1
00:00:03,909 --> 00:00:01,990
[Music]

2
00:00:05,510 --> 00:00:03,919
nasa's jet propulsion laboratory

3
00:00:08,150 --> 00:00:05,520
presents

4
00:00:10,230 --> 00:00:08,160
the von carmen lecture a series of talks

5
00:00:13,509 --> 00:00:10,240
by scientists and engineers who are

6
00:00:16,400 --> 00:00:13,519
exploring our planet our solar system

7
00:00:24,150 --> 00:00:16,410
and all that lies beyond

8
00:00:28,070 --> 00:00:25,910
good evening ladies and gentlemen how

9
00:00:29,429 --> 00:00:28,080
are we all tonight pretty good

10
00:00:30,470 --> 00:00:29,439
cool well thanks for coming out to join

11
00:00:32,389 --> 00:00:30,480
us as always

12
00:00:34,389 --> 00:00:32,399
so let's hop right in shall we

13
00:00:36,790 --> 00:00:34,399

earth science is a key to understanding

14
00:00:38,470 --> 00:00:36,800
our universe after all planetary science

15
00:00:40,790 --> 00:00:38,480
relies on ideas and technologies

16
00:00:43,510 --> 00:00:40,800
developed and tested here on earth

17
00:00:45,270 --> 00:00:43,520
like a star trek sensor sweep a remote

18
00:00:47,190 --> 00:00:45,280
sensing technique called spectral

19
00:00:48,389 --> 00:00:47,200
mapping is used to learn about celestial

20
00:00:50,709 --> 00:00:48,399
bodies

21
00:00:52,470 --> 00:00:50,719
these types of instruments use reflected

22
00:00:54,470 --> 00:00:52,480
sunlight to produce imagery of the

23
00:00:56,869 --> 00:00:54,480
chemical composition of planetary

24
00:00:58,549 --> 00:00:56,879
surfaces and the information captured by

25
00:01:01,430 --> 00:00:58,559
these instruments is useful to many

26
00:01:03,670 --> 00:01:01,440
fields of earth and planetary research

27
00:01:05,910 --> 00:01:03,680
in this talk our guest will share photos

28
00:01:07,990 --> 00:01:05,920
and videos of various spectral mapping

29
00:01:09,590 --> 00:01:08,000
field deployments and will discuss the

30
00:01:11,990 --> 00:01:09,600
science behind measuring spectra of

31
00:01:13,910 --> 00:01:12,000
reflected sunlight and perform physical

32
00:01:15,910 --> 00:01:13,920
demonstrations to illuminate a few of

33
00:01:17,910 --> 00:01:15,920
the phenomenon that makes spectral

34
00:01:20,149 --> 00:01:17,920
remote sensing possible

35
00:01:21,910 --> 00:01:20,159
tonight's guest received a bs in physics

36
00:01:24,870 --> 00:01:21,920
from the california state polytechnic

37
00:01:28,310 --> 00:01:24,880
university pomona in 1991.

