

1084
00:36:09,190 --> 00:36:07,920
model actually it's the one that's

1085
00:36:11,430 --> 00:36:09,200
sitting over there

1086
00:36:13,109 --> 00:36:11,440
in order to best test how we could put

1087
00:36:14,310 --> 00:36:13,119
this thing together

1088
00:36:15,750 --> 00:36:14,320

because you know they didn't exactly

1089
00:36:16,950 --> 00:36:15,760
give us a lot of time to build these

1090
00:36:19,190 --> 00:36:16,960
spacecraft

1091
00:36:20,950 --> 00:36:19,200
from concept to readiness for flight and

1092
00:36:23,829 --> 00:36:20,960
it would have been launched was less

1093
00:36:26,230 --> 00:36:23,839
than 14 months

1094
00:36:27,510 --> 00:36:26,240
this thing moved incredibly fast that

1095
00:36:29,349 --> 00:36:27,520
meant we needed to make a lot of

1096
00:36:31,750 --> 00:36:29,359
shortcuts along the way if you remember

1097
00:36:33,430 --> 00:36:31,760
that seesaw in there we threw out some

1098
00:36:35,750 --> 00:36:33,440
of the design analyses that are typical

1099
00:36:37,990 --> 00:36:35,760
for larger spacecraft and said we will

1100
00:36:39,990 --> 00:36:38,000
rapidly prototype these things whether

1101
00:36:42,069 --> 00:36:40,000
it is through 3d printing or through

1102
00:36:44,069 --> 00:36:42,079
other mechanical shops such that we can

1103
00:36:46,310 --> 00:36:44,079
build an early prototype and literally

1104
00:36:48,230 --> 00:36:46,320
see if it fits together

1105
00:36:50,230 --> 00:36:48,240
cad helped along the way as well we were

1106
00:36:51,510 --> 00:36:50,240
able to model all this in the computer

1107
00:36:53,190 --> 00:36:51,520
but there were many lessons that we

1108
00:36:54,630 --> 00:36:53,200
learned from assembling this even where

1109
00:36:56,390 --> 00:36:54,640
should the wiring and the harnesses go

1110
00:36:57,990 --> 00:36:56,400
on the inside

1111
00:36:59,750 --> 00:36:58,000
at the same time we successfully showed

1112
00:37:01,829 --> 00:36:59,760
that we fit in the box we could launch

1113
00:37:03,190 --> 00:37:01,839

with our rocket along the way and we

1114
00:37:04,550 --> 00:37:03,200
started to get other pieces of the

1115
00:37:06,150 --> 00:37:04,560
spacecraft in

1116
00:37:07,910 --> 00:37:06,160
including the thruster system that has

1117
00:37:10,150 --> 00:37:07,920
those eight thrusters to both steer us

1118
00:37:12,310 --> 00:37:10,160
and orient us towards mars as well as

1119
00:37:14,310 --> 00:37:12,320
the attitude control and this uh ever so

1120
00:37:15,750 --> 00:37:14,320
sensitive star tracker

1121
00:37:17,910 --> 00:37:15,760
now a star tracker is kind of like a

1122
00:37:19,510 --> 00:37:17,920
mini telescope that's inside and the

1123
00:37:21,270 --> 00:37:19,520
reaction wheels or these spinning wheels

1124
00:37:23,030 --> 00:37:21,280
are on there to give you a sense of

1125
00:37:24,710 --> 00:37:23,040
scale and everything that's in there

1126
00:37:26,790 --> 00:37:24,720
that's a one centimeter cube that's

1127
00:37:28,470 --> 00:37:26,800
sitting next to it

1128
00:37:30,710 --> 00:37:28,480
again we're talking about very very

1129
00:37:31,829 --> 00:37:30,720
small little pieces

1130
00:37:33,109 --> 00:37:31,839
we did go through many of the

1131
00:37:35,109 --> 00:37:33,119
environmental tests that larger

1132
00:37:37,190 --> 00:37:35,119
spacecraft go through and here you have

1133
00:37:38,550 --> 00:37:37,200
the flight model of this of marco

1134
00:37:40,069 --> 00:37:38,560
actually the first flight model since we

1135
00:37:41,109 --> 00:37:40,079
were flying too

1136
00:37:44,069 --> 00:37:41,119
when you look at the inside of the

1137
00:37:46,069 --> 00:37:44,079
spacecraft you can see it is a very

1138
00:37:47,910 --> 00:37:46,079

dense little craft in there

1139
00:37:49,829 --> 00:37:47,920
and yet everything has a purpose and was

1140
00:37:51,270 --> 00:37:49,839
able to get us to a successful mission

1141
00:37:52,550 --> 00:37:51,280
readiness level

1142
00:37:55,910 --> 00:37:52,560
and now we're waiting for our launch

1143
00:37:58,710 --> 00:37:55,920
opportunity to go with insight itself

1144
00:38:00,950 --> 00:37:58,720
here's the marco family flight unit 1

1145
00:38:02,630 --> 00:38:00,960
flight unit 2 and the engineering model

1146
00:38:04,390 --> 00:38:02,640
that you see over on the side

1147
00:38:05,829 --> 00:38:04,400
but it is never only the flight models

1148
00:38:07,430 --> 00:38:05,839
that you have to develop

1149
00:38:09,510 --> 00:38:07,440
in rapid prototyping and rapid

1150
00:38:10,950 --> 00:38:09,520
development or even on the longer scale

1151
00:38:13,030 --> 00:38:10,960
you always want to build something that

1152
00:38:14,230 --> 00:38:13,040
uh try it as a prototype on there see

1153
00:38:15,990 --> 00:38:14,240
that it works and have something to

1154
00:38:16,870 --> 00:38:16,000
tinker with when you actually launch it

1155
00:38:19,430 --> 00:38:16,880
out

1156
00:38:21,190 --> 00:38:19,440
into low earth orbit or beyond and so we

1157
00:38:23,109 --> 00:38:21,200
actually built another three or four

1158
00:38:25,030 --> 00:38:23,119
versions of marco all at different

1159
00:38:26,550 --> 00:38:25,040
levels of fidelity on there in order to

1160
00:38:29,190 --> 00:38:26,560
educate ourselves on how we should

1161
00:38:31,430 --> 00:38:29,200
actually fly this craft

1162
00:38:33,589 --> 00:38:31,440
on the big day once we actually get to

1163
00:38:34,630 --> 00:38:33,599

mars and insight is going in for landing

1164
00:38:36,150 --> 00:38:34,640
it will be

1165
00:38:37,829 --> 00:38:36,160
sending off its cruise stays and

1166
00:38:40,390 --> 00:38:37,839
separating out going through entry

1167
00:38:41,910 --> 00:38:40,400
descent and landing now as you know

1168
00:38:43,510 --> 00:38:41,920
insight down in the lower corner here is

1169
00:38:45,430 --> 00:38:43,520
going to hit that atmosphere at a

1170
00:38:47,030 --> 00:38:45,440
blisteringly high temperature

1171
00:38:48,069 --> 00:38:47,040
actually creates a plasma sheath on the

1172
00:38:49,829 --> 00:38:48,079
outside

1173
00:38:51,910 --> 00:38:49,839
meanwhile marco is passing overhead

1174
00:38:54,069 --> 00:38:51,920
about 3 500 kilometers away collecting

1175
00:38:55,589 --> 00:38:54,079
the data that inside is transmitting out

1176
00:38:58,550 --> 00:38:55,599
including when the parachute is actually

1177
00:39:00,150 --> 00:38:58,560
deployed when the back shell is released

1178
00:39:02,150 --> 00:39:00,160
once that back cell is released it's

1179
00:39:03,589 --> 00:39:02,160
able to look down at the planet start

1180
00:39:05,589 --> 00:39:03,599
finding its actual place that it would

1181
00:39:07,589 --> 00:39:05,599
like to land on there

1182
00:39:09,750 --> 00:39:07,599
and here the landing legs actually pop

1183
00:39:11,430 --> 00:39:09,760
out and remember inside is very close to

1184
00:39:13,349 --> 00:39:11,440
phoenix it's actually not going to land

1185
00:39:15,349 --> 00:39:13,359
on a parachute but in a second you'll

1186
00:39:18,069 --> 00:39:15,359
actually see it will fire rockets so

1187
00:39:19,670 --> 00:39:18,079
they can come down to the surface

1188
00:39:21,109 --> 00:39:19,680

if that's not terrifying enough remember

1189
00:39:22,710 --> 00:39:21,119
it's going from kilometers per second

1190
00:39:25,910 --> 00:39:22,720
speed down to zero and this takes only

1191
00:39:28,470 --> 00:39:25,920
about seven minutes so all this time jpl

1192
00:39:30,310 --> 00:39:28,480
is very interested did insight survive

1193
00:39:32,069 --> 00:39:30,320
or did it not

1194
00:39:34,790 --> 00:39:32,079
marco will continue to pass overhead it

1195
00:39:36,630 --> 00:39:34,800
does not enter orbit at mars it's in no

1196
00:39:38,630 --> 00:39:36,640
way critical for insight success but

1197
00:39:39,829 --> 00:39:38,640
gives us that additional information we

1198
00:39:42,950 --> 00:39:39,839
need to make additional missions

1199
00:39:44,950 --> 00:39:42,960
successful down the way as well these

1200
00:39:46,310 --> 00:39:44,960
vehicles serve as a prototype for those

1201
00:39:48,470 --> 00:39:46,320
missions that might take place with

1202
00:39:50,470 --> 00:39:48,480
critical events that either go behind

1203
00:39:53,190 --> 00:39:50,480
the planet itself or in otherwise

1204
00:39:54,550 --> 00:39:53,200
difficult to see areas

1205
00:39:56,550 --> 00:39:54,560
