Curiosity's First Year on Mars

COMING UP
7 pm PDT / 10 pm EDT

Jet Propulsion Laboratory
California Institute of Technology

von Kármán Lecture Series

1
00:00:00,000 --> 00:00:45,670
[Music]

2
00:00:45,680 --> 00:00:49,240
um

3
00:00:49,250 --> 00:01:14,149
[Music]

4
00:01:14,159 --> 00:01:19,150
uh

5
00:01:43,950 --> 00:01:41,670
[Music]

6
00:02:22,550 --> 00:01:43,960
uh

7
00:02:26,070 --> 00:02:24,470
nasa's jet propulsion laboratory

8
00:02:28,710 --> 00:02:26,080
presents

9
00:02:30,710 --> 00:02:28,720
the von carmen lecture a series of talks

10
00:02:34,070 --> 00:02:30,720
by scientists and engineers who are

11
00:02:36,190 --> 00:02:34,080
exploring our planet our solar system

12
00:02:47,750 --> 00:02:36,200
and all that lies beyond

13
00:02:49,830 --> 00:02:47,760

[Music]

14
00:02:52,390 --> 00:02:49,840
good evening my name is sarah marcotte

15
00:02:54,790 --> 00:02:52,400
from the mars public engagement team

16
00:02:57,750 --> 00:02:54,800
curiosity the rover that successfully

17
00:02:59,910 --> 00:02:57,760
landed on mars in early august 2012 has

18
00:03:01,110 --> 00:02:59,920
been busy refining much of what we know

19
00:03:03,830 --> 00:03:01,120
about mars

20
00:03:06,070 --> 00:03:03,840
gale crater has presented the rover with

21
00:03:08,229 --> 00:03:06,080
rich new environments to study such as

22
00:03:09,589 --> 00:03:08,239
ancient stream beds and shifting sand

23
00:03:11,910 --> 00:03:09,599
dunes

24
00:03:13,670 --> 00:03:11,920
with a suite of 10 science instruments

25
00:03:15,750 --> 00:03:13,680
the rover and science team have been

26
00:03:18,070 --> 00:03:15,760
working to reveal the answers to

27
00:03:19,910 --> 00:03:18,080
existing questions while of course

28
00:03:22,309 --> 00:03:19,920
generating new ones

29
00:03:24,630 --> 00:03:22,319
this talk will revisit the successful

30
00:03:26,309 --> 00:03:24,640
landing and reveal some of the results

31
00:03:28,470 --> 00:03:26,319
from the past year of work on the

32
00:03:29,830 --> 00:03:28,480
surface of the red planet

33
00:03:31,910 --> 00:03:29,840
tonight's guest

34
00:03:34,949 --> 00:03:31,920
holds a bachelor of science degree in

35
00:03:37,430 --> 00:03:34,959
geophysics from ucla and a phd in

36
00:03:39,910 --> 00:03:37,440
planetary science from caltech

37
00:03:42,390 --> 00:03:39,920
his research interests include the

38
00:03:44,630 --> 00:03:42,400

climate history of mars the weather on

39
00:03:47,110 --> 00:03:44,640
jupiter and saturn and the possibility

40
00:03:48,390 --> 00:03:47,120
of ice at the poles of our moon and of

41
00:03:50,869 --> 00:03:48,400
mercury

42
00:03:53,350 --> 00:03:50,879
he has participated in the operation and

43
00:03:54,309 --> 00:03:53,360
analysis of data from several nasa

44
00:03:57,429 --> 00:03:54,319
missions

45
00:04:00,149 --> 00:03:57,439
including the mars the lunar excuse me

46
00:04:02,550 --> 00:04:00,159
the lunar reconnaissance orbiter

47
00:04:05,030 --> 00:04:02,560
and the cassini mission to saturn

48
00:04:07,110 --> 00:04:05,040
currently he is a planetary scientist at

49
00:04:09,670 --> 00:04:07,120
the jet propulsion laboratory where he

50
00:04:11,990 --> 00:04:09,680
is deputy project scientist of the mars

51
00:04:15,030 --> 00:04:12,000
science laboratory mission in this

52
00:04:17,590 --> 00:04:15,040
capacity he leads an international team

53
00:04:19,110 --> 00:04:17,600
of over 400 scientists

54
00:04:19,990 --> 00:04:19,120
ladies and gentlemen please help me

55
00:04:34,390 --> 00:04:20,000
welcome

56
00:04:38,790 --> 00:04:36,550
all right well it's wonderful to be here

57
00:04:40,790 --> 00:04:38,800
it has been a wonderful year and a

58
00:04:43,030 --> 00:04:40,800
little bit of an exhausting year

59
00:04:44,870 --> 00:04:43,040
uh honestly but i'll tell you all about

60
00:04:46,870 --> 00:04:44,880
what we've been finding on mars

61
00:04:49,590 --> 00:04:46,880
and uh kind of just walk you through

62
00:04:51,430 --> 00:04:49,600
what the last year has been like for us

63
00:04:53,350 --> 00:04:51,440

starting with the you know wonderful

64
00:04:55,749 --> 00:04:53,360
arrival of the of the curiosity rover at

65
00:04:57,830 --> 00:04:55,759
mars more than a year ago at this point

66
00:04:59,749 --> 00:04:57,840
and then all the scientific scientific

67
00:05:01,510 --> 00:04:59,759
discoveries we made along the way

68
00:05:03,510 --> 00:05:01,520
so i'm looking forward to talking with

69
00:05:06,550 --> 00:05:03,520
you about that but before that i want to

70
00:05:09,350 --> 00:05:06,560
take us all back to august 5th last year

71
00:05:11,350 --> 00:05:09,360
about 10 30 p.m and even the time before

72
00:05:12,950 --> 00:05:11,360
that all the work by so many different

73
00:05:14,710 --> 00:05:12,960
people that went into getting this rover

74
00:05:21,029 --> 00:05:14,720
to mars

75
00:05:37,430 --> 00:05:24,780
you can all watch me do it

76
00:05:43,510 --> 00:05:41,350
that great things take

77
00:05:45,830 --> 00:05:43,520
many people working together to make

78
00:05:48,150 --> 00:05:45,840
them happen is one of the fantastic

79
00:05:49,909 --> 00:05:48,160
things of human existence

80
00:05:51,430 --> 00:05:49,919
not only we've driven the rover we've

81
00:05:53,270 --> 00:05:51,440
moved its arm put it all through its

82
00:05:55,749 --> 00:05:53,280
paces but it's been in a thermal vacuum

83
00:05:57,430 --> 00:05:55,759
chamber and kept very cold parts of it

84
00:05:59,909 --> 00:05:57,440
have been a centrifuge

85
00:06:02,870 --> 00:05:59,919
we've done drop tests pull tests drive

86
00:06:04,469 --> 00:06:02,880
tests load tests stress tests

87
00:06:06,390 --> 00:06:04,479
it's just an amazing amount of testing

88
00:06:07,990 --> 00:06:06,400

this vehicle has gone through we've

89
00:06:09,990 --> 00:06:08,000
tried every way of operating at the

90
00:06:12,469 --> 00:06:10,000
vehicle using the software literally

91
00:06:14,150 --> 00:06:12,479
thousands and thousands of hours of

92
00:06:17,110 --> 00:06:14,160
software testing

93
00:06:19,749 --> 00:06:17,120
it's been just a an amazing several

94
00:06:21,590 --> 00:06:19,759
years really a constant testing and

95
00:06:23,189 --> 00:06:21,600
development finding problems fixing

96
00:06:24,230 --> 00:06:23,199
those problems and going on to the next

97
00:06:28,309 --> 00:06:24,240
problem

98
00:06:33,189 --> 00:06:31,590
lc this is the ld on channel one lc you

99
00:06:35,430 --> 00:06:33,199
have permission to launch

100
00:06:37,110 --> 00:06:35,440
roger we're sitting with the count

101
00:06:42,790 --> 00:06:37,120
t-minus ten

102
00:06:44,790 --> 00:06:43,830
three

103
00:07:01,510 --> 00:06:44,800
two

104
00:07:04,710 --> 00:07:03,110
am i confident that she's going to go

105
00:07:06,150 --> 00:07:04,720
and she's going to be successful

106
00:07:12,629 --> 00:07:06,160
absolutely

107
00:07:17,990 --> 00:07:14,830
we should have parish employee around

108
00:07:19,460 --> 00:07:18,000
1.7 the parachute is deployed

109
00:07:23,029 --> 00:07:19,470
we are decelerating

110
00:07:24,950 --> 00:07:23,039
[Applause]

111
00:07:29,029 --> 00:07:24,960
has separated on the ground

112
00:07:31,909 --> 00:07:30,390
we are in power separation we're an

113
00:07:33,909 --> 00:07:31,919

altitude of one kilometer descending

114
00:07:42,950 --> 00:07:33,919
standing by for sky crane

115
00:07:42,960 --> 00:07:46,260
touchdown confirmed

116
00:07:46,270 --> 00:07:53,400
[Applause]

117
00:08:04,150 --> 00:08:00,790
[Music]