38
00:01:30,710 --> 00:01:28,320

from 1991 to 2005 he was the calibration

39
00:01:33,190 --> 00:01:30,720
and validation field engineer for the

40
00:01:34,550 --> 00:01:33,200
multi-angle imaging spectro radiometer

41
00:01:37,350 --> 00:01:34,560
here at jpl

42
00:01:39,670 --> 00:01:37,360
from 2005 to 2011 he was employed by

43
00:01:42,390 --> 00:01:39,680
northrop grumman aerospace systems as an

44
00:01:43,830 --> 00:01:42,400
electro optical calibration engineer he

45
00:01:45,429 --> 00:01:43,840
has also worked with lab sphere

46
00:01:47,830 --> 00:01:45,439
incorporated a maker of optical

47
00:01:49,830 --> 00:01:47,840
calibration systems as their worldwide

48
00:01:51,590 --> 00:01:49,840
remote sensing systems development and

49
00:01:53,830 --> 00:01:51,600
marketing manager

50
00:01:56,389 --> 00:01:53,840
during these gap years he was brought in

51
00:01:58,709 --> 00:01:56,399
part-time by various jpl projects to

52
00:02:01,270 --> 00:01:58,719
help out with ongoing field work he

53
00:02:04,230 --> 00:02:01,280
returned full-time to jpl in 2012 to

54
00:02:06,310 --> 00:02:04,240
augment jpl's imaging spectroscopy group

55
00:02:08,630 --> 00:02:06,320
there he helps calibrate operate and

56
00:02:10,949 --> 00:02:08,640
develop custom spectral remote sensing

57
00:02:12,949 --> 00:02:10,959
instruments and techniques for nasa and

58
00:02:14,550 --> 00:02:12,959
other customers as well as assist with

59
00:02:16,869 --> 00:02:14,560
planetary research and exploration

60
00:02:18,150 --> 00:02:16,879
development efforts right here at jpl

61
00:02:19,670 --> 00:02:18,160
ladies and gentlemen please help me

62
00:02:24,390 --> 00:02:19,680
welcome tonight's guest mr mark

63
00:02:24,400 --> 00:02:30,470

very good i thought that sounded good

64
00:02:35,350 --> 00:02:32,550
thank you everyone i'm honored to have

65
00:02:38,229 --> 00:02:35,360
been asked to speak this evening

66
00:02:40,150 --> 00:02:38,239
i'm part of a large dynamic team and you

67
00:02:42,790 --> 00:02:40,160
all know who you are

68
00:02:45,270 --> 00:02:42,800
i'm just one of the minions of jpl's

69
00:02:47,270 --> 00:02:45,280
imaging spectroscopy group

70
00:02:49,830 --> 00:02:47,280
this von carmen lecture is about the

71
00:02:52,470 --> 00:02:49,840
science application and pursuit of

72
00:02:55,110 --> 00:02:52,480
imaging spectroscopy i took this

73
00:02:57,509 --> 00:02:55,120
snapshot while flying aboard a research

74
00:02:59,430 --> 00:02:57,519
aircraft dodging storms in transit to

75
00:03:00,949 --> 00:02:59,440
our next experiment

76
00:03:03,589 --> 00:03:00,959
more on the pursuit of imaging

77
00:03:05,990 --> 00:03:03,599
spectroscopy later in this talk first

78
00:03:07,350 --> 00:03:06,000
let's put imaging spectroscopy in

79
00:03:09,589 --> 00:03:07,360
context

80
00:03:11,270 --> 00:03:09,599
jpl studies planets including the most

81
00:03:12,309 --> 00:03:11,280
important planet in the universe are

82
00:03:14,630 --> 00:03:12,319
earth

83
00:03:16,390 --> 00:03:14,640
it's sort of an inside joke here at jpl

84
00:03:19,030 --> 00:03:16,400
when a focused researcher has to be

85
00:03:21,509 --> 00:03:19,040
reminded of our place in the universe

86
00:03:24,790 --> 00:03:21,519
to jpl earth is one of a growing number

87
00:03:28,149 --> 00:03:24,800
of of evolving planets but so far the

88
00:03:30,149 --> 00:03:28,159

only oasis and example of life

89
00:03:34,229 --> 00:03:30,159
imaging spectroscopy is a powerful tool

90
00:03:36,630 --> 00:03:34,239
for studying planets white gray yellow

91
00:03:38,710 --> 00:03:36,640
blue green or red imaging spectroscopy

92
00:03:40,630 --> 00:03:38,720
lays bare the chemical composition of a

93
00:03:42,869 --> 00:03:40,640
planetary surface

94
00:03:44,869 --> 00:03:42,879
from the static climate of mars to the

95
00:03:47,430 --> 00:03:44,879
rapidly changing climate of earth

96
00:03:49,110 --> 00:03:47,440
imaging spectroscopy measures and maps

97
00:03:51,670 --> 00:03:49,120
the environment

98
00:03:54,630 --> 00:03:51,680
planets are best understood in context

99
00:03:57,030 --> 00:03:54,640
and earth is the planet we know best

100
00:03:59,429 --> 00:03:57,040
one of the things that is studied at jpl

101
00:04:01,750 --> 00:03:59,439
is comparative planetology

102
00:04:04,229 --> 00:04:01,760
that's an evolutionary understanding of

103
00:04:07,270 --> 00:04:04,239
planets which makes plain a couple of

104
00:04:09,589 --> 00:04:07,280
cosmic examples in our nearby heavens of

105
00:04:12,229 --> 00:04:09,599
rocky planets that started out with

106
00:04:15,509 --> 00:04:12,239
similar environmental inventories as we

107
00:04:17,349 --> 00:04:15,519
have here on earth but are now lethal

108
00:04:19,430 --> 00:04:17,359
venus is a planet that could have been a

109
00:04:23,830 --> 00:04:19,440
sister of earth but for a runaway

110
00:04:23,840 --> 00:04:27,110
mars

111
00:04:31,510 --> 00:04:28,870
and run away greenhouse effect that can

112
00:04:34,310 --> 00:04:31,520
melt lead on the surface mars is a

113
00:04:36,870 --> 00:04:34,320

planet with a surface blasted sterile by

114
00:04:39,670 --> 00:04:36,880
our sun's ultraviolet emissions because

115
00:04:41,030 --> 00:04:39,680
of no protective ozone layer

116
00:04:43,189 --> 00:04:41,040
and we know these things through the

117
00:04:47,430 --> 00:04:43,199
application of remote sensing techniques

118
00:04:50,390 --> 00:04:48,790
so

119
00:04:52,870 --> 00:04:50,400
if we look at

120
00:04:55,350 --> 00:04:52,880
this infographic

121
00:04:56,629 --> 00:04:55,360
it documents jpl's mission history where

122
00:04:57,830 --> 00:04:56,639
we've gone

123
00:04:59,189 --> 00:04:57,840
up at the top

124
00:05:01,030 --> 00:04:59,199
or in the middle where all the planets

125
00:05:02,550 --> 00:05:01,040
and bodies are and then on the bottom

126
00:05:04,629 --> 00:05:02,560
when you really can't see it but those

127
00:05:06,870 --> 00:05:04,639
are all dates down there right and you

128
00:05:09,029 --> 00:05:06,880
can tell by all the green lines

129
00:05:10,550 --> 00:05:09,039
going to the green planet that jpl's

130
00:05:11,990 --> 00:05:10,560
been to earth often

131
00:05:13,830 --> 00:05:12,000
and there's a deep and productive

132
00:05:15,909 --> 00:05:13,840
synergy between earth science and

133
00:05:18,550 --> 00:05:15,919
planetary science

134
00:05:20,629 --> 00:05:18,560
extra points for those who noticed that

135
00:05:23,990 --> 00:05:20,639
this infographic does not include the

136
00:05:26,550 --> 00:05:24,000
new horizons fly by a pluto

137
00:05:29,189 --> 00:05:26,560
yeah where's pluto it didn't get demoted

138
00:05:31,749 --> 00:05:29,199

this infographic was made before

139
00:05:33,270 --> 00:05:31,759
new horizons went by so spacecraft

140
00:05:36,230 --> 00:05:33,280
flying by

141
00:05:38,870 --> 00:05:36,240
or orbiting or rover the point is

142
00:05:40,950 --> 00:05:38,880
to figure out what's over there without

143
00:05:42,629 --> 00:05:40,960
going over there that's what remote

144
00:05:44,870 --> 00:05:42,639
sensing is

145
00:05:46,550 --> 00:05:44,880
so imaging spectroscopy is a scientific

146
00:05:48,469 --> 00:05:46,560
remote sensing tool

147
00:05:49,990 --> 00:05:48,479
and remote sensing is something nasa

148
00:05:52,230 --> 00:05:50,000
does best

149
00:05:54,230 --> 00:05:52,240
all of all of america's government

150
00:05:56,230 --> 00:05:54,240
agencies only nasa has the critical

151
00:05:58,150 --> 00:05:56,240
concentration of brains experience and

152
00:05:59,749 --> 00:05:58,160
know-how to get up there get out there

153
00:06:01,029 --> 00:05:59,759
and make the measurements of whole

154
00:06:03,110 --> 00:06:01,039
planets

155
00:06:05,029 --> 00:06:03,120
jpl is managed by caltech for nasa which

156
00:06:07,590 --> 00:06:05,039
has given jpl the mandate of robotic

157
00:06:09,189 --> 00:06:07,600
extraterrestrial exploration the group i

158
00:06:11,670 --> 00:06:09,199
work for has been a key part of many of

159
00:06:13,909 --> 00:06:11,680
those extraterrestrial missions

160
00:06:15,909 --> 00:06:13,919
galileo cassini the mars reconnaissance

161
00:06:18,230 --> 00:06:15,919
orbiter even the indian lunar chandra

162
00:06:19,110 --> 00:06:18,240
ion 1 mission

163
00:06:21,430 --> 00:06:19,120

have

164
00:06:23,670 --> 00:06:21,440
there has been a spectral imaging system

165
00:06:26,550 --> 00:06:23,680
on nearly every major planetary probe

166
00:06:28,390 --> 00:06:26,560
built or operated by jpl and the people

167
00:06:30,550 --> 00:06:28,400
of the imaging spectroscopy effort at

168
00:06:32,309 --> 00:06:30,560
jpl where i work

169
00:06:33,670 --> 00:06:32,319
have built or been involved with just

170
00:06:35,830 --> 00:06:33,680
about every one of those imaging

171
00:06:37,830 --> 00:06:35,840
spectroscopy instruments and it's been a

172
00:06:39,909 --> 00:06:37,840
steep learning curve for me ever since i

173
00:06:42,550 --> 00:06:39,919
walked through that door

174
00:06:43,990 --> 00:06:42,560
even curiosity uses remote sensing even

175
00:06:45,749 --> 00:06:44,000
though it's on the surface to make a

176
00:06:47,830 --> 00:06:45,759
decision about traveling to a potential

177
00:06:50,469 --> 00:06:47,840
site and collecting a sample to analyze

178
00:06:52,309 --> 00:06:50,479
with their onboard chemistry set

179
00:06:54,870 --> 00:06:52,319
for many remote sensing measurements and

180
00:06:56,790 --> 00:06:54,880
nearly all of the memorable images over

181
00:06:58,790 --> 00:06:56,800
the history of planetary exploration the

182
00:07:01,270 --> 00:06:58,800
amount of reflected sunlight has been

183
00:07:04,469 --> 00:07:01,280
the quantity measured for that fraction

184
00:07:08,710 --> 00:07:06,309
and that fraction of the solar spectrum

185
00:07:11,350 --> 00:07:08,720
or wavelength the number returned to the

186
00:07:13,589 --> 00:07:11,360
earth to us here on earth is the amount

187
00:07:15,189 --> 00:07:13,599
of reflected sunlight making it back to

188
00:07:17,029 --> 00:07:15,199

nasa's sensor

189
00:07:18,469 --> 00:07:17,039
as part of my career i've been sent to

190
00:07:20,230 --> 00:07:18,479
the corners of the earth to help

191
00:07:21,270 --> 00:07:20,240
calibrate instruments in the a train

192
00:07:24,070 --> 00:07:21,280
orbit

193
00:07:26,629 --> 00:07:24,080
depicted here in the lower left

194
00:07:28,230 --> 00:07:26,639
those instruments use reflected sunlight

195
00:07:30,309 --> 00:07:28,240
many of those instruments use reflected

196
00:07:31,749 --> 00:07:30,319
sunlight constellations of earth

197
00:07:33,430 --> 00:07:31,759
observing satellites are some of the

198
00:07:35,189 --> 00:07:33,440
most powerful tools of science for

199
00:07:37,670 --> 00:07:35,199
accurately measuring the ever-changing

200
00:07:39,270 --> 00:07:37,680
environment of our planet the a train or

201
00:07:41,270 --> 00:07:39,280
afternoon train of earth observing

202
00:07:43,270 --> 00:07:41,280
satellites and is in a special

203
00:07:45,430 --> 00:07:43,280
precessing polar orbit called sun

204
00:07:47,670 --> 00:07:45,440
synchronous that enables not only

205
00:07:49,510 --> 00:07:47,680
planetary coverage but consistent

206
00:07:51,749 --> 00:07:49,520
repeatable earth observation at the same

207
00:07:52,710 --> 00:07:51,759
angles of solar illumination for every

208
00:07:54,390 --> 00:07:52,720
orbit

209
00:07:56,070 --> 00:07:54,400
that's how carefully these measurements

210
00:07:58,230 --> 00:07:56,080
are made

211
00:08:00,790 --> 00:07:58,240
when it has to work for everyone

212
00:08:03,350 --> 00:08:00,800
everywhere every time no matter what

213
00:08:08,070 --> 00:08:03,360

science is used and at nasa it's our job

214
00:08:10,830 --> 00:08:09,990
i have to put the cursor there and then

215
00:08:13,830 --> 00:08:10,840
do

216
00:08:15,990 --> 00:08:13,840
this this talk is about a remote sensing

217
00:08:17,350 --> 00:08:16,000
technique called imaging spectroscopy it

218
00:08:18,950 --> 00:08:17,360
is a measurement strategy that

219
00:08:20,629 --> 00:08:18,960
identifies surface materials and their

220
00:08:22,710 --> 00:08:20,639
physical context

221
00:08:25,110 --> 00:08:22,720
lying next to each other right

222
00:08:26,869 --> 00:08:25,120
so down in the lower left hand corner

223
00:08:29,270 --> 00:08:26,879
this is a data cube a way of

224
00:08:30,950 --> 00:08:29,280
representing imaging spectrometer data

225
00:08:32,310 --> 00:08:30,960
the top of the cube is made of data from

226
00:08:34,149 --> 00:08:32,320
wavelengths of light that our eyes

227
00:08:35,509 --> 00:08:34,159
perceive as the colors red green and

228
00:08:37,829 --> 00:08:35,519
blue

229
00:08:39,990 --> 00:08:37,839
imagine that you could automatically

230
00:08:42,630 --> 00:08:40,000
discern what material predominates in

231
00:08:44,949 --> 00:08:42,640
each pixel of this image dirt vegetation

232
00:08:47,829 --> 00:08:44,959
asphalt concrete roofing automatically

233
00:08:49,590 --> 00:08:47,839
classified mapped counted and more

234
00:08:51,350 --> 00:08:49,600
how those materials interact with

235
00:08:54,150 --> 00:08:51,360
sunlight is represented in the third

236
00:08:55,190 --> 00:08:54,160
dimension of the cube those colors going

237
00:08:57,430 --> 00:08:55,200
back

238
00:08:59,829 --> 00:08:57,440

it's the spectral signature of reflected

239
00:09:02,070 --> 00:08:59,839
sunlight and it's by this signature that

240
00:09:04,070 --> 00:09:02,080
we know what's down there

241
00:09:06,230 --> 00:09:04,080
this all happens within the context of

242
00:09:09,030 --> 00:09:06,240
the electromagnetic spectrum represented

243
00:09:11,829 --> 00:09:09,040
up at the top there and that's measured

244
00:09:13,110 --> 00:09:11,839
by wavelength and we perceive

245
00:09:16,230 --> 00:09:13,120
wavelengths of different amounts of

246
00:09:18,389 --> 00:09:16,240
electromagnetic radiation as color

247
00:09:20,710 --> 00:09:18,399
but we only really see in three spectral

248
00:09:23,910 --> 00:09:20,720
bands and that's what

249
00:09:27,910 --> 00:09:26,070
the plot above where it says wavelength

250
00:09:30,070 --> 00:09:27,920
nanometers those are the three spectral

251
00:09:31,590 --> 00:09:30,080
bands that the cones of our eyes are

252
00:09:33,509 --> 00:09:31,600
sensitive to

253
00:09:35,430 --> 00:09:33,519
our brain interpolates the rest of the

254
00:09:38,790 --> 00:09:35,440
colors of the rainbow from the relative

255
00:09:41,990 --> 00:09:38,800
intensity of those three bands

256
00:09:44,949 --> 00:09:42,000
so i'm going to do a demonstration next

257
00:09:47,190 --> 00:09:44,959
but before we get there

258
00:09:49,190 --> 00:09:47,200
this image over on the right this rgb

259
00:09:51,110 --> 00:09:49,200
image is more than just a pretty picture

260
00:09:53,269 --> 00:09:51,120
it's actually a scientific image of

261
00:09:56,550 --> 00:09:53,279
physical reality

262
00:10:04,070 --> 00:09:56,560
and extra points you may have noticed

263
00:10:07,829 --> 00:10:05,829

anybody want to try

264
00:10:09,829 --> 00:10:07,839
they're eliminated by this blue glow of

265
00:10:11,590 --> 00:10:09,839
the sky that's right shadows are not

266
00:10:14,470 --> 00:10:11,600
illuminated by the white light of the

267
00:10:16,790 --> 00:10:14,480
sun they're eliminated by the blue sky

268
00:10:18,230 --> 00:10:16,800
but our eye does a lot of automatic

269
00:10:21,110 --> 00:10:18,240
white balancing that we're just not

270
00:10:23,190 --> 00:10:21,120
aware of so here we have an example of

271
00:10:25,110 --> 00:10:23,200
seeing is not believing

272
00:10:27,670 --> 00:10:25,120
our senses are limited and there's more

273
00:10:30,829 --> 00:10:27,680
to the universe than we can sense and so

274
00:10:34,550 --> 00:10:30,839
i'm going to do a demonstration my next

275
00:10:36,470 --> 00:10:34,560
slide to show that

276
00:10:38,630 --> 00:10:36,480
so i have here

277
00:10:40,550 --> 00:10:38,640
something called an integrating sphere i

278
00:10:44,389 --> 00:10:40,560
use these professionally

279
00:10:46,550 --> 00:10:44,399
they present a uniform field to the eye

280
00:10:48,630 --> 00:10:46,560
or to a camera every cell phone camera

281
00:10:50,470 --> 00:10:48,640
or professional camera ever made

282
00:10:53,030 --> 00:10:50,480
has stared at one of these things on the

283
00:10:55,190 --> 00:10:53,040
production line and had its relative

284
00:10:57,269 --> 00:10:55,200
responsivity field measured

285
00:10:58,870 --> 00:10:57,279
so what this integrating sphere does by

286
00:11:01,269 --> 00:10:58,880
the way integration is a fancy

287
00:11:03,110 --> 00:11:01,279
mathematical term for mushing up

288
00:11:05,190 --> 00:11:03,120

this has got some light bulbs inside of

289
00:11:07,509 --> 00:11:05,200
it and it's mushing up the light and so

290
00:11:08,949 --> 00:11:07,519
much that you really can't discern much

291
00:11:11,190 --> 00:11:08,959
see this is actually an empty sphere

292
00:11:15,910 --> 00:11:11,200
that's painted white on the inside

293
00:11:18,630 --> 00:11:15,920
i don't have a film over it right and

294
00:11:19,670 --> 00:11:18,640
this is a cake mold from michael's you

295
00:11:21,750 --> 00:11:19,680
can

296
00:11:23,509 --> 00:11:21,760
it's exactly the volume of one box of

297
00:11:25,030 --> 00:11:23,519
cake mix it comes in two halves you make

298
00:11:26,470 --> 00:11:25,040
the two halves you bake them glue them

299
00:11:27,670 --> 00:11:26,480
together and you've got your soccer ball

300
00:11:29,269 --> 00:11:27,680
cake

301
00:11:31,750 --> 00:11:29,279
my good wife susan turned me on to this

302
00:11:34,150 --> 00:11:31,760
thing that's great

303
00:11:36,069 --> 00:11:34,160
so um yeah i make these for teachers and

304
00:11:38,230 --> 00:11:36,079
it's what it's got illuminating in it

305
00:11:39,990 --> 00:11:38,240
are three leds so you see pretty much

306
00:11:43,590 --> 00:11:40,000
here a white light right

307
00:11:45,509 --> 00:11:43,600
but if we look inside

308
00:11:47,190 --> 00:11:45,519
we can see

309
00:11:49,269 --> 00:11:47,200
that there's really three

310
00:11:50,790 --> 00:11:49,279
light-emitting diodes in there that are

311
00:11:52,710 --> 00:11:50,800
the three colors that our eyes are

312
00:11:56,230 --> 00:11:52,720
sensitive to

313
00:11:57,670 --> 00:11:56,240

red green and blue and maybe if i walk

314
00:11:59,829 --> 00:11:57,680
around a little bit

315
00:12:01,110 --> 00:11:59,839
you can see it's just red green and blue

316
00:12:02,790 --> 00:12:01,120
inside there's no white light bulb

317
00:12:04,790 --> 00:12:02,800
inside so let me really freak everybody

318
00:12:08,470 --> 00:12:04,800
out

319
00:12:13,269 --> 00:12:11,269
really pretty yellow isn't it right

320
00:12:15,350 --> 00:12:13,279
very pretty yellow but if we look and

321
00:12:18,949 --> 00:12:15,360
see what lights are on inside all i did

322
00:12:22,629 --> 00:12:18,959
is i turned off the blue light

323
00:12:25,910 --> 00:12:24,470
so if there's a wise acre in the back of

324
00:12:27,670 --> 00:12:25,920
the room giving me trouble i'll say

325
00:12:31,670 --> 00:12:27,680
something like okay einstein where's the

326
00:12:35,350 --> 00:12:32,790
got to be a yellow light bulb in there

327
00:12:37,110 --> 00:12:35,360
somewhere right no

328
00:12:39,030 --> 00:12:37,120
yellow is the color in between red and

329
00:12:40,629 --> 00:12:39,040
green in the rainbow your brain knows

330
00:12:42,949 --> 00:12:40,639
this it's hard wired into your eyes

331
00:12:44,069 --> 00:12:42,959
actually into your optic nerve

332
00:12:46,470 --> 00:12:44,079
and