insight's going to be telling us all

1206
00:39:58,950 --> 00:39:56,560
about the internals of mars itself when

1207
00:40:00,550 --> 00:39:58,960
it launches in 2018 and marco is going

1208
00:40:01,910 --> 00:40:00,560
to be there in the very beginning in

1209
00:40:04,230 --> 00:40:01,920
order to tell us that it made it down

1210
00:40:06,310 --> 00:40:04,240
for its successful mission

1211
00:40:07,670 --> 00:40:06,320
but while we're very excited about marco

1212
00:40:09,510 --> 00:40:07,680
and everything that's going on with that

1213
00:40:10,790 --> 00:40:09,520

program over here that's not the only

1214
00:40:12,630 --> 00:40:10,800
thing that's happening in the cubesat

1215
00:40:14,710 --> 00:40:12,640
realm here at jpl

1216
00:40:16,710 --> 00:40:14,720
whether it be in low earth orbit

1217
00:40:18,870 --> 00:40:16,720
three spacecraft to go around the moon

1218
00:40:20,550 --> 00:40:18,880
we have a spacecraft using a solar sail

1219
00:40:23,270 --> 00:40:20,560
that is actually going to go out and

1220
00:40:24,390 --> 00:40:23,280
visit a small body object an asteroid

1221
00:40:26,069 --> 00:40:24,400
that's out there

1222
00:40:28,150 --> 00:40:26,079
or the marco spacecraft that are going

1223
00:40:30,470 --> 00:40:28,160
past mars this is really only the

1224
00:40:31,910 --> 00:40:30,480
beginning and these spacecraft are only

1225
00:40:34,069 --> 00:40:31,920
a sampling of the ones that actually

1226
00:40:35,829 --> 00:40:34,079
have funding here at jpl to go forward

1227
00:40:38,390 --> 00:40:35,839
and jpl is only one place in this

1228
00:40:39,829 --> 00:40:38,400
broader cubesat community

1229
00:40:41,589 --> 00:40:39,839
when we look at exploring the solar

1230
00:40:43,750 --> 00:40:41,599
system there are so many different

1231
00:40:45,430 --> 00:40:43,760
unknown places that are out there and so

1232
00:40:46,790 --> 00:40:45,440
many scientific questions that we could

1233
00:40:48,310 --> 00:40:46,800
answer

1234
00:40:50,950 --> 00:40:48,320
these days we have everything from

1235
00:40:52,550 --> 00:40:50,960
elementary school kids high schoolers

1236
00:40:53,910 --> 00:40:52,560
college students and graduate students

1237
00:40:56,069 --> 00:40:53,920
that are looking to learn more about

1238
00:40:58,470 --> 00:40:56,079

spacecraft before they come to jpl and

1239
00:41:00,390 --> 00:40:58,480
before they start working in industry

1240
00:41:02,470 --> 00:41:00,400
at the same time commercially we're

1241
00:41:04,710 --> 00:41:02,480
developing new markets for the data that

1242
00:41:07,109 --> 00:41:04,720
we're able to collect by using cubesats

1243
00:41:08,470 --> 00:41:07,119
around low earth orbit on here

1244
00:41:10,150 --> 00:41:08,480
and yet as we travel throughout the

1245
00:41:12,390 --> 00:41:10,160
solar system we have a brand new

1246
00:41:14,230 --> 00:41:12,400
platform a new way of exploring if we

1247
00:41:15,430 --> 00:41:14,240
take a little more risk or if we get a

1248
00:41:18,069 --> 00:41:15,440
little bit more focused on what we're

1249
00:41:20,550 --> 00:41:18,079
trying to do and given the low cost we

1250
00:41:21,750 --> 00:41:20,560
can send many of these out here so my

1251
00:41:24,230 --> 00:41:21,760
question for you

1252
00:41:36,230 --> 00:41:24,240
is where would you like to go

1253
00:41:40,470 --> 00:41:38,390
we are open for questions if you would

1254
00:41:45,990 --> 00:41:40,480
if you'd go to the mic in the center and

1255
00:41:50,870 --> 00:41:48,230
all right yes i have a question uh this

1256
00:41:52,870 --> 00:41:50,880
is very exciting and i can see how

1257
00:41:53,829 --> 00:41:52,880
this has just started and how it can

1258
00:41:55,910 --> 00:41:53,839
all

1259
00:41:58,470 --> 00:41:55,920
go in the long term but what about

1260
00:41:59,349 --> 00:41:58,480
security what about uh you know this is

1261
00:42:01,990 --> 00:41:59,359
like

1262
00:42:04,309 --> 00:42:02,000
at one point it could become space junk

1263
00:42:06,550 --> 00:42:04,319

and how how do you control that and what

1264
00:42:08,150 --> 00:42:06,560
if it collides with another bigger like

1265
00:42:10,069 --> 00:42:08,160
space station or something like that

1266
00:42:12,230 --> 00:42:10,079
just wanted to know how that goes so

1267
00:42:13,990 --> 00:42:12,240
there's two aspects to security on here

1268
00:42:15,829 --> 00:42:14,000
that i can address briefly one is on the

1269
00:42:17,990 --> 00:42:15,839
communication side and all the export

1270
00:42:19,349 --> 00:42:18,000
control regulations that we have and we

1271
00:42:20,950 --> 00:42:19,359
of course with these spacecraft with

1272
00:42:22,550 --> 00:42:20,960
others still have to adhere to those

1273
00:42:26,630 --> 00:42:22,560
laws and regulations

1274
00:42:29,190 --> 00:42:26,640
one particular one on orbital debris

1275
00:42:30,870 --> 00:42:29,200
that says for us with you have to be

1276
00:42:33,589 --> 00:42:30,880
down and have burnt up in earth's

1277
00:42:35,270 --> 00:42:33,599
atmosphere within 25 years end of life

1278
00:42:37,349 --> 00:42:35,280
and before any spacecraft actually

1279
00:42:38,950 --> 00:42:37,359
launches there is a report and analysis

1280
00:42:41,109 --> 00:42:38,960
that has to be done whether it be a

1281
00:42:42,630 --> 00:42:41,119
cubesat or larger vehicle to say that we

1282
00:42:44,230 --> 00:42:42,640
will be able to do that

1283
00:42:45,750 --> 00:42:44,240
on top of that the cubesat community is

1284
00:42:48,790 --> 00:42:45,760
actually developing technologies to

1285
00:42:50,790 --> 00:42:48,800
enhance or to speed up that

1286
00:42:51,990 --> 00:42:50,800
debris mitigation on there to burn up in

1287
00:42:53,190 --> 00:42:52,000
the atmosphere

1288
00:42:54,790 --> 00:42:53,200

many times you launch on the space

1289
00:42:56,790 --> 00:42:54,800
station and it's only a few months that

1290
00:42:57,829 --> 00:42:56,800
we are on orbit and the higher ones that

1291
00:42:59,190 --> 00:42:57,839
are out there have to show that they'll

1292
00:43:01,030 --> 00:42:59,200
get down

1293
00:43:02,550 --> 00:43:01,040
the nice thing is space is still very

1294
00:43:04,069 --> 00:43:02,560
big and we are tracking all these

1295
00:43:05,910 --> 00:43:04,079
spacecraft along the way at the same

1296
00:43:07,190 --> 00:43:05,920
time and working very closely with the

1297
00:43:09,109 --> 00:43:07,200
government on how would we handle

1298
00:43:10,790 --> 00:43:09,119
maneuvering and how can we safely

1299
00:43:13,750 --> 00:43:10,800
operate these spacecraft all together on

1300
00:43:16,069 --> 00:43:13,760
there yeah so say if one of these

1301
00:43:17,910 --> 00:43:16,079
cubesats goes rogue right i mean now you

1302
00:43:19,910 --> 00:43:17,920
you're talking about many many many

1303
00:43:22,069 --> 00:43:19,920
thousands of them right so anything can

1304
00:43:24,710 --> 00:43:22,079
happen you know it might go wrong it

1305
00:43:26,550 --> 00:43:24,720
might be a somebody puts a virus on it

1306
00:43:28,230 --> 00:43:26,560
and they might have programmed something

1307
00:43:30,710 --> 00:43:28,240
into it

1308
00:43:32,790 --> 00:43:30,720
would would you have control to vaporize

1309
00:43:34,710 --> 00:43:32,800
that thing out there

1310
00:43:36,470 --> 00:43:34,720
so we have no control to actually

1311
00:43:37,829 --> 00:43:36,480
vaporize these along the way in fact

1312
00:43:39,510 --> 00:43:37,839
because of the

1313
00:43:41,510 --> 00:43:39,520

criticality of trying to carry something

1314
00:43:42,870 --> 00:43:41,520
like that on board the primary launch

1315
00:43:45,109 --> 00:43:42,880
vehicle would rather we not have that

1316
00:43:46,790 --> 00:43:45,119
capability there

1317
00:43:48,550 --> 00:43:46,800
it's it's more to the point though that

1318
00:43:49,990 --> 00:43:48,560
we look at the space most of the

1319
00:43:51,430 --> 00:43:50,000
cubesats that are out there have no

1320
00:43:53,270 --> 00:43:51,440
ability to maneuver in space they're on

1321
00:43:54,710 --> 00:43:53,280
a fixed trajectory around

1322
00:43:56,550 --> 00:43:54,720
and that the ones that do have that

1323
00:43:58,309 --> 00:43:56,560
maneuverability have to go through an

1324
00:44:00,390 --> 00:43:58,319
increased set of both security

1325
00:44:02,069 --> 00:44:00,400
constraints in terms of communications

1326