118
00:08:10,150 --> 00:08:06,710
what a fantastic demonstration of what

119
00:08:12,150 --> 00:08:10,160
our nation and our agency can do

120
00:08:14,469 --> 00:08:12,160
i could only think of the words of teddy

121
00:08:16,469 --> 00:08:14,479
roosevelt as i was sitting there

122
00:08:18,869 --> 00:08:16,479
it is far better to their mighty things

123
00:08:20,790 --> 00:08:18,879
even so we might fail

124
00:08:23,430 --> 00:08:20,800
than to stay in the twilight that knows

125
00:08:26,469 --> 00:08:23,440
neither victory nor defeat and the team

126
00:08:28,950 --> 00:08:26,479
brought us victory today

127
00:08:30,710 --> 00:08:28,960
today right now the wheels of curiosity

128
00:08:33,269 --> 00:08:30,720
have begun to blaze the trail for human

129
00:08:34,469 --> 00:08:33,279
footprints on mars this is an amazing

130
00:08:37,269 --> 00:08:34,479
achievement

131
00:08:38,070 --> 00:08:37,279
well today on mars history was made on

132
00:08:40,949 --> 00:08:38,080
earth

133
00:08:43,430 --> 00:08:40,959
the successful landing of curiosity

134
00:08:45,829 --> 00:08:43,440
marks what is really an unprecedented

135
00:08:48,949 --> 00:08:45,839
technological tour de force it will

136
00:08:51,509 --> 00:08:48,959
stand as an american point of pride far

137
00:08:53,750 --> 00:08:51,519
into the future we've got a long mission

138
00:08:55,509 --> 00:08:53,760

ahead of us and and because of that and

139
00:08:57,269 --> 00:08:55,519
the capabilities are over we have this

140
00:08:59,670 --> 00:08:57,279
possibility for just monumental science

141
00:09:01,350 --> 00:08:59,680
accomplishment

142
00:09:03,269 --> 00:09:01,360
within two months the team found an

143
00:09:05,350 --> 00:09:03,279
ancient riverbed evidence of flowing

144
00:09:07,829 --> 00:09:05,360
water we have found a habitable

145
00:09:10,230 --> 00:09:07,839
environment that is so benign and

146
00:09:12,230 --> 00:09:10,240
supportive of life that probably if this

147
00:09:13,750 --> 00:09:12,240
water was around and you had been on the

148
00:09:28,389 --> 00:09:13,760
planet you would have been able to drink

149
00:09:32,470 --> 00:09:30,310
hardest part about giving talks like

150
00:09:36,310 --> 00:09:32,480
this is watching that video and and

151
00:09:38,150 --> 00:09:36,320
being able to speak after it

152
00:09:40,230 --> 00:09:38,160
yeah i i started working on curiosity in

153
00:09:42,470 --> 00:09:40,240
about 2004 and at that time there were

154
00:09:45,269 --> 00:09:42,480
already maybe a few dozen people we then

155
00:09:48,710 --> 00:09:45,279
expanded up to uh over a thousand people

156
00:09:50,389 --> 00:09:48,720
here at jpl and as sarah said over 400

157
00:09:52,389 --> 00:09:50,399
people around the world being science

158
00:09:54,550 --> 00:09:52,399
team members and even hundreds of other

159
00:09:56,389 --> 00:09:54,560
people at different nasa centers and uh

160
00:09:57,910 --> 00:09:56,399
and at other

161
00:09:59,590 --> 00:09:57,920
firms like lockheed martin who helped

162
00:10:00,870 --> 00:09:59,600
make a good part of the spacecraft that

163
00:10:01,750 --> 00:10:00,880

took us to mars

164
00:10:04,550 --> 00:10:01,760
so

165
00:10:09,750 --> 00:10:04,560
if i had to summarize 10 years in two

166
00:10:14,310 --> 00:10:11,190
for the first

167
00:10:16,470 --> 00:10:14,320
several years this was the challenge

168
00:10:18,230 --> 00:10:16,480
i i'm a scientist of course and so i

169
00:10:19,910 --> 00:10:18,240
came here

170
00:10:21,350 --> 00:10:19,920
having mostly spent all my time in

171
00:10:23,269 --> 00:10:21,360
research although i worked with these

172
00:10:25,110 --> 00:10:23,279
beautiful spacecraft like cassini but

173
00:10:26,630 --> 00:10:25,120
never so close to the engineering teams

174
00:10:29,829 --> 00:10:26,640
that build and design and test these

175
00:10:31,350 --> 00:10:29,839
spacecraft and the challenge for msl for

176
00:10:33,670 --> 00:10:31,360
mars science laboratory which we now

177
00:10:35,430 --> 00:10:33,680
call curiosity was to get a one-ton

178
00:10:37,190 --> 00:10:35,440
rover to the surface of mars with the

179
00:10:39,110 --> 00:10:37,200
most sophisticated science payload that

180
00:10:40,710 --> 00:10:39,120
had ever been conceived and do one of

181
00:10:42,949 --> 00:10:40,720
the most ambitious scientific uh

182
00:10:44,790 --> 00:10:42,959
research projects you could imagine

183
00:10:46,550 --> 00:10:44,800
which is to figure out if mars could

184
00:10:48,710 --> 00:10:46,560
have ever supported life

185
00:10:50,710 --> 00:10:48,720
and just getting there was a great part

186
00:10:51,910 --> 00:10:50,720
of the challenge and the engineers

187
00:10:54,550 --> 00:10:51,920
considered all kinds of different

188
00:10:56,550 --> 00:10:54,560

approaches landing on airbags landing

189
00:10:59,030 --> 00:10:56,560
with retro rockets all these different

190
00:11:00,470 --> 00:10:59,040
ways we've landed on planets before and

191
00:11:02,310 --> 00:11:00,480
the most efficient way to deliver this

192
00:11:03,430 --> 00:11:02,320
one-tone rover to mars was this

193
00:11:05,430 --> 00:11:03,440
contraption

194
00:11:07,590 --> 00:11:05,440
and this was the reaction when we told

195
00:11:09,190 --> 00:11:07,600
it to our bosses at nasa headquarters

196
00:11:11,190 --> 00:11:09,200
and this was the reaction every time i

197
00:11:13,750 --> 00:11:11,200
show a video of that in the you know the

198
00:11:15,110 --> 00:11:13,760
last decade to the public and honestly

199
00:11:17,750 --> 00:11:15,120
this was the reaction of a lot of us

200
00:11:19,750 --> 00:11:17,760
here at jpl including the engineers who

201
00:11:21,829 --> 00:11:19,760
designed this on paper

202
00:11:24,389 --> 00:11:21,839
and in all their computer simulations

203