333
00:12:49,190 --> 00:12:46,480
so you see yellow so the word magician

334
00:12:50,629 --> 00:12:49,200
means i'm going to fool you

335
00:12:52,389 --> 00:12:50,639
i've explained how i'm going to fool you

336
00:12:54,629 --> 00:12:52,399
and i'm still fooling you it's built in

337
00:12:58,629 --> 00:12:54,639
magicians know how we're built inside

338
00:13:02,949 --> 00:13:01,430

subjective versus objective objectively

339
00:13:04,629 --> 00:13:02,959
i've explained a way of looking at the

340
00:13:06,230 --> 00:13:04,639
universe but subjectively say that's a

341
00:13:08,230 --> 00:13:06,240
yellow light that's not a red and a

342
00:13:09,750 --> 00:13:08,240
green light and if you take a magnifying

343
00:13:11,670 --> 00:13:09,760
gla by the way i can get

344
00:13:13,430 --> 00:13:11,680
all kinds of other colors i don't know

345
00:13:16,710 --> 00:13:13,440
if yeah i can get all kinds of other

346
00:13:18,710 --> 00:13:16,720
colors just by changing

347
00:13:20,790 --> 00:13:18,720
the

348
00:13:23,110 --> 00:13:20,800
switching things on and off and changing

349
00:13:25,030 --> 00:13:23,120
the relative intensity that doesn't show

350
00:13:26,870 --> 00:13:25,040
up so quite so well

351
00:13:29,829 --> 00:13:26,880
and i can get magenta

352
00:13:32,230 --> 00:13:29,839
i can get yellow and and cyan

353
00:13:34,870 --> 00:13:32,240
so those are the intermediate colors

354
00:13:37,350 --> 00:13:34,880
so if you take a magnifying glass to any

355
00:13:38,790 --> 00:13:37,360
uh cell phone screen television screen

356
00:13:40,550 --> 00:13:38,800
computer screen

357
00:13:42,150 --> 00:13:40,560
you'll see it's made up of little dots

358
00:13:44,710 --> 00:13:42,160
pixels and they're all red green and

359
00:13:46,470 --> 00:13:44,720
blue and by the various intensities they

360
00:13:48,230 --> 00:13:46,480
fool you into seeing all the colors of

361
00:13:50,389 --> 00:13:48,240
the rainbow

362
00:13:53,030 --> 00:13:50,399
so science is about physical reality and

363
00:14:02,389 --> 00:13:53,040

much of the real world is beyond human

364
00:14:07,430 --> 00:14:04,710
and science really is the best survival

365
00:14:09,430 --> 00:14:07,440
tool ever devised by humankind and

366
00:14:11,030 --> 00:14:09,440
spectroscopy is a historically

367
00:14:13,110 --> 00:14:11,040
significant and powerful analytical

368
00:14:14,829 --> 00:14:13,120
method that enables remote measurement

369
00:14:17,150 --> 00:14:14,839
for scientific discovery and other

370
00:14:19,590 --> 00:14:17,160
applications the tools and ideas of

371
00:14:23,030 --> 00:14:19,600
spectroscopy are deeply woven into the

372
00:14:24,629 --> 00:14:23,040
development of the scientific method

373
00:14:26,790 --> 00:14:24,639
and that's why i say that imaging

374
00:14:28,470 --> 00:14:26,800
spectroscopy is a scientific remote

375
00:14:31,269 --> 00:14:28,480
sensing tool

376
00:14:33,269 --> 00:14:31,279
newton fraunhofer bunsen kirkhof hubble

377
00:14:35,910 --> 00:14:33,279
these are only some of the giants upon

378
00:14:37,910 --> 00:14:35,920
whose shoulders we stand

379
00:14:39,990 --> 00:14:37,920
measurements made with spectroscopy

380
00:14:42,470 --> 00:14:40,000
indeed show that the laws of physics are

381
00:14:45,110 --> 00:14:42,480
universal the furthest stars have the

382
00:14:47,110 --> 00:14:45,120
same elemental spectral fingerprints

383
00:14:49,350 --> 00:14:47,120
that we can generate first and measure

384
00:14:51,509 --> 00:14:49,360
for ourselves here on earth thereby

385
00:14:54,389 --> 00:14:51,519
showing the laws of physics apply

386
00:14:58,310 --> 00:14:56,389
so please at this time allow me to

387
00:15:00,710 --> 00:14:58,320
introduce my associate andrew thorpe

388
00:15:02,790 --> 00:15:00,720

he's a methane hunter

389
00:15:07,750 --> 00:15:02,800
in the upper left he's surveying a river

390
00:15:10,710 --> 00:15:09,269
in the lower left of the slide with the

391
00:15:12,230 --> 00:15:10,720
avarice he's with the average next

392
00:15:13,670 --> 00:15:12,240
generation instrument and a king air

393
00:15:15,750 --> 00:15:13,680
research aircraft during our recent

394
00:15:17,350 --> 00:15:15,760
campaign to india in the upper right

395
00:15:18,710 --> 00:15:17,360
he's carefully measuring upwelling

396
00:15:21,269 --> 00:15:18,720
spectral radiance from a known

397
00:15:23,350 --> 00:15:21,279
reflectance target at ivanpaw california

398
00:15:24,710 --> 00:15:23,360
which is a playa or dry-like bed many of

399
00:15:27,110 --> 00:15:24,720
you have driven across on the way to

400
00:15:29,269 --> 00:15:27,120
vegas it's right on the state line

401
00:15:31,350 --> 00:15:29,279
the imaging spectroscopy group at jpl

402
00:15:32,870 --> 00:15:31,360
uses it as an in-flight calibration

403
00:15:34,470 --> 00:15:32,880
target

404
00:15:36,790 --> 00:15:34,480
in the lower right here's andrew at

405
00:15:38,629 --> 00:15:36,800
jpl's open house in the center andrew is

406
00:15:41,350 --> 00:15:38,639
measuring methane emissions from sixteen

407
00:15:42,629 --> 00:15:41,360
thousand feet

408
00:15:44,710 --> 00:15:42,639
so now we're going to do another

409
00:15:47,430 --> 00:15:44,720
demonstration

410
00:15:49,110 --> 00:15:47,440
about light and about science and

411
00:15:51,030 --> 00:15:49,120
skepticism

412
00:15:52,069 --> 00:15:51,040
so you may have heard that sir isaac

413
00:15:53,509 --> 00:15:52,079

newton

414
00:15:56,150 --> 00:15:53,519
one of the giants upon whose shoulders

415
00:16:04,310 --> 00:15:59,189
used prisms to make rainbows and he had

416
00:16:09,590 --> 00:16:07,110
and that claim was that

417
00:16:11,350 --> 00:16:09,600
well let me turn this on

418
00:16:13,110 --> 00:16:11,360
with this this is by the way kids this

419
00:16:15,350 --> 00:16:13,120
is an overhead projector if you've never

420
00:16:17,030 --> 00:16:15,360
seen one before

421
00:16:18,389 --> 00:16:17,040
it really was a surprise for me i go to

422
00:16:20,069 --> 00:16:18,399
a lecture at a classroom and then what

423
00:16:21,990 --> 00:16:20,079
is it an overhead projector what do you

424
00:16:24,069 --> 00:16:22,000
want

425
00:16:26,710 --> 00:16:24,079
so what i'm doing is i'm using it to

426
00:16:29,350 --> 00:16:26,720
project a slit image which we have here

427
00:16:33,430 --> 00:16:29,360
on the card that andrew is holding

428
00:16:34,710 --> 00:16:33,440
white light so sir isaac newton took a

429
00:16:36,470 --> 00:16:34,720
prism by the way i think it was

430
00:16:37,269 --> 00:16:36,480
fraunhofer made his living

431
00:16:39,509 --> 00:16:37,279
by

432
00:16:41,749 --> 00:16:39,519
making glass clear enough and pure

433
00:16:43,670 --> 00:16:41,759
enough to make prisms and lenses out of

434
00:16:46,470 --> 00:16:43,680
was actually a german state secret for a

435
00:16:50,550 --> 00:16:47,269
and

436
00:16:52,230 --> 00:16:50,560
he newton put this thing into the light

437
00:16:53,990 --> 00:16:52,240
and he dispersed it it's called

438
00:16:55,350 --> 00:16:54,000

dispersion

439
00:16:57,749 --> 00:16:55,360
and he made all the colors of the

440
00:17:00,710 --> 00:16:57,759
rainbow and his extraordinary claim was

441
00:17:03,829 --> 00:17:02,230
the white light was made of the colors

442
00:17:06,390 --> 00:17:03,839
of the rainbow now extraordinary claims

443
00:17:07,590 --> 00:17:06,400
demand extraordinary proof

444
00:17:09,110 --> 00:17:07,600
and

445
00:17:11,350 --> 00:17:09,120
making that claim just wasn't enough for

446
00:17:12,390 --> 00:17:11,360
the truly skeptical now skepticism is

447
00:17:14,309 --> 00:17:12,400
part of science there's a difference

448
00:17:15,909 --> 00:17:14,319
between skepticism and cynicism a

449
00:17:18,390 --> 00:17:15,919
skeptic can be convinced with the

450
00:17:20,630 --> 00:17:18,400
correct evidence and a good argument

451
00:17:22,549 --> 00:17:20,640
cynic can never be convinced in our

452
00:17:25,189 --> 00:17:22,559
common language we often confuse the two

453
00:17:27,270 --> 00:17:25,199
terms but there is a distinction

454
00:17:28,710 --> 00:17:27,280
so

455
00:17:29,990 --> 00:17:28,720
the truly skeptical will say well the

456
00:17:32,630 --> 00:17:30,000
colors could be coming from the glass

457
00:17:35,270 --> 00:17:32,640
somehow newton said aha but

458
00:17:37,190 --> 00:17:35,280
if i recombine those colors so i'm going

459
00:17:38,870 --> 00:17:37,200
to put this other prism

460
00:17:40,710 --> 00:17:38,880
in

461
00:17:43,510 --> 00:17:40,720
the path of

462
00:17:45,350 --> 00:17:43,520
if i get it right andrew don't move

463
00:17:50,549 --> 00:17:45,360

i i always mess this part up because

464
00:17:56,150 --> 00:17:53,669
oh this way there we go

465
00:17:57,750 --> 00:17:56,160
so what i've done is all the colors are

466
00:17:59,830 --> 00:17:57,760
hitting this second prism and they're

467
00:18:01,990 --> 00:17:59,840
getting recombined and you can see the

468
00:18:05,430 --> 00:18:02,000
moving there we go

469
00:18:06,789 --> 00:18:05,440
so this bright slit on the left

470
00:18:08,549 --> 00:18:06,799
of this card

471
00:18:11,430 --> 00:18:08,559
is the recombined light that's gone

472
00:18:13,029 --> 00:18:11,440
through the two prisms the dimmer slit

473
00:18:14,870 --> 00:18:13,039
is what we call stray light but it's

474
00:18:17,190 --> 00:18:14,880
illustrative of where the light would be

475
00:18:19,190 --> 00:18:17,200
falling had it only gone through

476
00:18:20,630 --> 00:18:19,200
no prisms as a matter of fact so there's

477
00:18:22,470 --> 00:18:20,640
a little bit of an offset kind of like

478
00:18:23,990 --> 00:18:22,480
in a pair of binoculars because of the

479
00:18:26,390 --> 00:18:24,000
two prisms

480
00:18:27,590 --> 00:18:26,400
so that kind of circularity

481
00:18:29,830 --> 00:18:27,600
that

482
00:18:31,990 --> 00:18:29,840
reversibleness of a physical principle

483
00:18:34,070 --> 00:18:32,000
is an important part of demonstrating to

484
00:18:35,909 --> 00:18:34,080
a skeptical audience when you write your

485
00:18:37,510 --> 00:18:35,919
paper your peer review everything almost

486
00:18:39,510 --> 00:18:37,520
like that

487
00:18:41,110 --> 00:18:39,520
how the mechanism works

488
00:18:42,950 --> 00:18:41,120

and a truly

489
00:18:46,150 --> 00:18:42,960
in the consistent demonstration of

490
00:18:47,669 --> 00:18:46,160
mechanism how it works okay

491
00:18:50,549 --> 00:18:47,679
that's what sets science apart from

492
00:18:54,070 --> 00:18:52,390
and which is just a fancy way of saying

493
00:18:56,150 --> 00:18:54,080
that science is about finding what's

494
00:18:59,270 --> 00:18:56,160
physically true for everyone everywhere

495
00:19:02,230 --> 00:18:59,280
at all times no matter what

496
00:19:09,190 --> 00:19:03,750
i should probably turn

497
00:19:15,029 --> 00:19:11,430
so like i said when it has to work nasa

498
00:19:18,470 --> 00:19:16,549
we make it work

499
00:19:20,390 --> 00:19:18,480
imaging spectroscopy uses spectral

500
00:19:22,549 --> 00:19:20,400
fingerprints from reflected sunlight to

501
00:19:24,710 --> 00:19:22,559
detect identify quantify and monitor

502
00:19:26,549 --> 00:19:24,720
surface chemistry is physical structures

503
00:19:28,230 --> 00:19:26,559
and dynamics

504
00:19:30,549 --> 00:19:28,240
on earth

505
00:19:32,870 --> 00:19:30,559
its uses encompass a

506
00:19:34,470 --> 00:19:32,880
breathtaking range of applications

507
00:19:37,350 --> 00:19:34,480
involving science the environment

508
00:19:39,350 --> 00:19:37,360
resource management and economics

509
00:19:41,590 --> 00:19:39,360
this slide documents the flow of

510
00:19:44,710 --> 00:19:41,600
information from collection to

511
00:19:46,630 --> 00:19:44,720
processing to product

512
00:19:48,470 --> 00:19:46,640
now note for expediency not all of the

513
00:19:51,110 --> 00:19:48,480

data products or photos i am using are

514
00:19:52,630 --> 00:19:51,120
rigorously attributed

515
00:19:54,789 --> 00:19:52,640
suffice to say they represent the

516
00:19:56,549 --> 00:19:54,799
evidence of efforts of thousands of

517
00:19:58,390 --> 00:19:56,559
dedicated and hard-working folks who use

518
00:20:00,470 --> 00:19:58,400
imaging spectroscopy to answer questions

519
00:20:02,070 --> 00:20:00,480
about our world other planets and the

520
00:20:03,990 --> 00:20:02,080
universe

521
00:20:06,470 --> 00:20:04,000
so one of our imaging spectrometers

522
00:20:08,870 --> 00:20:06,480
actually two of them now fly

523
00:20:11,029 --> 00:20:08,880
sometimes aboard the er-2 which is a

524
00:20:13,510 --> 00:20:11,039
high-altitude research aircraft it's a

525
00:20:15,029 --> 00:20:13,520
jet powered glider flies at 65 000 feet

526
00:20:17,909 --> 00:20:15,039
20 kilometers twice as high as

527
00:20:19,909 --> 00:20:17,919
commercial jetliners

528
00:20:21,669 --> 00:20:19,919
the great thing about flying in the er

529
00:20:23,110 --> 00:20:21,679
ii it's even though it's at the top of

530
00:20:24,549 --> 00:20:23,120
the atmosphere it's almost like being in

531
00:20:25,830 --> 00:20:24,559
space but unlike space we get the

532
00:20:27,990 --> 00:20:25,840
instrument back

533
00:20:29,909 --> 00:20:28,000
when we're done

534
00:20:31,909 --> 00:20:29,919
and the way the instrument works it has

535
00:20:33,750 --> 00:20:31,919
uh several uh elements you would see the

536
00:20:36,230 --> 00:20:33,760
word telescope slit spectrometer and

537
00:20:38,310 --> 00:20:36,240
detector array on there well that gray

538
00:20:39,990 --> 00:20:38,320

line on the ground

539
00:20:41,590 --> 00:20:40,000
gets scanned by the forward motion of

540
00:20:43,830 --> 00:20:41,600
the airplane over the ground kind of

541
00:20:44,950 --> 00:20:43,840
like a scanner a platen scanner scans a

542
00:20:46,789 --> 00:20:44,960
document

543
00:20:48,870 --> 00:20:46,799
that light is then focused by the

544
00:20:50,789 --> 00:20:48,880
telescope onto a slit very similar to

545
00:20:52,470 --> 00:20:50,799
the slit i have set up

546
00:20:54,789 --> 00:20:52,480
uh in function

547
00:20:56,230 --> 00:20:54,799
on the overhead projector goes into a

548
00:20:57,590 --> 00:20:56,240
spectrometer which is a way of

549
00:20:58,710 --> 00:20:57,600
dispersing the light like what the

550
00:21:00,549 --> 00:20:58,720
prisms do

551
00:21:04,549 --> 00:21:00,559
that goes on to what's called a detector

552
00:21:05,990 --> 00:21:04,559
array or focal plane array one dimension

553
00:21:07,830 --> 00:21:06,000
sees all the differences in the

554
00:21:09,909 --> 00:21:07,840
brightness as it goes along and builds

555
00:21:12,310 --> 00:21:09,919
the picture up in the other dimension of

556
00:21:13,990 --> 00:21:12,320
the focal plane array it sees the

557
00:21:15,669 --> 00:21:14,000
spectral signatures

558
00:21:18,070 --> 00:21:15,679
and so that's kind of like because the

559
00:21:22,789 --> 00:21:18,080
focal plane arrays that we're using

560
00:21:27,270 --> 00:21:24,710
480 pixels

561
00:21:31,350 --> 00:21:27,280
we can see 480 different wavelengths and

562
00:21:33,190 --> 00:21:31,360
640 lines on the ground or it's like we

563
00:21:34,870 --> 00:21:33,200

have hundreds of parallel spectrometers

564
00:21:37,830 --> 00:21:34,880
and that's why that says that

565
00:21:39,909 --> 00:21:37,840
and each one of those spectrometers then

566
00:21:42,470 --> 00:21:39,919
assigns a spectral signature to each

567
00:21:44,470 --> 00:21:42,480
pixel in the data block that's what the

568
00:21:46,470 --> 00:21:44,480
calibrated image cube in the middle is

569
00:21:48,390 --> 00:21:46,480
all about and then over on the right

570
00:21:50,390 --> 00:21:48,400
from that we can use our understanding

571
00:21:52,230 --> 00:21:50,400
of physics and how sunlight interacts

572
00:21:54,950 --> 00:21:52,240
and reflects off of different chemical

573
00:21:57,190 --> 00:21:54,960
materials to make a material map now the

574
00:21:58,470 --> 00:21:57,200
difference between a pretty picture and

575
00:21:59,909 --> 00:21:58,480
a scientific image

576
00:22:02,230 --> 00:21:59,919
is actually

577
00:22:04,710 --> 00:22:02,240
the little key over on the

578
00:22:07,110 --> 00:22:04,720
on the right on in the white is what all

579
00:22:08,149 --> 00:22:07,120
the colors mean and that's how we learn

580
00:22:10,390 --> 00:22:08,159
about

581
00:22:12,470 --> 00:22:10,400
the uh relative positions of things and

582
00:22:13,990 --> 00:22:12,480
their relationships to each other and if

583
00:22:15,590 --> 00:22:14,000
you fly the same target many times you

584
00:22:17,590 --> 00:22:15,600
learn about the dynamics how it changes

585
00:22:19,590 --> 00:22:17,600
with time

586
00:22:21,270 --> 00:22:19,600
so this is an example of a geological

587
00:22:24,390 --> 00:22:21,280
data product made from imaging

588
00:22:26,549 --> 00:22:24,400

spectrometry spectrometry data

589
00:22:28,310 --> 00:22:26,559
actually wrapped onto a digital

590
00:22:30,710 --> 00:22:28,320
elevation map so

591
00:22:32,789 --> 00:22:30,720
in the background the hills are colored

592
00:22:35,270 --> 00:22:32,799
rendered in natural colors

593
00:22:36,630 --> 00:22:35,280
rendered meaning the data is turned into

594
00:22:38,390 --> 00:22:36,640
red green and blue channels that your

595
00:22:40,630 --> 00:22:38,400
eye can interpret

596
00:22:42,070 --> 00:22:40,640
false color imaging

597
00:22:44,310 --> 00:22:42,080
controlling those red green and blue

598
00:22:45,830 --> 00:22:44,320
channels of the display with other kinds

599
00:22:48,149 --> 00:22:45,840
of information

600
00:22:50,070 --> 00:22:48,159
it's often used to visualize data the

601
00:22:52,549 --> 00:22:50,080
colors in this case are key to the

602
00:22:54,230 --> 00:22:52,559
surface expression of mineral type and

603
00:22:57,669 --> 00:22:54,240
the placement of minerals that are

604
00:22:59,110 --> 00:22:57,679
otherwise invisible to the eye is shown

605
00:23:01,110 --> 00:22:59,120
so more than a pretty picture the

606
00:23:03,270 --> 00:23:01,120
mineral key at the bottom and the

607
00:23:05,270 --> 00:23:03,280
positions on the map enable a geologist

608
00:23:06,310 --> 00:23:05,280
to read the local story of a dynamic

609
00:23:08,070 --> 00:23:06,320
earth

610
00:23:10,149 --> 00:23:08,080
this is a story that can help locate

611
00:23:11,590 --> 00:23:10,159
economically exploitable resources with

612
00:23:13,350 --> 00:23:11,600
the confidence needed to justify

613
00:23:17,190 --> 00:23:13,360

large-scale investment in this case

614
00:23:21,110 --> 00:23:19,270
so mineral extraction can bring toxic

615
00:23:22,710 --> 00:23:21,120
materials to the surface and concentrate

616
00:23:24,390 --> 00:23:22,720
them and knowing what is happening and

617
00:23:26,789 --> 00:23:24,400
where can be used for exploitation

618
00:23:28,950 --> 00:23:26,799
choices with a lower overall cost here

619
00:23:31,350 --> 00:23:28,960
the airborne imaging spec here airborne

620
00:23:33,669 --> 00:23:31,360
imaging spectroscopy has been used to

621
00:23:38,950 --> 00:23:33,679
identify and map super fund hazards for

622
00:23:43,510 --> 00:23:41,190
this is another example of airborne

623
00:23:45,750 --> 00:23:43,520
imaging spectroscopy it can be used to

624
00:23:47,430 --> 00:23:45,760
map vegetation species and this is santa

625
00:23:49,830 --> 00:23:47,440
barbara california

626
00:23:52,070 --> 00:23:49,840
now some species are invasive some are

627
00:23:53,990 --> 00:23:52,080
dying out some are drying out

628
00:23:57,190 --> 00:23:54,000
others are on the move year after year

629
00:23:59,510 --> 00:23:57,200
in response to our changing climate and

630
00:24:00,870 --> 00:23:59,520