00:44:04,630 --> 00:44:02,079
and how to actually get it up to orbit

1327
00:44:06,390 --> 00:44:04,640
on there as well as additional look and

1328
00:44:08,470 --> 00:44:06,400
interaction with the people who are

1329
00:44:11,030 --> 00:44:08,480
actually tracking those on orbit

1330
00:44:14,390 --> 00:44:11,040
thank you thank you

1331
00:44:16,550 --> 00:44:14,400
i continue the theme of space junk can

1332
00:44:18,470 --> 00:44:16,560
you give us one man's junk is another

1333
00:44:19,990 --> 00:44:18,480
spacecraft so

1334
00:44:22,790 --> 00:44:20,000
the range of

1335
00:44:25,109 --> 00:44:22,800
orbits that these little

1336
00:44:27,109 --> 00:44:25,119
things will fly and also

1337
00:44:30,790 --> 00:44:27,119
uh what are the range of prices are we

1338
00:44:33,190 --> 00:44:30,800

talking you talk about chip device

1339
00:44:35,750 --> 00:44:33,200
what is the meaning of chip yes sure

1340
00:44:37,349 --> 00:44:35,760
so in terms of the orbits most of the

1341
00:44:39,589 --> 00:44:37,359
cubesats that have launched go between

1342
00:44:41,990 --> 00:44:39,599
about 300 kilometers up around space

1343
00:44:44,069 --> 00:44:42,000
station level to about 800 or so

1344
00:44:45,750 --> 00:44:44,079
kilometers up just below the van allen

1345
00:44:47,430 --> 00:44:45,760
radiation belts that are up there and

1346
00:44:49,349 --> 00:44:47,440
this has been a comfortable level of

1347
00:44:51,510 --> 00:44:49,359
course with marco and inspire in the

1348
00:44:53,910 --> 00:44:51,520
future deep space ones we will be headed

1349
00:44:55,910 --> 00:44:53,920
out and away and we call them disposal

1350
00:44:58,069 --> 00:44:55,920
orbits in some ways the second one is

1351
00:45:00,069 --> 00:44:58,079
the range of prices early on in the

1352
00:45:02,630 --> 00:45:00,079
cubesat movement when you had a craft

1353
00:45:04,069 --> 00:45:02,640
that was not very sophisticated on there

1354
00:45:06,390 --> 00:45:04,079
many people were using off-the-shelf

1355
00:45:08,470 --> 00:45:06,400
technology and you could get launches

1356
00:45:10,550 --> 00:45:08,480
for as little as 30 to 50 thousand

1357
00:45:12,390 --> 00:45:10,560
dollars and the cubesats in there

1358
00:45:15,190 --> 00:45:12,400
depending on how much testing you did

1359
00:45:16,630 --> 00:45:15,200
were on that or same order of magnitude

1360
00:45:18,470 --> 00:45:16,640
these days everybody's getting more

1361
00:45:20,230 --> 00:45:18,480
sophisticated the national science

1362
00:45:22,550 --> 00:45:20,240
foundation typically puts out a grant of

1363
00:45:23,990 --> 00:45:22,560

around a million dollars or so if you

1364
00:45:25,510 --> 00:45:24,000
were going to fly a science mission

1365
00:45:28,309 --> 00:45:25,520
around the earth

1366
00:45:30,790 --> 00:45:28,319
the inspire mission for testing in deep

1367
00:45:32,790 --> 00:45:30,800
space was about five and a half million

1368
00:45:34,630 --> 00:45:32,800
and then headquarters is advertising

1369
00:45:36,390 --> 00:45:34,640
that the marco mission is about 13

1370
00:45:38,710 --> 00:45:36,400
million for us to actually fly by mars

1371
00:45:42,630 --> 00:45:38,720
and all the development that's there

1372
00:45:52,950 --> 00:45:44,230
if you could use the mic actually over

1373
00:45:58,069 --> 00:45:54,390
we're all being webcast so they'd like

1374
00:46:03,190 --> 00:46:01,349
i got a two or three questions one

1375
00:46:06,470 --> 00:46:03,200
do you need the uh

1376
00:46:07,910 --> 00:46:06,480
the traditional ground ttmc for the uh

1377
00:46:10,069 --> 00:46:07,920
for the cubesat

1378
00:46:12,390 --> 00:46:10,079
two do you expect the uh the cubesat to

1379
00:46:13,670 --> 00:46:12,400
replace today's uh commercial geo

1380
00:46:15,990 --> 00:46:13,680
satellite

1381
00:46:18,710 --> 00:46:16,000
or maybe the third question is uh where

1382
00:46:20,230 --> 00:46:18,720
can we buy this a cubesat set

1383
00:46:21,750 --> 00:46:20,240
to play with

1384
00:46:23,670 --> 00:46:21,760
so a cubesat i'll start from the end

1385
00:46:25,670 --> 00:46:23,680
from the cubesat you can buy them right

1386
00:46:27,910 --> 00:46:25,680
now all those vendors that i showed you

1387
00:46:30,390 --> 00:46:27,920
can buy everything from individual parts

1388
00:46:32,710 --> 00:46:30,400

up to actually a full spacecraft in fact

1389
00:46:35,030 --> 00:46:32,720
there's a really neat one called kicksat

1390
00:46:37,109 --> 00:46:35,040
which is a 3u spacecraft and actually

1391
00:46:38,870 --> 00:46:37,119
has smaller chipsets on the inside and

1392
00:46:40,630 --> 00:46:38,880
you can buy one of these chipsets off of

1393
00:46:41,510 --> 00:46:40,640
kickstarter i believe is where it

1394
00:46:43,190 --> 00:46:41,520
started

1395
00:46:44,630 --> 00:46:43,200
put your own little program in there and

1396
00:46:46,309 --> 00:46:44,640
it's going to spin off and maybe you'll

1397
00:46:47,829 --> 00:46:46,319
get a little bit of data return off of

1398
00:46:49,349 --> 00:46:47,839
that thing so it'll fire off all these

1399
00:46:50,230 --> 00:46:49,359
chipsets once it's deployed from the

1400
00:46:52,470 --> 00:46:50,240
station

1401
00:46:53,829 --> 00:46:52,480
it flew once due to a software anomaly

1402
00:46:54,950 --> 00:46:53,839
it actually did not work so you know

1403
00:46:56,630 --> 00:46:54,960
what these things are cheap enough

1404
00:46:59,430 --> 00:46:56,640
they're flying it again

1405
00:47:01,270 --> 00:46:59,440
the second question in there uh was will

1406
00:47:04,230 --> 00:47:01,280
they replace things in

1407
00:47:06,470 --> 00:47:04,240
geo and uh

1408
00:47:08,309 --> 00:47:06,480
right will they replace directv or some

1409
00:47:10,309 --> 00:47:08,319
of the other stations that are there

1410
00:47:12,069 --> 00:47:10,319
and actually no these cubesats are not

1411
00:47:13,990 --> 00:47:12,079
really out there to replace the larger

1412
00:47:15,589 --> 00:47:14,000
ones there is so much capability

1413
00:47:17,349 --> 00:47:15,599

someone's contextual information that

1414
00:47:19,190 --> 00:47:17,359
you can get from the larger vehicles so

1415
00:47:21,270 --> 00:47:19,200
much power that's needed for directv and

1416
00:47:22,870 --> 00:47:21,280
others that you simply can't pack that

1417
00:47:24,790 --> 00:47:22,880
into one of these one of the things that

1418
00:47:26,550 --> 00:47:24,800
are this small that would be adding

1419
00:47:28,150 --> 00:47:26,560
additional mission requirements and so

1420
00:47:30,550 --> 00:47:28,160
to be able to do so you'd have to take

1421
00:47:32,630 --> 00:47:30,560
on additional risk or significant costs

1422
00:47:34,069 --> 00:47:32,640
down there to miniaturize things but the

1423
00:47:35,670 --> 00:47:34,079
nice thing about the marketplace is

1424
00:47:37,750 --> 00:47:35,680
every time i say that something cannot

1425
00:47:40,150 --> 00:47:37,760
be done such as an active radar and a

1426
00:47:41,589 --> 00:47:40,160
cubesat well now we have raincube and

1427
00:47:43,030 --> 00:47:41,599
things are actually going for it so i

1428
00:47:47,829 --> 00:47:43,040
don't want to say never

1429
00:47:51,109 --> 00:47:49,030
how do we actually talk to these

1430
00:47:53,030 --> 00:47:51,119
cubesats along the way a slight mis a

1431
00:47:54,630 --> 00:47:53,040
slight interpretation of it

1432
00:47:56,309 --> 00:47:54,640
for a lot of the cubesats especially the

1433
00:47:58,150 --> 00:47:56,319
academic ones it's the ham radio

1434
00:48:00,870 --> 00:47:58,160
operators that are out there and if you

1435
00:48:02,550 --> 00:48:00,880
look around on any number of roofs or in

1436
00:48:04,470 --> 00:48:02,560
large dishes at universities we're

1437
00:48:05,910 --> 00:48:04,480
talking to cubesats there

1438
00:48:07,430 --> 00:48:05,920

in fact the radio aurora explorer

1439
00:48:09,510 --> 00:48:07,440
mission the first time someone heard

1440
00:48:11,349 --> 00:48:09,520
from it it was a

1441
00:48:13,670 --> 00:48:11,359
high school student in hawaii pointing

1442
00:48:15,430 --> 00:48:13,680
his antenna up to the sky and that was

1443
00:48:17,589 --> 00:48:15,440
the first data that we see received

1444
00:48:19,030 --> 00:48:17,599
saying that the spacecraft survived

1445
00:48:20,630 --> 00:48:19,040
on the other hand for going large

1446
00:48:22,790 --> 00:48:20,640
distances we're using the deep space