00:11:26,310 --> 00:11:24,399
because a lot of the challenge is that

204
00:11:27,750 --> 00:11:26,320
there's nowhere to test this the first

205
00:11:30,230 --> 00:11:27,760
time this ever

206
00:11:32,550 --> 00:11:30,240
was tested end to end with everything

207
00:11:33,590 --> 00:11:32,560
working together was on august 5th of

208
00:11:35,269 --> 00:11:33,600
last year

209
00:11:43,590 --> 00:11:35,279
and

210
00:11:45,829 --> 00:11:43,600
i mean this is just um

211
00:11:47,509 --> 00:11:45,839
the product of these amazing people who

212
00:11:49,350 --> 00:11:47,519
uh this is the team that that brought

213
00:11:51,590 --> 00:11:49,360

curiosity from earth to mars and then

214
00:11:53,590 --> 00:11:51,600
landed it so you know this talk is

215
00:11:55,030 --> 00:11:53,600
dedicated to them

216
00:11:57,269 --> 00:11:55,040
but i'm a scientist so we're here to

217
00:11:59,269 --> 00:11:57,279
talk about science and uh for the next

218
00:12:00,949 --> 00:11:59,279
hour we'll go through that and we'll

219
00:12:02,470 --> 00:12:00,959
tell you all the things we've done since

220
00:12:04,870 --> 00:12:02,480
this wonderful group people brought us

221
00:12:07,110 --> 00:12:04,880
to mars

222
00:12:08,150 --> 00:12:07,120
here's sort of the the thing that drives

223
00:12:10,550 --> 00:12:08,160
this mission

224
00:12:12,629 --> 00:12:10,560
mars resembles earth in many respects

225
00:12:14,790 --> 00:12:12,639
especially in its early history and in

226
00:12:16,870 --> 00:12:14,800
fact if you look at mars just took you

227
00:12:18,389 --> 00:12:16,880
back three billion years

228
00:12:20,629 --> 00:12:18,399
mars may have looked like this it may

229
00:12:22,550 --> 00:12:20,639
have even had an ocean

230
00:12:23,829 --> 00:12:22,560
for certain it had a thicker atmosphere

231
00:12:25,910 --> 00:12:23,839
we're pretty sure of that now thanks to

232
00:12:27,910 --> 00:12:25,920
curiosity in part

233
00:12:29,430 --> 00:12:27,920
and we have lots of geologic evidence

234
00:12:31,110 --> 00:12:29,440
for rivers flowing on the surface for

235
00:12:34,230 --> 00:12:31,120
lakes

236
00:12:35,990 --> 00:12:34,240
and for a pretty active hydrologic cycle

237
00:12:37,350 --> 00:12:36,000
if all those pieces are in place and

238
00:12:39,670 --> 00:12:37,360

mars was so earth-like of course the

239
00:12:41,030 --> 00:12:39,680
natural question is did mars ever

240
00:12:43,030 --> 00:12:41,040
support life

241
00:12:44,470 --> 00:12:43,040
we've looked for life on mars with

242
00:12:47,670 --> 00:12:44,480
spacecraft before and it's pretty

243
00:12:49,430 --> 00:12:47,680
difficult in fact the more we study life

244
00:12:50,550 --> 00:12:49,440
on earth and how life evolved on earth

245
00:12:52,470 --> 00:12:50,560
it sort of goes in two different

246
00:12:54,230 --> 00:12:52,480
directions on the one hand we keep

247
00:12:55,910 --> 00:12:54,240
discovering more and more

248
00:12:57,590 --> 00:12:55,920
forms of life on earth that can live in

249
00:13:00,230 --> 00:12:57,600
extreme environments which sort of makes

250
00:13:01,509 --> 00:13:00,240
us think why not mars mars is so

251
00:13:03,670 --> 00:13:01,519
earth-like it's just sort of a more

252
00:13:04,949 --> 00:13:03,680
extreme environment than earth but on

253
00:13:07,190 --> 00:13:04,959
the other hand

254
00:13:08,870 --> 00:13:07,200
the more we study evidence of life on

255
00:13:10,389 --> 00:13:08,880
earth and search for it in

256
00:13:12,470 --> 00:13:10,399
billion-year-old three billion year old

257
00:13:14,310 --> 00:13:12,480
rocks on earth the more we realize it's

258
00:13:16,389 --> 00:13:14,320
pretty hard to detect so if you were to

259
00:13:17,670 --> 00:13:16,399
go to mars and pick up a three billion

260
00:13:19,750 --> 00:13:17,680
year old rock

261
00:13:21,110 --> 00:13:19,760
even if you go to canada and pick up a

262
00:13:23,110 --> 00:13:21,120
three billion year old rock when we know

263
00:13:25,030 --> 00:13:23,120

there was microbes all over earth it's

264
00:13:26,710 --> 00:13:25,040
pretty hard to tell life from other

265
00:13:28,710 --> 00:13:26,720
things that look like life once it's

266
00:13:30,870 --> 00:13:28,720
been around and degraded so much

267
00:13:32,710 --> 00:13:30,880
so curiosity chose a different goal was

268
00:13:33,670 --> 00:13:32,720
to ask which was to ask this question

269
00:13:35,829 --> 00:13:33,680
instead

270
00:13:37,350 --> 00:13:35,839
was mars ever a habitable planet it's

271
00:13:39,509 --> 00:13:37,360
more of a tactical problem it's one we

272
00:13:41,030 --> 00:13:39,519
could put our arms around as geologists

273
00:13:42,629 --> 00:13:41,040
on this mission

274
00:13:44,069 --> 00:13:42,639
and even actually working with a lot of

275
00:13:46,069 --> 00:13:44,079
paleontologists

276
00:13:48,389 --> 00:13:46,079
in in the earth community that help us

277
00:13:49,750 --> 00:13:48,399
figure out how to answer this question

278
00:13:51,350 --> 00:13:49,760
so we're not looking for life with this

279
00:13:52,790 --> 00:13:51,360
mission we're looking for

280
00:13:54,790 --> 00:13:52,800
answers to whether mars could have ever

281
00:13:56,310 --> 00:13:54,800
supported life

282
00:13:57,910 --> 00:13:56,320
and that's the goal that nasa gave us

283
00:13:59,189 --> 00:13:57,920
this was sort of the initial

284
00:14:01,509 --> 00:13:59,199
instructions we had from nasa

285
00:14:03,829 --> 00:14:01,519
headquarters back in 2004

286
00:14:06,310 --> 00:14:03,839
curiosity's prime scientific goal is to

287
00:14:08,710 --> 00:14:06,320
explore a local region on mars surface

288
00:14:10,790 --> 00:14:08,720

as a potential habitat for life

289
00:14:12,470 --> 00:14:10,800
and what does it mean to search

290
00:14:14,470 --> 00:14:12,480