all can impact property value for

631
00:24:02,630 --> 00:24:00,880
example

632
00:24:04,630 --> 00:24:02,640
if you wanted to buy a piece of land in

633
00:24:06,549 --> 00:24:04,640
santa barbara where there's a lot of

634
00:24:08,630 --> 00:24:06,559
california live oak you'd look for one

635
00:24:10,870 --> 00:24:08,640
of the redder parts of that plot in the

636
00:24:12,789 --> 00:24:10,880
lower right corner

637
00:24:14,950 --> 00:24:12,799
for industrial agriculture spectrum

638
00:24:17,029 --> 00:24:14,960

mapping assists with crop optimization

639
00:24:18,630 --> 00:24:17,039
and cost management irrigation and

640
00:24:21,029 --> 00:24:18,640
fertilizer application as well as

641
00:24:22,390 --> 00:24:21,039
optimize crops rotations to match

642
00:24:24,070 --> 00:24:22,400
climatic trends are some of the

643
00:24:27,350 --> 00:24:24,080
applications enabled by imaging

644
00:24:31,430 --> 00:24:29,190
now mixed species forest management

645
00:24:33,909 --> 00:24:31,440
helps preserve historic environmental

646
00:24:35,110 --> 00:24:33,919
conditions it also helps the tourism

647
00:24:36,710 --> 00:24:35,120
industry

648
00:24:38,470 --> 00:24:36,720
and a careful accounting of current and

649
00:24:39,909 --> 00:24:38,480
evolving conditions is essential to

650
00:24:42,310 --> 00:24:39,919
effective and economic resource

651
00:24:43,909 --> 00:24:42,320
management and so you can see the very

652
00:24:46,870 --> 00:24:43,919
very detailed

653
00:24:48,950 --> 00:24:46,880
map of speciation and these speciation

654
00:24:50,710 --> 00:24:48,960
maps will change with time

655
00:24:52,470 --> 00:24:50,720
be very interesting

656
00:24:55,430 --> 00:24:52,480
i've talked to those guys they make it

657
00:24:56,710 --> 00:24:55,440
sound really interesting

658
00:24:58,549 --> 00:24:56,720
avarice

659
00:25:00,070 --> 00:24:58,559
and other spectral imaging applications

660
00:25:02,630 --> 00:25:00,080
fire science perhaps of a little more

661
00:25:05,110 --> 00:25:02,640
interest to us locally this is data from

662
00:25:06,710 --> 00:25:05,120
the simi valley fire in 2003

663
00:25:08,549 --> 00:25:06,720

and here we have a thermal estimate

664
00:25:10,630 --> 00:25:08,559
product way on the right i'll show you

665
00:25:12,310 --> 00:25:10,640
how that works in a bit and data like

666
00:25:14,549 --> 00:25:12,320
this can answer the question of how hot

667
00:25:17,269 --> 00:25:14,559
did the fire burn and where

668
00:25:19,750 --> 00:25:17,279
so this is before the fire some spectral

669
00:25:21,669 --> 00:25:19,760
imaging in the santa barbara area

670
00:25:24,230 --> 00:25:21,679
and so we've got species type dry

671
00:25:26,230 --> 00:25:24,240
biomass and canopy water that can all be

672
00:25:29,430 --> 00:25:26,240
condensed into risk assessment fire

673
00:25:31,110 --> 00:25:29,440
prevention plans and preparation

674
00:25:32,710 --> 00:25:31,120
and this is the sort of on the ground

675
00:25:34,870 --> 00:25:32,720
knowledge that local government and the

676
00:25:37,029 --> 00:25:34,880
insurance industry have a stake in where

677
00:25:39,110 --> 00:25:37,039
is it going to burn the worst

678
00:25:40,710 --> 00:25:39,120
or is it more likely to really get going

679
00:25:43,430 --> 00:25:40,720
and then once it does get going here it

680
00:25:45,269 --> 00:25:43,440
is here's the simi valley fire with we

681
00:25:47,750 --> 00:25:45,279
we're actually mapping flame front

682
00:25:49,269 --> 00:25:47,760
progress and temperature and that can

683
00:25:50,870 --> 00:25:49,279
give you an immediate assessment of the

684
00:25:52,870 --> 00:25:50,880
severity and the damage that it's

685
00:25:56,390 --> 00:25:52,880
occurring and the likely recovery

686
00:25:57,990 --> 00:25:56,400
timetable and and the likelihood of of

687
00:25:59,430 --> 00:25:58,000
all kinds of consequences now in the

688
00:26:01,669 --> 00:25:59,440

upper

689
00:26:03,029 --> 00:26:01,679
left corner is a plot

690
00:26:05,510 --> 00:26:03,039
um as

691
00:26:07,110 --> 00:26:05,520
an object gets warmer and warmer it

692
00:26:08,710 --> 00:26:07,120
gives off more and more of different

693
00:26:11,190 --> 00:26:08,720
wavelengths of light it's called the

694
00:26:12,950 --> 00:26:11,200
planck emissions or black body emission

695
00:26:14,630 --> 00:26:12,960
if it gets hot enough it actually starts

696
00:26:16,070 --> 00:26:14,640
glowing

697
00:26:17,750 --> 00:26:16,080
and

698
00:26:20,950 --> 00:26:17,760
the different wavelengths that are

699
00:26:23,430 --> 00:26:20,960
represented to each each layer in the

700
00:26:25,350 --> 00:26:23,440
data cube of a spectral imaging

701
00:26:27,909 --> 00:26:25,360
instrument is actually just can be

702
00:26:30,390 --> 00:26:27,919
displayed as a black and white picture

703
00:26:31,830 --> 00:26:30,400
and each one of these slices is from

704
00:26:33,190 --> 00:26:31,840
progressively longer and longer

705
00:26:34,470 --> 00:26:33,200
wavelengths

706
00:26:35,909 --> 00:26:34,480
and

707
00:26:37,909 --> 00:26:35,919
some of those wavelengths are affected

708
00:26:40,230 --> 00:26:37,919
by gases in the atmosphere aren't useful

709
00:26:42,149 --> 00:26:40,240
but others will go up to just a certain

710
00:26:44,230 --> 00:26:42,159
maximum and that's as far as they go

711
00:26:45,750 --> 00:26:44,240
represented by that green line and if

712
00:26:47,190 --> 00:26:45,760
you can fit that green line to those

713
00:26:49,269 --> 00:26:47,200

areas that are more likely to get to

714
00:26:51,029 --> 00:26:49,279
that maximum you start matching what's

715
00:26:52,630 --> 00:26:51,039
called the planck curve

716
00:26:54,070 --> 00:26:52,640
of emission which is directly

717
00:26:55,269 --> 00:26:54,080
proportional to the temperature and so

718
00:26:57,590 --> 00:26:55,279
that's how they back out the burn

719
00:26:59,110 --> 00:26:57,600
temperature for particular pixels in

720
00:27:00,950 --> 00:26:59,120
this case way over on the right that

721
00:27:03,269 --> 00:27:00,960
where the arrow was pointing

722
00:27:05,029 --> 00:27:03,279
got pretty hot

723
00:27:07,190 --> 00:27:05,039
as you can see

724
00:27:10,070 --> 00:27:07,200
and then after the fire spectral imaging

725
00:27:11,830 --> 00:27:10,080
spectroscopy can be used

726
00:27:14,470 --> 00:27:11,840
to prepare for the next season you can

727
00:27:16,789 --> 00:27:14,480
do differential mapping before or after

728
00:27:19,029 --> 00:27:16,799
and plan for recovery and of course

729
00:27:20,390 --> 00:27:19,039
develop future management scenarios and

730
00:27:22,789 --> 00:27:20,400
actuarial

731
00:27:24,710 --> 00:27:22,799
databases

732
00:27:26,789 --> 00:27:24,720
so imaging spectroscopy can be used for

733
00:27:28,870 --> 00:27:26,799
shallow water spectroscopy the mapping

734
00:27:30,070 --> 00:27:28,880
of water quality and bottom composition

735
00:27:31,590 --> 00:27:30,080
and corals

736
00:27:33,750 --> 00:27:31,600
the overall environmental quality and

737
00:27:36,390 --> 00:27:33,760
ability to support fishery fishery

738
00:27:38,630 --> 00:27:36,400

populations can be mapped out and

739
00:27:40,390 --> 00:27:38,640
planned upon coral beds are the rain

740
00:27:42,230 --> 00:27:40,400
forest of the sea and there's that

741
00:27:44,710 --> 00:27:42,240
because they have tremendous biological

742
00:27:47,350 --> 00:27:44,720
activity and diversity the coral reef

743
00:27:48,870 --> 00:27:47,360
airborne library or coral program has

744
00:27:50,230 --> 00:27:48,880
just come back from measuring coral

745
00:27:52,950 --> 00:27:50,240
reefs in australia in the southern

746
00:27:54,870 --> 00:27:52,960
pacific and is about to depart in fact

747
00:27:57,350 --> 00:27:54,880
my colleagues are in plains right now

748
00:27:59,190 --> 00:27:57,360
for hawaii guam and palau

749
00:28:01,110 --> 00:27:59,200
and the the coral program uses an

750
00:28:03,430 --> 00:28:01,120
imaging spectrometer called prism the

751
00:28:04,950 --> 00:28:03,440
portable remote imaging spectrometer

752
00:28:07,909 --> 00:28:04,960
here at jpl we get extra points for

753
00:28:10,470 --> 00:28:07,919
making acronyms that make sense

754
00:28:14,950 --> 00:28:10,480
which has been designed for aquatic

755
00:28:19,510 --> 00:28:17,669
another application of this technology

756
00:28:22,549 --> 00:28:19,520
has been uh the airborne visible

757
00:28:24,630 --> 00:28:22,559
infrared imaging spectrometer oh andrew

758
00:28:26,470 --> 00:28:24,640
i brought stickers i forgot they're in

759
00:28:28,070 --> 00:28:26,480
my backpack

760
00:28:30,149 --> 00:28:28,080
everybody will put them out in the back

761
00:28:32,070 --> 00:28:30,159
the average program has its own stickers

762
00:28:34,310 --> 00:28:32,080
his own logo and everything

763
00:28:36,389 --> 00:28:34,320

so and we're jpl's premier imaging

764
00:28:38,310 --> 00:28:36,399
spectrometer and that imaging

765
00:28:40,310 --> 00:28:38,320
spectrometer took this data of a red

766
00:28:42,070 --> 00:28:40,320
tide bloom in monterey bay and red tides

767
00:28:44,549 --> 00:28:42,080
are toxic they can negatively impact

768
00:28:47,510 --> 00:28:44,559
fisheries shellfish beds and lobsters

769
00:28:49,909 --> 00:28:47,520
tourism etc

770
00:28:53,269 --> 00:28:49,919
so here's another application in april

771
00:28:55,029 --> 00:28:53,279
2010 avarice was used by a usgs noaa and

772
00:28:56,870 --> 00:28:55,039
nasa science team to estimate the

773
00:28:58,630 --> 00:28:56,880
thickness and volume of the surface oil

774
00:29:01,190 --> 00:28:58,640
spilled by the deepwater horizon

775
00:29:03,590 --> 00:29:01,200
platform the upper left corner is

776
00:29:05,990 --> 00:29:03,600
imagery from the bottom and the top of

777
00:29:07,990 --> 00:29:06,000
the ocean and we have an explanation of

778
00:29:10,149 --> 00:29:08,000
how the spectra were used in the

779
00:29:11,750 --> 00:29:10,159
estimate there's an aerial photo in the

780
00:29:14,630 --> 00:29:11,760
middle bottom of what it looked like to

781
00:29:15,750 --> 00:29:14,640
the eye and then this is over on the

782
00:29:18,950 --> 00:29:15,760
right

783
00:29:21,430 --> 00:29:18,960
and also in this slide over on the left

784
00:29:23,909 --> 00:29:21,440
the rgb bands from the avarice data but

785
00:29:25,269 --> 00:29:23,919
then we're able to use that spectral

786
00:29:27,269 --> 00:29:25,279
information

787
00:29:29,350 --> 00:29:27,279
in the middle block there we have

788
00:29:30,950 --> 00:29:29,360

something called the aerial fraction and

789
00:29:33,110 --> 00:29:30,960
that's the fraction of the surface

790
00:29:34,710 --> 00:29:33,120
covered by oil and then

791
00:29:36,630 --> 00:29:34,720
in the last block

792
00:29:38,230 --> 00:29:36,640
big block we have an estimate of the

793
00:29:40,710 --> 00:29:38,240
thickness of the oil those two can be

794
00:29:42,470 --> 00:29:40,720
put together to estimate the

795
00:29:44,070 --> 00:29:42,480
quantitative volume

796
00:29:45,350 --> 00:29:44,080
and that's what that list is you can't

797
00:29:47,190 --> 00:29:45,360
read the writing but it's just a list of

798
00:29:49,350 --> 00:29:47,200
numbers and that can automatically put

799
00:29:50,870 --> 00:29:49,360
into a computer all totaled up

800
00:29:52,470 --> 00:29:50,880
and see how much oil was actually

801
00:29:54,230 --> 00:29:52,480
spilled

802
00:29:56,070 --> 00:29:54,240
avarice has been used by a broad

803
00:29:57,830 --> 00:29:56,080
government and university science team

804
00:30:00,310 --> 00:29:57,840
since the spill to map vegetation

805
00:30:02,950 --> 00:30:00,320
species and physiological health

806
00:30:04,710 --> 00:30:02,960
of the gulf before and after these

807
00:30:06,549 --> 00:30:04,720
images and data

808
00:30:08,389 --> 00:30:06,559
are you know before and after so before

809
00:30:11,190 --> 00:30:08,399
along the top

810
00:30:13,590 --> 00:30:11,200
and ongoing monitoring and after on the

811
00:30:17,029 --> 00:30:13,600
bottom and then an oil impact product

812
00:30:19,430 --> 00:30:17,039
that can be useful to various agencies

813
00:30:21,510 --> 00:30:19,440

this is an example of science being used

814
00:30:23,990 --> 00:30:21,520
to count the cost of the consequences of

815
00:30:26,630 --> 00:30:24,789
now

816
00:30:29,029 --> 00:30:26,640
imaging spectroscopy is also used to

817
00:30:30,549 --> 00:30:29,039
study snow and ice here

818
00:30:32,630 --> 00:30:30,559
our colleague

819
00:30:35,029 --> 00:30:32,640
tom painter way at the top there t

820
00:30:37,430 --> 00:30:35,039
painter jpl has flown an imaging

821
00:30:40,230 --> 00:30:37,440
spectrometer along with a lidar

822
00:30:41,990 --> 00:30:40,240
over snow fields and he's found that how

823
00:30:46,070 --> 00:30:42,000
dusty the snow is

824
00:30:50,549 --> 00:30:48,389
make the snow melt a whole lot sooner so

825
00:30:52,710 --> 00:30:50,559
over on the left in the

826
00:30:54,789 --> 00:30:52,720
middle picture is a

827
00:30:55,590 --> 00:30:54,799
dusty snow with a little white plaque on

828
00:31:05,110 --> 00:30:55,600
it

829
00:31:07,190 --> 00:31:05,120
a broad range of wavelengths

830
00:31:09,909 --> 00:31:07,200
and you'd think snow would be as white

831
00:31:11,909 --> 00:31:09,919
as that stuff but not always and imaging

832
00:31:13,990 --> 00:31:11,919
spectroscopy can measure just how not

833
00:31:16,310 --> 00:31:14,000
white it is and how and make an estimate

834
00:31:17,750 --> 00:31:16,320
of how quickly it will melt

835
00:31:19,909 --> 00:31:17,760
and that's important because water

836
00:31:22,310 --> 00:31:19,919
availability and storage

837
00:31:24,070 --> 00:31:22,320
is as what happens with snow in the west

838
00:31:26,870 --> 00:31:24,080

and timing is everything especially for

839
00:31:28,149 --> 00:31:26,880
the american west and the colorado river

840
00:31:29,990 --> 00:31:28,159
one of the issues

841
00:31:31,669 --> 00:31:30,000
the california water system is facing

842
00:31:33,430 --> 00:31:31,679
right now is warmer storm systems that

843
00:31:35,830 --> 00:31:33,440
drop more rain than snow on the sierra

844
00:31:37,830 --> 00:31:35,840
nevada which is our great reservoir dr

845
00:31:40,149 --> 00:31:37,840
painter's program is called the airborne

846
00:31:41,669 --> 00:31:40,159
snow observatory or aso

847
00:31:43,590 --> 00:31:41,679
nasa jpl in partnership with the

848
00:31:44,789 --> 00:31:43,600
california department of water resources

849
00:31:47,190 --> 00:31:44,799
has developed

850
00:31:49,990 --> 00:31:47,200
aso it's an imaging spectrometer and

851
00:31:52,310 --> 00:31:50,000
scanning lidar system which quantifies

852
00:31:54,710 --> 00:31:52,320
snow water equivalent amounts and snow

853
00:31:57,029 --> 00:31:54,720
albedo albedo being how bright it is or

854
00:31:59,190 --> 00:31:57,039
how not bright it is it is used to

855
00:32:01,110 --> 00:31:59,200
generate unprecedented knowledge of snow

856
00:32:02,950 --> 00:32:01,120
properties for cutting-edge cryospheric

857
00:32:05,110 --> 00:32:02,960
science and provide complete robust

858
00:32:07,830 --> 00:32:05,120
inputs to water management models and

859
00:32:08,630 --> 00:32:07,840
systems of the future

860
00:32:10,870 --> 00:32:08,640
so

861
00:32:11,830 --> 00:32:10,880
another remote sensing product that can

862
00:32:13,350 --> 00:32:11,840
be

863
00:32:15,990 --> 00:32:13,360

gotten out of

864
00:32:17,590 --> 00:32:16,000
imaging spectroscopy data is the three

865
00:32:20,630 --> 00:32:17,600
phases of water

866
00:32:22,470 --> 00:32:20,640
and we've got the raw data on the left

867
00:32:23,350 --> 00:32:22,480
and on the right is the data product

868
00:32:26,470 --> 00:32:23,360
where

869
00:32:28,630 --> 00:32:26,480
water vapor is signified by blue liquid

870
00:32:31,190 --> 00:32:28,640
water by green and ice by red now we've

871
00:32:32,630 --> 00:32:31,200
seen how red and green together can make

872
00:32:34,310 --> 00:32:32,640
yellow

873
00:32:35,509 --> 00:32:34,320
so we've got ice and liquid water

874
00:32:37,430 --> 00:32:35,519
together

875
00:32:39,750 --> 00:32:37,440
just off the top of the

876
00:32:41,269 --> 00:32:39,760
volcanic this is mount rainier and so

877
00:32:43,110 --> 00:32:41,279
there's snow at the top

878
00:32:45,350 --> 00:32:43,120
and this again can be put into a

879
00:32:46,710 --> 00:32:45,360
computer to estimate how much is there

880
00:32:49,110 --> 00:32:46,720
how much is going to be there when it

881
00:32:51,269 --> 00:32:49,120
all melts maybe how quickly it will melt

882
00:32:54,549 --> 00:32:51,279
and volcanic ash on a volcano slope with

883
00:32:56,389 --> 00:32:54,559
too much water spells disaster

884
00:32:58,149 --> 00:32:56,399
so it's a good way to map that so this

885
00:32:59,830 --> 00:32:58,159
slide is an example of how an imaging

886
00:33:02,630 --> 00:32:59,840
spectrometer

887
00:33:04,470 --> 00:33:02,640
sees a water vapor in the air

888
00:33:06,549 --> 00:33:04,480

this was taken by avarice over rogers

889
00:33:09,110 --> 00:33:06,559
dry lake california note that the

890
00:33:10,789 --> 00:33:09,120
collects here are 15 minutes apart

891
00:33:13,110 --> 00:33:10,799
water vapor concentration in our

892
00:33:14,710 --> 00:33:13,120
atmosphere changes quickly and invisibly

893
00:33:15,830 --> 00:33:14,720
it was a clear day to anyone standing

894
00:33:17,669 --> 00:33:15,840
there

895
00:33:19,669 --> 00:33:17,679
a balanced amount of atmospheric water

896
00:33:20,950 --> 00:33:19,679
vapor is an important part of a planet

897
00:33:22,950 --> 00:33:20,960
that is alive

898
00:33:24,950 --> 00:33:22,960
water vapor drives the greenhouse effect

899
00:33:26,470 --> 00:33:24,960
which keeps the earth a little warmer

900
00:33:27,990 --> 00:33:26,480
than it would otherwise be at its

901
00:33:30,310 --> 00:33:28,000
distance from the sun

902
00:33:32,789 --> 00:33:30,320
someday soon and i think that day has

903
00:33:34,630 --> 00:33:32,799
come if i just saw an article about it

904
00:33:36,389 --> 00:33:34,640
when nasa looks for other earth-like

905
00:33:37,509 --> 00:33:36,399
planets with special spectrometers that

906
00:33:39,110 --> 00:33:37,519
can pick them out against the

907
00:33:41,430 --> 00:33:39,120
overwhelming light of the star they

908
00:33:43,590 --> 00:33:41,440
orbit the spectral fingerprint of water

909
00:33:45,430 --> 00:33:43,600
vapor will be particularly watched for

910
00:33:48,630 --> 00:33:45,440
and i think a british team just

911
00:33:50,870 --> 00:33:48,640
found that in the atmosphere of a 1.4

912
00:33:54,549 --> 00:33:50,880
earth mass equivalent planet that

913
00:33:56,310 --> 00:33:54,559

occulted its uh parent star and so in

914
00:33:58,230 --> 00:33:56,320
the occultation they're able to see the

915
00:33:59,990 --> 00:33:58,240
light that's gone through the atmosphere

916
00:34:02,070 --> 00:34:00,000
and tease out the spectral fingerprint

917
00:34:04,630 --> 00:34:02,080
that says water and i think they found

918
00:34:07,029 --> 00:34:04,640
methane there too

919
00:34:09,349 --> 00:34:07,039
it just happened today everest has also

920
00:34:11,510 --> 00:34:09,359
responded other national emergencies

921
00:34:13,829 --> 00:34:11,520
this is the emergency response five days

922
00:34:15,270 --> 00:34:13,839
after 9 11. and the questions we were

923
00:34:17,349 --> 00:34:15,280
trying to answer with that data was

924
00:34:19,109 --> 00:34:17,359
where did all the dust go

925
00:34:20,950 --> 00:34:19,119
what was the nature of the dust what was

926
00:34:22,470 --> 00:34:20,960
it made out of how big was it

