1
00:00:10,040 --> 00:00:05,840
NASA's Jet Propulsion Laboratory

2
00:00:12,470 --> 00:00:10,050
presents the von Karman lecture a series

3
00:00:14,839 --> 00:00:12,480
of talks by scientists and engineers who

4
00:00:17,500 --> 00:00:14,849
are exploring our planet our solar

5
00:00:25,430 --> 00:00:17,510
system and all that lies beyond

6
00:00:25,440 --> 00:00:32,750
[Applause]

7
00:00:37,619 --> 00:00:34,920
Brod I brought out some admirers

8
00:00:39,000 --> 00:00:37,629
apparently hello and welcome to NASA's

9
00:00:41,009 --> 00:00:39,010
Jet Propulsion Laboratory in Pasadena

10
00:00:42,180 --> 00:00:41,019
California and our monthly public

11
00:00:44,040 --> 00:00:42,190
lecture which we call the von Karman

12
00:00:45,959 --> 00:00:44,050
series I'm Preston dykes from the

13
00:00:48,540 --> 00:00:45,969

communications office here

14
00:00:51,780 --> 00:00:48,550
well they're small they're modular

15
00:00:54,420 --> 00:00:51,790
they're relatively inexpensive to build

16
00:00:57,630 --> 00:00:54,430
and launch our topic this month is Cube

17
00:00:59,430 --> 00:00:57,640
sets and small sets it's a field with

18
00:01:01,049 --> 00:00:59,440
immense potential and it's led to an

19
00:01:03,660 --> 00:01:01,059
explosion of new ideas in the last few

20
00:01:06,810 --> 00:01:03,670
years our two speakers today are helping

21
00:01:10,290 --> 00:01:06,820
to lead that innovation here at JPL now

22
00:01:12,270 --> 00:01:10,300
both Travis and Annie began their career

23
00:01:14,880 --> 00:01:12,280
journey as engineers working on small

24
00:01:16,590 --> 00:01:14,890
satellites and as you'll learn it's a

25
00:01:18,450 --> 00:01:16,600
field that offers a lot of opportunities

26
00:01:19,859 --> 00:01:18,460
for students and others who were earlier

27
00:01:21,779 --> 00:01:19,869
in their careers to play meaningful

28
00:01:24,090 --> 00:01:21,789
roles in actual spacecraft missions

29
00:01:25,680 --> 00:01:24,100
which is pretty exciting so after our

30
00:01:26,760 --> 00:01:25,690
two talks we'll take questions from here

31
00:01:28,649 --> 00:01:26,770
in the audience and if you're watching

32
00:01:30,389 --> 00:01:28,659
our live webcast we'll work in a few of

33
00:01:33,990 --> 00:01:30,399
your questions you can submit questions

34
00:01:35,850 --> 00:01:34,000
by the chat on youtube so to start us

35
00:01:38,190 --> 00:01:35,860
off our first speaker is a systems

36
00:01:39,960 --> 00:01:38,200
engineer here at JPL and he's worked on

37
00:01:42,389 --> 00:01:39,970
a variety of small satellite missions

38
00:01:45,810 --> 00:01:42,399

with interesting names like rain cube

39
00:01:47,819 --> 00:01:45,820
and lunar flashlights he serves as a

40
00:01:50,039 --> 00:01:47,829
subject matter expert for small

41
00:01:51,569 --> 00:01:50,049
satellite missions concepts that are our

42
00:01:53,880 --> 00:01:51,579
teams here that are formulating and

43
00:01:56,100 --> 00:01:53,890
designing new missions he's a graduate

44
00:01:59,370 --> 00:01:56,110
of the University of Texas at Austin

45
00:02:09,140 --> 00:01:59,380
and he's been with JPL since 2014 please

46
00:02:13,620 --> 00:02:11,070
all right well thank you for the

47
00:02:15,930 --> 00:02:13,630
introduction Preston this is really

48
00:02:17,400 --> 00:02:15,940
exciting to be here when Anna and I were

49
00:02:19,470 --> 00:02:17,410
talking yesterday preparing for this

50
00:02:21,270 --> 00:02:19,480
talk we both realized that we've worked

51
00:02:23,520 --> 00:02:21,280
on a lot of small satellites over our

52
00:02:24,960 --> 00:02:23,530
years and although we've had the office

53
00:02:26,640 --> 00:02:24,970
of opportunity to work on them here at

54
00:02:28,410 --> 00:02:26,650
JPL we've also been able to work on them

55
00:02:32,610 --> 00:02:28,420
in school as part of our path to get

56
00:02:34,380 --> 00:02:32,620
here so though about myself as Preston

57
00:02:36,090 --> 00:02:34,390
mentioned I'm originally from Texas I

58
00:02:37,830 --> 00:02:36,100
ended up getting both my bachelor's and

59
00:02:39,840 --> 00:02:37,840
master's from the University of Texas at

60
00:02:42,080 --> 00:02:39,850
Austin and aerospace engineering here's

61
00:02:44,970 --> 00:02:42,090
a picture of me before I had a beard

62
00:02:48,390 --> 00:02:44,980
this eventually led me to here at JPL to

63
00:02:51,030 --> 00:02:48,400

be a systems engineer since 2014 and

64
00:02:52,260 --> 00:02:51,040
then my time of both in the university

65
00:02:53,960 --> 00:02:52,270
and here at JPL have had the opportunity

66
00:02:56,730 --> 00:02:53,970
to work on seven different cube sets

67
00:02:58,260 --> 00:02:56,740
this beautiful one you see here is reine

68
00:03:01,670 --> 00:02:58,270
cube a mission I worked on from

69
00:03:04,830 --> 00:03:01,680
formulation through flight right now and

70
00:03:07,200 --> 00:03:04,840
as well as two other missions that have

71
00:03:09,390 --> 00:03:07,210
also been launched this is Bevo one and

72
00:03:10,950 --> 00:03:09,400
Bevo two for those of you not upon your

73
00:03:13,200 --> 00:03:10,960
University of Texas trivia that's the

74
00:03:15,570 --> 00:03:13,210
name of our Cal mascot Bevo so we named

75
00:03:18,240 --> 00:03:15,580
it as such I've worked on three others

76
00:03:20,190 --> 00:03:18,250
that are still in progress and there is

77
00:03:21,660 --> 00:03:20,200
one more but in this case I'll just say

78
00:03:23,790 --> 00:03:21,670
a picture's worth a thousand words

79
00:03:28,830 --> 00:03:23,800
on when that one tried to get into orbit

80
00:03:31,140 --> 00:03:28,840
so so what is a CubeSat well the CubeSat

81
00:03:34,620 --> 00:03:31,150
standard was first imagined 20 years ago

82
00:03:38,310 --> 00:03:34,630
in 1999 by Geordi boots wari and Bob

83
00:03:40,740 --> 00:03:38,320
Twiggs the CubeSat is this this is what

84
00:03:43,320 --> 00:03:40,750
we call a one unit or a 1u for short

85
00:03:45,720 --> 00:03:43,330
CubeSat is 10 centimeters on each side

86
00:03:46,980 --> 00:03:45,730
if you're going if the walls were solid

87
00:03:48,570 --> 00:03:46,990
and you're gonna fill it with water it

88
00:03:51,180 --> 00:03:48,580

would hold exactly one liter worth of

89
00:03:53,040 --> 00:03:51,190
liquid and once we finished cramming all

90
00:03:54,750 --> 00:03:53,050
of the metal electronics boards and

91
00:03:55,770 --> 00:03:54,760
other wires into this volume it ends up

92
00:04:01,620 --> 00:03:55,780
weighing about one in the third

93
00:04:03,930 --> 00:04:01,630
kilograms per unit so I CubeSat is

94
00:04:05,280 --> 00:04:03,940
miniature you can hold it in the hand

95
00:04:06,840 --> 00:04:05,290
you saw me holding on the previous slide

96
00:04:09,900 --> 00:04:06,850
here's a blown-up picture of our ibex

97
00:04:12,030 --> 00:04:09,910
CubeSat the CubeSat is also designed to

98
00:04:13,770 --> 00:04:12,040
a common standard so in this photo we

99
00:04:15,570 --> 00:04:13,780
see three one unit cube sets and

100
00:04:17,340 --> 00:04:15,580
although they all generally conform to

101
00:04:18,720 --> 00:04:17,350
the same outside form factors designed

102
00:04:20,340 --> 00:04:18,730
to fit within a dispenser you can see

103
00:04:22,140 --> 00:04:20,350
they look radically different they have

104
00:04:23,219 --> 00:04:22,150
different solar panel arrangements and

105
00:04:24,330 --> 00:04:23,229
you look closely at that one on the

106
00:04:26,610 --> 00:04:24,340
right you can actually see those yellow

107
00:04:28,560 --> 00:04:26,620
stripes well that team actually decided

108
00:04:29,760 --> 00:04:28,570
to use yellow painted spring steel tape

109
00:04:30,749 --> 00:04:29,770
measures just like you get a Home Depot

110
00:04:32,159 --> 00:04:30,759
and they're using those as their

111
00:04:36,420 --> 00:04:32,169
antennas so they can communicate back to

112
00:04:38,249 --> 00:04:36,430
her so instead of building three Cube

113
00:04:39,930 --> 00:04:38,259

sets some clever people have said well

114
00:04:41,430 --> 00:04:39,940
hey why don't we just stack them on top

115
00:04:43,650 --> 00:04:41,440
of each other fill in the space in

116
00:04:45,390 --> 00:04:43,660
between to make one monolithic satellite

117
00:04:47,040 --> 00:04:45,400
so this is what we have here this is

118
00:04:48,870 --> 00:04:47,050
what we call a three unit cube set or a

119
00:04:50,879 --> 00:04:48,880
3u for short basically we've taken all

120
00:04:52,650 --> 00:04:50,889
that volume then stacked it up from

121
00:04:54,120 --> 00:04:52,660
there the standard gets bigger we could

122
00:04:55,409 --> 00:04:54,130
double this and width would make it what

123
00:04:56,460 --> 00:04:55,419
we call a sixty like the rain cube

124
00:04:58,680 --> 00:04:56,470
satellite I showed in the previous slide

125
00:05:01,110 --> 00:04:58,690
and they can get even bigger twelve you

126
00:05:04,590 --> 00:05:01,120
eighteen you twenty seven you it's all

127
00:05:05,730 --> 00:05:04,600
modular another unique thing about it

128
00:05:07,980 --> 00:05:05,740
CubeSat is they're all delivered to

129
00:05:10,200 --> 00:05:07,990
space inside of a dispenser so this is a

130
00:05:12,090 --> 00:05:10,210
6u dispenser it's for the Marco cube

131
00:05:13,620 --> 00:05:12,100
says that and we'll talk about later so

132
00:05:14,730 --> 00:05:13,630
there's a CubeSat inside of this box and

133
00:05:16,560 --> 00:05:14,740
you can actually see there's a door here

134
00:05:18,839 --> 00:05:16,570
on this edge that would actually open up

135
00:05:19,860 --> 00:05:18,849
and fling the cubes out into space this

136
00:05:21,689 --> 00:05:19,870
is something that's unique about the

137
00:05:23,490 --> 00:05:21,699
CubeSat platform they're all delivered

138
00:05:24,749 --> 00:05:23,500

usually into space inside of a box and

139
00:05:28,920 --> 00:05:24,759
I'll talk a little bit more about why

140
00:05:30,870 --> 00:05:28,930
that is on a later slide so our talk

141
00:05:32,310 --> 00:05:30,880
tonight is about Cube sets and small

142
00:05:33,870 --> 00:05:32,320
sets and I'm mostly going to talk about

143
00:05:35,040 --> 00:05:33,880
cube SATs and then an we'll talk a

144
00:05:37,350 --> 00:05:35,050
little bit more about some of our small

145
00:05:38,460 --> 00:05:37,360
set concepts in her presentation but

146
00:05:40,620 --> 00:05:38,470
it's important to remember that a

147
00:05:43,020 --> 00:05:40,630
CubeSat is part of the small set family

148
00:05:45,600 --> 00:05:43,030
now one thing about small sets is

149
00:05:46,890 --> 00:05:45,610
they're not exactly new in fact the very

150
00:05:48,870 --> 00:05:46,900
first spacecraft that the Unites States

151
00:05:51,210 --> 00:05:48,880
ever launched into space was a small set

152
00:05:55,740 --> 00:05:51,220
so this is Explorer one I think from 51

153
00:05:57,810 --> 00:05:55,750
years ago in this picture I feature kind

154
00:05:59,070 --> 00:05:57,820
of some what we'd call small sets so in

155
00:06:00,240 --> 00:05:59,080
this case you can see some fundamental

156
00:06:01,980 --> 00:06:00,250
differences from what I talked about in

157
00:06:04,469 --> 00:06:01,990
the CubeSat you can see they're bigger

158
00:06:05,399 --> 00:06:04,479
maybe the size of a mini-fridge you can

159
00:06:06,990 --> 00:06:05,409
see they've kind of taken different

160
00:06:08,219 --> 00:06:07,000
shapes and sizes depending on what

161
00:06:10,200 --> 00:06:08,229
needed to be done for their missions

162
00:06:11,189 --> 00:06:10,210
what their payloads were and you can

163
00:06:13,850 --> 00:06:11,199

also see that they're the primary

164
00:06:16,050 --> 00:06:13,860
payload on top of this rocket

165
00:06:17,730 --> 00:06:16,060
however bringing back her old friend

166
00:06:19,140 --> 00:06:17,740
rain cube being constrained in a box

167
00:06:21,180 --> 00:06:19,150
doesn't actually affect the shape that

168
00:06:22,589 --> 00:06:21,190
your satellite takes in the end in our

169
00:06:24,180 --> 00:06:22,599
case though we went up in a nice square

170
00:06:25,500 --> 00:06:24,190
form factor we opened up our solar

171
00:06:27,240 --> 00:06:25,510
panels you can see here at the bottom

172
00:06:28,860 --> 00:06:27,250
and we added the pin furling this giant

173
00:06:33,060 --> 00:06:28,870
1/2 meter mesh antenna so we could

174
00:06:34,860 --> 00:06:33,070
complete our science mission so

175
00:06:35,730 --> 00:06:34,870
something that's really exciting about

176
00:06:37,410 --> 00:06:35,740
cube SATs

177
00:06:38,550 --> 00:06:37,420
is how similar they are to spacecraft

178
00:06:39,780 --> 00:06:38,560
but how different they are to some of

179
00:06:41,640 --> 00:06:39,790
the traditional spacecraft that you've

180
00:06:46,200 --> 00:06:41,650
that you've known up from JPL for

181
00:06:47,970 --> 00:06:46,210
example what's key is access to space so

182
00:06:50,850 --> 00:06:47,980
this is a picture I'm from the Indian

183
00:06:53,400 --> 00:06:50,860
Space Agency this is a launch from 2017

184
00:06:53,790 --> 00:06:53,410
and I want I want the audience to guess

185
00:06:55,170 --> 00:06:53,800
here

186
00:06:59,790 --> 00:06:55,180
how many cube SATs do you think were

187
00:07:01,320 --> 00:06:59,800
launched on this rocket anybody one okay

188
00:07:02,400 --> 00:07:01,330

I heard one it's more than one otherwise

189
00:07:05,160 --> 00:07:02,410
I wouldn't be showing this picture any

190
00:07:06,630 --> 00:07:05,170
other guesses okay if you said 100

191
00:07:08,100 --> 00:07:06,640
you're really close there were actually

192
00:07:10,410 --> 00:07:08,110
a hundred and four total satellites

193
00:07:12,390 --> 00:07:10,420
launched on this vehicle 103 of which

194
00:07:16,380 --> 00:07:12,400
were cube sets so that's a really big

195
00:07:18,180 --> 00:07:16,390
deal I also like to say that cube SATs

196
00:07:19,020 --> 00:07:18,190
are different than big spacecraft

197
00:07:20,970 --> 00:07:19,030
because they have was kind of a

198
00:07:22,170 --> 00:07:20,980
constrained complexity on our big

199
00:07:23,640 --> 00:07:22,180
missions like the ones you see in this

200
00:07:25,410 --> 00:07:23,650
room you can see they take the shape

201
00:07:27,810 --> 00:07:25,420
needed to complete their science mission

202
00:07:29,760 --> 00:07:27,820
in our case looking on the insides of

203
00:07:32,670 --> 00:07:29,770
rain cube you can see when we had to fit

204
00:07:34,740 --> 00:07:32,680
with on the box form factor we did our

205
00:07:37,080 --> 00:07:34,750
best to make this engineered web of

206
00:07:38,640 --> 00:07:37,090
cables RF connectors and electronics

207
00:07:40,380 --> 00:07:38,650
boards you can't imagine how we could

208
00:07:42,150 --> 00:07:40,390
actually stuff anymore in here so that

209
00:07:43,650 --> 00:07:42,160
limited the amount of redundancy we can

210
00:07:45,030 --> 00:07:43,660
have and for other missions that might

211
00:07:46,110 --> 00:07:45,040
limit the complexity of your payloads or

212
00:07:49,590 --> 00:07:46,120
even the number of payloads you carry

213
00:07:51,150 --> 00:07:49,600

over all keeps that's also leverage

214
00:07:52,710 --> 00:07:51,160
commercial components so if you learn

215
00:07:53,400 --> 00:07:52,720
one acronym tonight diadem you can learn

216
00:07:54,570 --> 00:07:53,410
is cots

217
00:07:57,330 --> 00:07:54,580
this stands for commercial off-the-shelf

218
00:07:58,920 --> 00:07:57,340
a cost component is something like the

219
00:08:00,210 --> 00:07:58,930
electronics you have in your laptop in

220
00:08:02,220 --> 00:08:00,220
your smartphone or maybe even your

221
00:08:04,560 --> 00:08:02,230
Fitbit so generally these are components

222
00:08:06,900 --> 00:08:04,570
that are very powerful in terms of like

223
00:08:09,240 --> 00:08:06,910
performance but also use low power in

224
00:08:11,370 --> 00:08:09,250
terms of watts there's also a lot of

225
00:08:12,780 --> 00:08:11,380
availability so you can go online you

226
00:08:14,100 --> 00:08:12,790
can buy components very cheap you can

227
00:08:16,820 --> 00:08:14,110
iterate and you can pack a lot of

228
00:08:19,020 --> 00:08:16,830
performance into these small packages

229
00:08:20,340 --> 00:08:19,030