something for as a as a potential

291
00:14:15,910 --> 00:14:14,480
habitat for life we can look at a few

292
00:14:17,829 --> 00:14:15,920
different things we can look at its

293
00:14:19,350 --> 00:14:17,839
biological potential

294
00:14:20,470 --> 00:14:19,360
does it have the basic ingredients of

295
00:14:23,910 --> 00:14:20,480
life

296
00:14:25,670 --> 00:14:23,920
such as carbon and water

297
00:14:27,030 --> 00:14:25,680
what about the geology and geochemistry

298
00:14:29,509 --> 00:14:27,040
are there certain environments where we

299
00:14:31,189 --> 00:14:29,519
know that life thrived on early earth

300
00:14:32,710 --> 00:14:31,199
and even thrives today

301
00:14:35,189 --> 00:14:32,720
lakes and places where water

302
00:14:36,870 --> 00:14:35,199
concentrates especially fresh water

303
00:14:38,310 --> 00:14:36,880
we want to study the water and weather

304
00:14:39,750 --> 00:14:38,320
even today mars has water in its

305
00:14:41,990 --> 00:14:39,760
atmosphere but in the past it had these

306
00:14:44,230 --> 00:14:42,000
rivers and lakes and possibly even an

307
00:14:45,509 --> 00:14:44,240
ocean a much more vigorous hydrologic

308
00:14:46,550 --> 00:14:45,519
cycle

309
00:14:48,550 --> 00:14:46,560
and then of course we want to look at

310
00:14:50,150 --> 00:14:48,560
the other side of the equation which is

311
00:14:52,470 --> 00:14:50,160
the hazards to life what would cause

312
00:14:53,829 --> 00:14:52,480
mars not to be a habitable planet so we

313
00:14:55,910 --> 00:14:53,839

have instruments on curiosity that look

314
00:14:56,870 --> 00:14:55,920
at radiation for example ultraviolet

315
00:15:00,949 --> 00:14:56,880
light

316
00:15:03,750 --> 00:15:00,959
as well as high energy atomic radiation

317
00:15:05,269 --> 00:15:03,760
so we outfitted this beast with 10

318
00:15:07,269 --> 00:15:05,279
scientific instruments

319
00:15:08,389 --> 00:15:07,279
that cover all these bases of what i

320
00:15:10,069 --> 00:15:08,399
just described to you and the science

321
00:15:12,310 --> 00:15:10,079
we're trying to do and it took this

322
00:15:13,990 --> 00:15:12,320
giant rover to carry all those

323
00:15:15,990 --> 00:15:14,000
instruments to mars to answer that

324
00:15:17,269 --> 00:15:16,000
breath of questions about habitability

325
00:15:19,670 --> 00:15:17,279
you simply couldn't have done it with a

326
00:15:21,269 --> 00:15:19,680
smaller rover so that was the challenge

327
00:15:22,710 --> 00:15:21,279
scientifically and it turned into the

328
00:15:24,150 --> 00:15:22,720
engineering challenge of landing this

329
00:15:27,350 --> 00:15:24,160
thing on mars

330
00:15:29,030 --> 00:15:27,360
so we have a mast with eyes beautiful hd

331
00:15:31,189 --> 00:15:29,040
color cameras a lot of the pictures

332
00:15:32,389 --> 00:15:31,199
you'll be seeing tonight are from them

333
00:15:33,670 --> 00:15:32,399
we have

334
00:15:35,990 --> 00:15:33,680
an instrument on the top here that

335
00:15:38,230 --> 00:15:36,000
shoots out a laser at rocks and is able

336
00:15:40,069 --> 00:15:38,240
to create little sparks on rocks and

337
00:15:41,590 --> 00:15:40,079
look at the color of those sparks and

338
00:15:43,910 --> 00:15:41,600

the color of those sparks tells you the

339
00:15:46,150 --> 00:15:43,920
composition of those rocks and soils so

340
00:15:48,470 --> 00:15:46,160
from up to 20 feet away we can just zap

341
00:15:50,310 --> 00:15:48,480
rocks and soils and do a quick survey of

342
00:15:51,990 --> 00:15:50,320
what's around us that really helps us to

343
00:15:54,470 --> 00:15:52,000
then zero in on places we want to go

344
00:15:56,949 --> 00:15:54,480
examine more closely we do that with

345
00:15:59,189 --> 00:15:56,959
this seven foot robotic arm

346
00:16:01,430 --> 00:15:59,199
that arm has a what we call a turret at

347
00:16:03,110 --> 00:16:01,440
the end of it which has a microscopic

348
00:16:04,949 --> 00:16:03,120
camera so we can take very close-in

349
00:16:07,030 --> 00:16:04,959
images of a rock or a soil just like a

350
00:16:08,629 --> 00:16:07,040
geologist would do with a magnifying

351
00:16:10,710 --> 00:16:08,639
lens here on earth

352
00:16:13,189 --> 00:16:10,720
we also have a spectrometer at the end

353
00:16:15,110 --> 00:16:13,199
of the arm so we can place a sensor on a

354
00:16:17,269 --> 00:16:15,120
rocker soil get a detailed chemical

355
00:16:18,710 --> 00:16:17,279
reading and if things look

356
00:16:19,670 --> 00:16:18,720
exciting after we've gone that second

357
00:16:20,949 --> 00:16:19,680
step

358
00:16:22,870 --> 00:16:20,959
the real

359
00:16:25,030 --> 00:16:22,880
critical capability that curiosity has

360
00:16:25,990 --> 00:16:25,040
that nothing had before is to actually

361
00:16:27,910 --> 00:16:26,000
sample

362
00:16:30,310 --> 00:16:27,920
the inside of that rock to drill into

363
00:16:31,829 --> 00:16:30,320

the rock gather powder from that rock

364
00:16:34,150 --> 00:16:31,839
and deliver that powder into

365
00:16:35,590 --> 00:16:34,160
laboratories on board the rover so the

366
00:16:37,829 --> 00:16:35,600
entire front end of the rover here and

367
00:16:39,189 --> 00:16:37,839
about a third of the way back

368
00:16:41,350 --> 00:16:39,199
consists of two

369
00:16:43,030 --> 00:16:41,360
state-of-the-art scientific geochemist

370
00:16:46,069 --> 00:16:43,040
geochemical laboratories that we can

371
00:16:47,670 --> 00:16:46,079
deliver samples of rocks and soils into

372
00:16:49,189 --> 00:16:47,680
and then we have even more instruments

373
00:16:51,110 --> 00:16:49,199
and and you know in talks like this i

374
00:16:53,110 --> 00:16:51,120
can't even get through all 10. uh it's a

375
00:16:54,949 --> 00:16:53,120
wonderful payload and here they are

376
00:16:56,710 --> 00:16:54,959
listed but one thing i do want to remind