927
00:34:23,669 --> 00:34:22,480
how bad was it

928
00:34:26,149 --> 00:34:23,679
and where are the hot spots in the

929
00:34:27,990 --> 00:34:26,159
wreckage again using that temperature

930
00:34:29,669 --> 00:34:28,000
profile technique that we were using for

931
00:34:31,190 --> 00:34:29,679
the fires

932
00:34:32,790 --> 00:34:31,200
and that's five days after there's still

933
00:34:36,310 --> 00:34:32,800
hot spots you can see down in the lower

934
00:34:40,230 --> 00:34:38,149
and here i am on the gulf coast during

935
00:34:41,909 --> 00:34:40,240
actually during the bp oil spill and

936
00:34:42,950 --> 00:34:41,919
note there's a field spectrometer on my

937
00:34:45,909 --> 00:34:42,960
back

938
00:34:48,069 --> 00:34:45,919

no it's not a ghostbusters machine

939
00:34:49,270 --> 00:34:48,079
and it's the same field spectrometer we

940
00:34:51,190 --> 00:34:49,280
have over there on the table and we'll

941
00:34:53,030 --> 00:34:51,200
do some demonstrations with and note

942
00:34:55,750 --> 00:34:53,040
these are a reflectant spectra these

943
00:34:57,829 --> 00:34:55,760
squiggly lines and we have wet sand

944
00:34:59,670 --> 00:34:57,839
which is the blue line dry sand which is

945
00:35:01,750 --> 00:34:59,680
the white line

946
00:35:03,750 --> 00:35:01,760
plants the green line

947
00:35:05,270 --> 00:35:03,760
and the yellow line that's actually the

948
00:35:06,550 --> 00:35:05,280
parking lot that's just out of the

949
00:35:08,069 --> 00:35:06,560
picture

950
00:35:10,069 --> 00:35:08,079
it's pretty dark right parking lot's

951
00:35:11,430 --> 00:35:10,079
kind of a low number dark

952
00:35:13,589 --> 00:35:11,440
by the way those two big bumps at

953
00:35:15,510 --> 00:35:13,599
fourteen hundred and eighteen something

954
00:35:17,430 --> 00:35:15,520
nanometers that's where there's actually

955
00:35:18,950 --> 00:35:17,440
no sunlight in the city the noise ratio

956
00:35:20,870 --> 00:35:18,960
of the instrument is rather high and so

957
00:35:22,390 --> 00:35:20,880
you kind of get nonsense and usually you

958
00:35:23,750 --> 00:35:22,400
blank it out but i was too lazy with

959
00:35:25,430 --> 00:35:23,760
excel to do that and so it just comes

960
00:35:26,550 --> 00:35:25,440
out kind of looking crazy so don't look

961
00:35:28,150 --> 00:35:26,560
behind the curtain ignore that man

962
00:35:28,950 --> 00:35:28,160
behind the curtain don't look at that

963
00:35:30,230 --> 00:35:28,960

part

964
00:35:31,910 --> 00:35:30,240
but actually if you could only see in

965
00:35:33,270 --> 00:35:31,920
those colors those wavelengths of light

966
00:35:34,870 --> 00:35:33,280
the earth will be dark all the time

967
00:35:37,349 --> 00:35:34,880
because the water vapor in the air has

968
00:35:38,870 --> 00:35:37,359
absorbed all of that sunlight

969
00:35:41,270 --> 00:35:38,880
at some wavelengths our planet just

970
00:35:42,790 --> 00:35:41,280
looks like a giant white cotton ball

971
00:35:44,950 --> 00:35:42,800
from the top and on the bottom it's

972
00:35:45,910 --> 00:35:44,960
totally dark even during the middle of

973
00:35:46,950 --> 00:35:45,920
the day

974
00:35:49,349 --> 00:35:46,960
so

975
00:35:50,390 --> 00:35:49,359
if you look at the green line

976
00:35:52,230 --> 00:35:50,400
uh

977
00:35:55,270 --> 00:35:52,240
if you look at the bottom

978
00:35:56,790 --> 00:35:55,280
you've got 350 500 650 well 550

979
00:35:57,750 --> 00:35:56,800
nanometers

980
00:35:59,270 --> 00:35:57,760
because that's the wavelength of

981
00:36:00,630 --> 00:35:59,280
nanometers on the bottom is what we

982
00:36:01,990 --> 00:36:00,640
perceive as green light and look at that

983
00:36:03,910 --> 00:36:02,000
there's a bump what do you know plants

984
00:36:05,510 --> 00:36:03,920
are green yay

985
00:36:09,030 --> 00:36:05,520
they're green because they use blue

986
00:36:12,950 --> 00:36:09,040
light and red light to turn sunlight and

987
00:36:14,310 --> 00:36:12,960
air and water into plant food and they

988
00:36:16,310 --> 00:36:14,320

don't use

989
00:36:17,990 --> 00:36:16,320
red light that's redder than red or

990
00:36:20,390 --> 00:36:18,000
infrared and that's kind of like plant

991
00:36:23,270 --> 00:36:20,400
sunblock and so they reflect it more a

992
00:36:24,870 --> 00:36:23,280
lot more that big tall sharp that's

993
00:36:26,950 --> 00:36:24,880
called the red edge that's indicative of

994
00:36:29,030 --> 00:36:26,960
plants if we ever see a spectra like

995
00:36:31,990 --> 00:36:29,040
that from another planet woo hoo

996
00:36:33,750 --> 00:36:32,000
it's photosynthetic life

997
00:36:35,349 --> 00:36:33,760
and those are what we call spectral

998
00:36:36,870 --> 00:36:35,359
signatures they're a list of numbers

999
00:36:38,950 --> 00:36:36,880
that can be used automatically by a

1000
00:36:41,589 --> 00:36:38,960
computer to identify the chemistry of

1001
00:36:43,990 --> 00:36:41,599
the target so now i'm going to make a

1002
00:36:47,030 --> 00:36:44,000
spectrometer with andrew's help

1003
00:36:50,069 --> 00:36:48,230
archaic

1004
00:36:52,950 --> 00:36:50,079
overhead projector

1005
00:36:54,710 --> 00:36:52,960
and these two prisms

1006
00:36:56,950 --> 00:36:54,720
now you saw how

1007
00:36:59,109 --> 00:36:56,960
sir isaac newton dispersed

1008
00:37:01,030 --> 00:36:59,119
the light with this one prism

1009
00:37:08,310 --> 00:37:01,040
well i'm going to disperse it even more

1010
00:37:08,320 --> 00:37:11,990
there we go

1011
00:37:16,310 --> 00:37:14,310
that's that doesn't look so good

1012
00:37:20,790 --> 00:37:16,320
there we go that's better

1013
00:37:26,150 --> 00:37:24,150

so what i have here

1014
00:37:28,470 --> 00:37:26,160
are two business cards distance cards

1015
00:37:29,990 --> 00:37:28,480
are a great way to find light

1016
00:37:31,270 --> 00:37:30,000
if you've ever worked with optics you

1017
00:37:32,950 --> 00:37:31,280
just wave your business card around

1018
00:37:33,829 --> 00:37:32,960
until you find it

1019
00:37:35,670 --> 00:37:33,839
and

1020
00:37:37,910 --> 00:37:35,680
what this device is

1021
00:37:41,589 --> 00:37:37,920
is a solar cell taped in the bottom of

1022
00:37:43,109 --> 00:37:41,599
the box and this slit here allows the

1023
00:37:47,910 --> 00:37:43,119
light coming

1024
00:37:50,870 --> 00:37:47,920
slit to go to an amplifier and a display

1025
00:37:52,630 --> 00:37:50,880
here those these leds going up and down

1026
00:37:54,790 --> 00:37:52,640
so this function here moving back and

1027
00:37:55,670 --> 00:37:54,800
forth like this is what a spectrometer

1028
00:37:58,230 --> 00:37:55,680
does

1029
00:38:00,950 --> 00:37:58,240
it either moves the

1030
00:38:03,190 --> 00:38:00,960
prism or the dispersion element or it

1031
00:38:05,510 --> 00:38:03,200
moves the detector or has a bunch of

1032
00:38:07,349 --> 00:38:05,520
detectors that's what our in-flight

1033
00:38:08,550 --> 00:38:07,359
instruments have so that for each

1034
00:38:10,870 --> 00:38:08,560
position

1035
00:38:11,990 --> 00:38:10,880
here at the focal point you can get a

1036
00:38:15,990 --> 00:38:12,000
number

1037
00:38:18,630 --> 00:38:16,000
spectral fingerprint now i said there's

1038
00:38:20,390 --> 00:38:18,640

more to reality than meets the eye right

1039
00:38:21,349 --> 00:38:20,400
so here i can put the spectrometer where

1040
00:38:24,790 --> 00:38:21,359
there's

1041
00:38:25,910 --> 00:38:24,800
and then i can put it where there is

1042
00:38:30,150 --> 00:38:25,920
light

1043
00:38:33,030 --> 00:38:30,160
if i rotate it a little bit more you can

1044
00:38:33,990 --> 00:38:33,040
see it so no light and then there is

1045
00:38:41,030 --> 00:38:34,000
light

1046
00:38:42,630 --> 00:38:41,040
agreed now if we go right over here

1047
00:38:44,470 --> 00:38:42,640
there's no light that going into that

1048
00:38:47,030 --> 00:38:44,480
slit oh but wait a minute the scale is

1049
00:38:48,870 --> 00:38:47,040
going up and down in fact this

1050
00:38:50,630 --> 00:38:48,880
this system is more sensitive to the

1051
00:38:52,390 --> 00:38:50,640
light that actually is here which is

1052
00:38:54,230 --> 00:38:52,400
near infrared light which we cannot see

1053
00:38:55,670 --> 00:38:54,240
with our eye there's a whole universe

1054
00:38:58,150 --> 00:38:55,680
out there you can't see

1055
00:38:59,430 --> 00:38:58,160
beyond your human senses

1056
00:39:01,109 --> 00:38:59,440
and that's where a lot of the chemical

1057
00:39:04,310 --> 00:39:01,119
fingerprints are and then finally the

1058
00:39:06,310 --> 00:39:04,320
responsivity of the silicon solar cell

1059
00:39:08,790 --> 00:39:06,320
goes away at about one micron so we're

1060
00:39:10,950 --> 00:39:08,800
looking at about .4 microns out here in

1061
00:39:12,310 --> 00:39:10,960
the blue to about one micron where it

1062
00:39:15,030 --> 00:39:12,320
finally

1063
00:39:18,230 --> 00:39:15,040

stops okay give you an idea of

1064
00:39:20,870 --> 00:39:18,240
measurement versus wavelength

1065
00:39:23,589 --> 00:39:20,880
and that is a spectrometer

1066
00:39:24,470 --> 00:39:23,599
a spectrometer measures the position

1067
00:39:26,470 --> 00:39:24,480
of

1068
00:39:28,390 --> 00:39:26,480
the focused light after it's been

1069
00:39:29,910 --> 00:39:28,400
dispersed

1070
00:39:31,030 --> 00:39:29,920
so it's really like taking a tape

1071
00:39:38,310 --> 00:39:31,040
measure and that's how we measure

1072
00:39:44,230 --> 00:39:40,390
ah time for another demo i needed to

1073
00:39:48,310 --> 00:39:46,950
so i promised you a ghostbusters

1074
00:39:50,310 --> 00:39:48,320
backpack no no no an imaging

1075
00:39:51,109 --> 00:39:50,320
spectrometer no no no wait a minute this

1076
00:39:53,589 --> 00:39:51,119
is

1077
00:39:55,750 --> 00:39:53,599
a single point spectrometer an imaging

1078
00:39:57,910 --> 00:39:55,760
spectrometer is like 600 of these things

1079
00:40:00,550 --> 00:39:57,920
looking at the ground at the same time

1080
00:40:02,150 --> 00:40:00,560
like that this is just one

1081
00:40:04,150 --> 00:40:02,160
and what we've got set up here what

1082
00:40:06,390 --> 00:40:04,160
andrew has set up here i'm going to rest

1083
00:40:07,670 --> 00:40:06,400
my weary feet

1084
00:40:10,069 --> 00:40:07,680
is

1085
00:40:12,390 --> 00:40:10,079
a spectral on plaque

1086
00:40:16,150 --> 00:40:14,390
light that's coming from our source is

1087
00:40:18,870 --> 00:40:16,160
reflecting off that plaque and it's

1088
00:40:20,710 --> 00:40:18,880

going into the pistol thing there that's

1089
00:40:22,550 --> 00:40:20,720
a sophisticated

1090
00:40:25,109 --> 00:40:22,560
device that we call the gazing to end

1091
00:40:27,990 --> 00:40:25,119
where the light goes into

1092
00:40:31,030 --> 00:40:28,000
and it gets piped in a fiber optic which

1093
00:40:33,270 --> 00:40:31,040
is in that armored cable that goes to

1094
00:40:35,270 --> 00:40:33,280
the body of the spectrometer which has

1095
00:40:37,030 --> 00:40:35,280
moving parts and if you stick your ear

1096
00:40:39,109 --> 00:40:37,040
to it and your heart is pure you can

1097
00:40:40,470 --> 00:40:39,119
hear it going zingers in gazinga and

1098
00:40:43,190 --> 00:40:40,480
it's measuring

1099
00:40:45,190 --> 00:40:43,200
the position versus time which it

1100
00:40:47,430 --> 00:40:45,200
interprets into wavelength

1101
00:40:49,270 --> 00:40:47,440
versus intensity and that's what's

1102
00:40:50,310 --> 00:40:49,280
displayed up here on the screen now what

1103
00:40:52,710 --> 00:40:50,320
i've done

1104
00:40:55,589 --> 00:40:52,720
or what andrew has done is he's taken a

1105
00:40:56,390 --> 00:40:55,599
reading of whatever that intensity is

1106
00:41:00,069 --> 00:40:56,400
and

1107
00:41:01,190 --> 00:41:00,079
he's dividing every subsequent reading

1108
00:41:03,349 --> 00:41:01,200
you can see

1109
00:41:05,109 --> 00:41:03,359
here this little bar graph display every

1110
00:41:08,150 --> 00:41:05,119
time that completes it's completed a

1111
00:41:09,829 --> 00:41:08,160
scan so we took one of those scans and

1112
00:41:12,390 --> 00:41:09,839
now we're dividing every other one that

1113
00:41:13,349 --> 00:41:12,400

comes along later on by that one that we

1114
00:41:15,270 --> 00:41:13,359
saved

1115
00:41:17,190 --> 00:41:15,280
and mathematically what do you get when

1116
00:41:18,390 --> 00:41:17,200
you divide the same thing by the same

1117
00:41:20,950 --> 00:41:18,400
thing

1118
00:41:22,630 --> 00:41:20,960
you always get the number one right

1119
00:41:25,670 --> 00:41:22,640
so that's what we see the line is at

1120
00:41:28,150 --> 00:41:25,680
number one and this is a testament

1121
00:41:30,230 --> 00:41:28,160
a demonstration of the stability of the

1122
00:41:32,790 --> 00:41:30,240
system the system is the source and the

1123
00:41:34,630 --> 00:41:32,800
system is the measuring instrument

1124
00:41:37,589 --> 00:41:34,640
and we have over on the left here the

1125
00:41:39,750 --> 00:41:37,599
reflectance the percentage of the light

1126
00:41:42,309 --> 00:41:39,760
from zero to a hundred percent or from

1127
00:41:43,109 --> 00:41:42,319
zero to one okay

1128
00:41:45,910 --> 00:41:43,119
so

1129
00:41:48,790 --> 00:41:45,920
if we were to substitute

1130
00:41:52,390 --> 00:41:48,800
that white reference plaque that we know

1131
00:41:54,069 --> 00:41:52,400
is scientifically 100 reflective

1132
00:41:56,069 --> 00:41:54,079
with a material

1133
00:41:58,069 --> 00:41:56,079
a mystery material

1134
00:41:58,790 --> 00:41:58,079
and we compare this spectral signature

1135
00:42:00,950 --> 00:41:58,800
to

1136
00:42:03,270 --> 00:42:00,960
what's here on the screen

1137
00:42:04,950 --> 00:42:03,280
what do you think never mind the letters

1138
00:42:06,790 --> 00:42:04,960

on the that's how i keep track of

1139
00:42:08,390 --> 00:42:06,800
everything these are white powders we're

1140
00:42:11,510 --> 00:42:08,400
putting under here that look totally

1141
00:42:12,950 --> 00:42:11,520
white and would be undiscernable without

1142
00:42:14,390 --> 00:42:12,960
sticking your finger in it tasting it

1143
00:42:16,309 --> 00:42:14,400
which i don't recommend for a couple of

1144
00:42:18,230 --> 00:42:16,319
them

1145
00:42:20,470 --> 00:42:18,240
and so this is how a computer would

1146
00:42:21,510 --> 00:42:20,480
recognize the chemical signature so what

1147
00:42:22,870 --> 00:42:21,520
do you what do you think that is we're

1148
00:42:24,710 --> 00:42:22,880
looking at there what does that look

1149
00:42:26,150 --> 00:42:24,720
like

1150
00:42:27,430 --> 00:42:26,160
yep

1151
00:42:37,990 --> 00:42:27,440
flower

1152
00:42:38,000 --> 00:42:42,829
so this one's a little different

1153
00:42:54,309 --> 00:42:44,550
yeah

1154
00:42:59,349 --> 00:42:56,870
now this this one's kind of fun because

1155
00:43:00,790 --> 00:42:59,359
only sugar has this little hook here

1156
00:43:02,550 --> 00:43:00,800
this little feature and this is due to a

1157
00:43:04,550 --> 00:43:02,560
very specific vibrational state of the

1158
00:43:06,710 --> 00:43:04,560
molecule

1159
00:43:08,550 --> 00:43:06,720
in fact that's people get their phds in

1160
00:43:12,790 --> 00:43:08,560
in figuring out exactly what this came

1161
00:43:12,800 --> 00:43:17,430
don't get him started anyway

1162
00:43:22,390 --> 00:43:19,270
now plaster is interesting because

1163
00:43:24,069 --> 00:43:22,400

plaster is actually gypsum and gypsum is

1164
00:43:25,430 --> 00:43:24,079
a mineral of interest here at jpl

1165
00:43:27,349 --> 00:43:25,440
because

1166
00:43:30,390 --> 00:43:27,359
so far the only way we know

1167
00:43:31,589 --> 00:43:30,400
gypsum is made is by planets is with

1168
00:43:33,910 --> 00:43:31,599
oceans

1169
00:43:35,750 --> 00:43:33,920
and we have found gypsum on mars through

1170
00:43:38,150 --> 00:43:35,760
this spectral signature

1171
00:43:40,470 --> 00:43:38,160
using an imaging spectrometer

1172
00:43:43,349 --> 00:43:40,480
called the uh on the mars reconnaissance

1173
00:43:45,990 --> 00:43:43,359
orbiter called chrism

1174
00:43:47,750 --> 00:43:46,000
and uh the rover has an imaging spec or

1175
00:43:51,510 --> 00:43:47,760
a spectrometer on it too not quite an

1176
00:43:55,670 --> 00:43:54,390
so we know here on earth where wherever

1177
00:43:57,990 --> 00:43:55,680
there is water

1178
00:43:59,589 --> 00:43:58,000
it doesn't matter how hot cold as long

1179
00:44:02,550 --> 00:43:59,599
as it's liquid water how salty it is

1180
00:44:03,910 --> 00:44:02,560
what the ph is how radioactive it is

1181
00:44:05,190 --> 00:44:03,920
if there's water there there's life

1182
00:44:07,349 --> 00:44:05,200
that's figured out a way to make its

1183
00:44:09,750 --> 00:44:07,359
living in that water so that's exciting

1184
00:44:11,589 --> 00:44:09,760
to us when we find minerals

1185
00:44:12,950 --> 00:44:11,599
that could only be made by large amounts

1186
00:44:14,950 --> 00:44:12,960
of water that have been hanging around

1187
00:44:17,270 --> 00:44:14,960
for long periods of time

1188
00:44:18,710 --> 00:44:17,280

so this is a pretty bland spectrum good

1189
00:44:20,470 --> 00:44:18,720
grief what is that

1190
00:44:29,510 --> 00:44:20,480
oh it must be the white stuff baking

1191
00:44:32,390 --> 00:44:30,710
and this is our

1192
00:44:34,790 --> 00:44:32,400
our favorite

1193
00:44:37,670 --> 00:44:34,800
sodium chloride and in fact those two

1194
00:44:39,510 --> 00:44:37,680
dips for sodium chloride which is the

1195
00:44:41,750 --> 00:44:39,520
purple line salt

1196
00:44:43,270 --> 00:44:41,760
they're influenced by the humidity and

1197
00:44:45,510 --> 00:44:43,280
how much water

1198
00:44:46,790 --> 00:44:45,520
which is and makes some playas that are

1199
00:44:48,870 --> 00:44:46,800
very salty

1200
00:44:51,030 --> 00:44:48,880
not as useful as others but they

1201
00:44:53,109 --> 00:44:51,040
actually make humidity detectors out of

1202
00:44:55,510 --> 00:44:53,119
certain salts and these spectral

1203
00:44:58,390 --> 00:44:55,520
features are one way that they

1204
00:45:00,309 --> 00:44:58,400
can use them as transducers so that's

1205
00:45:11,910 --> 00:45:00,319
how spectral fingerprints can be used to

1206
00:45:11,920 --> 00:45:14,309
all right

1207
00:45:19,510 --> 00:45:15,829
so i've mentioned the powerful

1208
00:45:21,109 --> 00:45:19,520
greenhouse gas of water vapor let me ask

1209
00:45:24,069 --> 00:45:21,119
andrew who's been so kind to help me

1210
00:45:30,710 --> 00:45:24,079
with these demos to speak to these next

1211
00:45:34,630 --> 00:45:33,349
great so as that last demo demonstrated

1212
00:45:36,550 --> 00:45:34,640
different

1213
00:45:38,390 --> 00:45:36,560

terrestrial land cover types like or

1214
00:45:41,030 --> 00:45:38,400
surfaces have their own

1215
00:45:43,190 --> 00:45:41,040
unique spectral signatures but also

1216
00:45:44,790 --> 00:45:43,200
trace gases in the atmosphere

1217
00:45:47,430 --> 00:45:44,800
also have absorption features that we

1218
00:45:49,910 --> 00:45:47,440
can see with our instruments

1219
00:45:53,270 --> 00:45:49,920
so really my focus of my work

1220
00:45:55,750 --> 00:45:53,280
here at jpl is to develop techniques

1221
00:45:57,670 --> 00:45:55,760
to identify and map greenhouse gas

1222
00:45:59,510 --> 00:45:57,680
emissions and we can do that with

1223
00:46:01,109 --> 00:45:59,520
various instruments we can do it with

1224
00:46:02,150 --> 00:46:01,119
orbital satellite instruments that are

1225
00:46:03,829 --> 00:46:02,160
designed

1226
00:46:05,270 --> 00:46:03,839
exclusively for this work

1227
00:46:07,030 --> 00:46:05,280
and we can also use some of the airborne

1228
00:46:09,270 --> 00:46:07,040