finally something that makes cube SATs

230
00:08:22,500 --> 00:08:20,350
unique is how many that you can simply

231
00:08:24,240 --> 00:08:22,510
launch at a time a lot of missions we

232
00:08:25,380 --> 00:08:24,250
have at JPL you launch one maybe two

233
00:08:27,390 --> 00:08:25,390
spacecraft that are similar to each

234
00:08:29,430 --> 00:08:27,400
other this is a picture I borrowed from

235
00:08:31,140 --> 00:08:29,440
Planet Labs and each of these

236
00:08:32,850 --> 00:08:31,150
spacecrafts is called a dove and they

237
00:08:34,980 --> 00:08:32,860
actually launch a flock of their doves

238
00:08:36,390 --> 00:08:34,990

into space so all of these cube sets are

239
00:08:38,250 --> 00:08:36,400
essentially copies of one another they

240
00:08:39,150 --> 00:08:38,260
all have an imaging payload and when

241
00:08:41,010 --> 00:08:39,160
they're launched together they actually

242
00:08:42,720 --> 00:08:41,020
spread out within the orbit and take

243
00:08:44,280 --> 00:08:42,730
images one after another in space at the

244
00:08:45,930 --> 00:08:44,290
same ground target and that gives us

245
00:08:48,240 --> 00:08:45,940
unprecedented access that's seeing kind

246
00:08:49,500 --> 00:08:48,250
of the small time variation on the two

247
00:08:51,090 --> 00:08:49,510
and be able to get if you only had one

248
00:08:53,310 --> 00:08:51,100
spacecraft may be flying over the same

249
00:08:57,510 --> 00:08:53,320
point every of hours days or maybe even

250
00:08:59,100 --> 00:08:57,520
weeks so I want to come back and talk

251
00:09:00,180 --> 00:08:59,110
about access to space because I think

252
00:09:03,180 --> 00:09:00,190
this is something that makes the keeps

253
00:09:05,280 --> 00:09:03,190
that platform truly unique so this is a

254
00:09:06,930 --> 00:09:05,290
picture of a satellite called NPP you

255
00:09:08,160 --> 00:09:06,940
can see a white frock person in the

256
00:09:09,960 --> 00:09:08,170
lower left corner for scale

257
00:09:11,310 --> 00:09:09,970
I need audience participation again can

258
00:09:14,070 --> 00:09:11,320
anybody find the cubes hats in this

259
00:09:15,360 --> 00:09:14,080
picture okay well I drew it a nice

260
00:09:16,950 --> 00:09:15,370
yellow circle so they're actually just

261
00:09:19,290 --> 00:09:16,960
stuff down here in the corner for scale

262
00:09:21,090 --> 00:09:19,300
so this is three three unit two CubeSat

263
00:09:22,470 --> 00:09:21,100

dispensers and this has been the more

264
00:09:25,050 --> 00:09:22,480
traditional way of how cube cells get

265
00:09:27,330 --> 00:09:25,060
into orbit so there's a very big payload

266
00:09:28,890 --> 00:09:27,340
that you can see here they've paid most

267
00:09:30,090 --> 00:09:28,900
of the cost for the rocket they're

268
00:09:31,890 --> 00:09:30,100
paying to get into the orbit they want

269
00:09:34,200 --> 00:09:31,900
to go to and they keep set say hey

270
00:09:35,820 --> 00:09:34,210
you've got extra volume extra mass let's

271
00:09:38,010 --> 00:09:35,830
tag along and they pay a much reduced

272
00:09:39,630 --> 00:09:38,020
price to get into space the only

273
00:09:40,890 --> 00:09:39,640
consequence of that is you ultimately

274
00:09:42,240 --> 00:09:40,900
kind of end up in a similar orbit

275
00:09:45,840 --> 00:09:42,250
similar to where the actual paying

276
00:09:47,070 --> 00:09:45,850
customer is going another method we have

277
00:09:49,410 --> 00:09:47,080
is through the International Space

278
00:09:51,420 --> 00:09:49,420
Station and this is rather rather Rube

279
00:09:53,460 --> 00:09:51,430
Goldberg process so the cube sets are

280
00:09:55,080 --> 00:09:53,470
actually packaged up as cargo with the

281
00:09:56,580 --> 00:09:55,090
astronauts food in their water were

282
00:09:59,010 --> 00:09:56,590
inside the pressurized environmentally

283
00:10:00,960 --> 00:09:59,020
controlled volume of the cargo capsules

284
00:10:02,460 --> 00:10:00,970
and they go up to the space station the

285
00:10:04,110 --> 00:10:02,470
astronauts will then actually pull the

286
00:10:05,880 --> 00:10:04,120
cube sets out carry them through the

287
00:10:08,190 --> 00:10:05,890
station or float through the station I

288
00:10:09,480 --> 00:10:08,200

suppose and then when time is right

289
00:10:11,040 --> 00:10:09,490
they'll actually open up the airlock on

290
00:10:13,380 --> 00:10:11,050
the Japanese module it's slide these

291
00:10:15,270 --> 00:10:13,390
dispensers out and then they fire the

292
00:10:17,400 --> 00:10:15,280
button and the CubeSat scum sailing out

293
00:10:18,900 --> 00:10:17,410
so here they were with the solar panels

294
00:10:21,240 --> 00:10:18,910
of ISS behind us and you'll see they

295
00:10:23,700 --> 00:10:21,250
rain cube which is on the left and then

296
00:10:24,990 --> 00:10:23,710
halo sat on the right sail off to begin

297
00:10:27,960 --> 00:10:25,000
their science missions

298
00:10:29,430 --> 00:10:27,970
I think the ISS is actually the most

299
00:10:30,570 --> 00:10:29,440
exciting way to launch keeps us because

300
00:10:34,710 --> 00:10:30,580
you get astronauts taking pictures of

301
00:10:37,170 --> 00:10:34,720
your satellites coming out something

302
00:10:38,880 --> 00:10:37,180
else that's being developed is really

303
00:10:40,290 --> 00:10:38,890
unique so in this first picture I showed

304
00:10:42,390 --> 00:10:40,300
you to keep that SERP at the bottom in

305
00:10:43,830 --> 00:10:42,400
this case though that keeps us are up at

306
00:10:45,150 --> 00:10:43,840
the top so this is a picture of the

307
00:10:48,150 --> 00:10:45,160
electron rocket from a company called

308
00:10:49,590 --> 00:10:48,160
rocket lab and they're part of an

309
00:10:50,580 --> 00:10:49,600
initiative to develop small launch

310
00:10:52,860 --> 00:10:50,590
vehicles and they're dedicated to

311
00:10:54,600 --> 00:10:52,870
launching cube sets so before that

312
00:10:55,650 --> 00:10:54,610
fairing installed this is actually what

313
00:10:58,560 --> 00:10:55,660

it looked like at the top of the rocket

314
00:11:00,420 --> 00:10:58,570
so if I counted right I see 15 different

315
00:11:02,970 --> 00:11:00,430
CubeSat dispensers and this is part of

316
00:11:03,720 --> 00:11:02,980
NASA's Elana 19 mission which actually

317
00:11:05,250 --> 00:11:03,730
launched 10 different

318
00:11:07,379 --> 00:11:05,260
nasa cube sets amongst other missions

319
00:11:09,150 --> 00:11:07,389
from these so in this case similar to

320
00:11:11,280 --> 00:11:09,160
the first picture I showed these keeps

321
00:11:12,660 --> 00:11:11,290
has both mostly all got to kind of pick

322
00:11:14,069 --> 00:11:12,670
the orbits that they went to it was one

323
00:11:15,300 --> 00:11:14,079
that was desirable to them although they

324
00:11:20,129 --> 00:11:15,310
all ended up kind of going to the same

325
00:11:24,600 --> 00:11:20,139
place so time for some data and I have

326
00:11:25,980 --> 00:11:24,610
one big chart so starting in 1999 people

327
00:11:28,769 --> 00:11:25,990
were developing cube sets the first

328
00:11:30,750 --> 00:11:28,779
launch we have recorded is from 2000 but

329
00:11:32,490 --> 00:11:30,760
you can see through 2012 we really into

330
00:11:35,129 --> 00:11:32,500
the plunging no more than about 25 a

331
00:11:38,579 --> 00:11:35,139
year in 2013 you can clearly see that

332
00:11:40,680 --> 00:11:38,589
exploded so my colleague Mike sward out

333
00:11:42,750 --> 00:11:40,690
in the st. Louis University collects

334
00:11:44,730 --> 00:11:42,760
this data and he's done a lot of work

335
00:11:47,519 --> 00:11:44,740
into defining who's building cube sets

336
00:11:50,639 --> 00:11:47,529
and what's going on so the first

337
00:11:52,470 --> 00:11:50,649
category here is hobbyists he defines

338
00:11:54,420 --> 00:11:52,480

this as organizations such as

339
00:11:55,829 --> 00:11:54,430
universities or amateur groups that are

340
00:11:57,269 --> 00:11:55,839
doing this for the learning experience

341
00:11:59,910 --> 00:11:57,279
or perhaps for other kinds of

342
00:12:01,590 --> 00:11:59,920
development activities and when I was

343
00:12:02,910 --> 00:12:01,600
reading up on this I actually learned

344
00:12:04,439 --> 00:12:02,920
that even though I thought I was really

345
00:12:06,120 --> 00:12:04,449
cool doing cube sets as a university

346
00:12:08,009 --> 00:12:06,130
student today there have actually been

347
00:12:10,319 --> 00:12:08,019
high schools middle schools and

348
00:12:14,490 --> 00:12:10,329
elementary schools that have actually

349
00:12:16,439 --> 00:12:14,500
launched cube SATs into space so the

350
00:12:18,360 --> 00:12:16,449
next category we have is traditional

351
00:12:20,009 --> 00:12:18,370
traditional would be institutions much

352
00:12:22,710 --> 00:12:20,019
like JPL where we're used to building

353
00:12:24,960 --> 00:12:22,720
big spacecraft and we build small

354
00:12:27,269 --> 00:12:24,970
spacecraft perhaps tailoring some of our

355
00:12:31,860 --> 00:12:27,279
practices down to meet the CubeSat form

356
00:12:33,569 --> 00:12:31,870
factor the next category is yellow it's

357
00:12:36,210 --> 00:12:33,579
a made-up word we call it the small

358
00:12:37,920 --> 00:12:36,220
satyrs so this is a group of companies

359
00:12:40,410 --> 00:12:37,930
whose core business model is based

360
00:12:42,389 --> 00:12:40,420
around the small satellite form JPL

361
00:12:44,309 --> 00:12:42,399
loves to partner with these companies in

362
00:12:46,139 --> 00:12:44,319
fact rain cube we built the radar

363
00:12:47,430 --> 00:12:46,149

payload for rain cube and a small set

364
00:12:49,110 --> 00:12:47,440
our company called tie vac down in

365
00:12:50,699 --> 00:12:49,120
Irvine built the spacecraft bus that

366
00:12:53,629 --> 00:12:50,709
hosted our payload and then together we

367
00:12:56,280 --> 00:12:53,639
flew that mission together as rain cube

368
00:12:57,750 --> 00:12:56,290
now you're saying okay well what's green

369
00:12:59,970 --> 00:12:57,760
that makes up most of this plot well

370
00:13:01,680 --> 00:12:59,980
Green is actually a subset of the small

371
00:13:02,819 --> 00:13:01,690
satyrs and these are the small set or

372
00:13:04,559 --> 00:13:02,829
companies that are actually in the

373
00:13:07,309 --> 00:13:04,569
business of making constellations much

374
00:13:10,379 --> 00:13:07,319
like the figure I showed of the planet

375
00:13:11,850 --> 00:13:10,389
flock of doves in this case you can see

376
00:13:13,710 --> 00:13:11,860
that once the constellation company

377
00:13:15,929 --> 00:13:13,720
starts launching they launch a lot and

378
00:13:17,100 --> 00:13:15,939
you really see this big bump here in

379
00:13:19,470 --> 00:13:17,110
2017

380
00:13:21,900 --> 00:13:19,480
so that launch of 103 cube SATs that was

381
00:13:25,350 --> 00:13:21,910
on the Israel launch 88 of those were

382
00:13:27,270 --> 00:13:25,360
from Planet so if you were to add all of

383
00:13:29,310 --> 00:13:27,280
this up I think this is the you know big

384
00:13:31,290 --> 00:13:29,320
take-home message of the night is that -

385
00:13:35,100 --> 00:13:31,300
through the end of 2018 we have launched

386
00:13:36,420 --> 00:13:35,110
over 1,000 cube SATs into space a few

387
00:13:39,660 --> 00:13:36,430
more statistics this has actually been

388
00:13:42,510 --> 00:13:39,670

done by over 256 unique organizations

389
00:13:44,100 --> 00:13:42,520
across 54 countries in the world so this

390
00:13:46,190 --> 00:13:44,110
is truly a worldwide initiative to get

391
00:13:48,660 --> 00:13:46,200
access to space

392
00:13:49,890 --> 00:13:48,670
another question that will probably come

393
00:13:51,330 --> 00:13:49,900
up the queue nice all addressed now is

394
00:13:52,920 --> 00:13:51,340
well okay you've launched a thousand

395
00:13:54,930 --> 00:13:52,930
into space what about the space debris

396
00:13:56,460 --> 00:13:54,940
problem and that's something that's kind

397
00:13:58,800 --> 00:13:56,470
of unique to the small set form factor

398
00:14:00,930 --> 00:13:58,810
since most of them stay in low-earth

399
00:14:02,400 --> 00:14:00,940
orbit they're actually only a few

400
00:14:03,690 --> 00:14:02,410
hundred kilometers above Earth and

401
00:14:04,980 --> 00:14:03,700
there's actually sufficient atmospheric

402
00:14:06,720 --> 00:14:04,990
drag that most of these actually will

403
00:14:09,300 --> 00:14:06,730
end up deorbiting within a few months to

404
00:14:10,770 --> 00:14:09,310
a few years after their launch that's

405
00:14:12,060 --> 00:14:10,780
why in the constellation since they

406
00:14:13,290 --> 00:14:12,070
actually have to keep launching more

407
00:14:17,970 --> 00:14:13,300
keep sets because they have to replenish

408
00:14:20,730 --> 00:14:17,980
the ones that are falling down so I

409
00:14:21,870 --> 00:14:20,740
borrowed this chart from headquarters

410
00:14:23,520 --> 00:14:21,880
the small satellite Coordination

411
00:14:26,100 --> 00:14:23,530
Committee on courtesy of Charles Norton

412
00:14:27,420 --> 00:14:26,110
and this is the subset of NASA Cube sets

413
00:14:29,040 --> 00:14:27,430

and small sets and we call this the

414
00:14:31,380 --> 00:14:29,050
fleet these are both operating missions

415
00:14:32,520 --> 00:14:31,390
and future now there's somebody to count

416
00:14:34,020 --> 00:14:32,530
here but I guess you're all here for a

417
00:14:35,160 --> 00:14:34,030
few hours tonight so we can probably go

418
00:14:35,700 --> 00:14:35,170
through each of these one by one if

419
00:14:37,620 --> 00:14:35,710
you'd like

420
00:14:39,450 --> 00:14:37,630
well I tease I'm actually I'm gonna get

421
00:14:41,670 --> 00:14:39,460
a feature for and then Anne will feature

422
00:14:43,560 --> 00:14:41,680
many more that are on this plot so ice

423
00:14:45,150 --> 00:14:43,570
ara and white is a technology and

424
00:14:46,620 --> 00:14:45,160
exploration mission we have Asteria

425
00:14:48,390 --> 00:14:46,630
which is an astrophysics mission and

426
00:14:51,590 --> 00:14:48,400
then tempest D and my own beloved rain

427
00:14:54,270 --> 00:14:51,600
cube I went to earth science missions

428
00:14:56,520 --> 00:14:54,280
alright so ice ara ice R is the

429
00:14:58,950 --> 00:14:56,530
integrated solar array and reflect array

430
00:15:00,990 --> 00:14:58,960
antenna mission this is a picture of it

431
00:15:04,440 --> 00:15:01,000
here so now the trail experts - anybody

432
00:15:06,060 --> 00:15:04,450
gets the form factor of this CubeSat 3u

433
00:15:08,850 --> 00:15:06,070
all right good you're up to speed on the

434
00:15:09,900 --> 00:15:08,860
lingo so you can see guys sir also

435
00:15:12,630 --> 00:15:09,910
didn't want to stay in the shape that

436
00:15:14,280 --> 00:15:12,640
they went up in so this is ice Aras

437
00:15:16,950 --> 00:15:14,290
reflect array you can kind of see this

438
00:15:17,970 --> 00:15:16,960

circle pattern here and this mission was

439
00:15:19,620 --> 00:15:17,980
demonstrating high data rate

440
00:15:21,390 --> 00:15:19,630
communications so there's a radio

441
00:15:23,190 --> 00:15:21,400
frequency feed right here that then

442
00:15:24,600 --> 00:15:23,200
bounced off of this antenna and then

443
00:15:27,630 --> 00:15:24,610
being high data-rate ka-band

444
00:15:28,950 --> 00:15:27,640
communications back to earth so here's a

445
00:15:30,180 --> 00:15:28,960
picture of it in orbit so you can

446
00:15:30,780 --> 00:15:30,190
basically see the same view although you

447
00:15:32,240 --> 00:15:30,790
can get

448
00:15:35,940 --> 00:15:32,250
but better view at the reflector ray

449
00:15:37,320 --> 00:15:35,950
excuse me the feed view up here now of

450
00:15:39,840 --> 00:15:37,330
course the acronym said was integrated

451
00:15:41,520 --> 00:15:39,850
solar ray and reflector antenna so a

452
00:15:43,530 --> 00:15:41,530
technology infusion we had on a saara

453
00:15:45,120 --> 00:15:43,540
was we actually took the reflector rate

454
00:15:46,260 --> 00:15:45,130
and on the opposite side and I did my

455
00:15:47,460 --> 00:15:46,270
best to find a picture but I couldn't

456
00:15:49,230 --> 00:15:47,470
but on the opposite side there's

457
00:15:50,820 --> 00:15:49,240