377
00:16:59,670 --> 00:16:56,720
you is that before we were called

378
00:17:02,310 --> 00:16:59,680
curiosity uh as a you know a naming

379
00:17:04,630 --> 00:17:02,320
contest that clara ma a sixth grader

380
00:17:06,390 --> 00:17:04,640
from kansas won and named us curiosity

381
00:17:08,150 --> 00:17:06,400
we were formally known

382
00:17:09,350 --> 00:17:08,160
as the mars science laboratory and

383
00:17:11,189 --> 00:17:09,360
that's because

384
00:17:12,870 --> 00:17:11,199
as i mentioned we have these wonderful

385
00:17:14,549 --> 00:17:12,880
scientific lab instruments in the front

386
00:17:15,990 --> 00:17:14,559
end of the rover this is how big they

387
00:17:18,150 --> 00:17:16,000
are

388
00:17:20,470 --> 00:17:18,160

that one is a size of an old 1970s

389
00:17:22,549 --> 00:17:20,480
microwave oven it's a very sophisticated

390
00:17:24,069 --> 00:17:22,559
mass spectrometer and tunable laser

391
00:17:26,549 --> 00:17:24,079
spectrometer and i'll talk a little

392
00:17:28,710 --> 00:17:26,559
about what it does and this one which is

393
00:17:30,870 --> 00:17:28,720
out is a is a sort of a field instrument

394
00:17:32,390 --> 00:17:30,880
that one of our principal investigators

395
00:17:34,150 --> 00:17:32,400
is carrying around is called an x-ray

396
00:17:35,590 --> 00:17:34,160
diffraction experiment it's the

397
00:17:37,029 --> 00:17:35,600
state-of-the-art way a geologist

398
00:17:39,750 --> 00:17:37,039
determines what minerals are present

399
00:17:42,470 --> 00:17:39,760
even on earth so we took this instrument

400
00:17:44,070 --> 00:17:42,480
and put it on the rover and we took

401
00:17:46,710 --> 00:17:44,080
what usually fills up an entire

402
00:17:48,150 --> 00:17:46,720
laboratory at a university

403
00:17:50,070 --> 00:17:48,160
compressed it down to the size of this

404
00:17:51,270 --> 00:17:50,080
box put a little gold plating on the

405
00:17:54,470 --> 00:17:51,280
side to make sure you know it's

406
00:17:57,270 --> 00:17:55,510
and then we

407
00:17:58,870 --> 00:17:57,280
put it inside the rover

408
00:18:00,870 --> 00:17:58,880
but before we

409
00:18:03,350 --> 00:18:00,880
can answer all these wonderful questions

410
00:18:04,789 --> 00:18:03,360
you have to ask where do you go that's

411
00:18:06,870 --> 00:18:04,799
another challenge of missions like this

412
00:18:09,270 --> 00:18:06,880
you only get to want to go to one spot

413
00:18:11,270 --> 00:18:09,280

if you had to tell your alien friend

414
00:18:13,029 --> 00:18:11,280
where you'd go on earth to figure out

415
00:18:15,350 --> 00:18:13,039
everything you want to know about earth

416
00:18:17,190 --> 00:18:15,360
or ancient earth life or how we got to

417
00:18:18,630 --> 00:18:17,200
be here you know would you go to the

418
00:18:20,390 --> 00:18:18,640
mahvi desert would you go to canada

419
00:18:22,070 --> 00:18:20,400
would you go to the middle of the ocean

420
00:18:24,230 --> 00:18:22,080
we have to search all of mars to find

421
00:18:25,750 --> 00:18:24,240
that one spot where we can send this

422
00:18:27,590 --> 00:18:25,760
multi-billion dollar

423
00:18:28,549 --> 00:18:27,600
10-year effort

424
00:18:30,390 --> 00:18:28,559
too

425
00:18:32,310 --> 00:18:30,400
so we did that we spent about five years

426
00:18:34,070 --> 00:18:32,320
scouring mars to find the perfect

427
00:18:35,990 --> 00:18:34,080
landing site involving hundreds of

428
00:18:38,390 --> 00:18:36,000
scientists around the world meeting in

429
00:18:40,549 --> 00:18:38,400
hotel ballrooms for once a year for five

430
00:18:42,630 --> 00:18:40,559
years hashing it out it was it was

431
00:18:44,070 --> 00:18:42,640
pretty fun arguments at times but it was

432
00:18:46,150 --> 00:18:44,080
good

433
00:18:48,070 --> 00:18:46,160
and here's the one we chose it's called

434
00:18:50,630 --> 00:18:48,080
gale crater

435
00:18:52,950 --> 00:18:50,640
it's an impact crater so a long time ago

436
00:18:56,470 --> 00:18:52,960
something huge hit mars and and tore

437
00:18:58,870 --> 00:18:56,480
this 150 kilometer hole in the ground it

438
00:19:01,190 --> 00:18:58,880

then later filled up with sediment

439
00:19:02,950 --> 00:19:01,200
something probably wind or water

440
00:19:04,630 --> 00:19:02,960
filled the whole crater up

441
00:19:06,230 --> 00:19:04,640
and we don't know how that happened but

442
00:19:07,990 --> 00:19:06,240
that just tells you mars has had a

443
00:19:09,909 --> 00:19:08,000
pretty vigorous history and we're just

444
00:19:11,830 --> 00:19:09,919
seeing the remnants of it today but this

445
00:19:14,230 --> 00:19:11,840
whole crater which is about five

446
00:19:16,150 --> 00:19:14,240
kilometers deep three miles deep filled

447
00:19:17,909 --> 00:19:16,160
up completely and then something else

448
00:19:19,430 --> 00:19:17,919
over another hundreds of millions

449
00:19:21,990 --> 00:19:19,440
billion years

450
00:19:23,750 --> 00:19:22,000
eroded a lot of that sediment away

451
00:19:25,830 --> 00:19:23,760
leaving this central mountain in the

452
00:19:27,909 --> 00:19:25,840
middle of it and we know it formed that

453
00:19:30,230 --> 00:19:27,919
way and it's not a volcano and it's not

454
00:19:32,150 --> 00:19:30,240
um some other uh

455
00:19:34,230 --> 00:19:32,160
process because when we look at it with

456
00:19:36,150 --> 00:19:34,240
some of our cameras from orbit we

457
00:19:39,110 --> 00:19:36,160
realize the whole mountain is made up of

458
00:19:41,190 --> 00:19:39,120
rock layers basically flat rock layers

459
00:19:42,950 --> 00:19:41,200
this is what really drew us to the site

460
00:19:44,710 --> 00:19:42,960
if you're a geologist on earth you love

461
00:19:47,750 --> 00:19:44,720
layered rock like the grand canyon

462
00:19:50,710 --> 00:19:47,760
because layered rock is a record of time