instruments that we discussed today the

1229
00:46:10,550 --> 00:46:09,280
avarice classic and average next-gen

1230
00:46:12,790 --> 00:46:10,560
instrument

1231
00:46:15,109 --> 00:46:12,800
and what i plotted here are the

1232
00:46:17,349 --> 00:46:15,119
atmospheric absorption features

1233
00:46:18,150 --> 00:46:17,359
for methane in the upper panel

1234
00:46:19,589 --> 00:46:18,160
um

1235
00:46:21,589 --> 00:46:19,599
and we can see

1236
00:46:23,750 --> 00:46:21,599
that over the entire wavelength range of

1237
00:46:24,870 --> 00:46:23,760
our instrument there are various

1238
00:46:26,710 --> 00:46:24,880

portions

1239
00:46:28,710 --> 00:46:26,720
of the electromagnetic spectrum in which

1240
00:46:31,109 --> 00:46:28,720
there are absorption features the most

1241
00:46:33,670 --> 00:46:31,119
strong absorption features are centered

1242
00:46:35,030 --> 00:46:33,680
somewhere between 2250 and 2450

1243
00:46:37,430 --> 00:46:35,040
nanometers

1244
00:46:39,430 --> 00:46:37,440
as shown in in the bright red curve

1245
00:46:41,430 --> 00:46:39,440
there and so it's those absorption

1246
00:46:43,109 --> 00:46:41,440
features that we can actually use to

1247
00:46:44,710 --> 00:46:43,119
quantify methane

1248
00:46:46,230 --> 00:46:44,720
within those average and average

1249
00:46:48,309 --> 00:46:46,240
next-gen scenes

1250
00:46:50,150 --> 00:46:48,319
for carbon dioxide we have

1251
00:46:51,750 --> 00:46:50,160
three very strong

1252
00:46:52,550 --> 00:46:51,760
absorption features that are

1253
00:47:08,309 --> 00:46:52,560
a

1254
00:47:10,550 --> 00:47:08,319
instruments to try to identify

1255
00:47:12,550 --> 00:47:10,560
emissions of both methane and carbon

1256
00:47:13,990 --> 00:47:12,560
dioxide this is a survey that we did a

1257
00:47:15,670 --> 00:47:14,000
few years ago

1258
00:47:17,030 --> 00:47:15,680
in the four corners area in the united

1259
00:47:18,950 --> 00:47:17,040
states

1260
00:47:22,790 --> 00:47:18,960
we took the average next-gen instrument

1261
00:47:25,109 --> 00:47:22,800
and we flew over 2500 square kilometers

1262
00:47:27,190 --> 00:47:25,119
over a few days and each of these push

1263
00:47:28,390 --> 00:47:27,200

pins indicates a location where we were

1264
00:47:33,510 --> 00:47:28,400
able to map

1265
00:47:37,270 --> 00:47:35,030
how do we actually do that in the

1266
00:47:39,030 --> 00:47:37,280
aircraft we have this real-time

1267
00:47:40,950 --> 00:47:39,040
detection capability that a colleague of

1268
00:47:42,470 --> 00:47:40,960
mine david thompson

1269
00:47:44,950 --> 00:47:42,480
really pioneered and this is another

1270
00:47:46,710 --> 00:47:44,960
colleague in our group ryan pavlick

1271
00:47:49,190 --> 00:47:46,720
supporting a recent campaign that we did

1272
00:47:51,349 --> 00:47:49,200
where we fly over regions looking for

1273
00:47:54,069 --> 00:47:51,359
methane emissions

1274
00:47:55,750 --> 00:47:54,079
so he's in the aircraft here i'm looking

1275
00:47:57,910 --> 00:47:55,760
at the computer monitor and on the

1276
00:47:59,510 --> 00:47:57,920
monitor we've got the data that's being

1277
00:48:01,109 --> 00:47:59,520
piped in from the instrument that's

1278
00:48:03,430 --> 00:48:01,119
looking down at the ground so you can

1279
00:48:06,150 --> 00:48:03,440
see on the right hand side sort of the

1280
00:48:08,550 --> 00:48:06,160
red green and blue bands of what we

1281
00:48:10,470 --> 00:48:08,560
would see with our eyes and what we've

1282
00:48:11,750 --> 00:48:10,480
overlaid are methane plumes in red and

1283
00:48:13,829 --> 00:48:11,760
you really can't see that in this

1284
00:48:16,230 --> 00:48:13,839
example but what this allows us to do is

1285
00:48:17,750 --> 00:48:16,240
to fly over large areas to look for

1286
00:48:20,069 --> 00:48:17,760
methane plumes

1287
00:48:21,670 --> 00:48:20,079
we can then flag them on the aircraft

1288
00:48:24,549 --> 00:48:21,680

and communicate that information down to

1289
00:48:26,150 --> 00:48:24,559
the ground for follow-up

1290
00:48:28,549 --> 00:48:26,160
so what do these plumes actually look

1291
00:48:31,109 --> 00:48:28,559
like well this is one example

1292
00:48:32,470 --> 00:48:31,119
of the 250 plumes that we observed at

1293
00:48:33,670 --> 00:48:32,480
four corners

1294
00:48:36,549 --> 00:48:33,680
you can see

1295
00:48:38,630 --> 00:48:36,559
that the pixel resolution for the plume

1296
00:48:40,309 --> 00:48:38,640
is it's a little bit coarse so each

1297
00:48:41,670 --> 00:48:40,319
image pixel of the average next-gen

1298
00:48:43,430 --> 00:48:41,680
instrument in this example i think is

1299
00:48:45,589 --> 00:48:43,440
somewhere between three and five meters

1300
00:48:48,309 --> 00:48:45,599
per pixel and we've overlaid it on

1301
00:48:49,670 --> 00:48:48,319
google earth which has uh improved

1302
00:48:50,790 --> 00:48:49,680
spatial resolutions you can actually

1303
00:48:52,870 --> 00:48:50,800
resolve

1304
00:48:54,950 --> 00:48:52,880
that individual well pad and that helps

1305
00:48:57,829 --> 00:48:54,960
us with interpretation so what you can

1306
00:49:00,309 --> 00:48:57,839
see from this example is the the red

1307
00:49:01,910 --> 00:49:00,319
the higher red values the more intense

1308
00:49:03,589 --> 00:49:01,920
red values are higher methane

1309
00:49:05,349 --> 00:49:03,599
concentrations and you can sort of

1310
00:49:06,790 --> 00:49:05,359
interpret this and

1311
00:49:08,790 --> 00:49:06,800
try to determine where the plume is

1312
00:49:10,230 --> 00:49:08,800
coming from it's pretty clear that it's

1313
00:49:14,069 --> 00:49:10,240

sort of from the northern portion of

1314
00:49:15,990 --> 00:49:14,079
this well pad as the emission source

1315
00:49:17,750 --> 00:49:16,000
what i had mentioned before is we have

1316
00:49:19,990 --> 00:49:17,760
this real-time capability so if we

1317
00:49:22,150 --> 00:49:20,000
identify this in the in the plane

1318
00:49:23,910 --> 00:49:22,160
uh folks can communicate it down to the

1319
00:49:26,790 --> 00:49:23,920
ground for follow-up

1320
00:49:28,470 --> 00:49:26,800
and um we do that with a thermal camera

1321
00:49:31,190 --> 00:49:28,480
which is shown here

1322
00:49:34,230 --> 00:49:31,200
on a tripod and this is a picture i

1323
00:49:35,510 --> 00:49:34,240
think that mark took of our colleagues

1324
00:49:37,270 --> 00:49:35,520
scott nolte

1325
00:49:39,190 --> 00:49:37,280
um as part of the four corners campaign

1326
00:49:40,710 --> 00:49:39,200
so we were driving around

1327
00:49:42,390 --> 00:49:40,720
trying to verify some of the observed

1328
00:49:45,109 --> 00:49:42,400
plumes with the average next-gen

1329
00:49:46,710 --> 00:49:45,119
instrument using this thermal camera

1330
00:49:47,990 --> 00:49:46,720
the thermal camera

1331
00:49:50,150 --> 00:49:48,000
is

1332
00:49:51,589 --> 00:49:50,160
sensitive at about seven microns for

1333
00:49:54,309 --> 00:49:51,599
methane absorption features and it

1334
00:49:56,230 --> 00:49:54,319
allows us to take videos of methane

1335
00:49:59,349 --> 00:49:56,240
plumes you may have seen some of these

1336
00:50:00,950 --> 00:49:59,359
types of examples from you know other

1337
00:50:04,309 --> 00:50:00,960
examples

1338
00:50:05,109 --> 00:50:04,319

for other methane leaks in in the area

1339
00:50:07,670 --> 00:50:05,119
so

1340
00:50:10,870 --> 00:50:07,680
this is the example of

1341
00:50:12,630 --> 00:50:10,880
the video that we acquired for that

1342
00:50:14,470 --> 00:50:12,640
methane plume that we saw with the iris

1343
00:50:16,390 --> 00:50:14,480
next gen instrument so this is

1344
00:50:18,549 --> 00:50:16,400
actually coming from a tank that's

1345
00:50:19,910 --> 00:50:18,559
buried partially

1346
00:50:21,670 --> 00:50:19,920
and if we were to look at this with a

1347
00:50:23,829 --> 00:50:21,680
bare eyes you would see nothing right

1348
00:50:26,790 --> 00:50:23,839
maybe you would smell something if there

1349
00:50:29,510 --> 00:50:26,800
was some type of additive added but this

1350
00:50:30,950 --> 00:50:29,520
is a great example of us verifying an

1351
00:50:35,510 --> 00:50:30,960
observation that we did with our

1352
00:50:39,030 --> 00:50:37,510
here's another example of a methane

1353
00:50:40,790 --> 00:50:39,040
plume that doesn't appear to be

1354
00:50:42,630 --> 00:50:40,800
associated with any visible

1355
00:50:44,630 --> 00:50:42,640
infrastructure in the scene we kind of

1356
00:50:47,190 --> 00:50:44,640
have a well pad in the southern portion

1357
00:50:49,109 --> 00:50:47,200
of the the scene but it appears to be

1358
00:50:50,150 --> 00:50:49,119
sort of emanating from around those dirt

1359
00:50:51,910 --> 00:50:50,160
roads

1360
00:50:54,230 --> 00:50:51,920
you can see that there's one pixel that

1361
00:50:56,870 --> 00:50:54,240
is the brightest red and that's the

1362
00:50:58,549 --> 00:50:56,880
highest concentration so that is the

1363
00:51:00,549 --> 00:50:58,559

location that we would target if we

1364
00:51:02,150 --> 00:51:00,559
wanted to try to verify if there was

1365
00:51:04,309 --> 00:51:02,160
actually methane

1366
00:51:06,309 --> 00:51:04,319
being emitted at that location and for

1367
00:51:07,349 --> 00:51:06,319
this example we also set up the thermal

1368
00:51:08,630 --> 00:51:07,359
camera

1369
00:51:10,950 --> 00:51:08,640
to look

1370
00:51:13,030 --> 00:51:10,960
off of the dirt road to try to verify

1371
00:51:14,630 --> 00:51:13,040
the methane plume that we saw

1372
00:51:17,190 --> 00:51:14,640
with the average next-gen instrument and

1373
00:51:19,030 --> 00:51:17,200
you can see that we have a dead tree in

1374
00:51:20,790 --> 00:51:19,040
the left-hand portion of the scene

1375
00:51:23,109 --> 00:51:20,800
what's interesting is that

1376
00:51:24,790 --> 00:51:23,119
plants can be killed by excess levels of

1377
00:51:26,870 --> 00:51:24,800
methane in the roots

1378
00:51:28,390 --> 00:51:26,880
so that was made it even more intriguing

1379
00:51:30,870 --> 00:51:28,400
for us to spend a little bit of time to

1380
00:51:32,470 --> 00:51:30,880
try to find this emission source what

1381
00:51:35,430 --> 00:51:32,480
was even more telling was the fact that

1382
00:51:37,349 --> 00:51:35,440
there was actually a few

1383
00:51:39,430 --> 00:51:37,359
yellow flags placed

1384
00:51:41,190 --> 00:51:39,440
in a line and it they had a 1 800 number

1385
00:51:43,910 --> 00:51:41,200
of the local

1386
00:51:47,030 --> 00:51:43,920
gas company so this was in fact a buried

1387
00:51:49,510 --> 00:51:47,040
natural gas pipeline in an area of of

1388
00:51:51,750 --> 00:51:49,520

natural gas extraction so we spent some

1389
00:51:54,069 --> 00:51:51,760
time to try to look for the plume using

1390
00:51:56,470 --> 00:51:54,079
a thermal camera and we did in fact see

1391
00:51:58,710 --> 00:51:56,480
methane um i apologize for the quality

1392
00:52:00,309 --> 00:51:58,720
of this uh video it's pretty poor but

1393
00:52:01,349 --> 00:52:00,319
you can see clearly we've got methane

1394
00:52:02,710 --> 00:52:01,359
coming

1395
00:52:04,309 --> 00:52:02,720
out of the ground

1396
00:52:05,990 --> 00:52:04,319
so this was a buried natural gas

1397
00:52:07,670 --> 00:52:06,000
pipeline

1398
00:52:09,829 --> 00:52:07,680
where concentrations were coming up

1399
00:52:14,390 --> 00:52:09,839
through the ground at high enough values

1400
00:52:18,390 --> 00:52:16,230
as part of this work we're developing

1401
00:52:20,870 --> 00:52:18,400
quantitative gas retrievals so that

1402
00:52:22,470 --> 00:52:20,880
means that for every image pixel that

1403
00:52:26,470 --> 00:52:22,480
has a color here

1404
00:52:29,109 --> 00:52:26,480
we're able to estimate how much methane

1405
00:52:32,150 --> 00:52:29,119
is in that pixel above background and

1406
00:52:34,630 --> 00:52:32,160
you can see our units are in in methane

1407
00:52:38,150 --> 00:52:34,640
enhancements in parts per million meters

1408
00:52:40,870 --> 00:52:38,160
and that's in excess of 8000 ppm m

1409
00:52:42,950 --> 00:52:40,880
for the the highest concentrations and

1410
00:52:45,990 --> 00:52:42,960
the way that we do these retrievals is

1411
00:52:48,710 --> 00:52:46,000
we take a measured radiance so for every

1412
00:52:51,670 --> 00:52:48,720
image pixel in this scene avarice

1413
00:52:53,510 --> 00:52:51,680

measures a radiance and we focus in a

1414
00:52:57,910 --> 00:52:53,520
portion of the shortwave infrared

1415
00:52:59,670 --> 00:52:57,920
spectrum from 2200 to 2400 nanometers

1416
00:53:02,549 --> 00:52:59,680
and we take our measured radians which

1417
00:53:05,030 --> 00:53:02,559
is black and we match it to a modeled

1418
00:53:07,430 --> 00:53:05,040
radiance as shown in red here

1419
00:53:09,910 --> 00:53:07,440
with a known elevated concentration of

1420
00:53:12,549 --> 00:53:09,920
gas so when they are best fit we can

1421
00:53:14,630 --> 00:53:12,559
estimate how much gas is present in that

1422
00:53:16,069 --> 00:53:14,640
pixel so we do that for the entire scene

1423
00:53:18,710 --> 00:53:16,079
and we can map out the plume

1424
00:53:20,390 --> 00:53:18,720
quantitatively

1425
00:53:21,430 --> 00:53:20,400
we're also looking at other emission

1426
00:53:23,190 --> 00:53:21,440
sources

1427
00:53:25,109 --> 00:53:23,200
not only oil and gas related so this is

1428
00:53:27,670 --> 00:53:25,119
an example of a methane plume coming off

1429
00:53:29,589 --> 00:53:27,680
of a landfill in southern california

1430
00:53:32,950 --> 00:53:29,599
it's clearly at least one plume maybe

1431
00:53:33,910 --> 00:53:32,960
two plumes and we've used purple and

1432
00:53:36,150 --> 00:53:33,920
pink

1433
00:53:37,829 --> 00:53:36,160
for the color scheme here and we also

1434
00:53:39,349 --> 00:53:37,839
collaborated with some german

1435
00:53:40,790 --> 00:53:39,359
researchers at the university of bremen

1436
00:53:42,870 --> 00:53:40,800
who have a map

1437
00:53:44,549 --> 00:53:42,880
instrument this is an instrument that's

1438
00:53:46,870 --> 00:53:44,559

related but has

1439
00:53:49,430 --> 00:53:46,880
non-imaging capabilities so they fly

1440
00:53:51,030 --> 00:53:49,440
back and forth over the landfill and

1441
00:53:52,950 --> 00:53:51,040
have measurements at each of those

1442
00:53:54,549 --> 00:53:52,960
points that are visible

1443
00:53:56,230 --> 00:53:54,559
so the red

1444
00:53:58,309 --> 00:53:56,240
points have higher methane than the

1445
00:53:59,829 --> 00:53:58,319
green ones and you can see there is

1446
00:54:02,069 --> 00:53:59,839
pretty good agreement between what we

1447
00:54:04,549 --> 00:54:02,079
saw with the ivor's next gen instrument

1448
00:54:09,270 --> 00:54:04,559
and what my map saw even though they

1449
00:54:14,150 --> 00:54:11,270
we're also working on carbon dioxide

1450
00:54:15,910 --> 00:54:14,160
related retrievals similar process we're

1451
00:54:18,790 --> 00:54:15,920
using a different wavelength range from

1452
00:54:21,349 --> 00:54:18,800
1900 to 2100 nanometers

1453
00:54:24,150 --> 00:54:21,359
same idea you

1454
00:54:25,589 --> 00:54:24,160
match your measured in model radiances

1455
00:54:27,430 --> 00:54:25,599
and with that i think we're going to go

1456
00:54:29,030 --> 00:54:27,440
ahead and have a co2 demo to kind of

1457
00:54:36,870 --> 00:54:29,040
illustrate this

1458
00:54:44,790 --> 00:54:39,349
did you say co2

1459
00:54:44,800 --> 00:54:50,549
so we're going to use this spectrometer

1460
00:54:54,790 --> 00:54:51,589
portable

1461
00:54:56,790 --> 00:54:54,800
non-imaging spectrometer

1462
00:55:01,349 --> 00:54:56,800
and we're going to use this

1463
00:55:04,630 --> 00:55:01,359

integrating sphere as a white cavity

1464
00:55:07,349 --> 00:55:04,640
and we have a light bulb here

1465
00:55:08,309 --> 00:55:07,359
now i'm using an incandes well

1466
00:55:13,990 --> 00:55:08,319
first

1467
00:55:18,230 --> 00:55:15,670
raw mode i was going to change things

1468
00:55:20,710 --> 00:55:18,240
first no no just uh i'll let you take

1469
00:55:22,790 --> 00:55:20,720
over sure go to uh

1470
00:55:25,190 --> 00:55:22,800
sorry i'm changing up on

1471
00:55:27,190 --> 00:55:25,200
poor andrew here because

1472
00:55:32,150 --> 00:55:27,200
i didn't go over this part so first

1473
00:55:36,710 --> 00:55:33,910
come on don't make a wire out of me

1474
00:55:40,710 --> 00:55:37,829
then we're going to turn on the green

1475
00:55:43,349 --> 00:55:40,720
led where'd it go

1476
00:55:44,790 --> 00:55:43,359
oh change the scale yeah yeah all right

1477
00:55:53,190 --> 00:55:44,800
so we're at

1478
00:55:58,230 --> 00:55:55,430
there we go and then uh the scale will

1479
00:55:59,670 --> 00:55:58,240
have to change to uh

1480
00:56:01,750 --> 00:55:59,680
well let's just see what the scale is

1481
00:56:02,789 --> 00:56:01,760
going to have to change it there we go

1482
00:56:06,150 --> 00:56:02,799
so

1483
00:56:08,150 --> 00:56:06,160
let's change the scale to

1484
00:56:10,309 --> 00:56:08,160
axes

1485
00:56:13,750 --> 00:56:10,319
0 to

1486
00:56:18,710 --> 00:56:16,150
oh well we've got more signal than that

1487
00:56:21,670 --> 00:56:18,720
there so yeah

1488
00:56:23,910 --> 00:56:21,680

that's what scientists like you know

1489
00:56:25,589 --> 00:56:23,920
all right

1490
00:56:26,950 --> 00:56:25,599
do i have a hundred or a thousand

1491
00:56:29,510 --> 00:56:26,960
hundred

1492
00:56:36,390 --> 00:56:29,520
oh you young eyes

1493
00:56:36,400 --> 00:56:46,150
all right so maybe go to five thousand

1494
00:56:52,390 --> 00:56:49,990
all right bump good bump at 600 and

1495
00:56:54,870 --> 00:56:52,400
almost 700 nanometers and i can turn the

1496
00:56:57,270 --> 00:56:54,880
bump up and down

1497
00:56:59,510 --> 00:56:57,280
with this knob here

1498
00:57:00,870 --> 00:56:59,520
and then here we have another bump

1499
00:57:05,430 --> 00:57:00,880
at

1500
00:57:07,349 --> 00:57:05,440
and then we have another bump

1501
00:57:09,030 --> 00:57:07,359
about 400 nanometers here's all three of

1502
00:57:11,589 --> 00:57:09,040
them put together

1503
00:57:14,390 --> 00:57:11,599
three bumps three light sources

1504
00:57:16,150 --> 00:57:14,400
but the radiation that the part of the

1505
00:57:17,910 --> 00:57:16,160
electromagnetic spectrum that we want to

1506
00:57:19,349 --> 00:57:17,920
use to measure methane is way out at two

1507
00:57:21,109 --> 00:57:19,359
thousand

1508
00:57:24,470 --> 00:57:21,119
these leds aren't putting out any light

1509
00:57:25,990 --> 00:57:24,480
at two thousand so i want to

1510
00:57:28,230 --> 00:57:26,000
put a light bulb in there an

1511
00:57:29,990 --> 00:57:28,240
incandescent source that puts out energy

1512
00:57:31,030 --> 00:57:30,000
at 2000 that was the whole point of that

1513
00:57:34,470 --> 00:57:31,040

so do

1514
00:57:38,470 --> 00:57:36,390
you want me to change the scales too and

1515
00:57:43,990 --> 00:57:38,480
then and then we'll do a write reference

1516
00:57:47,510 --> 00:57:45,510
i've carried this thing

1517
00:57:49,750 --> 00:57:47,520
or things like it on my back around the

1518
00:57:51,349 --> 00:57:49,760
world

1519
00:57:53,109 --> 00:57:51,359
it was a jpl or that originally

1520
00:57:57,990 --> 00:57:53,119
developed this tip portable technology

1521
00:58:01,829 --> 00:57:59,670
so i'm not being hard on andrew it's

1522
00:58:03,270 --> 00:58:01,839
just i know these things all right so

1523
00:58:06,230 --> 00:58:03,280
white reference and then change the

1524
00:58:08,789 --> 00:58:06,240
scale correct correct so uh what point

1525
00:58:11,349 --> 00:58:08,799
eight one point one to 0.8

1526
00:58:14,710 --> 00:58:13,270
everything's stable

1527
00:58:18,069 --> 00:58:14,720
dividing the same thing by the same