actually a solar panel so all of the

458
00:15:51,810 --> 00:15:50,830
solar rays are able to flop out you're

459
00:15:53,490 --> 00:15:51,820
able to generate lots of power and

460
00:15:54,960 --> 00:15:53,500
rapportive antenna at the Sun and you

461
00:15:56,400 --> 00:15:54,970
can also then turn and then point that

462
00:15:57,210 --> 00:15:56,410
into the doubt at earth on when you

463
00:15:59,880 --> 00:15:57,220

needed to do the high data-rate

464
00:16:01,230 --> 00:15:59,890
communication something else that was

465
00:16:02,550 --> 00:16:01,240
unique about a saara is that their

466
00:16:04,020 --> 00:16:02,560
primary mission was to demonstrate this

467
00:16:06,180 --> 00:16:04,030
high data-rate communication but they

468
00:16:07,890 --> 00:16:06,190
had extra payload volume so the

469
00:16:09,390 --> 00:16:07,900
Aerospace Corporation included these

470
00:16:12,510 --> 00:16:09,400
three infrared cameras that you can see

471
00:16:13,650 --> 00:16:12,520
right here and here's a picture from one

472
00:16:15,900 --> 00:16:13,660
of those cameras this is from the

473
00:16:17,520 --> 00:16:15,910
shortwave infrared camera this is

474
00:16:19,440 --> 00:16:17,530
actually a picture of Lake Superior and

475
00:16:20,790 --> 00:16:19,450
the frequency of this camera was tuned

476
00:16:22,830 --> 00:16:20,800
to actually differentiate between land

477
00:16:24,540 --> 00:16:22,840
and water so the white you see here is

478
00:16:26,190 --> 00:16:24,550
all the land surrounding Lake Superior

479
00:16:27,870 --> 00:16:26,200
so this is a really cool kind of

480
00:16:30,150 --> 00:16:27,880
technology innovation demonstrating

481
00:16:30,960 --> 00:16:30,160
these new infrared cameras and then as

482
00:16:32,580 --> 00:16:30,970
well as this high data rate

483
00:16:34,650 --> 00:16:32,590
communication and synergistic

484
00:16:36,290 --> 00:16:34,660
combination of the solar panel with the

485
00:16:38,850 --> 00:16:36,300
antenna

486
00:16:40,290 --> 00:16:38,860
alright so tempest D and then I always

487
00:16:42,120 --> 00:16:40,300
need to check my acronym here this is

488
00:16:43,770 --> 00:16:42,130

the temporal experiment for storms and

489
00:16:45,660 --> 00:16:43,780
tropical systems I don't know how they

490
00:16:48,180 --> 00:16:45,670
got tempest out of that but the D stands

491
00:16:51,030 --> 00:16:48,190
for the demonstrator so tempest D is

492
00:16:52,200 --> 00:16:51,040
this bird shaped mission you see here

493
00:16:55,890 --> 00:16:52,210
again does anybody want to guess the

494
00:16:57,810 --> 00:16:55,900
form-factor six to you all right yes and

495
00:16:58,980 --> 00:16:57,820
it carried a Radiometer and the

496
00:16:59,790 --> 00:16:58,990
radiometer actually viewed out of this

497
00:17:03,420 --> 00:16:59,800
hole right here

498
00:17:05,760 --> 00:17:03,430
and it was five different channels so

499
00:17:07,560 --> 00:17:05,770
the first channel is 87 gigahertz and in

500
00:17:09,930 --> 00:17:07,570
this case the 87 gigahertz is really de

501
00:17:11,520 --> 00:17:09,940
sensitive to saying where is water so in

502
00:17:12,780 --> 00:17:11,530
this animation you see here it can

503
00:17:15,360 --> 00:17:12,790
basically see the vapor clouds of

504
00:17:17,400 --> 00:17:15,370
precipitation as expected you have a lot

505
00:17:18,780 --> 00:17:17,410
of weather here around the equator kind

506
00:17:20,250 --> 00:17:18,790
of between the atrophic s-- and of

507
00:17:20,940 --> 00:17:20,260
course the land masses you see around or

508
00:17:22,290 --> 00:17:20,950
red because it's not a lot of

509
00:17:23,700 --> 00:17:22,300
precipitation there although if you look

510
00:17:25,260 --> 00:17:23,710
really closely on this animation you can

511
00:17:28,860 --> 00:17:25,270
actually see that it can pick up some of

512
00:17:30,810 --> 00:17:28,870
the the big lakes in Africa your other

513
00:17:32,520 --> 00:17:30,820

four channels of tempest e radiometer

514
00:17:34,200 --> 00:17:32,530
allowed to actually get cross-sections

515
00:17:37,560 --> 00:17:34,210
of the atmosphere each a few kilometers

516
00:17:38,790 --> 00:17:37,570
apart so the 181 gigahertz you see here

517
00:17:40,920 --> 00:17:38,800
in the top right is actually the highest

518
00:17:43,110 --> 00:17:40,930
cross-section then we stepped on to 184

519
00:17:43,860 --> 00:17:43,120
excuse me 164 gigahertz in the lowest

520
00:17:46,740 --> 00:17:43,870
cross

521
00:17:48,930 --> 00:17:46,750
so in this image we actually in

522
00:17:50,490 --> 00:17:48,940
September of 2018 tempis D flew over

523
00:17:52,560 --> 00:17:50,500
typhoon trami which was just off the

524
00:17:58,980 --> 00:17:52,570
coast of Japan and was able to get these

525
00:18:01,350 --> 00:17:58,990
four horizontal slices of the storm so

526
00:18:02,789 --> 00:18:01,360
the other earth science mission to

527
00:18:04,440 --> 00:18:02,799
feature is rain cube which hack I told

528
00:18:07,529 --> 00:18:04,450
you is my my own beloved mission so

529
00:18:09,749 --> 00:18:07,539
here's a big big version of it so we had

530
00:18:11,370 --> 00:18:09,759
this giant deployable antenna and of

531
00:18:12,960 --> 00:18:11,380
course seeing that we had something big

532
00:18:15,240 --> 00:18:12,970
and complicated to playing we had to put

533
00:18:17,399 --> 00:18:15,250
a camera on board to catch it see I can

534
00:18:18,990 --> 00:18:17,409
actually see here our motor driving our

535
00:18:21,600 --> 00:18:19,000
antenna out of the inside of the CubeSat

536
00:18:24,480 --> 00:18:21,610
it actually filled up this volume kind

537
00:18:25,590 --> 00:18:24,490
of inside and then as we were going over

538
00:18:29,310 --> 00:18:25,600

earth that took about three minutes to

539
00:18:31,889 --> 00:18:29,320
actually pop it out now fortunately both

540
00:18:34,860 --> 00:18:31,899
rain cube and tempest D both flew over

541
00:18:36,149 --> 00:18:34,870
typhoon trami around the same time so

542
00:18:38,909 --> 00:18:36,159
here you can see rain cube took a very

543
00:18:39,930 --> 00:18:38,919
similar track over the storm right over

544
00:18:41,279 --> 00:18:39,940
the eye which happen to be very

545
00:18:45,029 --> 00:18:41,289
fortuitous and we ended up producing

546
00:18:46,529 --> 00:18:45,039
this plot so if you look closely here's

547
00:18:48,029 --> 00:18:46,539
the left wall of the hurricane and we

548
00:18:50,249 --> 00:18:48,039
actually got the left wall of storms

549
00:18:51,629 --> 00:18:50,259
right here the eye is this space right

550
00:18:53,909 --> 00:18:51,639
here in the middle and then the right

551
00:18:55,320 --> 00:18:53,919
wall right here we then continued along

552
00:18:59,340 --> 00:18:55,330
our way until we actually caught another

553
00:19:00,240 --> 00:18:59,350
storm later in our track so you might

554
00:19:02,249 --> 00:19:00,250
see where this is going

555
00:19:03,869 --> 00:19:02,259
we had to cut to cube sets they both

556
00:19:06,690 --> 00:19:03,879
viewed the same storm about five minutes

557
00:19:08,190 --> 00:19:06,700
apart what can you do with that so

558
00:19:10,619 --> 00:19:08,200
refresher here's what the data looked

559
00:19:12,470 --> 00:19:10,629
like and we did some data processing and

560
00:19:14,909 --> 00:19:12,480
we actually ended up with this graphic

561
00:19:15,840 --> 00:19:14,919
so this is animated so don't let it get

562
00:19:18,419 --> 00:19:15,850
too dizzy because it will spin around

563
00:19:20,610 --> 00:19:18,429

spin around ad nauseam so this is taking

564
00:19:23,009 --> 00:19:20,620
those horizontal 2d slices from tempest

565
00:19:24,810 --> 00:19:23,019
D you can count the four slices here

566
00:19:26,549 --> 00:19:24,820
then with the vertical slice of rain

567
00:19:27,480 --> 00:19:26,559
cube going up and down and we're

568
00:19:29,009 --> 00:19:27,490
actually able to get a really

569
00:19:32,549 --> 00:19:29,019
interesting cross section of what

570
00:19:33,659 --> 00:19:32,559
typhoon trami looked like now although

571
00:19:34,950 --> 00:19:33,669
this is kind of an opportunistic

572
00:19:37,409 --> 00:19:34,960
measurement I think this is really

573
00:19:37,769 --> 00:19:37,419
exciting for what you might have in the

574
00:19:38,970 --> 00:19:37,779
future

575
00:19:41,340 --> 00:19:38,980
imagine that you might have

576
00:19:42,450 --> 00:19:41,350
constellations just like the imagers we

577
00:19:44,310 --> 00:19:42,460
have from Planet lives but

578
00:19:45,899 --> 00:19:44,320
constellations of these radars and

579
00:19:47,430 --> 00:19:45,909
radiometers where they could be flying

580
00:19:48,840 --> 00:19:47,440
one after another each collecting the

581
00:19:49,799 --> 00:19:48,850
same measurement or perhaps spread out

582
00:19:52,379 --> 00:19:49,809
in space so you're getting different

583
00:19:53,430 --> 00:19:52,389
vertical profiles side-by-side then you

584
00:19:54,750 --> 00:19:53,440
can combine all of these measurements

585
00:19:55,850 --> 00:19:54,760
together and you actually get a really

586
00:19:57,650 --> 00:19:55,860
unique insight

587
00:19:59,930 --> 00:19:57,660
the evolution of storms because when you

588
00:20:01,580 --> 00:19:59,940

have rapid passes of the same storm

589
00:20:03,260 --> 00:20:01,590
system you can begin to understand the

590
00:20:05,299 --> 00:20:03,270
short timescale evolutions of these

591
00:20:10,490 --> 00:20:05,309
storms which can be a huge boon to

592
00:20:11,630 --> 00:20:10,500
weather in climate modeling so my last

593
00:20:13,460 --> 00:20:11,640
mission I wanted to talk about is

594
00:20:15,320 --> 00:20:13,470
hysteria and that's the arcsecond

595
00:20:18,080 --> 00:20:15,330
telescope for enabling research in

596
00:20:20,000 --> 00:20:18,090
astrophysics so Assyria was a six unit

597
00:20:22,520 --> 00:20:20,010
CubeSat they also have these flop out

598
00:20:24,080 --> 00:20:22,530
solar arrays here now this blue thing

599
00:20:27,140 --> 00:20:24,090
you see here is actually their main

600
00:20:28,520 --> 00:20:27,150
payload that's their telescope so

601
00:20:30,890 --> 00:20:28,530
Asterius mission is to hunt for

602
00:20:32,330 --> 00:20:30,900
exoplanets and if you came to last

603
00:20:35,000 --> 00:20:32,340
month's von-karman talk you learned all

604
00:20:36,560 --> 00:20:35,010
about how to find exoplanets so although

605
00:20:39,020 --> 00:20:36,570
that CubeSat like platform does its best

606
00:20:40,700 --> 00:20:39,030
to get very still in space and compared

607
00:20:43,039 --> 00:20:40,710
Olivia gets pretty still if you're

608
00:20:45,320 --> 00:20:43,049
staring at a star very very very very

609
00:20:47,450 --> 00:20:45,330
far away you need to be very precise and

610
00:20:48,680 --> 00:20:47,460
how you look at it so this telescope was

611
00:20:50,030 --> 00:20:48,690
actually able to take out all of that

612
00:20:52,940 --> 00:20:50,040
noise that was still in the keeps that

613
00:20:54,380 --> 00:20:52,950

platform and focus in on one target it

614
00:20:57,110 --> 00:20:54,390
also achieved an incredible thermal

615
00:21:00,710 --> 00:20:57,120
stability which was needed to dwell on

616
00:21:02,630 --> 00:21:00,720
those targets for some time so what it

617
00:21:04,460 --> 00:21:02,640
looked like and the animation didn't

618
00:21:06,200 --> 00:21:04,470
work on this one but this is essentially

619
00:21:08,659 --> 00:21:06,210
what I serious cameras the raw data look

620
00:21:10,250 --> 00:21:08,669
like so this orange dot you see here is

621
00:21:11,480 --> 00:21:10,260
essentially the star and it would

622
00:21:12,620 --> 00:21:11,490
actually just stare at it and if this

623
00:21:14,000 --> 00:21:12,630
animation played you would actually see

624
00:21:15,350 --> 00:21:14,010
that the orange dot would not move

625
00:21:18,740 --> 00:21:15,360
throughout all of the frames so it was

626
00:21:20,600 --> 00:21:18,750
incredibly successful and what a serious

627
00:21:21,860 --> 00:21:20,610
mission was doing is it was waiting and

628
00:21:23,060 --> 00:21:21,870
staring and waiting for a planet to

629
00:21:25,250 --> 00:21:23,070
actually transit in front of That star

630
00:21:26,510 --> 00:21:25,260
so as it searches the star it would

631
00:21:28,549 --> 00:21:26,520
actually be looking for a dip in the

632
00:21:30,289 --> 00:21:28,559
brightness with the signature u-shape

633
00:21:32,510 --> 00:21:30,299
here and that would actually signal that

634
00:21:34,070 --> 00:21:32,520
an exoplanet had had come and had passed

635
00:21:35,330 --> 00:21:34,080
in front of that star so this is a

636
00:21:36,560 --> 00:21:35,340
really exciting mission as something

637
00:21:41,780 --> 00:21:36,570
that has really never been attempted on

638
00:21:44,210 --> 00:21:41,790

the CubeSat platform to date so here we

639
00:21:46,220 --> 00:21:44,220
are back at this chart and I'm wrapping

640
00:21:47,960 --> 00:21:46,230
up on my few missions but the future is

641
00:21:49,070 --> 00:21:47,970
really exciting or we've had some

642
00:21:50,299 --> 00:21:49,080
exciting missions that have led us this

643
00:21:52,010 --> 00:21:50,309
point and we have a lot of exciting

644
00:21:53,539 --> 00:21:52,020
missions coming up you can see that I've

645
00:21:55,220 --> 00:21:53,549
just covered a few of these we have many

646
00:21:57,200 --> 00:21:55,230
more earth science missions technology

647
00:21:58,190 --> 00:21:57,210
missions and astrophysics missions but

648
00:21:59,510 --> 00:21:58,200
we also have missions that are getting

649
00:22:01,280 --> 00:21:59,520
ready to explore throughout the solar

650
00:22:03,590 --> 00:22:01,290
system and Anne will tell you a lot

651
00:22:12,049 --> 00:22:03,600
about that so with that I'd like to say

652
00:22:16,849 --> 00:22:13,969
great thanks a lot Travis appreciate

653
00:22:18,379 --> 00:22:16,859
that well I assume you all feel like

654
00:22:20,450 --> 00:22:18,389
you're CubeSat experts now I think you

655
00:22:22,009 --> 00:22:20,460
should because I heard six you three you

656
00:22:24,289 --> 00:22:22,019
you guys are shouting out the form

657
00:22:26,749 --> 00:22:24,299
factors like like experts

658
00:22:28,099 --> 00:22:26,759
well I'm sure at this point you're ready

659
00:22:30,200 --> 00:22:28,109
to learn a little more about the

660
00:22:32,359 --> 00:22:30,210
potential of these fascinating little

661
00:22:33,649 --> 00:22:32,369
spacecraft so our next speaker will

662
00:22:34,759 --> 00:22:33,659
delve into some of the really neat

663
00:22:36,409 --> 00:22:34,769

things that we hope to do with these

664
00:22:38,479 --> 00:22:36,419
spacecraft going forward

665
00:22:40,459 --> 00:22:38,489
she's the lead engineer for JPL's

666
00:22:43,549 --> 00:22:40,469
collaborative design team for CubeSat

667
00:22:46,519 --> 00:22:43,559
and small set missions called team x c

668
00:22:48,619 --> 00:22:46,529
and the c is for CubeSat she served as a

669
00:22:50,779 --> 00:22:48,629
systems engineer on the first CubeSat

670
00:22:53,329 --> 00:22:50,789
mission sent to deep space the Mars cube

671
00:22:56,239 --> 00:22:53,339
one or Marco mission which last years

672
00:22:58,369 --> 00:22:56,249
successfully demonstrated that cube SATs

673
00:22:58,879 --> 00:22:58,379
can operate at destinations far beyond

674
00:23:01,039 --> 00:22:58,889
Earth

675
00:23:03,979 --> 00:23:01,049
she's an MIT graduate who's been with

676
00:23:12,150 --> 00:23:03,989
JPL since 2016 please welcome dr. Anne

677
00:23:17,440 --> 00:23:15,460
Thank You Preston hello

678
00:23:21,070 --> 00:23:17,450
I'm Ann I'm going to be talking about

679
00:23:23,610 --> 00:23:21,080
what happens or what we what we view for

680
00:23:27,040 --> 00:23:23,620
cube sets going beyond low-earth orbit

681
00:23:30,190 --> 00:23:27,050
so just like Travis I started in cube

682
00:23:31,780 --> 00:23:30,200
sets in the university program so that I

683
00:23:34,660 --> 00:23:31,790
actually wanted to be an astronaut when

684
00:23:37,150 --> 00:23:34,670
I was about nine years old I dug I dug

685
00:23:40,900 --> 00:23:37,160
up this photo of me at a Girl Scout

686
00:23:42,640 --> 00:23:40,910