463
00:19:52,710 --> 00:19:50,720

the older layers are known to form first

464
00:19:54,310 --> 00:19:52,720
unless something really catastrophic

465
00:19:56,789 --> 00:19:54,320
turned it all upside down

466
00:19:58,630 --> 00:19:56,799
not on mars probably and then the as you

467
00:20:00,870 --> 00:19:58,640
go up and up you get younger and younger

468
00:20:02,630 --> 00:20:00,880
in history and uh

469
00:20:04,070 --> 00:20:02,640
what made this attractive was the

470
00:20:05,909 --> 00:20:04,080
discovery that this mountain was made of

471
00:20:08,150 --> 00:20:05,919
layers what made it even more attractive

472
00:20:08,950 --> 00:20:08,160
and really into a winner was two other

473
00:20:10,870 --> 00:20:08,960
things

474
00:20:13,430 --> 00:20:10,880
the first is when we looked at the rock

475
00:20:16,549 --> 00:20:13,440
layers from orbit we found that they not

476
00:20:19,430 --> 00:20:16,559
only vary in their texture and color

477
00:20:21,590 --> 00:20:19,440
they vary in their mineral composition

478
00:20:23,510 --> 00:20:21,600
the bottom layers are made out of clays

479
00:20:26,470 --> 00:20:23,520
here we're looking at this layer here

480
00:20:27,990 --> 00:20:26,480
and then as you go up the mountain

481
00:20:30,310 --> 00:20:28,000
there's layers made out of a mineral

482
00:20:32,149 --> 00:20:30,320
called the sulfate

483
00:20:34,950 --> 00:20:32,159
now to make a long story short when we

484
00:20:37,350 --> 00:20:34,960
think it was a lot wet around mars when

485
00:20:39,750 --> 00:20:37,360
a lot of fresh water interacts with the

486
00:20:42,630 --> 00:20:39,760
kind of primary rocks on mars you would

487
00:20:44,710 --> 00:20:42,640
expect clays to form just like on hawaii

488
00:20:47,190 --> 00:20:44,720

a volcano erupts you get that nice fresh

489
00:20:49,350 --> 00:20:47,200
black lava over time it turns into clay

490
00:20:51,029 --> 00:20:49,360
soil that same thing would be expected

491
00:20:53,830 --> 00:20:51,039
to happen when mars was a lot more like

492
00:20:55,830 --> 00:20:53,840
earth as the water was drying up on mars

493
00:20:57,190 --> 00:20:55,840
and disappearing you get a little bit

494
00:20:59,669 --> 00:20:57,200
more

495
00:21:00,950 --> 00:20:59,679
dissolved things in the water volcanoes

496
00:21:03,830 --> 00:21:00,960
are going off putting sulfur in the

497
00:21:06,070 --> 00:21:03,840
atmosphere and you might get sulfates

498
00:21:08,870 --> 00:21:06,080
and then the entire upper half of this

499
00:21:10,470 --> 00:21:08,880
mountain is made up of just boring mars

500
00:21:12,070 --> 00:21:10,480
dust

501
00:21:14,310 --> 00:21:12,080
the unique thing about that is it really

502
00:21:15,110 --> 00:21:14,320
fits what we think mars entire history

503
00:21:17,510 --> 00:21:15,120
was

504
00:21:19,830 --> 00:21:17,520
we think that the earliest time had a

505
00:21:21,750 --> 00:21:19,840
lot of this fresh water around

506
00:21:23,590 --> 00:21:21,760
although we weren't sure of it

507
00:21:25,029 --> 00:21:23,600
then we think mars transitioned to where

508
00:21:27,029 --> 00:21:25,039
the water was being lost and a lot of

509
00:21:29,110 --> 00:21:27,039
sulfates should have been forming as the

510
00:21:31,909 --> 00:21:29,120
water would evaporate

511
00:21:35,750 --> 00:21:31,919
and then the most recent half of mars

512
00:21:37,350 --> 00:21:35,760
history is just a desert cold planet and

513
00:21:40,789 --> 00:21:37,360

all it's doing is wind blowing around

514
00:21:42,230 --> 00:21:40,799
eroding rocks and creating dust

515
00:21:44,710 --> 00:21:42,240
so

516
00:21:48,230 --> 00:21:44,720
this mountain may contain

517
00:21:50,230 --> 00:21:48,240
the entire geologic story of mars and if

518
00:21:52,070 --> 00:21:50,240
we can climb it if we can drive over to

519
00:21:54,390 --> 00:21:52,080
it check out those bottom layers which

520
00:21:55,909 --> 00:21:54,400
may be the oldest history of mars

521
00:21:57,830 --> 00:21:55,919
drive up through the sulfates look at

522
00:22:00,789 --> 00:21:57,840
the water being lost and then get to the

523
00:22:03,110 --> 00:22:00,799
dusty layer about halfway up we can

524
00:22:05,190 --> 00:22:03,120
hopefully really piece together for the

525
00:22:07,110 --> 00:22:05,200
first time in a really solid way the

526
00:22:10,549 --> 00:22:07,120
entire geologic and environmental

527
00:22:11,750 --> 00:22:10,559
history of mars so it's a cool site

528
00:22:14,149 --> 00:22:11,760
the next thing we discovered though

529
00:22:15,350 --> 00:22:14,159
which is just sort of fortuitous is that

530
00:22:16,870 --> 00:22:15,360
there's a river

531
00:22:19,190 --> 00:22:16,880
coming down the crater wall and

532
00:22:21,190 --> 00:22:19,200
spreading material across the floor it's

533
00:22:23,110 --> 00:22:21,200
all dried up now probably has been for a

534
00:22:24,630 --> 00:22:23,120
couple billion years but at some point

535
00:22:26,789 --> 00:22:24,640
there was a river flowing and and

536
00:22:28,950 --> 00:22:26,799
creating a little fan across the floor

537
00:22:31,029 --> 00:22:28,960
and it turned out the best place to land

538
00:22:32,549 --> 00:22:31,039

since we can't land on the mountain

539
00:22:34,149 --> 00:22:32,559
we have to land we have to find a place

540
00:22:35,110 --> 00:22:34,159
that's relatively flat about that big to

541
00:22:37,350 --> 00:22:35,120
land in

542
00:22:39,669 --> 00:22:37,360
and we found that the best place to land

543
00:22:41,110 --> 00:22:39,679
was just right on top of this fan

544
00:22:42,870 --> 00:22:41,120
so even if

545
00:22:44,549 --> 00:22:42,880
the mountain turned out to form in a

546
00:22:47,590 --> 00:22:44,559
different way and sort of our hypothesis

547
00:22:49,350 --> 00:22:47,600