1528
00:58:19,349 --> 00:58:18,079
thing we've taken our white reference

1529
00:58:22,069 --> 00:58:19,359
so what we're going to do is we're going

1530
00:58:23,510 --> 00:58:22,079
to add see an experiment adds one thing

1531
00:58:24,789 --> 00:58:23,520
so that you're sure you're measuring the

1532
00:58:26,630 --> 00:58:24,799
one thing

1533
00:58:28,710 --> 00:58:26,640
and in fact a

1534
00:58:31,670 --> 00:58:28,720
good science specific paper

1535
00:58:33,270 --> 00:58:31,680
goes into excruciating detail not only

1536
00:58:34,710 --> 00:58:33,280
this is what i measured but this is how

1537
00:58:37,750 --> 00:58:34,720
i measured it and this is how i know i

1538
00:58:39,270 --> 00:58:37,760

did it right

1539
00:58:41,270 --> 00:58:39,280
and a really good paper says and this is

1540
00:58:43,349 --> 00:58:41,280
how you might even improve on the

1541
00:58:44,549 --> 00:58:43,359
measurement

1542
00:58:48,870 --> 00:58:44,559
so

1543
00:58:50,470 --> 00:58:48,880
we'll take another white reference

1544
00:58:51,910 --> 00:58:50,480
the light bulb changes slightly in

1545
00:58:55,030 --> 00:58:51,920
temperature with time and so you get

1546
00:59:00,870 --> 00:58:58,150
so this is uh acetic acid white vinegar

1547
00:59:02,309 --> 00:59:00,880
this is sodium bicarbonate baking soda

1548
00:59:06,630 --> 00:59:02,319
you put them together

1549
00:59:07,589 --> 00:59:06,640
they make uh carbon dioxide

1550
00:59:09,670 --> 00:59:07,599
um

1551
00:59:12,630 --> 00:59:09,680
i've put it in a bolus here so this

1552
00:59:15,430 --> 00:59:12,640
slows the reaction down a little bit

1553
00:59:17,109 --> 00:59:15,440
our colleague morgan cable he's an

1554
00:59:19,109 --> 00:59:17,119
exochemist

1555
00:59:20,470 --> 00:59:19,119
taught us about that one

1556
00:59:22,069 --> 00:59:20,480
otherwise if you just dump a bunch of

1557
00:59:23,190 --> 00:59:22,079
baking soda in there you get a big mess

1558
00:59:23,990 --> 00:59:23,200
right

1559
00:59:25,829 --> 00:59:24,000
so

1560
00:59:27,910 --> 00:59:25,839
what's happening now is we've got

1561
00:59:30,870 --> 00:59:27,920
bubbling going on

1562
00:59:32,549 --> 00:59:30,880
and ostensibly we have co2 coming out of

1563
00:59:34,789 --> 00:59:32,559

this thing

1564
00:59:36,789 --> 00:59:34,799
and what co2 is a little heavier just a

1565
00:59:39,829 --> 00:59:36,799
little heavier than air

1566
00:59:41,190 --> 00:59:39,839
and we're going to

1567
00:59:43,349 --> 00:59:41,200
just kind of hold it there don't stick

1568
00:59:46,069 --> 00:59:43,359
it all the way in there you go

1569
00:59:47,910 --> 00:59:46,079
and with time as the sphere fills up

1570
00:59:50,150 --> 00:59:47,920
with co2 we should start seeing a

1571
00:59:52,150 --> 00:59:50,160
spectral feature at around two microns

1572
00:59:54,470 --> 00:59:52,160
two thousand nanometers

1573
00:59:56,069 --> 00:59:54,480
build up

1574
00:59:57,510 --> 00:59:56,079
now i'm kinda cheating here this is a

1575
00:59:59,990 --> 00:59:57,520
white

1576
01:00:01,910 --> 01:00:00,000
chamber which means that the light from

1577
01:00:04,069 --> 01:00:01,920
the bulb bounces around and goes through

1578
01:00:06,549 --> 01:00:04,079
a whole lot of co2 and picks up the

1579
01:00:10,390 --> 01:00:06,559
spectral signature of the co2 before it

1580
01:00:14,789 --> 01:00:12,150
but this is a demonstration of the

1581
01:00:16,150 --> 01:00:14,799
mechanism of the process by which we

1582
01:00:20,069 --> 01:00:16,160
measure

1583
01:00:24,150 --> 01:00:22,549
and this is directly analogous to

1584
01:00:26,150 --> 01:00:24,160
what we do with the airborne instrument

1585
01:00:27,910 --> 01:00:26,160
so it's those three absorption features

1586
01:00:29,990 --> 01:00:27,920
that are growing and growing that we're

1587
01:00:32,069 --> 01:00:30,000
mapping and how we do our quantitative

1588
01:00:34,069 --> 01:00:32,079

gas retrievals right per pixel basis

1589
01:00:35,670 --> 01:00:34,079
okay engine concept

1590
01:00:40,870 --> 01:00:35,680
we're getting some plastic tubing

1591
01:00:44,950 --> 01:00:42,309
this the one thing about an integrating

1592
01:00:47,349 --> 01:00:44,960
sphere it mushes up everything and

1593
01:00:50,630 --> 01:00:47,359
anything that gets next to it or in it

1594
01:00:52,549 --> 01:00:50,640
so we can we can uh do the circularity

1595
01:00:54,150 --> 01:00:52,559
skeptical proof

1596
01:00:57,109 --> 01:00:54,160
by um

1597
01:01:02,069 --> 01:00:57,119
emptying out the sphere and one way to

1598
01:01:02,079 --> 01:01:07,030
blow in it

1599
01:01:15,829 --> 01:01:08,870
there we go and it goes away but what

1600
01:01:21,670 --> 01:01:17,670
so besides bad breath what gas do you

1601
01:01:24,710 --> 01:01:21,680
think is responsible for those extra

1602
01:01:27,270 --> 01:01:24,720
yes water vapor

1603
01:01:30,470 --> 01:01:27,280
very powerful greenhouse gas so

1604
01:01:44,789 --> 01:01:32,150
i think we've covered

1605
01:01:47,589 --> 01:01:46,710
yes indeed we have

1606
01:01:50,950 --> 01:01:47,599
good

1607
01:01:54,470 --> 01:01:52,630
so um

1608
01:01:56,870 --> 01:01:54,480
next is a bunch of videos these next

1609
01:01:58,630 --> 01:01:56,880
videos and slides tell the story of what

1610
01:02:01,510 --> 01:01:58,640
it has been like to work with the

1611
01:02:02,950 --> 01:02:01,520
avarice airborne spectrometer

1612
01:02:04,630 --> 01:02:02,960
let's go for a ride on a research

1613
01:02:06,789 --> 01:02:04,640

aircraft that's carrying the average

1614
01:02:07,910 --> 01:02:06,799
next generation imaging spectrometer

1615
01:02:09,829 --> 01:02:07,920
this is a

1616
01:02:11,030 --> 01:02:09,839
let me back up

1617
01:02:14,950 --> 01:02:11,040
let's see it again this is a de

1618
01:02:16,950 --> 01:02:14,960
havilland canada dhc-6

1619
01:02:19,510 --> 01:02:16,960
twin otter taking off from bob hope

1620
01:02:21,750 --> 01:02:19,520
airport california

1621
01:02:22,950 --> 01:02:21,760
this is my favorite part takeoff besides

1622
01:02:24,789 --> 01:02:22,960
a good landing

1623
01:02:27,109 --> 01:02:24,799
here we are departing ponca city

1624
01:02:28,710 --> 01:02:27,119
oklahoma these planes were modified for

1625
01:02:30,230 --> 01:02:28,720
tourism with the installation of large

1626
01:02:32,470 --> 01:02:30,240
windows i'm taking the video from a

1627
01:02:34,309 --> 01:02:32,480
special bubble window looking forward

1628
01:02:35,510 --> 01:02:34,319
you can see the cockpit door handle

1629
01:02:37,030 --> 01:02:35,520
sticking out from the skin of the

1630
01:02:38,870 --> 01:02:37,040
airplane on the right

1631
01:02:41,349 --> 01:02:38,880
and it's pretty flat out there in punk

1632
01:02:44,150 --> 01:02:41,359
city oklahoma

1633
01:02:45,990 --> 01:02:44,160
so where here we are in flight i'm on

1634
01:02:47,510 --> 01:02:46,000
over four corners new mexico with the

1635
01:02:49,109 --> 01:02:47,520
avarice next generation instrument

1636
01:02:50,630 --> 01:02:49,119
collecting some of the data that andrew

1637
01:02:52,549 --> 01:02:50,640
just showed this is

1638
01:02:54,069 --> 01:02:52,559

my colleague

1639
01:02:55,430 --> 01:02:54,079
david thompson the guy who was

1640
01:02:57,349 --> 01:02:55,440
developing the

1641
01:02:59,910 --> 01:02:57,359
real-time analysis algorithm that

1642
01:03:02,549 --> 01:02:59,920
display showed we're flying at about 16

1643
01:03:03,990 --> 01:03:02,559
000 feet that's our real-time display

1644
01:03:05,990 --> 01:03:04,000
and i'll explain that more about that

1645
01:03:08,230 --> 01:03:06,000
later but here you see the layout of the

1646
01:03:09,990 --> 01:03:08,240
aircraft right uh what it looks like

1647
01:03:11,750 --> 01:03:10,000
behind uh the instrument is in front of

1648
01:03:13,109 --> 01:03:11,760
that fan that white fan by the way is

1649
01:03:15,029 --> 01:03:13,119
used to keep the plane cool in the hot

1650
01:03:16,710 --> 01:03:15,039
sun when we're not moving through the

1651
01:03:18,549 --> 01:03:16,720
air there's a green tank there with

1652
01:03:20,230 --> 01:03:18,559
oxygen in it and that's why we have

1653
01:03:22,630 --> 01:03:20,240
those cannula in our noses because we're

1654
01:03:24,710 --> 01:03:22,640
actually 16 000 feet then if you look

1655
01:03:26,470 --> 01:03:24,720
out the window those aren't ant hills

1656
01:03:28,710 --> 01:03:26,480
down there those are all natural gas

1657
01:03:31,270 --> 01:03:28,720
extraction pads

1658
01:03:33,029 --> 01:03:31,280
and that's that's how uh

1659
01:03:35,990 --> 01:03:33,039
that's how it's done in four corners new

1660
01:03:37,190 --> 01:03:36,000
mexico and there's uh more data and you

1661
01:03:39,430 --> 01:03:37,200
can see a little bit of red on the

1662
01:03:41,109 --> 01:03:39,440
display there on to the right that's the

1663
01:03:45,270 --> 01:03:41,119

real-time uh

1664
01:03:47,190 --> 01:03:45,280
extraction display bye david

1665
01:03:48,470 --> 01:03:47,200
okay did i mention there's a big hole in

1666
01:03:50,470 --> 01:03:48,480
the bottom of the airplane for the

1667
01:03:52,549 --> 01:03:50,480
instruments to look out of

1668
01:03:54,309 --> 01:03:52,559
that's why we wear oxygen because you

1669
01:03:56,069 --> 01:03:54,319
can't pressurize the plane and no the

1670
01:03:58,150 --> 01:03:56,079
instrument isn't moving the airplane is

1671
01:04:00,230 --> 01:03:58,160
moving it's on a stabilization mount to

1672
01:04:02,630 --> 01:04:00,240
keep things nice and straight and we're

1673
01:04:04,789 --> 01:04:02,640
in flight over the four corners area in

1674
01:04:06,549 --> 01:04:04,799
new mexico

1675
01:04:08,870 --> 01:04:06,559
another favorite thing while flying a

1676
01:04:12,069 --> 01:04:08,880
good landing so here we are landing in

1677
01:04:13,589 --> 01:04:12,079
ponca city and let me go back again note

1678
01:04:14,950 --> 01:04:13,599
the hole in the bottom of the airplane

1679
01:04:17,270 --> 01:04:14,960
and we can see the ground through the

1680
01:04:19,029 --> 01:04:17,280
hole right

1681
01:04:21,589 --> 01:04:19,039
and this is with the c fist spectrum

1682
01:04:23,750 --> 01:04:21,599
mapping instrument looking out that hole

1683
01:04:25,430 --> 01:04:23,760
and the chlorophyll fluorescence imaging

1684
01:04:27,829 --> 01:04:25,440
spectrometer directly measures

1685
01:04:30,390 --> 01:04:27,839
chlorophyll in action as it uses the

1686
01:04:32,789 --> 01:04:30,400
energy of sunlight to make food from air

1687
01:04:38,470 --> 01:04:32,799
and water it's very exciting brand new

1688
01:04:42,630 --> 01:04:40,789

the moment of touchdown a good pilot

1689
01:04:43,670 --> 01:04:42,640
nice and smooth

1690
01:04:45,910 --> 01:04:43,680
you can always tell the difference

1691
01:04:47,829 --> 01:04:45,920
between a navy train pilot and an army

1692
01:04:49,190 --> 01:04:47,839
train pilot

1693
01:04:50,950 --> 01:04:49,200
if if you've ever

1694
01:04:53,349 --> 01:04:50,960
flown commercially

1695
01:04:56,150 --> 01:04:53,359
and in the navy they learn how to catch

1696
01:04:59,029 --> 01:04:56,160
the tail hook right how to catch that

1697
01:05:00,950 --> 01:04:59,039
trap wire and so they put it down boom

1698
01:05:05,829 --> 01:05:00,960
whereas the army in the air force boys

1699
01:05:10,470 --> 01:05:07,990
here we are over zion national park in

1700
01:05:13,829 --> 01:05:12,549
and this is the visitor center below

1701
01:05:15,589 --> 01:05:13,839
this is during one of those transit

1702
01:05:17,829 --> 01:05:15,599
flights my favorite transit flight from

1703
01:05:19,750 --> 01:05:17,839
southern california to

1704
01:05:21,910 --> 01:05:19,760
central colorado where the facility is

1705
01:05:25,109 --> 01:05:21,920
where they maintain these airplanes

1706
01:05:28,309 --> 01:05:26,549
yeah those big windows are really

1707
01:05:30,230 --> 01:05:28,319
something

1708
01:05:32,069 --> 01:05:30,240
now this is what we're looking at in the

1709
01:05:33,910 --> 01:05:32,079
plane during data acquisition this is

1710
01:05:35,910 --> 01:05:33,920
our live readout for instrument

1711
01:05:38,950 --> 01:05:35,920
operators and over here on the left is

1712
01:05:41,190 --> 01:05:38,960
what we call a waterfall display

1713
01:05:43,190 --> 01:05:41,200

and it shows us what we've just flown

1714
01:05:44,870 --> 01:05:43,200
over and in this case our target is that

1715
01:05:47,109 --> 01:05:44,880
little square there with all the little

1716
01:05:48,150 --> 01:05:47,119
individual plots of different species of

1717
01:05:49,829 --> 01:05:48,160
plants

1718
01:05:52,789 --> 01:05:49,839
and then over on the right is our

1719
01:05:55,190 --> 01:05:52,799
real-time focal plane array display

1720
01:05:56,470 --> 01:05:55,200
indiscernible to the normal human eye if

1721
01:05:57,589 --> 01:05:56,480
you happen to build these things and

1722
01:05:59,270 --> 01:05:57,599
calibrate them you can actually

1723
01:06:01,589 --> 01:05:59,280
interpret what they have to say that's a

1724
01:06:03,589 --> 01:06:01,599
whole story just explaining what that is

1725
01:06:05,589 --> 01:06:03,599
but it helps gives us a warm fuzzy

1726
01:06:07,990 --> 01:06:05,599
feeling when it looks right

1727
01:06:10,309 --> 01:06:08,000
while we're operating the plane

1728
01:06:12,549 --> 01:06:10,319
here's head honcho michael eastwood and

1729
01:06:15,510 --> 01:06:12,559
primary investigator robert greene of

1730
01:06:17,910 --> 01:06:15,520
the avarice program sending avarice next

1731
01:06:19,910 --> 01:06:17,920
generation off from our loading dock at

1732
01:06:23,829 --> 01:06:19,920
jpl to india

1733
01:06:27,029 --> 01:06:25,270
travel to india

1734
01:06:28,710 --> 01:06:27,039
here we are the first day after arriving

1735
01:06:32,150 --> 01:06:28,720
and recuperating from jet lag in

1736
01:06:33,990 --> 01:06:32,160
hyderabad india the sven here and i were

1737
01:06:36,390 --> 01:06:34,000
waiting for our van from the airfield

1738
01:06:38,470 --> 01:06:36,400

gate back to the hotel after installing

1739
01:06:40,309 --> 01:06:38,480
the instrument in the plane and the call

1740
01:06:42,470 --> 01:06:40,319
of the museum to prayer started just as

1741
01:06:44,309 --> 01:06:42,480
i turned on the camera and india is

1742
01:06:46,549 --> 01:06:44,319
definitely a multicultural place i

1743
01:06:47,270 --> 01:06:46,559
highly recommend visiting my wife loved

1744
01:06:51,109 --> 01:06:47,280
it

1745
01:06:57,109 --> 01:06:54,870
so here we are uh in mangalor in

1746
01:06:59,109 --> 01:06:57,119
yes over mangalore

1747
01:07:01,109 --> 01:06:59,119
and you can see here's andrew inside the

1748
01:07:03,829 --> 01:07:01,119
plane on the ground before we took off

1749
01:07:06,710 --> 01:07:03,839
and ernesto over on the right

1750
01:07:07,750 --> 01:07:06,720
about to take off on yet another mission

1751
01:07:09,589 --> 01:07:07,760
and

1752
01:07:11,750 --> 01:07:09,599
this is a freighter leaving the port of

1753
01:07:15,430 --> 01:07:11,760
mangaluru on the southwest coast of

1754
01:07:19,430 --> 01:07:17,510
and we did make the local papers here we

1755
01:07:22,230 --> 01:07:19,440
are in bhuvaneshwar

1756
01:07:24,630 --> 01:07:22,240
which is over on the uh eastern

1757
01:07:27,270 --> 01:07:24,640
side of southern india

1758
01:07:29,750 --> 01:07:27,280
and that's a span again in front of the

1759
01:07:32,950 --> 01:07:29,760
indian aircraft uh king air aircraft

1760
01:07:37,910 --> 01:07:35,270
yeah that that actually uh the reason

1761
01:07:40,710 --> 01:07:37,920
why we used that particular aircraft is

1762
01:07:43,349 --> 01:07:40,720
they were using it for photographic um

1763
01:07:44,630 --> 01:07:43,359

mapping right they had a system made by

1764
01:07:46,309 --> 01:07:44,640
kodak

1765
01:07:47,990 --> 01:07:46,319
uh looking out a hole in the bottom of

1766
01:07:50,230 --> 01:07:48,000
the plane that was just big enough for

1767
01:07:52,630 --> 01:07:50,240
us to look out of and we knew that and

1768
01:07:54,230 --> 01:07:52,640
we found the same model plane with the

1769
01:07:56,069 --> 01:07:54,240
same hole cut in it

1770
01:07:57,750 --> 01:07:56,079
same size hole cut in it in in the

1771
01:07:58,870 --> 01:07:57,760
states and we fitted everything to that

1772
01:08:00,470 --> 01:07:58,880
and then we took it all apart and took

1773
01:08:02,230 --> 01:08:00,480
it to india it was cheaper to do that

1774
01:08:06,950 --> 01:08:02,240
than it was to fly the plane from the

1775
01:08:12,390 --> 01:08:10,069
and another airplane we use is the er2

1776
01:08:15,029 --> 01:08:12,400
high altitude aircraft research craft

1777
01:08:16,309 --> 01:08:15,039
nasa has two of them they're old u2 spy

1778
01:08:17,910 --> 01:08:16,319
planes that have been converted for

1779
01:08:21,669 --> 01:08:17,920
scientific use

1780
01:08:24,149 --> 01:08:21,679
and this photo was taken from the ground

1781
01:08:25,990 --> 01:08:24,159
old er2 pilots that were you two trained

1782
01:08:27,189 --> 01:08:26,000
back in the day kind of would look on

1783
01:08:28,149 --> 01:08:27,199
these pictures with chagrin because

1784
01:08:30,070 --> 01:08:28,159
you're not supposed to know where they

1785
01:08:31,349 --> 01:08:30,080
are they're a spy plane right but if

1786
01:08:32,870 --> 01:08:31,359
you're the scientist that said i want

1787
01:08:34,950 --> 01:08:32,880
you to fly over this spot at this

1788
01:08:36,470 --> 01:08:34,960

particular time and it better be a clear

1789
01:08:38,070 --> 01:08:36,480
day then you know when to point your

1790
01:08:39,430 --> 01:08:38,080
camera straight up and take a picture

1791
01:08:41,269 --> 01:08:39,440
and that's how we were able to get some

1792
01:08:44,709 --> 01:08:41,279
of these pictures

1793
01:08:46,950 --> 01:08:44,719
and uh this was taken by a researcher at

1794
01:08:49,990 --> 01:08:46,960
kilauea lava lake

1795
01:08:51,510 --> 01:08:50,000
of the er2 and on the er2 was this

1796
01:08:56,550 --> 01:08:51,520
instrument here that we're filling with

1797
01:09:00,709 --> 01:08:58,630
some of the technology we use requires

1798
01:09:02,630 --> 01:09:00,719
low temperatures to operate

1799
01:09:05,269 --> 01:09:02,640
properly and then here's the er2 taking

1800
01:09:07,669 --> 01:09:05,279
off from the palmdale airport just north

1801
01:09:09,590 --> 01:09:07,679
of los angeles it's got these pogos in

1802
01:09:11,669 --> 01:09:09,600
the wings because they're so long when

1803
01:09:14,229 --> 01:09:11,679
they're full of fuel they would drag on

1804
01:09:16,149 --> 01:09:14,239
the ground

1805
01:09:18,950 --> 01:09:16,159
and as it takes off

1806
01:09:20,229 --> 01:09:18,960
those pogos will fall out

1807
01:09:22,789 --> 01:09:20,239
one than the other that's why we're

1808
01:09:25,510 --> 01:09:22,799
chasing the plane to make sure

1809
01:09:27,269 --> 01:09:25,520
we can pick them up and then the pilot

1810
01:09:30,390 --> 01:09:27,279
pulls the stick back

1811
01:09:32,149 --> 01:09:30,400
and uh shoots up to 65 000 feet faster

1812
01:09:32,950 --> 01:09:32,159
than any other plane

1813
01:09:35,269 --> 01:09:32,960

just

1814
01:09:37,269 --> 01:09:35,279
goes

1815
01:09:38,630 --> 01:09:37,279
now this plane actually surfs pressure

1816
01:09:41,510 --> 01:09:38,640
waves at the upper part of the

1817
01:09:45,349 --> 01:09:41,520
stratosphere uh the engine is at full

1818
01:09:47,430 --> 01:09:45,359
out uh at that altitude and at that out

1819
01:09:49,349 --> 01:09:47,440
pressure it has 18 percent of the thrust

1820
01:09:53,669 --> 01:09:49,359
that it does down on the ground give you

1821
01:09:58,070 --> 01:09:55,870
so

1822
01:09:59,669 --> 01:09:58,080
[Music]