Space Camp the fun fact about two years

687
00:23:45,730 --> 00:23:42,650
after this picture was taken was when

688
00:23:48,790 --> 00:23:45,740

small CubeSat form factor was actually

689
00:23:49,870 --> 00:23:48,800
invented so I had no idea about it at

690
00:23:53,290 --> 00:23:49,880
the time but that's a pretty cool

691
00:23:54,940 --> 00:23:53,300
overlay in time I did a my bachelor's in

692
00:23:57,070 --> 00:23:54,950
aerospace engineering at the University

693
00:23:59,080 --> 00:23:57,080
of Michigan that's when I was there

694
00:24:01,210 --> 00:23:59,090
there was just starting up a lab that

695
00:24:02,920 --> 00:24:01,220
worked specifically on cube sets I

696
00:24:04,960 --> 00:24:02,930
worked on a couple things particularly

697
00:24:07,000 --> 00:24:04,970
with my senior design class actually

698
00:24:10,660 --> 00:24:07,010
designing a CubeSat that later flew

699
00:24:13,120 --> 00:24:10,670
after I graduated and then at MIT we I

700
00:24:15,820 --> 00:24:13,130
helped design and build and fly the very

701
00:24:18,630 --> 00:24:15,830
first CubeSat that MIT built so just

702
00:24:23,140 --> 00:24:18,640
like Travis I've worked on I think

703
00:24:24,760 --> 00:24:23,150
Counting and with differing levels of

704
00:24:26,470 --> 00:24:24,770
involvement in the missions I worked on

705
00:24:29,170 --> 00:24:26,480
about seven cube sets including the ones

706
00:24:32,350 --> 00:24:29,180
at JPL so I've been at JPL for about

707
00:24:34,090 --> 00:24:32,360
almost three years now and here I've

708
00:24:35,890 --> 00:24:34,100
worked on the Marco mission going to

709
00:24:37,840 --> 00:24:35,900
deep space and another mission going to

710
00:24:40,450 --> 00:24:37,850
deep space called nia scout that I will

711
00:24:41,620 --> 00:24:40,460
also be talking about later but with

712
00:24:44,230 --> 00:24:41,630
these cube sets because they're all

713
00:24:46,510 --> 00:24:44,240

about the same size there's very little

714
00:24:48,670 --> 00:24:46,520
difference between the integration and

715
00:24:51,040 --> 00:24:48,680
the experience you get in a university

716
00:24:52,690 --> 00:24:51,050
setting versus than what you do turning

717
00:24:55,120 --> 00:24:52,700
around and working at a place like JPL

718
00:24:58,390 --> 00:24:55,130
it's an amazing opportunity and it's

719
00:25:03,040 --> 00:24:58,400
surprisingly applicable for getting for

720
00:25:07,780 --> 00:25:03,050
future careers in space exploration so

721
00:25:10,960 --> 00:25:07,790
what do I mean by beyond Earth and when

722
00:25:13,840 --> 00:25:10,970
you fly into when you fly a CubeSat into

723
00:25:16,810 --> 00:25:13,850
or any satellite into lower or lower

724
00:25:18,850 --> 00:25:16,820
Earth orbit the there are certain

725
00:25:20,380 --> 00:25:18,860
advantages you can there's certain

726
00:25:23,170 --> 00:25:20,390
things you can take advantage of so of

727
00:25:24,790 --> 00:25:23,180
the the thousand cube sets that Travis

728
00:25:26,140 --> 00:25:24,800
mentioned launched only two

729
00:25:28,900 --> 00:25:26,150
of them have actually gone beyond

730
00:25:30,940 --> 00:25:28,910
low-earth orbit so somewhat advantages

731
00:25:34,570 --> 00:25:30,950
of being in low-earth orbit you have

732
00:25:36,250 --> 00:25:34,580
your only I say only only about a few

733
00:25:37,750 --> 00:25:36,260
hundred kilometers away from the surface

734
00:25:39,520 --> 00:25:37,760
of the earth when you're trying to

735
00:25:43,480 --> 00:25:39,530
communicate to a satellite you have a

736
00:25:45,070 --> 00:25:43,490
fairly a fairly wide range of bandwidths

737
00:25:46,810 --> 00:25:45,080
that you can play with and so you can

738
00:25:48,430 --> 00:25:46,820

have ground stations all over the world

739
00:25:49,960 --> 00:25:48,440
at different frequencies you can there

740
00:25:51,520 --> 00:25:49,970
are universities that even build their

741
00:25:53,650 --> 00:25:51,530
own ground stations to talk to these

742
00:25:56,710 --> 00:25:53,660
satellites you can also take advantage

743
00:25:58,470 --> 00:25:56,720
of systems in orbit around Earth like

744
00:26:00,640 --> 00:25:58,480
global positioning systems or

745
00:26:02,890 --> 00:26:00,650
communications networks like iridium and

746
00:26:05,140 --> 00:26:02,900
global star to actually figure out where

747
00:26:08,350 --> 00:26:05,150
your satellite is and have another way

748
00:26:10,360 --> 00:26:08,360
of getting the data down and another

749
00:26:12,190 --> 00:26:10,370
cool thing that you can do with around

750
00:26:14,860 --> 00:26:12,200
Earth is actually take advantage of its

751
00:26:16,420 --> 00:26:14,870
magnetic field so if you're flying close

752
00:26:18,130 --> 00:26:16,430
enough to the surface of the earth it

753
00:26:20,170 --> 00:26:18,140
kind of acts as a shield for high

754
00:26:21,400 --> 00:26:20,180
energetic higher energetic particles

755
00:26:23,860 --> 00:26:21,410
that come from the Sun and for

756
00:26:25,750 --> 00:26:23,870
interstellar space you can also use the

757
00:26:28,360 --> 00:26:25,760
magnetic field and put sensors on your

758
00:26:30,220 --> 00:26:28,370
spacecraft to tell how it's oriented to

759
00:26:32,050 --> 00:26:30,230
some extent where it is in the orbit and

760
00:26:34,480 --> 00:26:32,060
actually use magnets onboard your

761
00:26:36,820 --> 00:26:34,490
spacecraft to orient it by aligning it

762
00:26:40,480 --> 00:26:36,830
and not aligning that with the magnetic

763
00:26:43,780 --> 00:26:40,490

field in space you don't have any of

764
00:26:46,000 --> 00:26:43,790
that so with the two marcos satellites

765
00:26:48,400 --> 00:26:46,010
and I'll talk about their technologies

766
00:26:50,410 --> 00:26:48,410
in particulars there's the the first two

767
00:26:53,830 --> 00:26:50,420
that have actually successfully gone

768
00:26:56,260 --> 00:26:53,840
into a space beyond low-earth orbit in

769
00:26:58,210 --> 00:26:56,270
the CubeSat form factor so when you go

770
00:26:59,740 --> 00:26:58,220
beyond earth some of the issues you have

771
00:27:01,540 --> 00:26:59,750
to deal with is a the earth is much

772
00:27:03,730 --> 00:27:01,550
farther away so instead of being

773
00:27:05,500 --> 00:27:03,740
hundreds of kilometers from the surface

774
00:27:08,350 --> 00:27:05,510
of the earth you're now millions and

775
00:27:10,720 --> 00:27:08,360
millions of billions of miles or

776
00:27:13,000 --> 00:27:10,730
kilometers away from the surface of the

777
00:27:15,280 --> 00:27:13,010
earth so your radio has to be more

778
00:27:18,550 --> 00:27:15,290
powerful your antennas have to be bigger

779
00:27:21,640 --> 00:27:18,560
and right now the only way you can

780
00:27:23,680 --> 00:27:21,650
really communicate with and with

781
00:27:26,140 --> 00:27:23,690
spacecraft that far away is through the

782
00:27:28,720 --> 00:27:26,150
NASA Deep Space Network these are it's

783
00:27:31,300 --> 00:27:28,730
an array of 12 satellites or satellite

784
00:27:33,160 --> 00:27:31,310
dishes around the globe so you can in

785
00:27:34,840 --> 00:27:33,170
they're spaced about 120 degrees apart

786
00:27:36,490 --> 00:27:34,850
so you can get continuous coverage of

787
00:27:39,340 --> 00:27:36,500
anything in the solar system

788
00:27:41,140 --> 00:27:39,350

and these are there's 34 meter size in a

789
00:27:42,550 --> 00:27:41,150
70 meter size and in order to take

790
00:27:44,410 --> 00:27:42,560
advantage of that you have to have a

791
00:27:46,480 --> 00:27:44,420
radio that is compatible with this

792
00:27:48,490 --> 00:27:46,490
network but what it gets you is

793
00:27:50,530 --> 00:27:48,500
communication with your satellite and a

794
00:27:52,720 --> 00:27:50,540
way to figure out where your satellite

795
00:27:55,540 --> 00:27:52,730
is and how fast it's going and where

796
00:27:58,000 --> 00:27:55,550
it's going just based on the radio

797
00:28:00,460 --> 00:27:58,010
signals so if you don't have GPS you

798
00:28:02,080 --> 00:28:00,470
kind of need something like this you

799
00:28:04,150 --> 00:28:02,090
also don't have a magnetic field to

800
00:28:07,090 --> 00:28:04,160
torque against an orient your satellite

801
00:28:08,680 --> 00:28:07,100
so anything any way you want to move

802
00:28:10,630 --> 00:28:08,690
your satellite or change its position

803
00:28:12,820 --> 00:28:10,640
you have to bring it on board and that

804
00:28:16,510 --> 00:28:12,830
usually takes the form of propellant of

805
00:28:18,970 --> 00:28:16,520
some sort and in interstellar space you

806
00:28:22,000 --> 00:28:18,980
also have an interplanetary space or not

807
00:28:23,830 --> 00:28:22,010
an interstellar keeps us yet then there

808
00:28:25,150 --> 00:28:23,840
is a much more extreme thermal or

809
00:28:26,620 --> 00:28:25,160
radiation environments a harsher

810
00:28:28,090 --> 00:28:26,630
environment that you have to deal with

811
00:28:30,160 --> 00:28:28,100
when you're closer to the Sun your

812
00:28:32,380 --> 00:28:30,170
satellites get a lot hotter you have to

813
00:28:33,940 --> 00:28:32,390

deal with thermal issues that you don't

814
00:28:34,540 --> 00:28:33,950
necessarily have to deal with around low

815
00:28:36,220 --> 00:28:34,550
Earth orbit

816
00:28:38,950 --> 00:28:36,230
obviously the farther away you get from

817
00:28:41,200 --> 00:28:38,960
the Sun the dimmer the Sun is the colder

818
00:28:43,360 --> 00:28:41,210
it tends to be and not only is it colder

819
00:28:46,510 --> 00:28:43,370
now because the Sun is dimmer you have

820
00:28:48,340 --> 00:28:46,520
to deal with less power being generated

821
00:28:50,310 --> 00:28:48,350
so most CubeSat missions use solar

822
00:28:53,080 --> 00:28:50,320
panels and batteries very effectively

823
00:29:04,240 --> 00:28:53,090
missions like Cassini and Voyager had

824
00:29:08,680 --> 00:29:04,250
radioisotope thermoelectric reiated that

825
00:29:10,900 --> 00:29:08,690
way too so Marco as was mentioned

826
00:29:12,310 --> 00:29:10,910
several times Mars cube one mission

827
00:29:15,820 --> 00:29:12,320
these were two satellites that were

828
00:29:17,920 --> 00:29:15,830
launched with the insight Lander so NASA

829
00:29:20,800 --> 00:29:17,930
launched a mission called insight to

830
00:29:22,630 --> 00:29:20,810
Mars in 2018 it want it landed on the

831
00:29:26,650 --> 00:29:22,640
surface of Mars in November the Monday

832
00:29:29,050 --> 00:29:26,660
after Thanksgiving and the orbit of the

833
00:29:31,420 --> 00:29:29,060
orbit of the orbiters that were on that

834
00:29:33,520 --> 00:29:31,430
are around Mars weren't quite in the

835
00:29:35,440 --> 00:29:33,530
right position to get the data back real

836
00:29:37,450 --> 00:29:35,450
time there was an orbiter that flew over

837
00:29:39,100 --> 00:29:37,460
a while insight was going through its

838
00:29:41,710 --> 00:29:39,110

entry descent and landing to pick up the

839
00:29:43,000 --> 00:29:41,720
data but it wasn't going to it wasn't

840
00:29:45,160 --> 00:29:43,010
going to get the data back to earth

841
00:29:47,230 --> 00:29:45,170
until several hours after the saddle

842
00:29:47,610 --> 00:29:47,240
after the lander had actually landed on

843
00:29:50,640 --> 00:29:47,620
the search

844
00:29:53,730 --> 00:29:50,650
of Mars so very shortly before insight

845
00:29:54,900 --> 00:29:53,740
launched at least very shortly before it

846
00:29:58,650 --> 00:29:54,910
was supposed to launch the first time

847
00:30:02,070 --> 00:29:58,660
that they came up with this idea of well

848
00:30:04,020 --> 00:30:02,080
could we fly cube sets along with it to

849
00:30:06,030 --> 00:30:04,030
be in the right position to relay that

850
00:30:08,370 --> 00:30:06,040
data back so the to Marco spacecraft

851
00:30:10,770 --> 00:30:08,380
actually launched on the same vehicle

852
00:30:13,350 --> 00:30:10,780
that insight did and it was kind of in

853
00:30:15,990 --> 00:30:13,360
what we we consider steerage class

854
00:30:17,880 --> 00:30:16,000
almost they were active the dispensers

855
00:30:21,180 --> 00:30:17,890
were put right next to the engine bell

856
00:30:23,780 --> 00:30:21,190
of the upper stage insight was inside

857
00:30:27,090 --> 00:30:23,790
the fairing all nice and protective the

858
00:30:28,830 --> 00:30:27,100
but the true Marco satellites had to be

859
00:30:31,680 --> 00:30:28,840
in the correct place at the correct time

860
00:30:34,440 --> 00:30:31,690
to really that data back from insight so

861
00:30:36,780 --> 00:30:34,450
that was one of the primary things that

862
00:30:38,280 --> 00:30:36,790
Marco flew for and it was to demonstrate

863
00:30:40,310 --> 00:30:38,290

this architecture of these small

864
00:30:42,630 --> 00:30:40,320
satellites providing a critical mission

865
00:30:44,610 --> 00:30:42,640
critical mission support for a primary

866
00:30:47,520 --> 00:30:44,620
mission like in sight but in order to do

867
00:30:49,680 --> 00:30:47,530
that it had just both satellites had to

868
00:30:51,240 --> 00:30:49,690
survive six months in this brand new

869
00:30:52,020 --> 00:30:51,250
environment with technology they had

870
00:30:55,590 --> 00:30:52,030
never flown before

871
00:30:57,540 --> 00:30:55,600
so the some of the key technologies that

872
00:31:00,030 --> 00:30:57,550
were developed for the Marco mission are

873
00:31:01,290 --> 00:31:00,040
radio and antennas they have to be

874
00:31:03,600 --> 00:31:01,300
compatible with the Deep Space Network

875
00:31:05,280 --> 00:31:03,610
they have to be big enough in order to

876
00:31:07,350 --> 00:31:05,290
get enough gain to send all that data

877
00:31:09,930 --> 00:31:07,360
back to earth so this pattern might look

878
00:31:12,990 --> 00:31:09,940
familiar to you it's it's a reflector

879
00:31:14,910 --> 00:31:13,000
antenna very it's essentially what I saw

880
00:31:16,650 --> 00:31:14,920
I flew just had just modified for a

881
00:31:17,940 --> 00:31:16,660
different wavelengths so a lot of the

882
00:31:19,919 --> 00:31:17,950
technology that's developed for

883
00:31:22,860 --> 00:31:19,929
low-earth orbit like Travis mentioned is

884
00:31:24,870 --> 00:31:22,870
then flown in deep space because you can

885
00:31:27,540 --> 00:31:24,880
have it gives you a lot of the same

886
00:31:31,280 --> 00:31:27,550
advantages same thing with the

887
00:31:34,500 --> 00:31:31,290
deployable solar arrays so there again

888
00:31:36,990 --> 00:31:34,510

Marco went by Mars it's about half the

889
00:31:39,120 --> 00:31:37,000
power that you're getting from solar

890
00:31:40,950 --> 00:31:39,130
panels at Earth and so we had to have

891
00:31:43,290 --> 00:31:40,960
these deployable solar arrays to get all

892
00:31:45,570 --> 00:31:43,300
the power we needed to perform the

893
00:31:47,880 --> 00:31:45,580
mission and then we also demonstrated a

894
00:31:50,310 --> 00:31:47,890
propulsion system so as there is a cold

895
00:31:52,230 --> 00:31:50,320
gas thrusters system the volume of the

896
00:31:56,040 --> 00:31:52,240
propellant itself was about half of this

897
00:31:57,510 --> 00:31:56,050
6u volume and there are tiny little

898
00:31:58,710 --> 00:31:57,520
thrusters you can't even see them in

899
00:32:01,379 --> 00:31:58,720
this picture but there are eight of them

900
00:32:03,419 --> 00:32:01,389
in on this face of the

901
00:32:05,849 --> 00:32:03,429
satellite and the propellant onboard was

902
00:32:08,940 --> 00:32:05,859
fire extinguisher fluid it was cold gas

903
00:32:10,709 --> 00:32:08,950
and you heated it up and then spouted

904
00:32:14,039 --> 00:32:10,719
out in little spurts and that was enough

905
00:32:16,529 --> 00:32:14,049
to change and adjust the trajectory of

906
00:32:22,849 --> 00:32:16,539
each Marco spacecraft so that we flew by

907
00:32:22,859 --> 00:32:33,330
Marco a and Marco be canceled entry

908
00:32:33,340 --> 00:32:38,299
[Applause]

909
00:32:47,609 --> 00:32:41,999
Lander separation commanded altitude 600

910
00:32:50,430 --> 00:32:47,619
meters 200 meters 50 meters constant

911
00:32:55,060 --> 00:32:50,440
velocity 17 meters standing by for

912
00:33:00,150 --> 00:32:55,070
touchdown touchdown confirmed

913
00:33:02,890 --> 00:33:00,160

[Applause]