1447
00:48:25,109 --> 00:48:22,800
network we're talking to arecibo which

1448
00:48:26,549 --> 00:48:25,119
is a 300 meter dish that's out there

1449
00:48:28,549 --> 00:48:26,559
we're talking to all different entities

1450
00:48:30,470 --> 00:48:28,559
there so we can scale the range from

1451
00:48:33,990 --> 00:48:30,480
amateur to professional and all of them

1452
00:48:36,630 --> 00:48:34,000
are useful to these cubesats

1453
00:48:38,790 --> 00:48:36,640
yeah i had a couple of musings here uh

1454
00:48:42,230 --> 00:48:38,800
thinking about uh your example with the

1455
00:48:43,670 --> 00:48:42,240
pluto flyby uh is there

1456
00:48:46,630 --> 00:48:43,680
would you be able to identify some

1457
00:48:49,190 --> 00:48:46,640
missions in the pluto kuiper

1458
00:48:51,030 --> 00:48:49,200
area where they would go out to multiple

1459
00:48:53,270 --> 00:48:51,040
uh bodies each on their own trajectory

1460
00:48:54,790 --> 00:48:53,280
more of a widely dispersed

1461
00:48:57,990 --> 00:48:54,800
kind of mission

1462
00:49:02,790 --> 00:49:00,549
possibility is there any

1463
00:49:05,670 --> 00:49:02,800

value that you would see in these uh

1464
00:49:07,349 --> 00:49:05,680
being part of a uh an earth orbit

1465
00:49:09,670 --> 00:49:07,359
space-based solar

1466
00:49:12,630 --> 00:49:09,680
uh sort of a station keeping perimeter

1467
00:49:14,069 --> 00:49:12,640
around a space based solar array

1468
00:49:15,990 --> 00:49:14,079
for power

1469
00:49:17,990 --> 00:49:16,000
direct yeah microwave power transmission

1470
00:49:19,910 --> 00:49:18,000
to the earth to get rid of all the

1471
00:49:21,670 --> 00:49:19,920
fossil fuels and that i know there have

1472
00:49:23,510 --> 00:49:21,680
been concepts out there on how we can

1473
00:49:26,470 --> 00:49:23,520
use these in arrays and actually send

1474
00:49:27,990 --> 00:49:26,480
power into in between the the spacecraft

1475
00:49:29,750 --> 00:49:28,000
that are out there though i don't

1476
00:49:31,750 --> 00:49:29,760
believe anyone has looked at what that

1477
00:49:32,950 --> 00:49:31,760
overall space has

1478
00:49:35,190 --> 00:49:32,960
something on the drawing board something

1479
00:49:37,190 --> 00:49:35,200
like 10 10 kilometers

1480
00:49:38,710 --> 00:49:37,200
and that's and that is the large problem

1481
00:49:40,230 --> 00:49:38,720
that we have with small spacecraft and

1482
00:49:41,030 --> 00:49:40,240
i'll address it from a constellation

1483
00:49:42,390 --> 00:49:41,040
sense

1484
00:49:43,829 --> 00:49:42,400
when we're trying to send these these

1485
00:49:45,349 --> 00:49:43,839
spacecraft out there they work well in

1486
00:49:47,430 --> 00:49:45,359
the constellation because when any one

1487
00:49:49,510 --> 00:49:47,440
of them goes bad we can replace that

1488
00:49:52,069 --> 00:49:49,520

single one rather than having to replace

1489
00:49:53,750 --> 00:49:52,079
a very large spacecraft the problem with

1490
00:49:56,230 --> 00:49:53,760
power though along the way is that it is

1491
00:49:57,829 --> 00:49:56,240
still dependent upon area and we have to

1492
00:49:59,030 --> 00:49:57,839
have a very large area whether they be

1493
00:50:00,549 --> 00:49:59,040
small spacecraft or whether they be

1494
00:50:02,790 --> 00:50:00,559
large spacecraft in order to get that

1495
00:50:04,069 --> 00:50:02,800
power put together and get it back down

1496
00:50:05,670 --> 00:50:04,079
to the ground

1497
00:50:07,750 --> 00:50:05,680
the small spacecraft will be useful as a

1498
00:50:09,430 --> 00:50:07,760
constellation in order to replace the

1499
00:50:10,870 --> 00:50:09,440
ones that go bad along the way and so i

1500
00:50:12,790 --> 00:50:10,880
can see where the concept might develop

1501
00:50:14,230 --> 00:50:12,800
there but in terms of the number of

1502
00:50:16,309 --> 00:50:14,240
launches to get them up there or at

1503
00:50:18,390 --> 00:50:16,319
least the area that we need with the

1504
00:50:19,589 --> 00:50:18,400
solar rays on there may end up being

1505
00:50:22,069 --> 00:50:19,599
prohibitive and that's of course the

1506
00:50:23,990 --> 00:50:22,079
trade to be done later in the concept

1507
00:50:25,750 --> 00:50:24,000
the other question was on do we do i see

1508
00:50:28,150 --> 00:50:25,760
any missions going out toward the kuiper

1509
00:50:30,069 --> 00:50:28,160
belt objects or pluto on there with

1510
00:50:31,589 --> 00:50:30,079
independent trajectories well the

1511
00:50:33,430 --> 00:50:31,599
problem there again is power because

1512
00:50:34,950 --> 00:50:33,440
power decreases so greatly as you head

1513
00:50:36,390 --> 00:50:34,960

out there so i don't see them

1514
00:50:37,910 --> 00:50:36,400
independently leaving the earth and

1515
00:50:40,069 --> 00:50:37,920
heading all the way out there depending

1516
00:50:41,990 --> 00:50:40,079
on solar panels along the way what i do

1517
00:50:44,069 --> 00:50:42,000
see though is i guess

1518
00:50:46,309 --> 00:50:44,079
yeah what i do see at least based on

1519
00:50:48,230 --> 00:50:46,319
today's technology is that we use

1520
00:50:50,470 --> 00:50:48,240
primary batteries and that once we're

1521
00:50:52,230 --> 00:50:50,480
out at the pluto region to go on trickle

1522
00:50:54,470 --> 00:50:52,240
charge be released and then could

1523
00:50:56,150 --> 00:50:54,480
individually target things along the way

1524
00:50:58,150 --> 00:50:56,160
either that or using solar panels to

1525
00:50:59,829 --> 00:50:58,160
very slowly charge the system and just

1526
00:51:01,190 --> 00:50:59,839
have a burst back to earth whenever they

1527
00:51:02,710 --> 00:51:01,200
need to communicate

1528
00:51:04,069 --> 00:51:02,720
otherwise being in a fairly dormant

1529
00:51:05,829 --> 00:51:04,079
state there

1530
00:51:09,670 --> 00:51:05,839
so there are few different possibilities

1531
00:51:13,670 --> 00:51:11,430
uh one more question piggyback on my

1532
00:51:15,589 --> 00:51:13,680
security thing now i understand you know

1533
00:51:17,349 --> 00:51:15,599
you said you can you can control

1534
00:51:19,829 --> 00:51:17,359
you know all our friendly but what about

1535
00:51:20,710 --> 00:51:19,839
rogue nations right i mean we're talking

1536
00:51:22,950 --> 00:51:20,720
about

1537
00:51:24,470 --> 00:51:22,960
this is such available that i can go buy

1538
00:51:25,910 --> 00:51:24,480

on the internet i can

1539
00:51:28,069 --> 00:51:25,920
package put it up

1540
00:51:29,829 --> 00:51:28,079
what stops one of the rogue nations to

1541
00:51:32,710 --> 00:51:29,839
contract with another rogue nations to

1542
00:51:35,670 --> 00:51:32,720
take their satellites up right and then

1543
00:51:37,270 --> 00:51:35,680
so anyway that's that almost brings back

1544
00:51:38,549 --> 00:51:37,280
reagan star wars

1545
00:51:40,230 --> 00:51:38,559
we need to have something on space

1546
00:51:41,190 --> 00:51:40,240
station like a laser zap or something

1547
00:51:43,190 --> 00:51:41,200
that you see

1548
00:51:45,910 --> 00:51:43,200
something you need to destroy

1549
00:51:47,990 --> 00:51:45,920
like it's it's it's what you know ronald

1550
00:51:50,309 --> 00:51:48,000
reagan was talking about star wars

1551
00:51:51,109 --> 00:51:50,319
for the spacecraft that might launch

1552
00:51:53,030 --> 00:51:51,119
with

1553
00:51:54,549 --> 00:51:53,040
a different nation that's out there we

1554
00:51:56,230 --> 00:51:54,559
have miniaturization of technology

1555
00:51:57,910 --> 00:51:56,240
around the world so of course we cannot

1556
00:51:59,589 --> 00:51:57,920
control individual ones but for those

1557
00:52:01,190 --> 00:51:59,599
that we can control there are

1558
00:52:03,190 --> 00:52:01,200
significant regulations that have to be

1559
00:52:05,190 --> 00:52:03,200
gone through for any country to launch

1560
00:52:06,710 --> 00:52:05,200
with any other country on there and in

1561
00:52:08,870 --> 00:52:06,720
the cubesat business since we are in

1562
00:52:10,390 --> 00:52:08,880
that pea pod they actually if we don't

1563
00:52:12,150 --> 00:52:10,400

adhere to those regulations or if

1564
00:52:13,829 --> 00:52:12,160
something is broken on there they zip

1565
00:52:15,190 --> 00:52:13,839
tie the p-pod shut

1566
00:52:17,270 --> 00:52:15,200
just one of those little zip ties

1567
00:52:19,109 --> 00:52:17,280
prevents this multi-million dollar

1568
00:52:20,870 --> 00:52:19,119