didn't work out we knew we had a chance

548
00:22:50,470 --> 00:22:49,360
of being near a feature that did form in

549
00:22:52,230 --> 00:22:50,480
water

550
00:22:54,390 --> 00:22:52,240
and so this just made a great site for

551
00:22:58,710 --> 00:22:54,400
us

552
00:22:59,830 --> 00:22:58,720
this is a the set movie that we took

553
00:23:01,510 --> 00:22:59,840
with one of our

554
00:23:03,350 --> 00:23:01,520
cameras that's mounted looking down on

555
00:23:04,870 --> 00:23:03,360
the rover so this is now when the rover

556
00:23:06,310 --> 00:23:04,880
was hanging

557
00:23:08,390 --> 00:23:06,320
actually was

558
00:23:10,070 --> 00:23:08,400
inside with the rockets firing and

559
00:23:12,710 --> 00:23:10,080
flying down to the surface

560
00:23:15,270 --> 00:23:12,720
uh and the the heat shield separated and

561
00:23:17,350 --> 00:23:15,280
fell down to mars this heat shield took

562
00:23:18,789 --> 00:23:17,360
us from space into mars atmosphere when

563
00:23:20,310 --> 00:23:18,799

it gets really hot and you have to burn

564
00:23:22,310 --> 00:23:20,320
off a lot of friction

565
00:23:23,669 --> 00:23:22,320
we got rid of it once we got inside mars

566
00:23:26,549 --> 00:23:23,679
atmosphere and this is a frame of the

567
00:23:28,230 --> 00:23:26,559
movie that is taken as it's falling away

568
00:23:30,470 --> 00:23:28,240
and just like hollywood uh have you ever

569
00:23:31,750 --> 00:23:30,480
seen like uh when your photographers

570
00:23:33,270 --> 00:23:31,760
have to have that little

571
00:23:34,710 --> 00:23:33,280
white balance card

572
00:23:36,630 --> 00:23:34,720
uh to make sure the colors come out

573
00:23:38,310 --> 00:23:36,640
right we were filming a movie on mars

574
00:23:39,510 --> 00:23:38,320
and this piece of cloth here was there

575
00:23:42,470 --> 00:23:39,520
to make sure we understood the white

576
00:23:46,789 --> 00:23:44,390
true story

577
00:23:48,870 --> 00:23:46,799
okay and then this is a i just took this

578
00:23:50,390 --> 00:23:48,880
other frame from the movie because it's

579
00:23:51,750 --> 00:23:50,400
to me it brings back all these memories

580
00:23:53,669 --> 00:23:51,760
when i was a kid watching the apollo

581
00:23:56,390 --> 00:23:53,679
landings i didn't watch them but when i

582
00:24:00,470 --> 00:23:56,400
was later a kid you know

583
00:24:04,870 --> 00:24:02,070
i mean i watched those movies so many

584
00:24:06,390 --> 00:24:04,880
times on you know as i was growing up

585
00:24:08,789 --> 00:24:06,400
and this just reminds me of those final

586
00:24:10,390 --> 00:24:08,799
moments as they were landing on the moon

587
00:24:12,870 --> 00:24:10,400
we had our own moment like that last

588
00:24:14,470 --> 00:24:12,880

august this is uh i think the second

589
00:24:15,590 --> 00:24:14,480
picture the curiosity gap back from the

590
00:24:17,909 --> 00:24:15,600
surface

591
00:24:19,990 --> 00:24:17,919
and this is the words that my friend

592
00:24:21,990 --> 00:24:20,000
alan chen said as he called the landing

593
00:24:23,430 --> 00:24:22,000
on the movie that you just saw he said

594
00:24:25,110 --> 00:24:23,440
touchdown confirmed let's see where

595
00:24:27,269 --> 00:24:25,120
curiosity will take us

596
00:24:29,110 --> 00:24:27,279
and i love this picture because it kind

597
00:24:31,669 --> 00:24:29,120
of set the tone for the whole mission we

598
00:24:33,590 --> 00:24:31,679
count ourselves very fortunate of course

599
00:24:35,750 --> 00:24:33,600
for how everything had turned out

600
00:24:37,590 --> 00:24:35,760
and what one of those things where we

601
00:24:39,669 --> 00:24:37,600
got the feeling that

602
00:24:41,830 --> 00:24:39,679
it was going to be a pretty cool year uh

603
00:24:44,070 --> 00:24:41,840
was this when this picture came down we

604
00:24:45,350 --> 00:24:44,080
had no control over which way we landed

605
00:24:46,710 --> 00:24:45,360
on mars

606
00:24:49,110 --> 00:24:46,720
and of course we didn't really plan any

607
00:24:50,870 --> 00:24:49,120
of this but we got the picture we saw

608
00:24:52,149 --> 00:24:50,880
mount sharp in the background here this

609
00:24:54,310 --> 00:24:52,159
this mountain in the middle of crater

610
00:24:56,789 --> 00:24:54,320
our ultimate target got this beautiful

611
00:24:59,669 --> 00:24:56,799
shadow of the rover it just couldn't set

612
00:25:05,269 --> 00:25:02,549
afterwards we took some uh a couple days

613
00:25:07,350 --> 00:25:05,279

to deploy our mast which has the cameras

614
00:25:08,230 --> 00:25:07,360
on it we landed with it fastened to the

615
00:25:09,669 --> 00:25:08,240
deck

616
00:25:11,430 --> 00:25:09,679
so it was a big moment for us when we

617
00:25:13,269 --> 00:25:11,440
saw that the mast had deployed and our

618
00:25:14,630 --> 00:25:13,279
cameras started taking these beautiful

619
00:25:16,390 --> 00:25:14,640
color pictures

620
00:25:18,310 --> 00:25:16,400
and this is mount sharp in color now you

621
00:25:20,710 --> 00:25:18,320
can see the dusty layer the clays and

622
00:25:23,029 --> 00:25:20,720
sulfates are in here and the black line

623
00:25:25,430 --> 00:25:23,039
is some dark sand dunes that sort of

624
00:25:27,510 --> 00:25:25,440
encircle the mountain

625
00:25:29,190 --> 00:25:27,520
what we noticed though after landing and

626
00:25:31,430 --> 00:25:29,200
again we had never landed of course with

627
00:25:33,830 --> 00:25:31,440
this system before so it was sort of new

628
00:25:36,710 --> 00:25:33,840
is that the rocket engines even though

629
00:25:38,230 --> 00:25:36,720
they were some 40 feet off the ground

630
00:25:40,230 --> 00:25:38,240
picked up a lot of this gravel and

631
00:25:41,990 --> 00:25:40,240
created a couple marks on either side of

632
00:25:43,750 --> 00:25:42,000
the rover so two engines firing on

633