914
00:33:04,510 --> 00:33:02,900
not only got the data from inside as it

915
00:33:10,900 --> 00:33:04,520
went through the Martian atmosphere in

916
00:33:12,760 --> 00:33:10,910
real-time we saw the first it's just a

917
00:33:14,799 --> 00:33:12,770
great tribute to the pole Marko team

918
00:33:17,169 --> 00:33:14,809
that exceeded all of our wildest

919
00:33:18,820 --> 00:33:17,179
expectations that both worked perfectly

920
00:33:20,860 --> 00:33:18,830
we just opened the door to a new class

921
00:33:25,000 --> 00:33:20,870
of planetary science I think to the

922
00:33:25,390 --> 00:33:25,010
Marco's this was seen all around the

923
00:33:29,500 --> 00:33:25,400
world

924
00:33:32,440 --> 00:33:29,510
crowds watch live in LA Chicago and New

925
00:33:34,540 --> 00:33:32,450
York insight was followed to Mars by two

926
00:33:36,910 --> 00:33:34,550
miniature NASA spacecraft called Mars

927
00:33:38,860 --> 00:33:36,920
cube one or Marco shortly after landing

928
00:33:41,380 --> 00:33:38,870
the first picture relayed by two

929
00:33:43,690 --> 00:33:41,390
miniature NASA spacecraft called Marco

930
00:33:46,270 --> 00:33:43,700
but on board Marco itself we had one

931
00:33:48,940 --> 00:33:46,280
more gift this image was taken from

932
00:33:50,640 --> 00:33:48,950
marco 10-15 minutes after GDLs self

933
00:33:55,340 --> 00:33:50,650
happened

934
00:34:00,210 --> 00:33:57,960
so this is the picture that Marco took

935
00:34:03,960 --> 00:34:00,220
right after insight EDL so this is a

936
00:34:06,299 --> 00:34:03,970
very very I love this picture then so

937
00:34:08,399 --> 00:34:06,309
like I saw it and like green cube if you

938
00:34:09,869 --> 00:34:08,409

have a deployable on a cube set like

939
00:34:11,490 --> 00:34:09,879
this you want to have a camera on there

940
00:34:14,460 --> 00:34:11,500
to make sure it works so we had the

941
00:34:18,450 --> 00:34:14,470
equivalent of like a flip phone quality

942
00:34:21,359 --> 00:34:18,460
grade camera but it's a cube set but you

943
00:34:23,430 --> 00:34:21,369
can see the the feed here from the feed

944
00:34:26,790 --> 00:34:23,440
going on to this reflector II and then

945
00:34:27,840 --> 00:34:26,800
this is the flat high gain antenna you

946
00:34:29,399 --> 00:34:27,850
can see the edge of it and we actually

947
00:34:31,830 --> 00:34:29,409
compared it to pictures we took on the

948
00:34:34,080 --> 00:34:31,840
ground to verify that did deploy fully

949
00:34:35,750 --> 00:34:34,090
but we had this camera on board and even

950
00:34:39,720 --> 00:34:35,760
though it's not a great quality camera

951
00:34:42,720 --> 00:34:39,730
you get Mars which is amazing and so our

952
00:34:45,119 --> 00:34:42,730
navigation engineers I overlaid where

953
00:34:46,950 --> 00:34:45,129
the landing locations are for a lot of

954
00:34:49,409 --> 00:34:46,960
other missions that have flown to Mars

955
00:34:53,520 --> 00:34:49,419
this is a very cool thing to see from

956
00:34:54,960 --> 00:34:53,530
something the size of a cereal box so

957
00:34:57,090 --> 00:34:54,970
the applications that Marco could have

958
00:35:00,120 --> 00:34:57,100
enabled to go into deep space so a lot

959
00:35:01,440 --> 00:35:00,130
like low-earth orbit you can these cube

960
00:35:03,510 --> 00:35:01,450
sets are enabling a lot of different

961
00:35:05,340 --> 00:35:03,520
kinds of mission architectures so one is

962
00:35:07,530 --> 00:35:05,350
like Marco performing functions to

963
00:35:09,540 --> 00:35:07,540

support a main mission like insight in

964
00:35:12,810 --> 00:35:09,550
in the case of Marco is a communications

965
00:35:15,990 --> 00:35:12,820
relay capability there's a mission that

966
00:35:18,390 --> 00:35:16,000
the European Space Agency is flying in a

967
00:35:20,070 --> 00:35:18,400
few years called Hera that is visiting

968
00:35:22,740 --> 00:35:20,080
an asteroid called didymus in its

969
00:35:24,900 --> 00:35:22,750
companion and it will be carrying two

970
00:35:26,790 --> 00:35:24,910
spacecraft unlike Marco these spacecraft

971
00:35:30,060 --> 00:35:26,800
will actually be carried on the

972
00:35:32,160 --> 00:35:30,070
mothership and they will have science

973
00:35:34,200 --> 00:35:32,170
instruments on them to complement that

974
00:35:36,450 --> 00:35:34,210
main mission so it's so now we're

975
00:35:38,520 --> 00:35:36,460
talking about CubeSat some small sensor

976
00:35:41,400 --> 00:35:38,530
with instruments on them performing

977
00:35:45,380 --> 00:35:41,410
science to supplement a mission already

978
00:35:48,060 --> 00:35:45,390
going to another body you can also think

979
00:35:49,890 --> 00:35:48,070
you can also take that a step farther

980
00:35:52,650 --> 00:35:49,900
and go even farther out into the solar

981
00:35:54,210 --> 00:35:52,660
system where these outer planets have

982
00:35:56,550 --> 00:35:54,220
really interesting moons and really

983
00:35:59,400 --> 00:35:56,560
interesting behaviors that we don't

984
00:36:02,370 --> 00:35:59,410
really understand so you can have almost

985
00:36:04,510 --> 00:36:02,380
disposable or single-use probes they

986
00:36:06,370 --> 00:36:04,520
don't they won't necessarily be being a

987
00:36:08,440 --> 00:36:06,380
that form-factor like I mentioned if you

988
00:36:10,720 --> 00:36:08,450

go beyond low-earth orbit you have all

989
00:36:14,109 --> 00:36:10,730
these challenges in terms of power

990
00:36:16,000 --> 00:36:14,119
generation and data volume and all in

991
00:36:17,350 --> 00:36:16,010
thermal and everything that you have to

992
00:36:19,570 --> 00:36:17,360
deal with so it might not look like a

993
00:36:21,580 --> 00:36:19,580
cube but a lot of the technology being

994
00:36:24,580 --> 00:36:21,590
developed is directly applicable to

995
00:36:25,960 --> 00:36:24,590
missions like this and then they can

996
00:36:29,680 --> 00:36:25,970
also do their own science with a whole

997
00:36:32,830 --> 00:36:29,690
flock to talk wine to use the planet

998
00:36:35,530 --> 00:36:32,840
term of these small sets so you can

999
00:36:37,720 --> 00:36:35,540
apply the same principle of using a

1000
00:36:40,000 --> 00:36:37,730
constellation or formation flying on in

1001
00:36:42,970 --> 00:36:40,010
low-earth orbit and apply it to either

1002
00:36:45,250 --> 00:36:42,980
observing locations beyond the solar

1003
00:36:48,580 --> 00:36:45,260
system or even going to locations beyond

1004
00:36:53,950 --> 00:36:48,590
the solar system and making these

1005
00:36:56,230 --> 00:36:53,960
observations so the next upcoming event

1006
00:36:59,680 --> 00:36:56,240
in small satellite deep space

1007
00:37:01,270 --> 00:36:59,690
applications is em1 so this e-m1 stands

1008
00:37:02,800 --> 00:37:01,280
for exploration mission-1

1009
00:37:05,260 --> 00:37:02,810
it's the first launch of the Space

1010
00:37:09,730 --> 00:37:05,270
Launch System in the Space Launch System

1011
00:37:12,640 --> 00:37:09,740
or SLS is a high heavy lift launch

1012
00:37:14,140 --> 00:37:12,650
vehicle in development by NASA and so

1013
00:37:16,870 --> 00:37:14,150

the first launch of this it's going to

1014
00:37:19,270 --> 00:37:16,880
carry the Orion spacecraft nominally to

1015
00:37:22,060 --> 00:37:19,280
the moon but the first demonstration

1016
00:37:25,330 --> 00:37:22,070
launch will actually have 13 of these

1017
00:37:27,490 --> 00:37:25,340
six you Cube sets on a ring that sits

1018
00:37:29,170 --> 00:37:27,500
under like underneath the Orion payload

1019
00:37:34,810 --> 00:37:29,180
they're called the lucky 13 cube sets

1020
00:37:37,150 --> 00:37:34,820
the and they do a variety of science and

1021
00:37:40,270 --> 00:37:37,160
engineering demonstrations so of these

1022
00:37:42,670 --> 00:37:40,280
13 missions four of them I think come

1023
00:37:45,330 --> 00:37:42,680
from NASA and then the other ones come

1024
00:37:47,590 --> 00:37:45,340
from universities even and and

1025
00:37:49,810 --> 00:37:47,600
organizations around the world so it is

1026
00:37:53,670 --> 00:37:49,820
a very global effort to put these

1027
00:37:55,990 --> 00:37:53,680
satellites into interplanetary space and

1028
00:37:57,910 --> 00:37:56,000
they're all going to different locations

1029
00:37:59,230 --> 00:37:57,920
so a lot of them are going around the

1030
00:38:01,599 --> 00:37:59,240
moon and they're demonstrating these new

1031
00:38:03,670 --> 00:38:01,609
for new propellant propulsion

1032
00:38:06,250 --> 00:38:03,680
capabilities in order to get these small

1033
00:38:08,230 --> 00:38:06,260
satellites into a lunar orbit they're

1034
00:38:11,740 --> 00:38:08,240
also demonstrating new communications

1035
00:38:13,420 --> 00:38:11,750
capabilities and new science instruments

1036
00:38:15,580 --> 00:38:13,430
and ways of generating power actually

1037
00:38:16,359 --> 00:38:15,590
staying alive in interplanetary space

1038
00:38:18,670 --> 00:38:16,369

but there

1039
00:38:20,170 --> 00:38:18,680
are also capitalizing on a lot of the

1040
00:38:22,180 --> 00:38:20,180
technology that was developed and flown

1041
00:38:25,210 --> 00:38:22,190
on the Marco mission six of these Cube

1042
00:38:27,099 --> 00:38:25,220
sets are using the same radio or the

1043
00:38:30,789 --> 00:38:27,109
next generation version of the radio

1044
00:38:32,289 --> 00:38:30,799
that flew successfully on Mirko so just

1045
00:38:34,180 --> 00:38:32,299
highlighting a couple of them that JPL

1046
00:38:35,380 --> 00:38:34,190
is involved with so near-earth asteroid

1047
00:38:36,730 --> 00:38:35,390
Scout that I'm working on it's a

1048
00:38:39,279 --> 00:38:36,740
collaboration between Marshall Space

1049
00:38:40,809 --> 00:38:39,289
Flight Center and JPL some Marshall

1050
00:38:42,309 --> 00:38:40,819
Space Flight Center is a NASA Center in

1051
00:38:44,650 --> 00:38:42,319
Alabama they are managing the mission

1052
00:38:48,509 --> 00:38:44,660
and this mission is actually using a

1053
00:38:51,130 --> 00:38:48,519
solar sail as its primary method of

1054
00:38:53,140 --> 00:38:51,140
propel Earth propulsion to get this

1055
00:38:55,509 --> 00:38:53,150
these spacecraft to and near-earth

1056
00:38:59,739 --> 00:38:55,519
asteroid and there's a camera on board

1057
00:39:01,720 --> 00:38:59,749
to image image and characterize and get

1058
00:39:03,339 --> 00:39:01,730
more information about small near-earth

1059
00:39:05,349 --> 00:39:03,349
asteroids that are difficult to

1060
00:39:07,079 --> 00:39:05,359
characterize from the surface of the

1061
00:39:09,430 --> 00:39:07,089
earth

1062
00:39:11,499 --> 00:39:09,440
another one that JPL is involved with is

1063
00:39:15,940 --> 00:39:11,509

called lunar flashlight JPL is managing

1064
00:39:18,130 --> 00:39:15,950
this mission this the flashlight is a

1065
00:39:20,109 --> 00:39:18,140
laser on board that will illuminate

1066
00:39:22,259 --> 00:39:20,119
permanently shadowed craters on the moon

1067
00:39:25,059 --> 00:39:22,269
we know there is water ice in these

1068
00:39:26,950 --> 00:39:25,069
shadowed craters so lunar flashlights

1069
00:39:28,479 --> 00:39:26,960
will fly in an orbit a very highly

1070
00:39:30,460 --> 00:39:28,489
elliptical orbit around the moon it only

1071
00:39:31,809 --> 00:39:30,470
gets about 15 kilometers from the

1072
00:39:34,180 --> 00:39:31,819
surface of the Moon when it's out the

1073
00:39:35,499 --> 00:39:34,190
South Pole and it will illuminate these

1074
00:39:37,960 --> 00:39:35,509
craters and then there's a reflect

1075
00:39:41,229 --> 00:39:37,970
amador instrument onboard that's tuned

1076
00:39:43,749 --> 00:39:41,239
to water wavelengths that will detect

1077
00:39:46,749 --> 00:39:43,759
water ice and try to map where that ice

1078
00:39:48,819 --> 00:39:46,759
is in these craters and it's also

1079
00:39:51,069 --> 00:39:48,829
demonstrating a new propulsion

1080
00:39:56,170 --> 00:39:51,079
capability it's using this green mana

1081
00:39:57,789 --> 00:39:56,180
propellant fluid which is it's it's more

1082
00:39:59,559 --> 00:39:57,799
energetic than a cold gas like a fire

1083
00:40:01,239 --> 00:39:59,569
extinguisher it's less energetic than

1084
00:40:06,789 --> 00:40:01,249
something like hydrazine but it's also

1085
00:40:09,220 --> 00:40:06,799
not as toxic so good another thing that

1086
00:40:12,670 --> 00:40:09,230
JPL has involved with this is sunrise

1087
00:40:15,009 --> 00:40:12,680
it's another fleet of six you cube sets

1088
00:40:16,630 --> 00:40:15,019

this is currently in a study phase right

1089
00:40:18,640 --> 00:40:16,640
now and it's been proposed to the NASA

1090
00:40:21,309 --> 00:40:18,650
small Explorer call and I do want to

1091
00:40:23,380 --> 00:40:21,319
point out here that the a lot of NASA

1092
00:40:26,259 --> 00:40:23,390
has regular calls that go out for

1093
00:40:27,960 --> 00:40:26,269
missions to do science for earth earth

1094
00:40:29,700 --> 00:40:27,970
science astrophysics heliophysics

1095
00:40:31,680 --> 00:40:29,710
planetary science

1096
00:40:34,320 --> 00:40:31,690
and more and more of these calls are

1097
00:40:36,599 --> 00:40:34,330
being expanded to include cube sets and

1098
00:40:38,670 --> 00:40:36,609
small satellites because in the last few

1099
00:40:40,260 --> 00:40:38,680
years alone the number of missions who

1100
00:40:42,540 --> 00:40:40,270
have been able to demonstrate really

1101
00:40:44,670 --> 00:40:42,550
good science like Travis talked about

1102
00:40:46,440 --> 00:40:44,680
with Riaan cuban tempest tea has really

1103
00:40:48,390 --> 00:40:46,450
shown the community that these are these

1104
00:40:51,480 --> 00:40:48,400
are viable science platforms now so

1105
00:40:54,060 --> 00:40:51,490
there the the proposal calls have

1106
00:40:55,650 --> 00:40:54,070
started to reflect that and so this is

1107
00:40:57,810 --> 00:40:55,660
flying a constellation of sixty Cube

1108
00:40:59,520 --> 00:40:57,820
sets in a geostationary orbit so it's

1109
00:41:01,680 --> 00:40:59,530
still around Earth but I'm considering

1110
00:41:03,990 --> 00:41:01,690
it kind of interplanetary because there

1111
00:41:06,089 --> 00:41:04,000
it's far enough away that you have to do

1112
00:41:07,050 --> 00:41:06,099
a lot of you have to you still have to

1113
00:41:09,150 --> 00:41:07,060