spacecraft from going out there

1569
00:52:22,950 --> 00:52:20,880
so that but they do actually very

1570
00:52:24,390 --> 00:52:22,960
carefully go through the regulations and

1571
00:52:25,829 --> 00:52:24,400
make sure that they know what's going in

1572
00:52:27,109 --> 00:52:25,839
there and what is to be launched you

1573
00:52:28,470 --> 00:52:27,119
have to have launch approval from your

1574
00:52:29,910 --> 00:52:28,480
host nation

1575
00:52:31,349 --> 00:52:29,920
on the second one on there it does go

1576
00:52:32,549 --> 00:52:31,359
back to the debris problem and there

1577
00:52:35,109 --> 00:52:32,559
actually have been cubesats that have

1578
00:52:36,630 --> 00:52:35,119
been hit by larger vehicles on there as

1579
00:52:38,549 --> 00:52:36,640
well as other debris that might be on

1580
00:52:40,390 --> 00:52:38,559
orbit of course we have the same problem

1581
00:52:42,390 --> 00:52:40,400
with any large vehicle there it's just

1582
00:52:44,870 --> 00:52:42,400
things are becoming more accessible in

1583
00:52:45,910 --> 00:52:44,880
miniaturization along the way

1584
00:52:47,430 --> 00:52:45,920
and that is one of the things that we

1585
00:52:50,630 --> 00:52:47,440
always find with technology we always

1586
00:52:52,710 --> 00:52:50,640
find a way to take a new technology such

1587
00:52:54,470 --> 00:52:52,720
as cell phones or other such things and

1588
00:52:55,910 --> 00:52:54,480

need to be able to look at both the

1589
00:52:57,589 --> 00:52:55,920
positives and the negatives there as we

1590
00:52:58,870 --> 00:52:57,599
go forward so while i don't have a

1591
00:53:00,950 --> 00:52:58,880
definite answer on how they might

1592
00:53:02,630 --> 00:53:00,960
address such a rogue nation it is why we

1593
00:53:06,390 --> 00:53:02,640
have the security industry and others

1594
00:53:11,829 --> 00:53:08,150
uh this would seem to be kind of the

1595
00:53:13,750 --> 00:53:11,839
first step or stepping stone

1596
00:53:16,870 --> 00:53:13,760
toward what's been discussed uh just

1597
00:53:19,430 --> 00:53:16,880
this last week the the hawkings

1598
00:53:21,349 --> 00:53:19,440
alpha centauri you got any observations

1599
00:53:23,510 --> 00:53:21,359
or thoughts along those lines

1600
00:53:25,190 --> 00:53:23,520
we continued so for the those that don't

1601
00:53:27,109 --> 00:53:25,200
know stephen hawking along with others

1602
00:53:29,349 --> 00:53:27,119
proposed that we actually use a solar

1603
00:53:31,430 --> 00:53:29,359
sail just head out to alpha centauri

1604
00:53:33,190 --> 00:53:31,440
with a very small spacecraft on there

1605
00:53:34,630 --> 00:53:33,200
and he's again taking an advantage they

1606
00:53:36,230 --> 00:53:34,640
i should say the foundation there is

1607
00:53:37,589 --> 00:53:36,240
taking advantage of the miniaturization

1608
00:53:39,109 --> 00:53:37,599
of electronics

1609
00:53:40,150 --> 00:53:39,119
well we have used off the shelf

1610
00:53:41,349 --> 00:53:40,160
different pieces of hardware and

1611
00:53:43,190 --> 00:53:41,359
assembled them together to make a

1612
00:53:45,430 --> 00:53:43,200
cubesat they are looking at doing the

1613
00:53:46,870 --> 00:53:45,440

same thing on a chip based scale

1614
00:53:48,630 --> 00:53:46,880
and then looking at the feasibility of

1615
00:53:51,030 --> 00:53:48,640
getting information back from alpha

1616
00:53:52,069 --> 00:53:51,040
centauri to earth on there i certainly

1617
00:53:53,829 --> 00:53:52,079
wish them luck and i see the

1618
00:53:56,390 --> 00:53:53,839
miniaturization of technology continuing

1619
00:53:57,910 --> 00:53:56,400
such that such things will be enabled

1620
00:54:00,390 --> 00:53:57,920
however solar sails are still in their

1621
00:54:01,990 --> 00:54:00,400
infancy as we've seen with nano cld as

1622
00:54:03,829 --> 00:54:02,000
we've seen with light sail and continue

1623
00:54:04,710 --> 00:54:03,839
to as we continue to test forward on

1624
00:54:06,069 --> 00:54:04,720
there

1625
00:54:07,349 --> 00:54:06,079
everything we develop for that mission

1626
00:54:11,510 --> 00:54:07,359
will be important for our explorers in

1627
00:54:15,270 --> 00:54:13,430
yes i would like to ask a question about

1628
00:54:16,470 --> 00:54:15,280
launching capabilities so today if you

1629
00:54:18,630 --> 00:54:16,480
want to launch your cubesat you have to

1630
00:54:20,790 --> 00:54:18,640
go either from space station

1631
00:54:22,790 --> 00:54:20,800
alongside a larger spacecraft do you see

1632
00:54:24,150 --> 00:54:22,800
a future for dedicated launchers is it

1633
00:54:25,190 --> 00:54:24,160
something that could be useful that

1634
00:54:27,430 --> 00:54:25,200
could be

1635
00:54:29,030 --> 00:54:27,440
interesting for markets or something

1636
00:54:30,390 --> 00:54:29,040
there is actually a market that is out

1637
00:54:32,549 --> 00:54:30,400
there and many companies are actually

1638
00:54:34,630 --> 00:54:32,559

trying for it in a very

1639
00:54:36,150 --> 00:54:34,640
disappointing twist one of the first

1640
00:54:38,950 --> 00:54:36,160
called the super stripey launched from

1641
00:54:40,790 --> 00:54:38,960
hawaii back in january with only a few

1642
00:54:42,950 --> 00:54:40,800
cubesats and small sats on board and

1643
00:54:44,150 --> 00:54:42,960
unfortunately the rocket failed just

1644
00:54:45,589 --> 00:54:44,160
after launch

1645
00:54:47,190 --> 00:54:45,599
so just as we're going and trying to

1646
00:54:48,870 --> 00:54:47,200
test these things with small spacecraft

1647
00:54:50,150 --> 00:54:48,880
the small dedicated launchers are also

1648
00:54:51,750 --> 00:54:50,160
going forward

1649
00:54:55,030 --> 00:54:51,760
some of them are actually quite fun in

1650
00:54:57,030 --> 00:54:55,040
their description such as using a a

1651
00:54:59,109 --> 00:54:57,040
missile carried by an f-15 that goes

1652
00:55:00,630 --> 00:54:59,119
high into orbit launches the missile and

1653
00:55:02,950 --> 00:55:00,640
there is a cubesat that's actually

1654
00:55:05,109 --> 00:55:02,960
deployed off of that on there

1655
00:55:06,710 --> 00:55:05,119
that is a rapid response and you can

1656
00:55:09,589 --> 00:55:06,720
target anywhere you'd like to go when

1657
00:55:10,950 --> 00:55:09,599
you have that kind of cubesat capability

1658
00:55:12,230 --> 00:55:10,960
all new sorts of launches whether

1659
00:55:14,230 --> 00:55:12,240
dedicated from the ground or from

1660
00:55:20,950 --> 00:55:14,240
aircraft such as that are being

1661
00:55:26,150 --> 00:55:23,349
and we have a question from the web tech

1662
00:55:28,069 --> 00:55:26,160
spacey asks what is the current cost per

1663
00:55:29,910 --> 00:55:28,079

pound to get to low earth orbit and what

1664
00:55:33,030 --> 00:55:29,920
is the cost savings for launching a 1u

1665
00:55:33,349 --> 00:55:33,040
cubesat as compared to a larger

1666
00:55:35,990 --> 00:55:33,359
a satellite

1667
00:55:37,750 --> 00:55:36,000
you cube set compared to some of the uh

1668
00:55:40,069 --> 00:55:37,760
larger spacecraft that we have in the

1669
00:55:42,150 --> 00:55:40,079
cubesat form factor really is just a

1670
00:55:45,190 --> 00:55:42,160
multiple of the number of views in fact

1671
00:55:47,109 --> 00:55:45,200
they'll often cost a function

1672
00:55:49,910 --> 00:55:47,119
cost the spacecraft as how many u's do

1673
00:55:52,390 --> 00:55:49,920
you have for leaving low earth orbit it

1674
00:55:55,270 --> 00:55:52,400
might be a million or more than that for

1675
00:55:57,750 --> 00:55:55,280
a spacecraft whereas for a 3u going up

1676
00:55:59,270 --> 00:55:57,760
to orbit is on the order of 300 to 400

1677
00:56:02,390 --> 00:55:59,280
000 on there

1678
00:56:05,030 --> 00:56:02,400
now if you looked at the dedicated mass

1679
00:56:07,510 --> 00:56:05,040
per pound of a launch vehicle it is much

1680
00:56:09,430 --> 00:56:07,520
more effective for you to large or much

1681
00:56:10,789 --> 00:56:09,440
more cost effective to launch a much

1682
00:56:12,789 --> 00:56:10,799
larger vehicle

1683
00:56:14,230 --> 00:56:12,799
than to launch that same mass in

1684
00:56:16,150 --> 00:56:14,240
cubesats on there

1685
00:56:18,789 --> 00:56:16,160
and that's because the the cost of

1686
00:56:21,430 --> 00:56:18,799
launch is more than just the fuel and

1687
00:56:23,109 --> 00:56:21,440
the rocket itself it's all the testing

1688