1823
01:10:01,430 --> 01:09:59,679
and there's a link on the last slide to

1824
01:10:03,669 --> 01:10:01,440
give a much better report of er2

1825
01:10:04,790 --> 01:10:03,679
operations during our hawaiian campaign

1826
01:10:07,510 --> 01:10:04,800
so here we are looking through the

1827
01:10:09,350 --> 01:10:07,520
targeting periscope the pilot sees

1828
01:10:11,750 --> 01:10:09,360
and this is looking at hawaii volcanoes

1829
01:10:13,669 --> 01:10:11,760
national park and the plume

1830
01:10:14,550 --> 01:10:13,679
on the right hand side of that crater is

1831
01:10:16,709 --> 01:10:14,560
from

1832
01:10:18,950 --> 01:10:16,719
hale

1833
01:10:20,870 --> 01:10:18,960
crater on the right side of kilauea

1834
01:10:26,070 --> 01:10:20,880
crater the larger crater note the

1835
01:10:28,070 --> 01:10:26,080
altimeter down here it says 64 550

1836
01:10:30,950 --> 01:10:28,080
and this photo is by er2 pilot stupe

1837
01:10:32,229 --> 01:10:30,960
roche and it's so cool to work with a

1838
01:10:34,070 --> 01:10:32,239

team

1839
01:10:36,390 --> 01:10:34,080
and and you get a photo like this in

1840
01:10:37,910 --> 01:10:36,400
your email box like right after he lands

1841
01:10:40,229 --> 01:10:37,920
it's like oh look what i did today it's

1842
01:10:42,630 --> 01:10:40,239
so cool right it really validates your

1843
01:10:44,870 --> 01:10:42,640
contribution uh to the overall effort

1844
01:10:45,990 --> 01:10:44,880
and this is another picture that he took

1845
01:10:47,910 --> 01:10:46,000
and sent

1846
01:10:50,070 --> 01:10:47,920
after he landed

1847
01:10:51,350 --> 01:10:50,080
he's so high he can actually you know

1848
01:10:53,590 --> 01:10:51,360
he's right at the boundary of the

1849
01:11:00,070 --> 01:10:53,600
atmosphere so the sky's not blue above

1850
01:11:00,080 --> 01:11:03,110
way too cool

1851
01:11:06,550 --> 01:11:05,030
so here's some links to websites with

1852
01:11:09,350 --> 01:11:06,560
more information about imaging

1853
01:11:10,470 --> 01:11:09,360
spectroscopy at jpl and many of you

1854
01:11:12,630 --> 01:11:10,480
probably

1855
01:11:14,550 --> 01:11:12,640
know that this image was taken by

1856
01:11:17,990 --> 01:11:14,560
astronaut william anders with a chemical

1857
01:11:19,510 --> 01:11:18,000
film camera aboard apollo 8 in 1968

1858
01:11:21,910 --> 01:11:19,520
with the lifeless craters of the moon in

1859
01:11:23,830 --> 01:11:21,920
the foreground this photograph shows our

1860
01:11:25,350 --> 01:11:23,840
finite earth where all of human history

1861
01:11:27,110 --> 01:11:25,360
has happened against the cold

1862
01:11:29,590 --> 01:11:27,120
nothingness of space

1863
01:11:31,510 --> 01:11:29,600

it has become an icon of planetary

1864
01:11:33,590 --> 01:11:31,520
environmental awareness

1865
01:11:35,910 --> 01:11:33,600
and it reminds us of how by exploring

1866
01:11:37,030 --> 01:11:35,920
other planets we learn so much about our

1867
01:11:39,030 --> 01:11:37,040
own

1868
01:11:40,630 --> 01:11:39,040
personally it is fascinating to work

1869
01:11:41,910 --> 01:11:40,640
with people who have a planetary

1870
01:11:43,430 --> 01:11:41,920
perspective

1871
01:11:45,590 --> 01:11:43,440
i've been standing out in the field in

1872
01:11:47,669 --> 01:11:45,600
the middle of nowhere with a researcher

1873
01:11:49,110 --> 01:11:47,679
when they point to the strata in a

1874
01:11:50,870 --> 01:11:49,120
nearby hill and rattle off a

1875
01:11:53,030 --> 01:11:50,880
billion-year story of terrestrial

1876
01:11:55,030 --> 01:11:53,040
geology cosmic events and planetary

1877
01:11:56,950 --> 01:11:55,040
evolution that connects in a deep

1878
01:11:58,790 --> 01:11:56,960
context to the purpose of the campaign

1879
01:12:00,870 --> 01:11:58,800
that brought us together

1880
01:12:02,950 --> 01:12:00,880
my purpose this evening has been to

1881
01:12:05,030 --> 01:12:02,960
share with you my own fascination of the

1882
01:12:07,990 --> 01:12:05,040
science in action that i've been exposed

1883
01:12:10,310 --> 01:12:08,000
to and to illuminate through lecture and

1884
01:12:12,390 --> 01:12:10,320
demonstration a few key points

1885
01:12:14,310 --> 01:12:12,400
jpl studies planets including the most

1886
01:12:15,669 --> 01:12:14,320
important planet in our universe are

1887
01:12:17,750 --> 01:12:15,679
earth

1888
01:12:19,590 --> 01:12:17,760

imaging spectroscopy is a powerful tool

1889
01:12:21,830 --> 01:12:19,600
for studying planets

1890
01:12:23,990 --> 01:12:21,840
imaging spectroscopy is a scientific

1891
01:12:25,830 --> 01:12:24,000
remote sensing tool

1892
01:12:27,189 --> 01:12:25,840
remote sensing is something that nasa

1893
01:12:28,950 --> 01:12:27,199
does best

1894
01:12:31,750 --> 01:12:28,960
and i've had another goal to leave you

1895
01:12:33,750 --> 01:12:31,760
with an appreciation of the philosophy

1896
01:12:36,229 --> 01:12:33,760
and process of the best survival tool

1897
01:12:48,149 --> 01:12:36,239
ever created science thank you for your

1898
01:12:51,510 --> 01:12:49,750
andrew and i would be very pleased to

1899
01:12:52,709 --> 01:12:51,520
entertain questions but if you have a

1900
01:12:55,510 --> 01:12:52,719
question please step up to the

1901
01:12:57,110 --> 01:12:55,520
microphone so everybody online

1902
01:12:59,030 --> 01:12:57,120
and uh out there and the rest of the

1903
01:13:01,510 --> 01:12:59,040
world behind these camera lenses can

1904
01:13:10,630 --> 01:13:01,520
hear your question

1905
01:13:10,640 --> 01:13:19,110
step right on up don't be shy

1906
01:13:19,120 --> 01:13:25,350
don't be shy i'm going to make you stand

1907
01:13:30,950 --> 01:13:28,390
hello um thank you mark and andrew

1908
01:13:33,270 --> 01:13:30,960
that's really cool um i was wondering

1909
01:13:34,229 --> 01:13:33,280
how many avarice rigs do you guys have

1910
01:13:36,550 --> 01:13:34,239
and

1911
01:13:38,229 --> 01:13:36,560
where what's the current status of

1912
01:13:39,750 --> 01:13:38,239
avarice research

1913
01:13:41,350 --> 01:13:39,760

well uh

1914
01:13:43,910 --> 01:13:41,360
adverse rigs

1915
01:13:45,590 --> 01:13:43,920
are um instruments instruments yeah

1916
01:13:47,830 --> 01:13:45,600
right yeah kits

1917
01:13:50,870 --> 01:13:47,840
well uh right now there's a team flying

1918
01:13:52,149 --> 01:13:50,880
the prism uh imaging spectrometer out to

1919
01:13:54,709 --> 01:13:52,159
hawaii and they're going to be flying

1920
01:13:58,830 --> 01:13:54,719
for the next several weeks over hawaii

1921
01:14:06,630 --> 01:14:02,070
avarice uh next generation just finished

1922
01:14:09,510 --> 01:14:06,640
a stint on uh the er2 over um

1923
01:14:12,229 --> 01:14:09,520
the southwest

1924
01:14:14,470 --> 01:14:12,239
uh avarice classic is uh on its way to

1925
01:14:19,350 --> 01:14:14,480
georgia it's going to be flying

1926
01:14:19,360 --> 01:14:23,510
geosynchronous weather satellite

1927
01:14:26,870 --> 01:14:25,030
i calibrate

1928
01:14:28,229 --> 01:14:26,880
the average instruments and so they're

1929
01:14:29,830 --> 01:14:28,239
using my calibrate to calibrate their

1930
01:14:30,950 --> 01:14:29,840
satellite it's really neat

1931
01:14:32,790 --> 01:14:30,960
anyway

1932
01:14:34,470 --> 01:14:32,800
there's actually some uh related

1933
01:14:36,790 --> 01:14:34,480
instruments that we built at jpl that

1934
01:14:38,950 --> 01:14:36,800
are now deployed to other organizations

1935
01:14:40,310 --> 01:14:38,960
so there's a group at stanford that has

1936
01:14:42,550 --> 01:14:40,320
an instrument

1937
01:14:45,590 --> 01:14:42,560
that they fly uh there's also that's the

1938
01:14:47,430 --> 01:14:45,600

carnegie airborne observatory cao they

1939
01:14:49,270 --> 01:14:47,440
have their own website it's fascinating

1940
01:14:51,590 --> 01:14:49,280
because they have a lidar mounted with

1941
01:14:53,990 --> 01:14:51,600
it and they're able to map uh jungles

1942
01:14:56,070 --> 01:14:54,000
and forests and uh they've got these

1943
01:14:57,990 --> 01:14:56,080
really cool videos and i highly

1944
01:15:01,110 --> 01:14:58,000
recommend it carnegie airborne

1945
01:15:03,110 --> 01:15:01,120
observatory that's an ngo basically and

1946
01:15:04,310 --> 01:15:03,120
then we have a there's a neon program as

1947
01:15:05,910 --> 01:15:04,320
well which has

1948
01:15:08,790 --> 01:15:05,920
multiple spectrometers that were built

1949
01:15:10,870 --> 01:15:08,800
by jpl that is also flying to do the

1950
01:15:13,830 --> 01:15:10,880
similar types of work but neon is the

1951
01:15:15,750 --> 01:15:13,840
national ecological observatory network

1952
01:15:18,709 --> 01:15:15,760
they have the mandate to

1953
01:15:21,910 --> 01:15:18,719
measure for the next 30 years changes to

1954
01:15:23,590 --> 01:15:21,920
50 representative environmental types in

1955
01:15:26,149 --> 01:15:23,600
north america

1956
01:15:28,070 --> 01:15:26,159
and their response to climate change

1957
01:15:30,390 --> 01:15:28,080
a very interesting website as well and

1958
01:15:32,229 --> 01:15:30,400
they have a very active airborne program

1959
01:15:34,470 --> 01:15:32,239
and we've made spectrometers for other

1960
01:15:36,229 --> 01:15:34,480
government agencies and that's about all

1961
01:15:38,229 --> 01:15:36,239
we're always looking to make new new

1962
01:15:39,590 --> 01:15:38,239
spectrometers for new applications make

1963
01:15:41,270 --> 01:15:39,600

them smaller

1964
01:15:43,669 --> 01:15:41,280
lighter more efficient better

1965
01:15:44,630 --> 01:15:43,679
signal-to-noise ratio you know better

1966
01:15:46,149 --> 01:15:44,640
better

1967
01:15:48,310 --> 01:15:46,159
and

1968
01:15:49,669 --> 01:15:48,320
it's great but jpl isn't in the business

1969
01:15:51,910 --> 01:15:49,679
of mass producing things we're in the

1970
01:15:58,390 --> 01:15:51,920
business of researching things how to do

1971
01:16:01,350 --> 01:15:59,430
yes sir

1972
01:16:04,070 --> 01:16:01,360
in your section about tracking methane

1973
01:16:05,110 --> 01:16:04,080
plumes over like oil wells and

1974
01:16:06,709 --> 01:16:05,120
what do you

1975
01:16:08,310 --> 01:16:06,719
who requests those

1976
01:16:09,669 --> 01:16:08,320
those measurements and what happens to

1977
01:16:11,590 --> 01:16:09,679
the data after you collect it like do

1978
01:16:14,149 --> 01:16:11,600
you report it somewhere or does the

1979
01:16:16,630 --> 01:16:14,159
repair team come out and fix the leak or

1980
01:16:18,390 --> 01:16:16,640
yeah that's a great question so we have

1981
01:16:20,790 --> 01:16:18,400
multiple flight campaigns i think i'll

1982
01:16:23,110 --> 01:16:20,800
talk mostly about the one we did at four

1983
01:16:25,990 --> 01:16:23,120
corners but that was a nasa funded

1984
01:16:28,070 --> 01:16:26,000
project science based to really focus on

1985
01:16:30,149 --> 01:16:28,080
demonstrating capabilities

1986
01:16:32,630 --> 01:16:30,159
so we had really never demonstrated the

1987
01:16:34,310 --> 01:16:32,640
real-time capability before and we

1988
01:16:36,470 --> 01:16:34,320

targeted that region because we knew

1989
01:16:38,790 --> 01:16:36,480
that we'd have a good uh level of

1990
01:16:41,270 --> 01:16:38,800
success in identifying those plumes so

1991
01:16:42,870 --> 01:16:41,280
that was uh funded uh for really for

1992
01:16:44,229 --> 01:16:42,880
scientific research

1993
01:16:45,590 --> 01:16:44,239
and though in the examples where we did

1994
01:16:47,189 --> 01:16:45,600
find interesting plumes we did

1995
01:16:50,790 --> 01:16:47,199
communicate those

1996
01:16:52,470 --> 01:16:50,800
to as i stated to local um

1997
01:16:54,790 --> 01:16:52,480
operators on the ground

1998
01:16:56,470 --> 01:16:54,800
so for those natural gas pipelines

1999
01:16:59,990 --> 01:16:56,480
courtesy right they actually came out to

2000
01:17:02,390 --> 01:17:00,000
fix one of the things we found yep so

2001
01:17:04,950 --> 01:17:02,400
in that context we view it as a kind of

2002
01:17:07,110 --> 01:17:04,960
a win for everyone it's a win for the

2003
01:17:09,110 --> 01:17:07,120
environment because it's less methane in

2004
01:17:10,790 --> 01:17:09,120
the atmosphere for the oil and gas

2005
01:17:12,870 --> 01:17:10,800
company or for the

2006
01:17:14,870 --> 01:17:12,880
pipeline operator that's lost product

2007
01:17:15,990 --> 01:17:14,880
that if they know about they can do

2008
01:17:17,350 --> 01:17:16,000
something about so they're not losing

2009
01:17:21,270 --> 01:17:17,360
money

2010
01:17:22,709 --> 01:17:21,280
we're also working with other agencies

2011
01:17:24,390 --> 01:17:22,719
and

2012
01:17:26,390 --> 01:17:24,400
you know these are it's a good point to

2013
01:17:27,590 --> 01:17:26,400

bring up so we do have a data sharing

2014
01:17:29,910 --> 01:17:27,600
policy

2015
01:17:31,750 --> 01:17:29,920
where we do have to make data available

2016
01:17:33,189 --> 01:17:31,760
to users including

2017
01:17:34,790 --> 01:17:33,199
the data that we

2018
01:17:36,310 --> 01:17:34,800
measure with our instruments and we we

2019
01:17:38,709 --> 01:17:36,320
do that routinely

2020
01:17:40,149 --> 01:17:38,719
on our websites that are that are

2021
01:17:42,870 --> 01:17:40,159
publicly available

2022
01:17:44,550 --> 01:17:42,880
nasa is a publicly funded agency all of

2023
01:17:45,990 --> 01:17:44,560
the data we collect is publicly

2024
01:17:48,229 --> 01:17:46,000
available you may need to have your own

2025
01:17:51,350 --> 01:17:48,239
super computer to look at it but

2026
01:17:55,910 --> 01:17:51,360
it's publicly available

2027
01:18:01,030 --> 01:17:58,550
oh we have

2028
01:18:02,870 --> 01:18:01,040
questions from the web

2029
01:18:04,630 --> 01:18:02,880
the the connecting network of pipes and

2030
01:18:06,390 --> 01:18:04,640
tubes right

2031
01:18:09,189 --> 01:18:06,400
so z

2032
01:18:10,310 --> 01:18:09,199
halle asks mark

2033
01:18:16,709 --> 01:18:10,320
what is your favorite part of

2034
01:18:20,390 --> 01:18:18,790
i was being literal but seriously blue

2035
01:18:22,070 --> 01:18:20,400
light is very difficult and very

2036
01:18:24,470 --> 01:18:22,080
challenging to deal with and to

2037
01:18:26,229 --> 01:18:24,480
calibrate with because the incandescent

2038
01:18:28,709 --> 01:18:26,239

sources we use in the laboratory are

2039
01:18:30,229 --> 01:18:28,719
blue bereft they just don't put out

2040
01:18:31,750 --> 01:18:30,239
nearly as much blue light as they do

2041
01:18:32,550 --> 01:18:31,760
everything else

2042
01:18:34,070 --> 01:18:32,560
but

2043
01:18:35,510 --> 01:18:34,080
i think

2044
01:18:37,350 --> 01:18:35,520
z mahali

2045
01:18:39,350 --> 01:18:37,360
means this question and perhaps a little

2046
01:18:41,910 --> 01:18:39,360
more generic

2047
01:18:44,390 --> 01:18:41,920
uh spectroscopy has taken me to the

2048
01:18:46,790 --> 01:18:44,400
corners of the earth it's

2049
01:18:48,870 --> 01:18:46,800
helped me meet people i would have never

2050
01:18:50,709 --> 01:18:48,880
had an opportunity to talk to and learn

2051
01:18:51,750 --> 01:18:50,719
from otherwise

2052
01:18:54,630 --> 01:18:51,760
to

2053
01:18:56,070 --> 01:18:54,640
cast my gaze upon the northern lights

2054
01:18:59,669 --> 01:18:56,080
and the

2055
01:19:01,510 --> 01:18:59,679
southern star or the southern cross

2056
01:19:03,590 --> 01:19:01,520
and to

2057
01:19:05,510 --> 01:19:03,600
interact with

2058
01:19:07,189 --> 01:19:05,520
scientific colleagues

2059
01:19:09,350 --> 01:19:07,199
who come from

2060
01:19:11,830 --> 01:19:09,360
wildly different cultures and have

2061
01:19:13,910 --> 01:19:11,840
different perspectives on life but we

2062
01:19:15,750 --> 01:19:13,920
share this one thing you know science in

2063
01:19:18,390 --> 01:19:15,760

common and being able to talk the

2064
01:19:20,149 --> 01:19:18,400
language of science has been has enabled

2065
01:19:22,709 --> 01:19:20,159
me to

2066
01:19:24,630 --> 01:19:22,719
just you know form that bridge uh with

2067
01:19:26,070 --> 01:19:24,640
that real connection with uh people on a

2068
01:19:29,510 --> 01:19:26,080
very deep level

2069
01:19:32,630 --> 01:19:29,520
so um yeah and in short the travel

2070
01:19:36,790 --> 01:19:34,470
yes i have one more question but i will

2071
01:19:40,550 --> 01:19:36,800
take yours first are there other

2072
01:19:43,030 --> 01:19:40,560
applications like uh the radar mapping

2073
01:19:44,630 --> 01:19:43,040
with imaging it's a different you know

2074
01:19:45,830 --> 01:19:44,640
different wavelength different part of

2075
01:19:47,750 --> 01:19:45,840
the spectrum don't know anything about

2076
01:19:48,709 --> 01:19:47,760
it different specs

2077
01:19:50,870 --> 01:19:48,719
and

2078
01:19:54,470 --> 01:19:50,880
i mean if you combine i'm sure that it

2079
01:19:56,870 --> 01:19:54,480
has been done before you combine the

2080
01:19:59,030 --> 01:19:56,880
laser mapping like yes that's actually a

2081
01:20:01,030 --> 01:19:59,040
very powerful way to do remote sensing

2082
01:20:01,830 --> 01:20:01,040
is to combine google mapping started

2083
01:20:04,950 --> 01:20:01,840
with

2084
01:20:06,229 --> 01:20:04,960
ladder mapping well uh yeah you can

2085
01:20:07,350 --> 01:20:06,239
layer up

2086
01:20:11,270 --> 01:20:07,360
the data

2087
01:20:14,550 --> 01:20:11,280
you have the the uh magellan

2088
01:20:16,709 --> 01:20:14,560

the venus reader mapping okay yep

2089
01:20:19,270 --> 01:20:16,719
and saw through the clouds that way

2090
01:20:20,149 --> 01:20:19,280
how do you do or how is that done that

2091
01:20:25,750 --> 01:20:20,159
you

2092
01:20:27,510 --> 01:20:25,760
and onto the uh

2093
01:20:29,510 --> 01:20:27,520
the leather mapping

2094
01:20:33,110 --> 01:20:29,520
what's called geo referencing yeah how

2095
01:20:34,870 --> 01:20:33,120
do you do it well um you can do it by um

2096
01:20:36,149 --> 01:20:34,880
recognizing points that you know where

2097
01:20:37,350 --> 01:20:36,159
they are that's one way to do it and the

2098
01:20:40,310 --> 01:20:37,360
other way to do it is to know the

2099
01:20:41,430 --> 01:20:40,320
geometry of observation very very well

2100
01:20:43,750 --> 01:20:41,440
it's kind of like the idea of what's

2101
01:20:45,830 --> 01:20:43,760
called photogametry you know where your

2102
01:20:47,590 --> 01:20:45,840
camera's pointing and you know where

2103
01:20:49,669 --> 01:20:47,600
every part of the film projects through

2104
01:20:51,830 --> 01:20:49,679
the lens and then hits on the ground so

2105
01:20:53,510 --> 01:20:51,840
when i say pixels it's a digital way of

2106
01:20:55,990 --> 01:20:53,520
thinking of imagery

2107
01:20:57,590 --> 01:20:56,000
we're not actually projecting squares

2108
01:20:58,950 --> 01:20:57,600
like these tiles on the floor on the

2109
01:21:00,470 --> 01:20:58,960
ground it's really just a bunch of

2110
01:21:03,110 --> 01:21:00,480
blurry spots that happen to be

2111
01:21:04,470 --> 01:21:03,120
representable in a pattern like a

2112
01:21:06,229 --> 01:21:04,480
checkerboard

2113
01:21:09,350 --> 01:21:06,239

but

2114
01:21:11,510 --> 01:21:09,360
for precision photogametry and precision

2115
01:21:13,430 --> 01:21:11,520
geo-referencing we know the latitude and

2116
01:21:14,390 --> 01:21:13,440
longitude of each corner of each one of

2117
01:21:16,470 --> 01:21:14,400
those

2118
01:21:18,470 --> 01:21:16,480
imaginary squares that's projected on

2119
01:21:21,270 --> 01:21:18,480
the ground as if we were shining a light

2120
01:21:23,110 --> 01:21:21,280
from the instrument to the ground and if

2121
01:21:25,590 --> 01:21:23,120
you know the latitude longitudes of

2122
01:21:27,590 --> 01:21:25,600
those four corners you know the area

2123
01:21:29,830 --> 01:21:27,600
that you've averaged your measurement

2124
01:21:32,229 --> 01:21:29,840
over and then if you happen to fly over

2125
01:21:33,910 --> 01:21:32,239
again you know how the other pixels line

2126
01:21:35,669 --> 01:21:33,920
up with that and you can do what's

2127
01:21:37,669 --> 01:21:35,679
called change detection which is a very

2128
01:21:39,270 --> 01:21:37,679
sensitive thing to do but it's that

2129
01:21:41,990 --> 01:21:39,280
precision

2130
01:21:45,270 --> 01:21:42,000
registration of your instruments

2131
01:21:47,669 --> 01:21:45,280
geometric uh characteristics how the

2132
01:21:49,750 --> 01:21:47,679
image is warped where everything

2133
01:21:53,590 --> 01:21:49,760
actually hits the ground

2134
01:21:55,750 --> 01:21:53,600
and uh that goes into a a big electronic

2135
01:21:57,350 --> 01:21:55,760
file in a way that it's associated with

2136
01:22:00,229 --> 01:21:57,360
each pixel and then there's there's

2137
01:22:03,189 --> 01:22:00,239
specific uh you know like jpeg or tiff

2138
01:22:06,070 --> 01:22:03,199

or well there's something else called

2139
01:22:08,790 --> 01:22:06,080
a mental block right now but it's a file

2140
01:22:10,709 --> 01:22:08,800
type that has all of that information

2141
01:22:13,110 --> 01:22:10,719
you know not only the wavelength but

2142
01:22:14,870 --> 01:22:13,120
where it was looking on the earth and so

2143
01:22:16,870 --> 01:22:14,880
that's how you line up

2144
01:22:18,870 --> 01:22:16,880
all of those different layers of data

2145
01:22:21,030 --> 01:22:18,880
for interpretation

2146
01:22:22,310 --> 01:22:21,040
but that interpretation sometimes is

2147
01:22:24,149 --> 01:22:22,320
more than just looking at it and

2148
01:22:26,709 --> 01:22:24,159
recognizing something with your eye

2149
01:22:28,390 --> 01:22:26,719
because you know the universe is not a

2150
01:22:30,790 --> 01:22:28,400
human thing right

2151
01:22:33,350 --> 01:22:30,800
and so it's not always recognizable

2152
01:22:35,990 --> 01:22:33,360
easily to a human being what's going on

2153
01:22:38,070 --> 01:22:36,000
and so we program computers with the

2154
01:22:40,229 --> 01:22:38,080
laws of physics to try and understand

2155
01:22:42,070 --> 01:22:40,239
and interpret these things and imagery

2156
01:22:44,149 --> 01:22:42,080
is one of the ways we've evolved to

2157
01:22:46,070 --> 01:22:44,159
understand data and that's how it's

2158
01:22:48,149 --> 01:22:46,080
displayed but that's not necessarily the

2159
01:22:49,590 --> 01:22:48,159
most powerful way it is there is to look

2160
01:22:51,270 --> 01:22:49,600
at it

2161
01:22:54,310 --> 01:22:51,280
and i guess that answers a question

2162
01:22:56,310 --> 01:22:54,320
there are airborne radar systems that

2163
01:22:58,149 --> 01:22:56,320

that more and more folks are using we

2164
01:23:00,390 --> 01:22:58,159
have satellite radar systems we have

2165
01:23:02,229 --> 01:23:00,400
airborne radar systems uh we mentioned

2166
01:23:04,629 --> 01:23:02,239
the lidar system which is an active

2167
01:23:06,550 --> 01:23:04,639
laser pulse that's also used and what we

2168
01:23:08,229 --> 01:23:06,560
like to do is to wherever we can we try

2169
01:23:10,070 --> 01:23:08,239
to do sensor fusion you bring data

2170
01:23:11,110 --> 01:23:10,080
products and measurements together so

2171
01:23:12,950 --> 01:23:11,120
you can answer questions that you

2172
01:23:15,669 --> 01:23:12,960
couldn't necessarily answer only with

2173
01:23:17,510 --> 01:23:15,679
radar only with average next gen only

2174
01:23:18,629 --> 01:23:17,520
with lidar so that's why we're trying to

2175
01:23:20,470 --> 01:23:18,639
bring things together right i've

2176
01:23:22,229 --> 01:23:20,480
concentrated on reflected sunlight but

2177
01:23:23,910 --> 01:23:22,239
there are other ways to do it

2178
01:23:25,750 --> 01:23:23,920
reflective sunlight is passive remote

2179
01:23:27,350 --> 01:23:25,760
sensing there's active remote sensing so

2180
01:23:28,629 --> 01:23:27,360
instead of taking a picture using the

2181
01:23:30,310 --> 01:23:28,639
ambient light in the room take a

2182
01:23:32,310 --> 01:23:30,320
flashlight along with you that's active

2183
01:23:35,669 --> 01:23:32,320
remote sensing right so that could be

2184
01:23:37,270 --> 01:23:35,679
radar that can be a laser lidar

2185
01:23:38,709 --> 01:23:37,280
you can also do remote sensing in the

2186
01:23:40,229 --> 01:23:38,719
thermal part of the spectrum and all

2187
01:23:42,149 --> 01:23:40,239
these layers and the physical

2188
01:23:43,830 --> 01:23:42,159

understanding of where that radiation

2189
01:23:45,590 --> 01:23:43,840
radiation being something that emits

2190
01:23:48,229 --> 01:23:45,600
from a point goes to another point in a

2191
01:23:50,149 --> 01:23:48,239
straight line it radiates right

2192
01:23:52,550 --> 01:23:50,159
understanding the physics of all that

2193
01:23:53,590 --> 01:23:52,560
and the phenomenology of it because

2194
01:23:54,629 --> 01:23:53,600
you're when you're doing a remote

2195
01:23:57,030 --> 01:23:54,639
sensing you're not measuring your

2196
01:23:58,470 --> 01:23:57,040
quantity directly you're measuring some

2197
01:24:00,550 --> 01:23:58,480
indirect effect

2198
01:24:03,189 --> 01:24:00,560
in in the case of reflected sunlight how

2199
01:24:04,709 --> 01:24:03,199
the spectral fingerprint is manifested

2200
01:24:06,550 --> 01:24:04,719
and from that indirect effect you're

2201
01:24:08,470 --> 01:24:06,560
making an estimate

2202
01:24:13,110 --> 01:24:08,480
so that's that's a general view of

2203
01:24:16,470 --> 01:24:14,790
so i have another question and i would

2204
01:24:19,669 --> 01:24:16,480
encourage anybody else to step up to the

2205
01:24:22,149 --> 01:24:19,679
microphone step on up to the microphone

2206
01:24:24,629 --> 01:24:22,159
clayton asks on the internet could we

2207
01:24:27,350 --> 01:24:24,639
use the spectrum of light from an

2208
01:24:30,870 --> 01:24:27,360
exoplanet to detect organic matter boy

2209
01:24:32,870 --> 01:24:30,880
you just asked the right people or would

2210
01:24:35,030 --> 01:24:32,880
the atmosphere block it out not

2211
01:24:37,110 --> 01:24:35,040
necessarily it kind of depends on the

2212
01:24:38,470 --> 01:24:37,120
atmosphere and that's called atmospheric

2213
01:24:41,270 --> 01:24:38,480

correction and if you know what the

2214
01:24:42,310 --> 01:24:41,280
atmosphere is you can correct for that

2215
01:24:45,110 --> 01:24:42,320
but

2216
01:24:46,950 --> 01:24:45,120
there may be an exo moon that doesn't

2217
01:24:48,550 --> 01:24:46,960
have much of an atmosphere that might

2218
01:24:51,189 --> 01:24:48,560
have evidence of life

2219
01:24:53,830 --> 01:24:51,199
leaking out of the cracks in the ice

2220
01:24:55,910 --> 01:24:53,840
europa we know it's blue ice with this

2221
01:24:57,510 --> 01:24:55,920
reddish material coming out of the

2222
01:24:59,910 --> 01:24:57,520
cracks well we sure would like to get

2223
01:25:01,830 --> 01:24:59,920
some spectral detection and there's a

2224
01:25:05,110 --> 01:25:01,840
mission that andrew and i are involved

2225
01:25:06,790 --> 01:25:05,120
with that mice that will is proposed to

2226
01:25:08,390 --> 01:25:06,800
go to europa and make those measurements

2227
01:25:10,830 --> 01:25:08,400
to figure out what that red stuff is and

2228
01:25:13,750 --> 01:25:10,840
if it's organic material but an

2229
01:25:15,990 --> 01:25:13,760
exoplanet um

2230
01:25:17,750 --> 01:25:16,000
the atmosphere block it out

2231
01:25:20,629 --> 01:25:17,760
no there are clear windows in the

2232
01:25:23,270 --> 01:25:20,639
atmosphere uh atmospheres are complex

2233
01:25:24,709 --> 01:25:23,280
and compound things with many spectra

2234
01:25:26,870 --> 01:25:24,719
all put together and teasing those

2235
01:25:29,350 --> 01:25:26,880
spectra apart but some of the spectra

2236
01:25:31,510 --> 01:25:29,360
like the spectrum of water vapor are so

2237
01:25:32,950 --> 01:25:31,520
distinct you just can't miss it and

2238
01:25:39,110 --> 01:25:32,960

that's one of the things we would look

2239
01:25:39,120 --> 01:25:43,189
okay we're all hungry want to go home

2240
01:25:43,199 --> 01:26:04,480
thank you great thanks

2241
01:26:04,490 --> 01:26:26,709
[Music]

2242
01:26:26,719 --> 01:26:38,790
nice

2243
01:26:38,800 --> 01:27:08,709
uh

2244
01:28:02,550 --> 01:27:37,669
um