take into account a lot of

1114
00:41:11,220 --> 00:41:09,160
considerations that you that are more

1115
00:41:13,770 --> 00:41:11,230
like interplanetary space than like

1116
00:41:16,079 --> 00:41:13,780
low-earth orbit and the purpose of

1117
00:41:19,109 --> 00:41:16,089
sunrise is to observe the Sun and

1118
00:41:22,530 --> 00:41:19,119
essentially it's a it's acting as a ten

1119
00:41:24,810 --> 00:41:22,540
kilometer radio telescope you can never

1120
00:41:27,560 --> 00:41:24,820
launch a ten kilometer telescope so

1121
00:41:30,030 --> 00:41:27,570
they're using these six Cube sets to

1122
00:41:35,010 --> 00:41:30,040
synthesize that aperture by flying them

1123
00:41:36,510 --> 00:41:35,020
in a loose formation and this ice stuck

1124
00:41:38,400 --> 00:41:36,520
in there you'll notice it's not a

1125
00:41:40,410 --> 00:41:38,410
CubeSat but there's definitely a cube

1126
00:41:43,440 --> 00:41:40,420
element to it so this is the Mars

1127
00:41:45,599 --> 00:41:43,450
helicopter it is flying with Mars 2020

1128
00:41:48,270 --> 00:41:45,609
it's supposed to launch next year too

1129
00:41:50,790 --> 00:41:48,280
and the helicopter is kind of a

1130
00:41:52,530 --> 00:41:50,800
companion to the rover its mission is to

1131
00:41:54,870 --> 00:41:52,540
fly around and be able to take pictures

1132
00:42:28,880 --> 00:41:54,880
and then relay the pictures of the train

1133
00:42:35,700 --> 00:42:33,660
wait so like the so the with helicopter

1134
00:42:37,770 --> 00:42:35,710
and similar missions like that it's it's

1135
00:42:39,660 --> 00:42:37,780
you know you don't launch it in a

1136
00:42:42,690 --> 00:42:39,670
dispenser it's not what some might

1137
00:42:44,940 --> 00:42:42,700
consider a real CubeSat but a lot of the

1138
00:42:46,980 --> 00:42:44,950

the technology advancements that came

1139
00:42:48,420 --> 00:42:46,990
with the CubeSat and small set paradigm

1140
00:42:51,210 --> 00:42:48,430
involves shrinking all of these

1141
00:42:53,340 --> 00:42:51,220
technologies that are would normally fit

1142
00:42:55,230 --> 00:42:53,350
in a satellite the size of a bus like

1143
00:42:57,690 --> 00:42:55,240
Cassini or Voyager for the people in

1144
00:43:02,850 --> 00:42:57,700
this room and really making them

1145
00:43:05,070 --> 00:43:02,860
extremely making very capable satellites

1146
00:43:06,450 --> 00:43:05,080
and payloads that are very small and so

1147
00:43:09,960 --> 00:43:06,460
there's no reason why you can't use

1148
00:43:12,420 --> 00:43:09,970
these small new technologies in bigger

1149
00:43:16,170 --> 00:43:12,430
missions or new new missions that aren't

1150
00:43:18,540 --> 00:43:16,180
the shape of a cube so the next couple

1151
00:43:22,200 --> 00:43:18,550
charts are sketches like literal

1152
00:43:24,480 --> 00:43:22,210
sketches there's a there's a the graphic

1153
00:43:26,730 --> 00:43:24,490
designer who did these her name is Kat

1154
00:43:30,330 --> 00:43:26,740
Park she works here at JPL in a studio

1155
00:43:31,920 --> 00:43:30,340
and the idea is none of these these are

1156
00:43:34,230 --> 00:43:31,930
all mission concepts but it's kind of an

1157
00:43:36,990 --> 00:43:34,240
idea of what kind of missions you could

1158
00:43:40,200 --> 00:43:37,000
see in the not so distant future with

1159
00:43:42,750 --> 00:43:40,210
these small sets and cube sets so one is

1160
00:43:44,490 --> 00:43:42,760
very similar to Marco flying small sets

1161
00:43:46,590 --> 00:43:44,500
to Mars these would probably be a little

1162
00:43:48,330 --> 00:43:46,600
bit bigger than a lot of the six use

1163
00:43:49,410 --> 00:43:48,340

that we've been presenting but they

1164
00:43:50,910 --> 00:43:49,420
would have their own propulsion they

1165
00:43:53,160 --> 00:43:50,920
would have these big solar panels and

1166
00:43:55,110 --> 00:43:53,170
they could go go to destinations like

1167
00:43:57,810 --> 00:43:55,120
Phobos and Deimos and they could use

1168
00:44:00,120 --> 00:43:57,820
novel propulsion capabilities like solar

1169
00:44:02,670 --> 00:44:00,130
electric propulsion or even ones that

1170
00:44:06,210 --> 00:44:02,680
we've never thought of to do cool

1171
00:44:09,510 --> 00:44:06,220
science without a primary mission to go

1172
00:44:12,150 --> 00:44:09,520
along with there's also this idea that

1173
00:44:15,510 --> 00:44:12,160
you could go to an asteroid and fly a

1174
00:44:17,220 --> 00:44:15,520
small set or some probe through plumes

1175
00:44:18,240 --> 00:44:17,230
to get kind of institution measurements

1176
00:44:20,910 --> 00:44:18,250
of what might be there you would never

1177
00:44:22,860 --> 00:44:20,920
want to fly a big expensive spacecraft

1178
00:44:25,890 --> 00:44:22,870
because it's a little bit risky with

1179
00:44:28,050 --> 00:44:25,900
particles flying at your satellite but

1180
00:44:29,610 --> 00:44:28,060
it could community and it could either

1181
00:44:31,290 --> 00:44:29,620
communicate directly to earth or you

1182
00:44:32,760 --> 00:44:31,300
could have an architecture where there's

1183
00:44:34,980 --> 00:44:32,770
a mothership sending that information

1184
00:44:37,770 --> 00:44:34,990
back to earth and making its own

1185
00:44:38,930 --> 00:44:37,780
measurements potentially or you can send

1186
00:44:40,910 --> 00:44:38,940
them to a comment and

1187
00:44:42,500 --> 00:44:40,920
Kasich comments it's spewing a lot more

1188
00:44:44,210 --> 00:44:42,510

particles out there as the tale forms

1189
00:44:45,859 --> 00:44:44,220
and so you could fly a whole fleet of

1190
00:44:47,569 --> 00:44:45,869
them and maybe even have them start

1191
00:44:50,420 --> 00:44:47,579
talking to each other to coordinate

1192
00:44:51,980 --> 00:44:50,430
better measurements and again you could

1193
00:44:54,020 --> 00:44:51,990
have them talk back to a mothership you

1194
00:44:57,020 --> 00:44:54,030
can have them talk back to kind of a

1195
00:44:58,970 --> 00:44:57,030
leader spacecraft back to earth and so a

1196
00:45:02,839 --> 00:44:58,980
lot of these concepts is not just

1197
00:45:04,760 --> 00:45:02,849
physical you don't have just physical

1198
00:45:06,319 --> 00:45:04,770
limitations in terms of getting bigger

1199
00:45:07,670 --> 00:45:06,329
antennas and bigger solar panels and

1200
00:45:09,980 --> 00:45:07,680
bigger propulsion systems you also have

1201
00:45:13,700 --> 00:45:09,990
to make the satellites smarter so a lot

1202
00:45:16,069 --> 00:45:13,710
of autonomy and and advances in

1203
00:45:17,420 --> 00:45:16,079
computing capabilities would really

1204
00:45:18,589 --> 00:45:17,430
enable missions like this so the

1205
00:45:20,599 --> 00:45:18,599
satellites can kind of think for

1206
00:45:23,210 --> 00:45:20,609
themselves and decide which observations

1207
00:45:25,819 --> 00:45:23,220
are the most interesting or figure out

1208
00:45:27,859 --> 00:45:25,829
if if they lose a satellite that's fine

1209
00:45:31,280 --> 00:45:27,869
we can reconfigure to still get the

1210
00:45:35,089 --> 00:45:31,290
measurement we want and thinking even

1211
00:45:37,430 --> 00:45:35,099
farther out there so the if you're going

1212
00:45:40,010 --> 00:45:37,440
to an outer planet could you bring a

1213
00:45:42,470 --> 00:45:40,020

bunch of really small sensors and

1214
00:45:44,089 --> 00:45:42,480
instead of getting again like a lot of

1215
00:45:46,670 --> 00:45:44,099
low Earth orbit applications instead of

1216
00:45:48,140 --> 00:45:46,680
sending one spacecraft to get a bunch of

1217
00:45:50,270 --> 00:45:48,150
measurements over a certain period of

1218
00:45:52,640 --> 00:45:50,280
time if you send a whole flock of

1219
00:45:55,520 --> 00:45:52,650
spacecraft a fleet of really tiny

1220
00:45:58,490 --> 00:45:55,530
sensors to get a whole distributed

1221
00:46:00,380 --> 00:45:58,500
spatial set of measurements out of at a

1222
00:46:02,210 --> 00:46:00,390
specific point in time it's a different

1223
00:46:03,710 --> 00:46:02,220
kind of measurement technique than has

1224
00:46:05,630 --> 00:46:03,720
historically been done and it's very

1225
00:46:07,130 --> 00:46:05,640
exciting especially if you're kind of on

1226
00:46:11,150 --> 00:46:07,140
a flyby trajectory and you only get one

1227
00:46:13,490 --> 00:46:11,160
shot similar thing if you want to go

1228
00:46:14,750 --> 00:46:13,500
into orbit or a slower flyby or

1229
00:46:16,520 --> 00:46:14,760
something like Clipper where it kind of

1230
00:46:19,460 --> 00:46:16,530
goes Europa clipper is a mission that

1231
00:46:22,640 --> 00:46:19,470
JPL is working on to go to Europa I mean

1232
00:46:24,349 --> 00:46:22,650
a moon of Jupiter and it kind of it it's

1233
00:46:26,300 --> 00:46:24,359
not quite a flyby but it doesn't go

1234
00:46:29,630 --> 00:46:26,310
entirely into orbit it gets a bunch of

1235
00:46:31,250 --> 00:46:29,640
orbits around Europa and then leaves but

1236
00:46:34,040 --> 00:46:31,260
if you maybe if you brought a whole

1237
00:46:36,440 --> 00:46:34,050
swarm of cube sets or small sets these

1238
00:46:39,260 --> 00:46:36,450

would probably be bigger they could

1239
00:46:41,829 --> 00:46:39,270
again do that kind of formation flying

1240
00:46:46,250 --> 00:46:41,839
and coordinated architecture of

1241
00:46:47,569 --> 00:46:46,260
measurement X measurements and science

1242
00:46:49,730 --> 00:46:47,579
that you can't do with just one

1243
00:46:51,470 --> 00:46:49,740
spacecraft or you gonna have to send a

1244
00:46:52,320 --> 00:46:51,480
whole fleet of them a lot like Assyria

1245
00:46:55,740 --> 00:46:52,330
and

1246
00:46:57,210 --> 00:46:55,750
have look at interests look at look more

1247
00:46:59,910 --> 00:46:57,220
into interstellar space than a whole

1248
00:47:02,790 --> 00:46:59,920
fleet of them to look at of little

1249
00:47:04,740 --> 00:47:02,800
imagers to look at one star instead of

1250
00:47:07,230 --> 00:47:04,750
one telescope looking at multiple stars

1251
00:47:09,450 --> 00:47:07,240
or even what would it look like if you

1252
00:47:12,570 --> 00:47:09,460
try to send one of these interstellar so

1253
00:47:15,990 --> 00:47:12,580
that's theirs this is actually a chipset

1254
00:47:17,130 --> 00:47:16,000
so the going into interstellar space you

1255
00:47:18,780 --> 00:47:17,140
have to go really far you have to go

1256
00:47:20,190 --> 00:47:18,790
really fast it's really it's a lot

1257
00:47:21,930 --> 00:47:20,200
easier to do that if it's really small

1258
00:47:24,270 --> 00:47:21,940
so if these new advances in

1259
00:47:25,890 --> 00:47:24,280
miniaturizing technologies could you

1260
00:47:27,780 --> 00:47:25,900
potentially envision something that's

1261
00:47:29,670 --> 00:47:27,790
the size of a postage stamp that

1262
00:47:32,430 --> 00:47:29,680
actually has all of the capability and

1263
00:47:37,320 --> 00:47:32,440

needs to go beyond the solar system I

1264
00:47:40,350 --> 00:47:37,330
don't know it's conjecture so yeah so

1265
00:47:42,270 --> 00:47:40,360
interplanetary travel with cube sets has

1266
00:47:43,710 --> 00:47:42,280
really only been around for the last

1267
00:47:45,540 --> 00:47:43,720
five years as I mentioned of the

1268
00:47:47,670 --> 00:47:45,550
thousand cube sets that have launched

1269
00:47:49,800 --> 00:47:47,680
two of them have gone below low-earth

1270
00:47:51,450 --> 00:47:49,810
orbits so it's still a very new field

1271
00:47:53,130 --> 00:47:51,460
but it's a really exciting field

1272
00:47:54,510 --> 00:47:53,140
especially because a lot of these

1273
00:47:56,100 --> 00:47:54,520
technologies that have been developed

1274
00:47:58,230 --> 00:47:56,110
for low-earth orbit are directly

1275
00:48:00,930 --> 00:47:58,240
applicable in many cases to flying

1276
00:48:03,900 --> 00:48:00,940
beyond low-earth orbit and it'd be

1277
00:48:05,340 --> 00:48:03,910
really interesting to see if how many of

1278
00:48:07,710 --> 00:48:05,350
these bodies you could actually have

1279
00:48:11,580 --> 00:48:07,720
small satellites on in the next 10 years

1280
00:48:12,870 --> 00:48:11,590
or so that is the end of my talk thank

1281
00:48:23,520 --> 00:48:12,880
you very much for listening and I

1282
00:48:28,320 --> 00:48:26,520
all right well thanks Annie

1283
00:48:30,780 --> 00:48:28,330
this is the part of the show where we

1284
00:48:32,580 --> 00:48:30,790
transition to your questions so if you

1285
00:48:35,040 --> 00:48:32,590
if you have a question here in the

1286
00:48:37,740 --> 00:48:35,050
audience we'll have a microphone in the

1287
00:48:40,140 --> 00:48:37,750
center and you can step right up there

1288
00:48:42,840 --> 00:48:40,150

to the to the middle aisle and prepare

1289
00:48:44,220 --> 00:48:42,850
your question and if you submitted a

1290
00:48:45,540 --> 00:48:44,230
question online on the YouTube chat

1291
00:48:49,350 --> 00:48:45,550
we'll get to a couple of those as well

1292
00:48:51,060 --> 00:48:49,360
so do we have any questions here there

1293
00:48:52,980 --> 00:48:51,070
comes John with the microphone well I'll

1294
00:48:56,160 --> 00:48:52,990
get started because I because I had a I

1295
00:48:58,800 --> 00:48:56,170
have all kinds of questions so just

1296
00:49:03,180 --> 00:48:58,810
since you both talked a lot about how

1297
00:49:06,120 --> 00:49:03,190
you you started your careers working on

1298
00:49:07,830 --> 00:49:06,130
Cube sets how has has it this topic

1299
00:49:14,400 --> 00:49:07,840
specifically shaped your careers as

1300
00:49:16,670 --> 00:49:14,410
engineers okay well I kind of maintain

1301
00:49:19,200 --> 00:49:16,680
that the experience that I got in

1302
00:49:20,790 --> 00:49:19,210
undergrad and well that's probably more

1303
00:49:24,720 --> 00:49:20,800
in grad school of actually building and

1304
00:49:26,310 --> 00:49:24,730
flying one of these satellites I don't

1305
00:49:28,590 --> 00:49:26,320
think I would have gotten the position I

1306
00:49:30,590 --> 00:49:28,600
did on the Marco team without having

1307
00:49:33,300 --> 00:49:30,600
that experience and so there's a lot of

1308
00:49:35,310 --> 00:49:33,310
getting real hands on it space it's hard

1309
00:49:36,990 --> 00:49:35,320
no matter who's actually flying the

1310
00:49:38,520 --> 00:49:37,000
satellite into space so I think it's