00:56:24,309 --> 00:56:23,119

it's the paperwork it's all the

1689
00:56:25,589 --> 00:56:24,319
development along the way in that

1690
00:56:27,670 --> 00:56:25,599
interaction both with the team and the

1691
00:56:29,990 --> 00:56:27,680
spacecraft provider that is also

1692
00:56:31,990 --> 00:56:30,000
taking into account for the cost of

1693
00:56:33,829 --> 00:56:32,000
going up to orbit on there so it's more

1694
00:56:35,030 --> 00:56:33,839
effective cost effective to launch

1695
00:56:37,109 --> 00:56:35,040
something large

1696
00:56:40,789 --> 00:56:37,119
but you can perform more missions if you

1697
00:56:45,510 --> 00:56:42,630
two questions

1698
00:56:48,230 --> 00:56:45,520
how do you prevent commercialization

1699
00:56:50,789 --> 00:56:48,240
from interfering ideas within the

1700
00:56:52,870 --> 00:56:50,799
university community

1701
00:56:54,710 --> 00:56:52,880
and the other question is how are the

1702
00:56:57,190 --> 00:56:54,720
big corporations going to make them

1703
00:56:59,190 --> 00:56:57,200
profit

1704
00:57:00,390 --> 00:56:59,200
so for the second question it's actually

1705
00:57:01,990 --> 00:57:00,400
been interesting some of the

1706
00:57:04,630 --> 00:57:02,000
corporations are looking to make a

1707
00:57:06,230 --> 00:57:04,640
profit in terms of the the launches and

1708
00:57:07,190 --> 00:57:06,240
some of them actually just want to cover

1709
00:57:08,870 --> 00:57:07,200
costs

1710
00:57:10,549 --> 00:57:08,880
ula just announced an initiative and

1711
00:57:13,109 --> 00:57:10,559
they were giving a talk at this workshop

1712
00:57:14,150 --> 00:57:13,119
this past week where they actually were

1713
00:57:15,589 --> 00:57:14,160

launching

1714
00:57:17,510 --> 00:57:15,599
several cubesats for free from

1715
00:57:18,789 --> 00:57:17,520
educational institutions on every one of

1716
00:57:20,710 --> 00:57:18,799
their rockets

1717
00:57:22,230 --> 00:57:20,720
and then the other slots that are there

1718
00:57:23,589 --> 00:57:22,240
the only profit that they have is

1719
00:57:25,109 --> 00:57:23,599
actually to pay for those free

1720
00:57:26,789 --> 00:57:25,119
educational ones

1721
00:57:28,630 --> 00:57:26,799
they see it as an overall boon to the

1722
00:57:30,710 --> 00:57:28,640
community if they can launch more

1723
00:57:32,870 --> 00:57:30,720
vehicles up to perform more missions

1724
00:57:34,150 --> 00:57:32,880
either for educational training or for

1725
00:57:36,069 --> 00:57:34,160
these other vehicles there and they

1726
00:57:37,109 --> 00:57:36,079
might as well make up the mass

1727
00:57:38,870 --> 00:57:37,119
on the first one many of the

1728
00:57:41,030 --> 00:57:38,880
corporations that i pointed out earlier

1729
00:57:42,390 --> 00:57:41,040
actually come from the universities it's

1730
00:57:43,670 --> 00:57:42,400
the students that are developing the

1731
00:57:45,750 --> 00:57:43,680
technology at these universities that

1732
00:57:47,190 --> 00:57:45,760
spin off their own companies on there

1733
00:57:48,789 --> 00:57:47,200
and it is through a partnership that

1734
00:57:50,549 --> 00:57:48,799
they actually continue to do so whether

1735
00:57:52,230 --> 00:57:50,559
it be through internships or new

1736
00:57:54,549 --> 00:57:52,240
technology in the research bed that is

1737
00:57:56,069 --> 00:57:54,559
the university than commercializing out

1738
00:57:57,829 --> 00:57:56,079

in the corporate world

1739
00:57:59,349 --> 00:57:57,839
the cubesat community is a wonderful

1740
00:58:01,270 --> 00:57:59,359
place where there are partnerships all

1741
00:58:03,030 --> 00:58:01,280
over the place we could not have done

1742
00:58:04,789 --> 00:58:03,040
inspire marco without our partners that

1743
00:58:06,390 --> 00:58:04,799
are out there and so that's where we're

1744
00:58:07,750 --> 00:58:06,400
hoping to continue that and why we have

1745
00:58:09,670 --> 00:58:07,760
things like the cubesat developers

1746
00:58:12,789 --> 00:58:09,680
workshop which is going on right now in

1747
00:58:17,589 --> 00:58:12,799
order to continue that effort

1748
00:58:22,710 --> 00:58:20,390
i'm not a engineer or a proportional

1749
00:58:23,750 --> 00:58:22,720
expert or anything but is it is it

1750
00:58:25,270 --> 00:58:23,760
feasible

1751
00:58:27,589 --> 00:58:25,280
that you can launch one of these things

1752
00:58:29,349 --> 00:58:27,599
from a hot air balloon like if you if

1753
00:58:31,190 --> 00:58:29,359
the hot air balloon went up and then you

1754
00:58:33,109 --> 00:58:31,200
you have a rocket on the cubesat that

1755
00:58:35,349 --> 00:58:33,119
just pushes out outer space

1756
00:58:37,430 --> 00:58:35,359
yes there is a uh there is a company

1757
00:58:39,109 --> 00:58:37,440
that is trying to do just that with a

1758
00:58:40,390 --> 00:58:39,119
high altitude balloon looks like a

1759
00:58:42,470 --> 00:58:40,400
weather balloon that's essentially

1760
00:58:44,150 --> 00:58:42,480
carrying out and there are as you might

1761
00:58:46,230 --> 00:58:44,160
imagine significant challenges there and

1762
00:58:47,829 --> 00:58:46,240
how they might accomplish that but all

1763
00:58:53,270 --> 00:58:47,839

sorts of different dedicated launches

1764
00:58:58,710 --> 00:58:56,470
so in this vein how about the tether

1765
00:59:00,789 --> 00:58:58,720
how about the space tether the space

1766
00:59:03,349 --> 00:59:00,799
ladder for the

1767
00:59:05,990 --> 00:59:03,359
tiny box like this

1768
00:59:07,510 --> 00:59:06,000
the uh so the space tether itself is

1769
00:59:09,190 --> 00:59:07,520
generally based on a mass that is

1770
00:59:10,549 --> 00:59:09,200
orbiting the earth and is connected down

1771
00:59:11,670 --> 00:59:10,559
so you have an elevator that's actually

1772
00:59:13,109 --> 00:59:11,680
going up

1773
00:59:15,030 --> 00:59:13,119
there is a history of tethers with

1774
00:59:16,549 --> 00:59:15,040
cubesats mostly one that we try and

1775
00:59:18,230 --> 00:59:16,559
tether two together for various science

1776
00:59:20,390 --> 00:59:18,240
experiments and virtually all of them

1777
00:59:22,069 --> 00:59:20,400
have has ended in mission disaster where

1778
00:59:23,990 --> 00:59:22,079
they've gotten tangled up or something

1779
00:59:25,589 --> 00:59:24,000
has gone wrong so cube since the tethers

1780
00:59:27,190 --> 00:59:25,599
don't get along to begin with

1781
00:59:29,349 --> 00:59:27,200
but the space elevator is continued to

1782
00:59:31,190 --> 00:59:29,359
be an interesting concept for low low

1783
00:59:32,870 --> 00:59:31,200
cost access to space

1784
00:59:35,349 --> 00:59:32,880
what we've really found with the cubesat

1785
00:59:36,870 --> 00:59:35,359
is if you bring low-cost access you can

1786
00:59:38,470 --> 00:59:36,880
accomplish more missions and everybody

1787
00:59:40,230 --> 00:59:38,480
wants them to happen if you bring it

1788
00:59:42,069 --> 00:59:40,240

they will come so if the elevator

1789
00:59:43,829 --> 00:59:42,079
actually happens then of course we will

1790
00:59:45,910 --> 00:59:43,839
use it to get more payload up to earth

1791
00:59:47,430 --> 00:59:45,920
orbit but these things are so low in

1792
00:59:49,190 --> 00:59:47,440
mass they would not be able to support a

1793
00:59:50,390 --> 00:59:49,200
space elevator at least in the terms

1794
00:59:52,069 --> 00:59:50,400
that have been traditionally been talked

1795
00:59:53,750 --> 00:59:52,079
about on there and it would require

1796
01:00:07,109 --> 00:59:53,760
something much more massive in order to

1797
01:00:10,789 --> 01:00:08,549
one of the pieces of components that

1798
01:00:13,589 --> 01:00:10,799
you've highlighted in the images of the

1799
01:00:15,589 --> 01:00:13,599
various cubesats are the processors that

1800
01:00:18,230 --> 01:00:15,599
are on board what are the technical

1801
01:00:19,030 --> 01:00:18,240
requirements that these uh that the cpus

1802
01:00:20,789 --> 01:00:19,040
are

1803
01:00:22,230 --> 01:00:20,799
required to perform and

1804
01:00:25,190 --> 01:00:22,240
are you able to

1805
01:00:27,750 --> 01:00:25,200
describe any models that fit the bill

1806
01:00:30,789 --> 01:00:27,760
sure so marco and inspire the main

1807
01:00:32,910 --> 01:00:30,799
flight computer on there is a small chip

1808
01:00:36,150 --> 01:00:32,920
from texas instruments ti called the

1809
01:00:37,430 --> 01:00:36,160
msp430 2618.