1311
00:49:41,160 --> 00:49:38,530
it's giving me a lot of hands-on

1312
00:49:44,070 --> 00:49:41,170
experience in a much more in-depth

1313
00:49:45,660 --> 00:49:44,080

appreciation for how difficult flying

1314
00:49:47,580 --> 00:49:45,670
something in space is and the challenges

1315
00:49:49,860 --> 00:49:47,590
you have to overcome and kind of

1316
00:49:50,970 --> 00:49:49,870
experience you know banging your head

1317
00:49:53,460 --> 00:49:50,980
against the wall trying to figure out

1318
00:49:55,530 --> 00:49:53,470
why it's not working before you even get

1319
00:49:57,330 --> 00:49:55,540
out of school so I think it's I think

1320
00:50:00,210 --> 00:49:57,340
it's invaluable to have that hands-on

1321
00:50:02,010 --> 00:50:00,220
experience yes I think I think it's

1322
00:50:03,540 --> 00:50:02,020
unique about the CubeSat form factor as

1323
00:50:04,650 --> 00:50:03,550
if you remember I showed my picture of

1324
00:50:06,750 --> 00:50:04,660
how we tried to jam everything we

1325
00:50:08,880 --> 00:50:06,760
couldn't to the box but that means that

1326
00:50:10,530 --> 00:50:08,890
you as an engineer can actually kind of

1327
00:50:12,030 --> 00:50:10,540
understand everything that's in that box

1328
00:50:13,980 --> 00:50:12,040
all the subsystems are touching

1329
00:50:15,540 --> 00:50:13,990
literally and electronically and

1330
00:50:17,010 --> 00:50:15,550
everything else but you can begin to

1331
00:50:18,330 --> 00:50:17,020
understand how your power subsystem

1332
00:50:19,920 --> 00:50:18,340
connects to everything else how your

1333
00:50:21,390 --> 00:50:19,930
radio subsystem is connected everything

1334
00:50:22,770 --> 00:50:21,400
that's how your payload requires the

1335
00:50:25,200 --> 00:50:22,780
whole spacecraft to perform perfectly

1336
00:50:26,970 --> 00:50:25,210
and working on these payloads when one

1337
00:50:27,960 --> 00:50:26,980
thing goes wrong you kind of see how it

1338
00:50:28,770 --> 00:50:27,970

flows through the system and what

1339
00:50:30,450 --> 00:50:28,780
something goes right you see how it

1340
00:50:31,950 --> 00:50:30,460
flows out the system that's the thing I

1341
00:50:33,900 --> 00:50:31,960
think this is unique when it's small you

1342
00:50:35,340 --> 00:50:33,910
actually have the capability as a single

1343
00:50:36,100 --> 00:50:35,350
person to understand everything you're

1344
00:50:38,680 --> 00:50:36,110
working on

1345
00:50:40,690 --> 00:50:38,690
and that was kind of a good introduction

1346
00:50:43,090 --> 00:50:40,700
to all sorts of different disciplines of

1347
00:50:45,130 --> 00:50:43,100
engineering and science and physics and

1348
00:50:50,040 --> 00:50:45,140
other topics some through school and

1349
00:50:54,430 --> 00:50:53,140
given that there are limited numbers

1350
00:50:56,350 --> 00:50:54,440
that can be launched even though there

1351
00:50:58,690 --> 00:50:56,360
are a thousand out there I suspect

1352
00:51:00,070 --> 00:50:58,700
there's a great desire for more by those

1353
00:51:02,970 --> 00:51:00,080
who are making them and studying them

1354
00:51:05,230 --> 00:51:02,980
I'm curious about the decision-making

1355
00:51:08,470 --> 00:51:05,240
that's involved of the competitiveness

1356
00:51:10,030 --> 00:51:08,480
to end up on a launch vehicle to get out

1357
00:51:13,210 --> 00:51:10,040
there you showed for instance that there

1358
00:51:15,280 --> 00:51:13,220
would be 13 on an upcoming mission how

1359
00:51:18,700 --> 00:51:15,290
did you decide or how did somebody

1360
00:51:20,470 --> 00:51:18,710
decide so I won't quote the number but

1361
00:51:21,850 --> 00:51:20,480
there are actually many companies that

1362
00:51:23,380 --> 00:51:21,860
we call news space companies the new

1363
00:51:24,370 --> 00:51:23,390

space are kind of these aerospace

1364
00:51:26,350 --> 00:51:24,380
companies that have just come around

1365
00:51:27,850 --> 00:51:26,360
within the past decade or so and there's

1366
00:51:30,370 --> 00:51:27,860
actually several companies that are

1367
00:51:31,900 --> 00:51:30,380
competing both through NASA funds and

1368
00:51:33,730 --> 00:51:31,910
privately funded to actually develop

1369
00:51:35,770 --> 00:51:33,740
this whole a kind of small fleet of

1370
00:51:37,330 --> 00:51:35,780
rocket launchers so much like that

1371
00:51:39,970 --> 00:51:37,340
electron rocket I showed from rocket

1372
00:51:43,240 --> 00:51:39,980
labs there's a thing just virgin orbit

1373
00:51:44,200 --> 00:51:43,250
one company vector Firefly are all

1374
00:51:46,030 --> 00:51:44,210
companies that are actually being

1375
00:51:48,100 --> 00:51:46,040
designed for kind of this 100 kilogram

1376
00:51:50,080 --> 00:51:48,110
class payload and whether that hundred

1377
00:51:51,610 --> 00:51:50,090
kilogram is one spacecraft or a company

1378
00:51:53,980 --> 00:51:51,620
that wants to launch you know 33

1379
00:51:55,690 --> 00:51:53,990
kilogram spacecraft they can do it so

1380
00:51:56,860 --> 00:51:55,700
there's actually a huge investment from

1381
00:51:58,660 --> 00:51:56,870
the launch services side to actually

1382
00:52:00,820 --> 00:51:58,670
meet the commercial demand from these

1383
00:52:03,670 --> 00:52:00,830
small satyrs especially constellation

1384
00:52:06,190 --> 00:52:03,680
companies until your question on tm1

1385
00:52:07,930 --> 00:52:06,200
payloads so some of them like the ones

1386
00:52:09,760 --> 00:52:07,940
that were proposed they're funded by

1387
00:52:11,350 --> 00:52:09,770
NASA so is the proposal process a lot

1388
00:52:13,180 --> 00:52:11,360

like you'd have a discovery or new

1389
00:52:14,560 --> 00:52:13,190
frontiers kind of mission there are

1390
00:52:16,030 --> 00:52:14,570
actually three cubes that's on there

1391
00:52:18,430 --> 00:52:16,040
that are part of a thing called a cube

1392
00:52:20,200 --> 00:52:18,440
quest competition and there was it was

1393
00:52:22,840 --> 00:52:20,210
mostly universities but some hobbyists

1394
00:52:25,690 --> 00:52:22,850
actually in there that had to go through

1395
00:52:27,130 --> 00:52:25,700
a series of I forget what they called

1396
00:52:30,310 --> 00:52:27,140
them but essentially student knowledge

1397
00:52:31,750 --> 00:52:30,320
yeah I'm crunches - I kind of milestones

1398
00:52:33,700 --> 00:52:31,760
and they were whittled down from I

1399
00:52:35,710 --> 00:52:33,710
forgot how many initially proposed but

1400
00:52:39,880 --> 00:52:35,720
then they had but they've filled three

1401
00:52:44,130 --> 00:52:39,890
slots of those 13 so it's it does it is

1402
00:52:45,860 --> 00:52:44,140
also partially competitive hey there oh

1403
00:52:49,650 --> 00:52:45,870
yeah

1404
00:52:52,500 --> 00:52:49,660
thanks for the great talk question on

1405
00:52:56,520 --> 00:52:52,510
your open Enceladus and cube sets in

1406
00:53:00,440 --> 00:52:56,530
that domain how how much easier or more

1407
00:53:03,480 --> 00:53:00,450
complicated our planetary protection

1408
00:53:07,200 --> 00:53:03,490
needs in the case of building some of my

1409
00:53:08,730 --> 00:53:07,210
excel for smaller smaller craft that are

1410
00:53:11,940 --> 00:53:08,740
going to travel into those environments

1411
00:53:13,140 --> 00:53:11,950
it's a really good question so then you

1412
00:53:14,460 --> 00:53:13,150
still have to meet the planetary

1413
00:53:15,180 --> 00:53:14,470

protection requirements kind of no

1414
00:53:17,400 --> 00:53:15,190
matter how big you are

1415
00:53:19,560 --> 00:53:17,410
with the Marco spacecraft we also had

1416
00:53:21,630 --> 00:53:19,570
planetary protection requirements we had

1417
00:53:23,910 --> 00:53:21,640
to meet and there are a couple ways to

1418
00:53:26,280 --> 00:53:23,920
do that one is to show that your

1419
00:53:27,840 --> 00:53:26,290
trajectory if you're completely off and

1420
00:53:30,300 --> 00:53:27,850
kind of a brick and that's how you

1421
00:53:31,860 --> 00:53:30,310
essentially to be safe that's kind of

1422
00:53:34,530 --> 00:53:31,870
what you assume that the cube sets are a

1423
00:53:36,690 --> 00:53:34,540
secondary payload is one way is to show

1424
00:53:38,760 --> 00:53:36,700
that your trajectory will never impact

1425
00:53:40,290 --> 00:53:38,770
something that is protected in this

1426
00:53:42,690 --> 00:53:40,300
planetary protection environment the

1427
00:53:45,720 --> 00:53:42,700
other way is to do a lot of simulations

1428
00:53:48,230 --> 00:53:45,730
and put what's called a bio burden on

1429
00:53:50,760 --> 00:53:48,240
the satellite and so it's you basically

1430
00:53:53,100 --> 00:53:50,770
give a metric for how clean the

1431
00:53:55,200 --> 00:53:53,110
satellite has to be when it launches to

1432
00:53:58,380 --> 00:53:55,210
get the probability of it bringing

1433
00:54:00,240 --> 00:53:58,390
unwanted life with it below a certain

1434
00:54:02,460 --> 00:54:00,250
threshold so you have to do that same

1435
00:54:04,680 --> 00:54:02,470
kind of analysis on a small satellite as

1436
00:54:06,330 --> 00:54:04,690
you would with a larger satellite with

1437
00:54:08,340 --> 00:54:06,340
the Marco process we were able to tailor

1438
00:54:11,010 --> 00:54:08,350

it a little bit and kind of through

1439
00:54:13,140 --> 00:54:11,020
measurements show that we were meeting

1440
00:54:17,490 --> 00:54:13,150
requirements without having to kind of

1441
00:54:21,240 --> 00:54:17,500
jump through a lot of Hoops to to do it

1442
00:54:22,920 --> 00:54:21,250
in a more analytical kind of way heard

1443
00:54:24,780 --> 00:54:22,930
you mentioned sylph so for those in the

1444
00:54:26,490 --> 00:54:24,790
audience self was a small set concept to

1445
00:54:28,590 --> 00:54:26,500
JPL produced which would fly through a

1446
00:54:31,140 --> 00:54:28,600
plume on Europa and it was a trash can

1447
00:54:33,150 --> 00:54:31,150
size satellite so like a propane tank is

1448
00:54:34,710 --> 00:54:33,160
about 80 kilograms and from planetary

1449
00:54:37,260 --> 00:54:34,720
protection in that case we actually

1450
00:54:39,480 --> 00:54:37,270
leverage some of the CubeSat concepts so

1451
00:54:40,710 --> 00:54:39,490
by going from a square form factor to

1452
00:54:43,260 --> 00:54:40,720
this round form factor we actually

1453
00:54:44,580 --> 00:54:43,270
designed it to to basically meet the

1454
00:54:47,070 --> 00:54:44,590
planetary protection requirements of

1455
00:54:48,600 --> 00:54:47,080
Europa and because it was small we said

1456
00:54:50,610 --> 00:54:48,610
we took the approach of saying what if

1457
00:54:52,260 --> 00:54:50,620
it does impact and design it to be that

1458
00:54:54,030 --> 00:54:52,270
designed it to basically meet those

1459
00:54:55,140 --> 00:54:54,040
requirements the thing that made it kind

1460
00:54:56,520 --> 00:54:55,150
of cute that like even though it was

1461
00:54:58,260 --> 00:54:56,530
cylinder shaped in that in that

1462
00:54:59,790 --> 00:54:58,270
Jupiter's environment was

1463
00:55:01,260 --> 00:54:59,800

it was actually in a dispenser of its

1464
00:55:03,180 --> 00:55:01,270
own that actually acted as the bio

1465
00:55:05,370 --> 00:55:03,190
barrier to keep outside contamination

1466
00:55:06,540 --> 00:55:05,380
from getting on that probe itself so

1467
00:55:08,400 --> 00:55:06,550
that's kind of a leveraging of those

1468
00:55:12,420 --> 00:55:08,410
technologies which actually was really

1469
00:55:14,760 --> 00:55:12,430
interesting thank you so I got a twofer

1470
00:55:15,870 --> 00:55:14,770
for you from from YouTube from our

1471
00:55:18,420 --> 00:55:15,880
viewers on YouTube because I think

1472
00:55:20,490 --> 00:55:18,430
they're connected so the first question

1473
00:55:23,550 --> 00:55:20,500
comes from yan who asks is the

1474
00:55:25,500 --> 00:55:23,560
probability of a CubeSat collision with

1475
00:55:30,120 --> 00:55:25,510
space debris so small that it's not a

1476
00:55:32,880 --> 00:55:30,130
concern but sue Miyagi asks what is the

1477
00:55:34,710 --> 00:55:32,890
lifetime of a CubeSat and I am i right

1478
00:55:36,660 --> 00:55:34,720
that those are connected they are

1479
00:55:38,010 --> 00:55:36,670
connected so in the case of rain cube

1480
00:55:39,780 --> 00:55:38,020
you know we saw our had we had our

1481
00:55:41,340 --> 00:55:39,790
deployables and there's actually a low

1482
00:55:43,020 --> 00:55:41,350
there's very little atmosphere in our

1483
00:55:44,400 --> 00:55:43,030
altitude we're up at about 400

1484
00:55:47,070 --> 00:55:44,410
kilometers which is similar to the space

1485
00:55:48,660 --> 00:55:47,080
station depending on if we're flying

1486
00:55:51,330 --> 00:55:48,670
with our solar panels like right in the

1487
00:55:52,740 --> 00:55:51,340
in I would call the wind but depending

1488
00:55:55,020 --> 00:55:52,750

on how much drag you have to fix your

1489
00:55:56,460 --> 00:55:55,030
life so we designed rain cube for a

1490
00:55:58,530 --> 00:55:56,470
three month mission thinking it might

1491
00:55:59,520 --> 00:55:58,540
come down as quickly as six months but

1492
00:56:01,440 --> 00:55:59,530
it looks like it can actually stay up

1493
00:56:02,940 --> 00:56:01,450
for a few years as you get a little bit

1494
00:56:05,310 --> 00:56:02,950
higher in the few hundred kilometer

1495
00:56:06,600 --> 00:56:05,320
category it might take more years but

1496
00:56:08,280 --> 00:56:06,610
generally there is a requirement that

1497
00:56:11,430 --> 00:56:08,290
you have to show that your spacecraft

1498
00:56:12,810 --> 00:56:11,440
will deorbit within 25 years so you can

1499
00:56:14,550 --> 00:56:12,820
do that through either analysis saying

1500
00:56:17,040 --> 00:56:14,560
that the atmospheric drag models say you

1501
00:56:18,840 --> 00:56:17,050
will or perhaps you put on a propulsion

1502
00:56:20,280 --> 00:56:18,850
system to push you down there's also

1503
00:56:22,200 --> 00:56:20,290
concepts that have these giant

1504
00:56:23,520 --> 00:56:22,210
inflatable airbags basically to increase

1505
00:56:26,700 --> 00:56:23,530
their drag to actually pull them down

1506
00:56:30,030 --> 00:56:26,710
down faster I don't know if there's been

1507
00:56:33,140 --> 00:56:30,040
a collision I don't know of one with a

1508
00:56:33,150 --> 00:56:38,900
[Laughter]