1810
01:00:38,870 --> 01:00:37,440
what's nice about this chip is you can

1811
01:00:40,549 --> 01:00:38,880
find it in all sorts of things you can

1812
01:00:42,150 --> 01:00:40,559
find it in toasters you can find it in

1813
01:00:44,710 --> 01:00:42,160

razer blades you can find it in shower

1814
01:00:47,829 --> 01:00:44,720
heads it's actually so small it runs at

1815
01:00:49,670 --> 01:00:47,839
about 16 megahertz has about 128

1816
01:00:51,349 --> 01:00:49,680
kilobytes of memory in about eight

1817
01:00:53,829 --> 01:00:51,359
kilobytes of ram

1818
01:00:55,670 --> 01:00:53,839
on the order of a little of a little

1819
01:00:57,910 --> 01:00:55,680
less than what was on apollo along the

1820
01:00:58,950 --> 01:00:57,920
way there yet we're able to perform our

1821
01:01:00,309 --> 01:00:58,960
mission

1822
01:01:01,990 --> 01:01:00,319
now for us that's because it's not the

1823
01:01:03,510 --> 01:01:02,000
only processor that's on board we

1824
01:01:05,510 --> 01:01:03,520
distribute our processing amongst

1825
01:01:07,349 --> 01:01:05,520
different subsystems the attitude

1826
01:01:08,789 --> 01:01:07,359
control system has an fpga that's on

1827
01:01:10,870 --> 01:01:08,799
board that's actually running at a much

1828
01:01:12,549 --> 01:01:10,880
higher speed and various other

1829
01:01:13,270 --> 01:01:12,559
subsystems handle their own technology

1830
01:01:15,510 --> 01:01:13,280
there

1831
01:01:17,510 --> 01:01:15,520
but through unique and very carefully

1832
01:01:18,950 --> 01:01:17,520
done software engineering there isn't a

1833
01:01:20,950 --> 01:01:18,960
whole lot that these spacecraft have to

1834
01:01:22,230 --> 01:01:20,960
do and that focus allows us to reduce

1835
01:01:23,510 --> 01:01:22,240
the requirements on the processors

1836
01:01:25,109 --> 01:01:23,520
themselves

1837
01:01:26,150 --> 01:01:25,119
at the same time we have emissions that

1838
01:01:27,589 --> 01:01:26,160

are actually doing technology

1839
01:01:28,870 --> 01:01:27,599
demonstrations for

1840
01:01:30,230 --> 01:01:28,880
different processes that can be used on

1841
01:01:31,990 --> 01:01:30,240
large vehicles

1842
01:01:34,150 --> 01:01:32,000
m-cubed was one such mission where they

1843
01:01:35,990 --> 01:01:34,160
actually flew a new fpga had never been

1844
01:01:37,430 --> 01:01:36,000
flown in space before

1845
01:01:38,950 --> 01:01:37,440
to show that that processor could

1846
01:01:40,549 --> 01:01:38,960
actually be could work in the space

1847
01:01:42,470 --> 01:01:40,559
environment and could be useful when

1848
01:01:43,750 --> 01:01:42,480
they have thousands and thousands of

1849
01:01:46,309 --> 01:01:43,760
megabytes that are streaming through it

1850
01:01:48,230 --> 01:01:46,319
at any given time for uh enhanced

1851
01:01:50,069 --> 01:01:48,240
science mission in the future

1852
01:01:51,589 --> 01:01:50,079
so cubesats take advantage of commercial

1853
01:01:53,670 --> 01:01:51,599
parts things that are out there things

1854
01:01:55,190 --> 01:01:53,680
that are in your cell phone in fact cell

1855
01:01:57,670 --> 01:01:55,200
phones themselves have been put on

1856
01:01:59,030 --> 01:01:57,680
several cubesats and flown there is even

1857
01:02:02,630 --> 01:01:59,040
one that had a finger that touched the

1858
01:02:05,270 --> 01:02:03,829
so these are the sorts of things what

1859
01:02:06,950 --> 01:02:05,280
you see out in the commercial industry

1860
01:02:08,470 --> 01:02:06,960
is possible to fly on these different

1861
01:02:09,910 --> 01:02:08,480
spacecraft assuming you take the

1862
01:02:11,910 --> 01:02:09,920
appropriate risk and you're using it for

1863
01:02:14,230 --> 01:02:11,920

the appropriate mission there as we go

1864
01:02:15,589 --> 01:02:14,240
further out with commercial components

1865
01:02:17,030 --> 01:02:15,599
we need to look at the lifetime in the

1866
01:02:18,789 --> 01:02:17,040
space environment and this is dealing

1867
01:02:21,109 --> 01:02:18,799
with radiation with dealing with the

1868
01:02:22,549 --> 01:02:21,119
power but for many missions especially

1869
01:02:25,510 --> 01:02:22,559
when they're trying to stay low cost

1870
01:02:27,910 --> 01:02:25,520
when they have a very small objective

1871
01:02:30,470 --> 01:02:27,920
having that small processor that can use

1872
01:02:42,870 --> 01:02:30,480
so little power is extremely beneficial

1873
01:02:49,430 --> 01:02:43,910
uh

1874
01:02:53,030 --> 01:02:49,440
cards components right so can we throw

1875
01:02:54,630 --> 01:02:53,040
away all the uh spacecraft new standards

1876
01:02:56,309 --> 01:02:54,640
so it all comes down to risk most

1877
01:02:57,109 --> 01:02:56,319
cubesats on here

1878
01:02:58,710 --> 01:02:57,119
are

1879
01:03:00,870 --> 01:02:58,720
actually flying commercial off the shelf

1880
01:03:02,390 --> 01:03:00,880
or cots components but it's because

1881
01:03:03,589 --> 01:03:02,400
they're willing to take additional risks

1882
01:03:05,589 --> 01:03:03,599
because they want to keep that cost

1883
01:03:08,069 --> 01:03:05,599
number low

1884
01:03:10,630 --> 01:03:08,079
and they all

1885
01:03:12,950 --> 01:03:10,640
they also don't need to handle the

1886
01:03:14,470 --> 01:03:12,960
robustness of larger spacecraft

1887
01:03:16,069 --> 01:03:14,480
if you have a 500 million dollar

1888
01:03:17,910 --> 01:03:16,079

spacecraft you want it to survive you

1889
01:03:19,750 --> 01:03:17,920
want it to work you want to test and

1890
01:03:21,349 --> 01:03:19,760
make sure that actually will work and as

1891
01:03:23,510 --> 01:03:21,359
part of the testing process you test the

1892
01:03:24,710 --> 01:03:23,520
parts all the way down to the individual

1893
01:03:26,309 --> 01:03:24,720
components

1894
01:03:28,230 --> 01:03:26,319
to make sure that they will survive and

1895
01:03:30,549 --> 01:03:28,240
work along the way

1896
01:03:31,670 --> 01:03:30,559
now those are space hardened parts these

1897
01:03:32,630 --> 01:03:31,680
are parts that we know tolerate

1898
01:03:34,150 --> 01:03:32,640
radiation they have been through

1899
01:03:36,069 --> 01:03:34,160
environmental testing they've been

1900
01:03:38,150 --> 01:03:36,079
through all sorts of analyses that

1901
01:03:39,670 --> 01:03:38,160
raises the costs so the very fact that

1902
01:03:41,589 --> 01:03:39,680
you want to cut you want to build for a

1903
01:03:44,390 --> 01:03:41,599
500 million dollar mission itself makes

1904
01:03:46,630 --> 01:03:44,400
it a 500 million dollar mission with a

1905
01:03:47,829 --> 01:03:46,640
cubesat we're saying low cost because we

1906
01:03:49,029 --> 01:03:47,839
say we have a fixed budget if you're

1907
01:03:50,549 --> 01:03:49,039