1509
00:56:43,890 --> 00:56:41,040
sorry I'm new to the CubeSat

1510
00:56:46,890 --> 00:56:43,900
technology so sorry if I misinterpret

1511
00:56:50,220 --> 00:56:46,900
the acronyms but my question was how

1512
00:56:51,840 --> 00:56:50,230
long is the cube stats that are out

1513
00:56:53,640 --> 00:56:51,850

there what's the longest that they've

1514
00:56:55,140 --> 00:56:53,650
been out there the one that thousands or

1515
00:56:58,200 --> 00:56:55,150
so that you had mentioned that are up in

1516
00:57:00,450 --> 00:56:58,210
space what like what's the longest time

1517
00:57:02,490 --> 00:57:00,460
that they've been out in orbit the first

1518
00:57:09,030 --> 00:57:02,500
ones that his phone is actually still

1519
00:57:13,800 --> 00:57:11,430
as a Japanese one and I'm gonna have to

1520
00:57:16,410 --> 00:57:13,810
look up the name now but then yeah it's

1521
00:57:18,480 --> 00:57:16,420
it's still operating it's it is this

1522
00:57:20,130 --> 00:57:18,490
it's at a slightly higher orbit so I

1523
00:57:21,960 --> 00:57:20,140
think it'll that one in particular might

1524
00:57:25,140 --> 00:57:21,970
stay up there for a little longer than

1525
00:57:27,300 --> 00:57:25,150
25 years but the yeah that's that's the

1526
00:57:29,100 --> 00:57:27,310
longest-running one that I know of a lot

1527
00:57:31,260 --> 00:57:29,110
of the more recent ones are flown to an

1528
00:57:32,760 --> 00:57:31,270
International Space Station orbit and

1529
00:57:36,270 --> 00:57:32,770
those are low enough that they kind of

1530
00:57:39,750 --> 00:57:36,280
come down within a few years give or

1531
00:57:41,130 --> 00:57:39,760
take and the for those I think most of

1532
00:57:44,190 --> 00:57:41,140
us have actually been limited by the

1533
00:57:47,310 --> 00:57:44,200
lifetime they've still been working it's

1534
00:57:49,770 --> 00:57:47,320
like there's kind of a within the first

1535
00:57:53,010 --> 00:57:49,780
day or like early part of the mission if

1536
00:57:56,310 --> 00:57:53,020
there's kind of a bimodal failure so

1537
00:57:57,630 --> 00:57:56,320
there's some that die very quickly but

1538
00:58:00,390 --> 00:57:57,640

if you kind of get past that initial

1539
00:58:02,490 --> 00:58:00,400
hump they actually tend to last pretty

1540
00:58:04,560 --> 00:58:02,500
long time I'm trying to get my brain

1541
00:58:07,820 --> 00:58:04,570
wrapped around what keeps them staying

1542
00:58:10,890 --> 00:58:07,830
up that long like what's the I guess the

1543
00:58:12,300 --> 00:58:10,900
energy that they use they're in orbit so

1544
00:58:14,190 --> 00:58:12,310
just like the International Space

1545
00:58:16,350 --> 00:58:14,200
Station and other big satellites out

1546
00:58:18,510 --> 00:58:16,360
there they're designed and high enough

1547
00:58:20,520 --> 00:58:18,520
and going fast enough that they're

1548
00:58:23,550 --> 00:58:20,530
essentially continuously falling but

1549
00:58:25,650 --> 00:58:23,560
they're falling at a speed high in a

1550
00:58:26,880 --> 00:58:25,660
speed high enough and an altitude high

1551
00:58:28,290 --> 00:58:26,890
enough that they will never hit the

1552
00:58:30,150 --> 00:58:28,300
surface of the earth so they keep

1553
00:58:31,680 --> 00:58:30,160
sustaining that okay thank you so much

1554
00:58:34,230 --> 00:58:31,690
you could put a propulsion like some

1555
00:58:35,610 --> 00:58:34,240
missions that like Marco which have a

1556
00:58:37,650 --> 00:58:35,620
propulsion system you can actually use

1557
00:58:39,750 --> 00:58:37,660
that to actually keep yourself up so in

1558
00:58:40,890 --> 00:58:39,760
the case of rain cube if we had a future

1559
00:58:42,660 --> 00:58:40,900
mission that we one of the last for many

1560
00:58:44,070 --> 00:58:42,670
years a future concept could have a

1561
00:58:46,020 --> 00:58:44,080
propulsion system that actually keep us

1562
00:58:52,620 --> 00:58:46,030
at the specific altitude we needed for

1563
00:58:54,930 --> 00:58:52,630

science so I heard you mentioning that

1564
00:58:56,660 --> 00:58:54,940
the cube SATs are starting to even be

1565
00:58:59,490 --> 00:58:56,670
used in high schools and middle schools

1566
00:59:02,220 --> 00:58:59,500
are these seen in like the future more

1567
00:59:03,630 --> 00:59:02,230
as like an educational tool or like you

1568
00:59:05,760 --> 00:59:03,640
know introduction into like you know

1569
00:59:10,290 --> 00:59:05,770
aerospace engineering class type of

1570
00:59:12,510 --> 00:59:10,300
thing oh well I guess yeah so I'm not I

1571
00:59:13,800 --> 00:59:12,520
know that some of the schools that have

1572
00:59:15,030 --> 00:59:13,810
been featured like the high schools and

1573
00:59:17,430 --> 00:59:15,040
missile have actually been partnerships

1574
00:59:18,990 --> 00:59:17,440
with NASA centers so similar I think you

1575
00:59:20,430 --> 00:59:19,000
might select some robotics programs that

1576
00:59:21,600 --> 00:59:20,440
have partnerships but they are

1577
00:59:23,309 --> 00:59:21,610
traditionally used as kind of an

1578
00:59:24,990 --> 00:59:23,319
educational platform

1579
00:59:26,430 --> 00:59:25,000
with the proliferation of the standard

1580
00:59:29,279 --> 00:59:26,440
you've actually seen companies that are

1581
00:59:30,990 --> 00:59:29,289
basically developing kits that you can

1582
00:59:31,950 --> 00:59:31,000
buy and you can take to your school and

1583
00:59:33,750 --> 00:59:31,960
you can learn kind of the first

1584
00:59:35,609 --> 00:59:33,760
principles of engineering but then it

1585
00:59:37,289 --> 00:59:35,619
kind of has this open perhaps has an

1586
00:59:38,460 --> 00:59:37,299
open interface for you could plug in

1587
00:59:40,019 --> 00:59:38,470
your own camera or plug in a different

1588
00:59:41,069 --> 00:59:40,029

payload so they've done a lot of the

1589
00:59:42,809 --> 00:59:41,079
engineering to kind of make something

1590
00:59:44,039 --> 00:59:42,819
that will get up there and power on and

1591
00:59:46,349 --> 00:59:44,049
communicate back to you and then you can

1592
00:59:47,940 --> 00:59:46,359
kind of grow from there I'm not too

1593
00:59:50,010 --> 00:59:47,950
familiar with some of these packages but

1594
00:59:52,529 --> 00:59:50,020
I'm sure you know it'd be easy to find

1595
00:59:53,970 --> 00:59:52,539
and and it'd be a great opportunity for

1596
00:59:55,019 --> 00:59:53,980
young people I wish I had been able to

1597
00:59:56,309 --> 00:59:55,029
work on keep stats when I was in

1598
01:00:02,279 --> 00:59:56,319
elementary school but I was just you

1599
01:00:04,319 --> 01:00:02,289
know I don't know NASA Ames is actually

1600
01:00:06,359 --> 01:00:04,329
running a program called tech ed set and

1601
01:00:09,539 --> 01:00:06,369
so they fly a lot of essentially they

1602
01:00:12,000 --> 01:00:09,549
would they fly the main spacecraft and

1603
01:00:14,279 --> 01:00:12,010
then you can kind of buy a slice or

1604
01:00:16,140 --> 01:00:14,289
design a slice to go in that CubeSat and

1605
01:00:18,390 --> 01:00:16,150
kind of fly your own payload along with

1606
01:00:20,250 --> 01:00:18,400
it so that's another way that it from

1607
01:00:24,660 --> 01:00:20,260
kind of more educational perspectives

1608
01:00:32,549 --> 01:00:24,670
and a little bit of a smaller bite to

1609
01:00:35,309 --> 01:00:32,559
chew on I am my name is Susan Park from

1610
01:00:39,210 --> 01:00:35,319
South Korea today and I prepared some

1611
01:00:42,710 --> 01:00:39,220
questions about in addition to her

1612
01:00:46,769 --> 01:00:42,720
question do you think it is possible for

1613
01:00:50,010 --> 01:00:46,779

individuals to explore and use space by

1614
01:00:52,589 --> 01:00:50,020
Cuba sets in the future can you repeat

1615
01:00:56,329 --> 01:00:52,599
the question again sorry do you think it

1616
01:01:00,480 --> 01:00:56,339
is possible to utilize the space and

1617
01:01:02,549 --> 01:01:00,490
explore the space by using Cuba says so

1618
01:01:05,069 --> 01:01:02,559
I think your are you asking if an

1619
01:01:08,250 --> 01:01:05,079
individual person might be make their

1620
01:01:11,960 --> 01:01:08,260
own CubeSat yeah if you have the right

1621
01:01:17,940 --> 01:01:14,519
yeah it's a lot of it's almost like

1622
01:01:21,150 --> 01:01:17,950
building a computer but the computer has

1623
01:01:22,289 --> 01:01:21,160
to work a lot farther away from you and

1624
01:01:23,849 --> 01:01:22,299
you have to be able to talk to it and

1625
01:01:26,789 --> 01:01:23,859
you can't touch it if something breaks

1626
01:01:28,920 --> 01:01:26,799
so it's a lot more complicated than you

1627
01:01:30,210 --> 01:01:28,930
might initially think but Dad on to that

1628
01:01:32,910 --> 01:01:30,220
I think you know with the proliferation

1629
01:01:34,289 --> 01:01:32,920
of these small set companies you now

1630
01:01:36,049 --> 01:01:34,299
have companies that are dedicated to

1631
01:01:37,279 --> 01:01:36,059
providing ground stations

1632
01:01:38,989 --> 01:01:37,289
so they're building the antennas and

1633
01:01:40,880 --> 01:01:38,999
they build a beautiful web interface for

1634
01:01:42,799 --> 01:01:40,890
you to just log in and you can point the

1635
01:01:44,599 --> 01:01:42,809
antenna at your CubeSat so there's been

1636
01:01:46,039 --> 01:01:44,609
a huge push as all these other companies

1637
01:01:47,979 --> 01:01:46,049
have grown for I think a great

1638
01:01:50,660 --> 01:01:47,989

opportunity for individuals to start

1639
01:01:53,959 --> 01:01:50,670
getting their own access into space and

1640
01:01:58,699 --> 01:01:53,969
thank you and I have read the fact sheet

1641
01:02:02,679 --> 01:01:58,709
about Marco and do you have any special

1642
01:02:05,809 --> 01:02:02,689
reason to use identical two chipsets

1643
01:02:07,670 --> 01:02:05,819
mostly because when you build two of the

1644
01:02:09,920 --> 01:02:07,680
same thing you know how to do it so you

1645
01:02:11,089 --> 01:02:09,930
if you build one you know exactly how to

1646
01:02:12,459 --> 01:02:11,099
build the second one you don't have to

1647
01:02:15,469 --> 01:02:12,469
change anything

1648
01:02:16,880 --> 01:02:15,479
it was also redundancy so I actually

1649
01:02:18,739 --> 01:02:16,890
worked on the other side I was actually

1650
01:02:21,259 --> 01:02:18,749
working on insight I'm during the the

1651
01:02:22,459 --> 01:02:21,269
EDL day and when both mark both markers

1652
01:02:23,599 --> 01:02:22,469
were actually collecting the data but

1653
01:02:24,979 --> 01:02:23,609
that way in case there was a hiccup with

1654
01:02:25,880 --> 01:02:24,989
one if the other one was still there

1655
01:02:29,319 --> 01:02:25,890
would still be able to get it back

1656
01:02:33,289 --> 01:02:29,329
although they both works perfectly so

1657
01:02:38,709 --> 01:02:33,299
and one more and during the way to Mars

1658
01:02:41,749 --> 01:02:38,719
for the two cube sets and it it will be

1659
01:02:45,529 --> 01:02:41,759
exposed to very high particles and

1660
01:02:49,069 --> 01:02:45,539
radiations how can we simulate the

1661
01:02:52,669 --> 01:02:49,079
situation in Earth's there are actually

1662
01:02:55,309 --> 01:02:52,679
test facilities a few of them throughout

1663
01:02:57,410 --> 01:02:55,319

the world that do radiation testing so

1664
01:02:59,539 --> 01:02:57,420
it's a very it's a very controlled test

1665
01:03:02,630 --> 01:02:59,549
but you essentially have you can send an

1666
01:03:04,880 --> 01:03:02,640
ion beam to simulate like high energetic

1667
01:03:07,429 --> 01:03:04,890
high energy particles you can also have

1668
01:03:10,549 --> 01:03:07,439
it just sitting next to a source of

1669
01:03:13,309 --> 01:03:10,559
radiation and kind of getting a total

1670
01:03:15,019 --> 01:03:13,319
dose accumulating on it and you

1671
01:03:18,709 --> 01:03:15,029
essentially put test boards in there and

1672
01:03:20,599 --> 01:03:18,719
just see when they fail we're gonna take

1673
01:03:23,120 --> 01:03:20,609
another question here from YouTube we

1674
01:03:26,179 --> 01:03:23,130
have SSR 98 who's asking

1675
01:03:28,279 --> 01:03:26,189
what are the most most used or preferred

1676
01:03:29,749 --> 01:03:28,289
materials for building cube sets you

1677
01:03:32,150 --> 01:03:29,759
talked about tape measures from the

1678
01:03:35,449 --> 01:03:32,160
hardware store what else do you use to

1679
01:03:37,099 --> 01:03:35,459
make these things a lot of aluminum and

1680
01:03:40,459 --> 01:03:37,109
I remember once when I was in the

1681
01:03:43,189 --> 01:03:40,469
university we actually bought like 5

1682
01:03:45,229 --> 01:03:43,199
feet of an aluminum block it was five

1683
01:03:47,539 --> 01:03:45,239
feet in is 5 inches on each side and we

1684
01:03:49,109 --> 01:03:47,549
actually ended up slicing that up and

1685
01:03:50,460 --> 01:03:49,119
then we milled out the inside

1686
01:03:52,529 --> 01:03:50,470
the outsides to actually make the walls

1687
01:03:54,690 --> 01:03:52,539
of our CubeSat and I remember thinking

1688
01:03:56,670 --> 01:03:54,700

like oh we got like you know 300 pounds

1689
01:03:58,140 --> 01:03:56,680
of aluminum it was only like $200 you

1690
01:04:01,650 --> 01:03:58,150
know for all of that so a lot of

1691
01:04:03,900 --> 01:04:01,660
aluminum a lot of circuit boards a lot

1692
01:04:05,160 --> 01:04:03,910
of wiring wiring takes up a lot of the

1693
01:04:07,109 --> 01:04:05,170
volume especially when you realize that

1694
01:04:09,120 --> 01:04:07,119
wires have to bend around each other so

1695
01:04:10,920 --> 01:04:09,130
that was one of the challenge would in

1696
01:04:12,539 --> 01:04:10,930
school are one of our preferred tools

1697
01:04:14,640 --> 01:04:12,549
for assembly was actually using dental

1698
01:04:15,660 --> 01:04:14,650
tools so we would actually like stick

1699
01:04:16,769 --> 01:04:15,670
you know you know in these to scrape

1700
01:04:17,910 --> 01:04:16,779
your teeth to actually like stick that

1701
01:04:19,559 --> 01:04:17,920
inside the CubeSat and use that to pull

1702
01:04:24,599 --> 01:04:19,569
the wires through our little nooks and

1703
01:04:27,150 --> 01:04:24,609
crannies so that gentleman's question

1704
01:04:30,150 --> 01:04:27,160
about individuals using or building and

1705
01:04:32,579 --> 01:04:30,160
using cube sets to do their own sort of

1706
01:04:35,579 --> 01:04:32,589
private exploration of space got me

1707
01:04:37,559 --> 01:04:35,589
wondering what are the legal regimes

1708
01:04:39,029 --> 01:04:37,569
that govern the launch of these the

1709
01:04:40,769 --> 01:04:39,039
crafts is the same as just launching

1710
01:04:41,849 --> 01:04:40,779
larger satellites in other words how do

1711
01:04:45,180 --> 01:04:41,859
you get that clearance who gives the

1712
01:04:48,480 --> 01:04:45,190
clearance etc yeah so a lot of it is the

1713
01:04:49,980 --> 01:04:48,490

FCC which is how you know know like

1714
01:04:53,390 --> 01:04:49,990
Federal Communications Commission's

1715
01:04:55,829 --> 01:04:53,400
Commission yeah so the so spectrum and

1716
01:04:59,539 --> 01:04:55,839
one of them big things you really need

1717
01:05:01,349 --> 01:04:59,549
to get approved regulation wise is the

1718
01:05:03,359 --> 01:05:01,359
communication spectrum you use in the

1719
01:05:05,970 --> 01:05:03,369
band you're using theirs in the

1720
01:05:08,569 --> 01:05:05,980
frequencies that are typically used by

1721
01:05:11,130 --> 01:05:08,579
cube sensing like the UHF regime

1722
01:05:15,089 --> 01:05:11,140
specifically there is a lot there are a

1723
01:05:16,259 --> 01:05:15,099
lot of assets using that band so it can

1724
01:05:17,970 --> 01:05:16,269
get very noisy and so there are

1725
01:05:19,440 --> 01:05:17,980
restrictions on what kind of bandwidth

1726
01:05:21,120 --> 01:05:19,450
you can use what kind of power levels

1727
01:05:23,160 --> 01:05:21,130
you can have when you can transmit them

1728
01:05:26,150 --> 01:05:23,170
so that's that's one of the big ones in

1729
01:05:28,559 --> 01:05:26,160
terms of regulations for flying these

1730
01:05:30,690 --> 01:05:28,569
all right well there's a question from

1731
01:05:32,430 --> 01:05:30,700
YouTube from ultimate who wants to know

1732
01:05:35,999 --> 01:05:32,440
how are you planning to improve these

1733
01:05:37,319 --> 01:05:36,009
satellites how are you you know what are

1734
01:05:38,370 --> 01:05:37,329
you talked about some of the places you

1735
01:05:40,650 --> 01:05:38,380
want to send them and some of the things

1736
01:05:42,450 --> 01:05:40,660
they could do but what would you like to

1737
01:05:48,989 --> 01:05:42,460
them to do better do they need to be

1738
01:05:55,109 --> 01:05:48,999

smaller I think we're doing a great job

1739
01:05:56,759 --> 01:05:55,119
right now I well so an mentioned a lot

1740
01:05:59,339 --> 01:05:56,769
of the grand challenges that I think

1741
01:06:00,870 --> 01:05:59,349
keeps had to have earth is really nice

1742
01:06:02,400 --> 01:06:00,880
because you know you go you have

1743
01:06:02,820 --> 01:06:02,410
sunshine but you have a clip so you got

1744
01:06:06,090 --> 01:06:02,830
the magnet

1745
01:06:07,680 --> 01:06:06,100
field designing everything I think in my

1746
01:06:09,600 --> 01:06:07,690
opinion altum Utley boils down to power

1747
01:06:11,220 --> 01:06:09,610
so you need power to communicate back to

1748
01:06:13,650 --> 01:06:11,230
earth at these incredible distances and

1749
01:06:15,570 --> 01:06:13,660
you need power to keep yourself warm at

1750
01:06:17,310 --> 01:06:15,580
these incredible distances and one of

1751
01:06:18,510 --> 01:06:17,320
the grand challenges is once you start

1752
01:06:19,910 --> 01:06:18,520
going out farther in the solar system

1753
01:06:23,460 --> 01:06:19,920
how do you generate enough electricity

1754
01:06:24,600 --> 01:06:23,470
so you know if we have Voyager sitting

1755
01:06:26,490 --> 01:06:24,610
over here which you used to know the

1756
01:06:28,590 --> 01:06:26,500
radioisotope power sources we have

1757
01:06:30,270 --> 01:06:28,600
Europa clipper which is using solar

1758
01:06:32,940 --> 01:06:30,280
panels out at Jupiter's distances but

1759
01:06:34,050 --> 01:06:32,950
those solar panels are so huge compared

1760
01:06:37,350 --> 01:06:34,060
to the size of the actual spacecraft

1761
01:06:39,420 --> 01:06:37,360
itself and on the small form-factor it

1762
01:06:42,150 --> 01:06:39,430
can be very difficult to fit these very

1763
01:06:44,250 --> 01:06:42,160

giant arrays onto such kind of a small

1764
01:06:47,190 --> 01:06:44,260
box it doesn't really quite scale as

1765
01:06:49,020 --> 01:06:47,200
nicely so I think a grand challenge is

1766
01:06:49,950 --> 01:06:49,030
how do we get enough power when we're

1767
01:06:51,390 --> 01:06:49,960
far away I think we know how to

1768
01:06:53,760 --> 01:06:51,400
communicate and keep ourselves warm when

1769
01:06:58,040 --> 01:06:53,770
we're there but I would personally like

1770
01:07:02,220 --> 01:07:00,540
the 3u is the perfect size in the next

1771
01:07:03,900 --> 01:07:02,230
heat of this all of ours were 6 use and

1772
01:07:08,670 --> 01:07:03,910
they're like ah but 12 use those are the

1773
01:07:09,540 --> 01:07:08,680
future now so I'm interested in the the

1774
01:07:11,040 --> 01:07:09,550
dream of the future and that's

1775
01:07:12,990 --> 01:07:11,050
interstellar and going to some other

1776
01:07:15,000 --> 01:07:13,000
planet or star and get bringing back

1777
01:07:17,130 --> 01:07:15,010
images do we have electronics that are

1778
01:07:18,990 --> 01:07:17,140
that are capable of handling that sort

1779
01:07:20,760 --> 01:07:19,000
of hard life or you know hard radiation

1780
01:07:22,470 --> 01:07:20,770
because you're gonna have to do a nav

1781
01:07:24,690 --> 01:07:22,480
system and you can't communicate it

1782
01:07:26,820 --> 01:07:24,700
light at Lightyear distances how are we

1783
01:07:28,860 --> 01:07:26,830
getting in there I said to my knowledge

1784
01:07:30,150 --> 01:07:28,870
we don't have any technology right now

1785
01:07:32,930 --> 01:07:30,160
but I know a lot of people are

1786
01:07:37,080 --> 01:07:32,940
interested in doing that and so I'm sure

1787
01:07:43,830 --> 01:07:37,090
we'll see it at some point comes back to

1788
01:07:46,740 --> 01:07:43,840

power power had communications question

1789
01:07:49,260 --> 01:07:46,750
given the sub our second pointing

1790
01:07:51,780 --> 01:07:49,270
accuracy of Asteria what are your

1791
01:07:54,270 --> 01:07:51,790
thoughts on optical communications Opel

1792
01:07:58,890 --> 01:07:54,280
style from cue sets within cislunar

1793
01:08:01,710 --> 01:07:58,900
space to earth optical communications is

1794
01:08:03,030 --> 01:08:01,720
it is an active area of research and

1795
01:08:05,250 --> 01:08:03,040
there have been a couple of payloads

1796
01:08:07,440 --> 01:08:05,260
that have flown and and demonstrated the

1797
01:08:09,740 --> 01:08:07,450
capability to do optical communications

1798
01:08:12,510 --> 01:08:09,750
from and keeps that platform from

1799
01:08:14,520 --> 01:08:12,520
distances beyond low-earth orbit it

1800
01:08:15,910 --> 01:08:14,530
becomes more challenging for any kind of

1801
01:08:18,640 --> 01:08:15,920
spacecraft because the you know

1802
01:08:21,340 --> 01:08:18,650
pointing does have to be better I think

1803
01:08:23,710 --> 01:08:21,350
there's at least one of the e/m payload

1804
01:08:26,590 --> 01:08:23,720
em1 payloads that might be demonstrating

1805
01:08:27,640 --> 01:08:26,600
that but I might be thinking of a

1806
01:08:29,530 --> 01:08:27,650
different one yeah they've been

1807
01:08:31,510 --> 01:08:29,540
universities and other institutions that

1808
01:08:34,530 --> 01:08:31,520
have worked on optical on communication

1809
01:08:36,880 --> 01:08:34,540
demonstration technologies thanks

1810
01:08:43,060 --> 01:08:36,890
alright last question the honor goes to

1811
01:08:44,320 --> 01:08:43,070
you sir sorry so regarding CubeSat C you

1812
01:08:46,270 --> 01:08:44,330
know how in space we have larger

1813
01:08:48,100 --> 01:08:46,280

satellites communicating with the earth

1814
01:08:49,630 --> 01:08:48,110
right I'm wondering if we could have

1815
01:08:51,160 --> 01:08:49,640
CubeSat to be the new future of

1816
01:08:54,160 --> 01:08:51,170
technology to communicate with the rest

1817
01:08:55,870 --> 01:08:54,170
of us if so how yes so there are

1818
01:08:57,730 --> 01:08:55,880
companies like there's a company called

1819
01:08:59,620 --> 01:08:57,740
one web and I believe SpaceX is looking

1820
01:09:01,840 --> 01:08:59,630
into this too of building sending

1821
01:09:03,310 --> 01:09:01,850
constellations of small sets not

1822
01:09:06,100 --> 01:09:03,320
necessarily keep sets but definitely

1823
01:09:07,960 --> 01:09:06,110
small sets to do just that to kind of

1824
01:09:10,180 --> 01:09:07,970
provide this global internet or global

1825
01:09:13,020 --> 01:09:10,190
communications capability so it's

1826
01:09:15,070 --> 01:09:13,030
especially with the new with advances in

1827
01:09:17,080 --> 01:09:15,080
shrinking this technology to fit on a

1828
01:09:18,460 --> 01:09:17,090
smaller platform obviously the smaller

1829
01:09:20,050 --> 01:09:18,470
it is the easier it is to launch the

1830
01:09:22,990 --> 01:09:20,060
easier it is to launch a lot of them so

1831
01:09:27,730 --> 01:09:23,000
that is a very very attractive thing to

1832
01:09:29,830 --> 01:09:27,740
want to do well folks that's all the

1833
01:09:32,230 --> 01:09:29,840
time we have for today thanks to

1834
01:09:34,450 --> 01:09:32,240
everyone for joining us here and online

1835
01:09:36,730 --> 01:09:34,460
of course thanks to our speakers join us

1836
01:09:39,610 --> 01:09:36,740
again next month for a look at how we

1837
01:09:41,530 --> 01:09:39,620
develop new space missions from concept

1838
01:09:43,150 --> 01:09:41,540

to the launch pad so we'll see you then

1839
01:09:55,540 --> 01:09:43,160
thank you so much for joining us