building your kitchen you have one

1908
01:03:51,750 --> 01:03:50,559
budget that you can go with or else you

1909
01:03:54,230 --> 01:03:51,760
won't have a kitchen you can't cook your

1910
01:03:55,750 --> 01:03:54,240
food i can't fly my spacecraft so we

1911
01:03:57,349 --> 01:03:55,760
have to make those risk trades on there

1912
01:03:58,630 --> 01:03:57,359
and it's because of that that we often

1913
01:04:00,230 --> 01:03:58,640

choose the commercial off the shelf

1914
01:04:03,029 --> 01:04:00,240
parts

1915
01:04:05,829 --> 01:04:03,039
and on those cubes like it does have a

1916
01:04:07,270 --> 01:04:05,839
battery life as well right and what is

1917
01:04:09,829 --> 01:04:07,280
the estimated time like until the

1918
01:04:12,390 --> 01:04:09,839
failure of it

1919
01:04:13,589 --> 01:04:12,400
in terms of lifetime of the battery

1920
01:04:15,109 --> 01:04:13,599
it's usually that the batteries can

1921
01:04:15,990 --> 01:04:15,119
survive for at least several years on

1922
01:04:17,349 --> 01:04:16,000
orbit

1923
01:04:19,589 --> 01:04:17,359
we saw with

1924
01:04:21,990 --> 01:04:19,599
psi4 that the mission is still operating

1925
01:04:23,270 --> 01:04:22,000
after 13 years on orbit on there but we

1926
01:04:25,349 --> 01:04:23,280
do go back to the manufacturer's

1927
01:04:27,029 --> 01:04:25,359
specifications to see how it does we

1928
01:04:28,950 --> 01:04:27,039
also treat our batteries very carefully

1929
01:04:31,910 --> 01:04:28,960
along the way for instance on marco

1930
01:04:33,670 --> 01:04:31,920
which has a 26 month shelf time now as

1931
01:04:34,789 --> 01:04:33,680
we're waiting for launch we have to

1932
01:04:36,710 --> 01:04:34,799
check in on the batteries and actually

1933
01:04:38,789 --> 01:04:36,720
keep them at a regular charge every

1934
01:04:41,510 --> 01:04:38,799
three months or so so it's doing things

1935
01:04:44,390 --> 01:04:41,520
like this is there any plan to

1936
01:04:46,630 --> 01:04:44,400
send those boxes cubes back in to the

1937
01:04:48,789 --> 01:04:46,640
earth is there like any future thoughts

1938
01:04:50,309 --> 01:04:48,799

about it so there are several cubesat

1939
01:04:52,549 --> 01:04:50,319
efforts that are actually looking at how

1940
01:04:54,150 --> 01:04:52,559
can we return things from orbit

1941
01:04:55,829 --> 01:04:54,160
with a small spacecraft you don't get a

1942
01:04:57,190 --> 01:04:55,839
lot of data down and for some of the

1943
01:04:59,510 --> 01:04:57,200
missions you're actually acquiring a lot

1944
01:05:01,029 --> 01:04:59,520
of data and so because of that there's

1945
01:05:03,349 --> 01:05:01,039
actually been the idea of well there's

1946
01:05:04,950 --> 01:05:03,359
an sd card that's storing data on board

1947
01:05:06,390 --> 01:05:04,960
why can't we bring that sd card back

1948
01:05:07,829 --> 01:05:06,400
down to earth

1949
01:05:09,349 --> 01:05:07,839
the problem in general has not been

1950
01:05:11,190 --> 01:05:09,359
getting it down through the atmosphere

1951
01:05:13,190 --> 01:05:11,200
it's finding it afterwards so there's a

1952
01:05:14,470 --> 01:05:13,200
lot of ocean out there

1953
01:05:16,549 --> 01:05:14,480
so there are a number of companies that

1954
01:05:19,270 --> 01:05:16,559
are out there and they have published

1955
01:05:21,510 --> 01:05:19,280
from aerospace corporation to

1956
01:05:23,270 --> 01:05:21,520
various universities and such that are

1957
01:05:25,510 --> 01:05:23,280
actually trying to go forward and do

1958
01:05:27,109 --> 01:05:25,520
some kind of return from orbit from

1959
01:05:31,109 --> 01:05:27,119
cubesats

1960
01:05:35,910 --> 01:05:33,589
why not put some charging stations up in

1961
01:05:38,230 --> 01:05:35,920
space so when you go out further they're

1962
01:05:39,190 --> 01:05:38,240
nuclear powered or something and then

1963
01:05:42,789 --> 01:05:39,200

when

1964
01:05:44,870 --> 01:05:42,799
the cubesat has reached its certain

1965
01:05:46,470 --> 01:05:44,880
battery limit or gone out further they

1966
01:05:47,829 --> 01:05:46,480
can get recharged at these stations and

1967
01:05:49,109 --> 01:05:47,839
go further

1968
01:05:50,870 --> 01:05:49,119
so for all of these things and there's

1969
01:05:52,230 --> 01:05:50,880
been talk about fuel depots throughout

1970
01:05:54,309 --> 01:05:52,240
the solar system for our larger

1971
01:05:55,990 --> 01:05:54,319
spacecraft along the way it depends on

1972
01:05:57,430 --> 01:05:56,000
what we want to use these craft for and

1973
01:05:59,589 --> 01:05:57,440
how much money would it take to actually

1974
01:06:00,870 --> 01:05:59,599
put a charging station out there and

1975
01:06:02,789 --> 01:06:00,880
what is the actual benefit that you

1976
01:06:04,789 --> 01:06:02,799
would get with these cubesats as they go

1977
01:06:06,150 --> 01:06:04,799
further out we found with our larger

1978
01:06:08,309 --> 01:06:06,160
spacecraft than in the outer solar

1979
01:06:09,670 --> 01:06:08,319
system that we typically go with these

1980
01:06:10,789 --> 01:06:09,680
radio

1981
01:06:13,270 --> 01:06:10,799
iso

1982
01:06:15,270 --> 01:06:13,280
radio electric

1983
01:06:17,109 --> 01:06:15,280
generators that we have on board rtgs

1984
01:06:18,549 --> 01:06:17,119
radio thermal electric generators

1985
01:06:20,230 --> 01:06:18,559
and that allows us to have power much

1986
01:06:21,990 --> 01:06:20,240
further out voyager of course is using

1987
01:06:25,029 --> 01:06:22,000
these along the way

1988
01:06:26,549 --> 01:06:25,039

for cubesats so far the most useful spot

1989
01:06:27,910 --> 01:06:26,559
has still been in the inner solar system

1990
01:06:30,069 --> 01:06:27,920
because there are so many desirable

1991
01:06:31,750 --> 01:06:30,079
targets that we have yet to hit

1992
01:06:33,190 --> 01:06:31,760
plus the power and thermal and all the

1993
01:06:34,710 --> 01:06:33,200
other challenges that you have as you go

1994
01:06:36,470 --> 01:06:34,720
further and further out

1995
01:06:38,069 --> 01:06:36,480
for now i foresee that cubesats are

1996
01:06:39,990 --> 01:06:38,079
primarily going to be the disposable

1997
01:06:41,430 --> 01:06:40,000
probes of space such that we won't

1998
01:06:42,950 --> 01:06:41,440
necessarily need to recharge them and

1999
01:06:44,870 --> 01:06:42,960
that we'll have the larger motherships

2000
01:06:46,789 --> 01:06:44,880
along the way that either will carry the

2001
01:06:47,910 --> 01:06:46,799
rtgs and can charge before deploying

2002
01:06:49,670 --> 01:06:47,920
these things

2003
01:06:51,109 --> 01:06:49,680
or that we will find other methods of

2004
01:06:57,589 --> 01:06:51,119
kind of deploying them or running with

2005
01:07:00,710 --> 01:06:58,829
any last