00:25:46,070 --> 00:25:43,760
either side and they created what we

634
00:25:47,909 --> 00:25:46,080
call these scour marks

635
00:25:49,269 --> 00:25:47,919
and so we of course as scientists the

636
00:25:51,750 --> 00:25:49,279
first thing people wanted to do was go

637
00:25:52,710 --> 00:25:51,760
check those things out

638
00:25:56,070 --> 00:25:52,720

and so

639
00:25:58,149 --> 00:25:56,080
we did we took some telephoto images we

640
00:25:59,669 --> 00:25:58,159
weren't quite comfortable deploying the

641
00:26:01,590 --> 00:25:59,679
arm yet or doing any of our advanced

642
00:26:03,190 --> 00:26:01,600
capabilities just a few weeks after

643
00:26:04,149 --> 00:26:03,200
landing so we took some high-res

644
00:26:06,070 --> 00:26:04,159
pictures

645
00:26:07,510 --> 00:26:06,080
and then just kind of moved on but these

646
00:26:09,750 --> 00:26:07,520
pictures were pretty interesting because

647
00:26:11,909 --> 00:26:09,760
they revealed that the gravel that we

648
00:26:13,510 --> 00:26:11,919
landed on didn't go very deep in fact

649
00:26:15,990 --> 00:26:13,520
only a couple centimeters below where we

650
00:26:17,750 --> 00:26:16,000
landed there was bedrock

651
00:26:19,430 --> 00:26:17,760
it was strange looking bedrock we sort

652
00:26:21,029 --> 00:26:19,440
of puzzled over this

653
00:26:23,590 --> 00:26:21,039
but kind of didn't know what we were

654
00:26:25,110 --> 00:26:23,600
looking at really so we moved on

655
00:26:25,990 --> 00:26:25,120
but you know you can see that it looks

656
00:26:27,190 --> 00:26:26,000
like

657
00:26:29,350 --> 00:26:27,200
a bunch of

658
00:26:30,710 --> 00:26:29,360
different rocks kind of stuck together

659
00:26:33,269 --> 00:26:30,720
doesn't look like a massive piece of

660
00:26:35,190 --> 00:26:33,279
bedrock so those little puzzling

661
00:26:37,830 --> 00:26:35,200
but then we got out of there

662
00:26:39,029 --> 00:26:37,840
and this is a map now looking down from

663
00:26:40,630 --> 00:26:39,039

space

664
00:26:42,789 --> 00:26:40,640
bradbury landing is named after ray

665
00:26:44,549 --> 00:26:42,799
bradbury we we dedicated the landing

666
00:26:47,909 --> 00:26:44,559
site to him

667
00:26:49,830 --> 00:26:47,919
and we the rocket engines blew dust off

668
00:26:51,190 --> 00:26:49,840
of a whole area about 100 meters on

669
00:26:53,190 --> 00:26:51,200
either side of the

670
00:26:55,269 --> 00:26:53,200
of the rover so we kind of cleaned off

671
00:26:56,470 --> 00:26:55,279
mars temporarily i'm sure it's dusty

672
00:26:58,310 --> 00:26:56,480
again

673
00:26:59,750 --> 00:26:58,320
and then we drove out of there and and

674
00:27:01,269 --> 00:26:59,760
we decided

675
00:27:03,669 --> 00:27:01,279
well here's the here's the funny thing

676
00:27:06,390 --> 00:27:03,679
mount sharp is this way

677
00:27:07,669 --> 00:27:06,400
so why do we drive that way

678
00:27:09,909 --> 00:27:07,679
good question

679
00:27:11,669 --> 00:27:09,919
so we drove that way because

680
00:27:13,350 --> 00:27:11,679
remember that fan i told you about the

681
00:27:14,950 --> 00:27:13,360
river coming down spreading material

682
00:27:16,390 --> 00:27:14,960
across the crater floor

683
00:27:18,789 --> 00:27:16,400
we really wanted to go see what that was

684
00:27:22,149 --> 00:27:18,799
about and it turns out we landed just

685
00:27:24,710 --> 00:27:22,159
off of it maybe about 400 meters away

686
00:27:26,149 --> 00:27:24,720
from the edge of that fan material and

687
00:27:28,070 --> 00:27:26,159
so we thought hey you know let's go

688
00:27:29,990 --> 00:27:28,080

check that out i think we were up here

689
00:27:31,590 --> 00:27:30,000
in in von carmen giving a press

690
00:27:33,909 --> 00:27:31,600
conference we said

691
00:27:35,830 --> 00:27:33,919
my the project scientist who i who i

692
00:27:37,350 --> 00:27:35,840
work with he said you know well we'll go

693
00:27:38,950 --> 00:27:37,360
check this out the team wants to go see

694
00:27:41,190 --> 00:27:38,960
what this fan material is about and

695
00:27:42,390 --> 00:27:41,200
we'll turn around by around christmas

696
00:27:43,990 --> 00:27:42,400
and this was august you know and i

697
00:27:45,510 --> 00:27:44,000
thought christmas you got to be kidding

698
00:27:47,830 --> 00:27:45,520
me i would just go over there for two

699
00:27:52,149 --> 00:27:47,840
weeks and you know turn around

700
00:27:57,909 --> 00:27:55,269
so yeah um but you'll see why

701
00:27:59,430 --> 00:27:57,919
uh so we drove the wrong direction

702
00:28:01,669 --> 00:27:59,440
and we drove over to this place where

703
00:28:03,029 --> 00:28:01,679
this fan material comes down and it

704
00:28:04,710 --> 00:28:03,039
turned out we found a place where three

705
00:28:05,990 --> 00:28:04,720
different trains all come together the

706
00:28:07,269 --> 00:28:06,000
fan material which we call this

707
00:28:09,110 --> 00:28:07,279
fractured unit

708
00:28:10,950 --> 00:28:09,120
uh the the material we landed on this

709
00:28:12,149 --> 00:28:10,960
gravelly hummucky unit helmets are just

710
00:28:13,750 --> 00:28:12,159
kind of hills

711
00:28:15,510 --> 00:28:13,760
and then this cratered unit there's a

712
00:28:17,510 --> 00:28:15,520
lot more craters here meaning for some

713
00:28:19,510 --> 00:28:17,520

reason that little patchy ground is

714
00:28:21,750 --> 00:28:19,520
older than the rest and has had more

715
00:28:23,430 --> 00:28:21,760
time to collect craters

716
00:28:25,510 --> 00:28:23,440
or at least has not had them wiped away

717
00:28:26,870 --> 00:28:25,520
by some other process so we drove over

718
00:28:27,990 --> 00:28:26,880
there and it took

719
00:28:29,830 --> 00:28:28,000
a few months

720
00:28:31,350 --> 00:28:29,840
to get over there because we stopped a

721
00:28:33,750 --> 00:28:31,360
few times on the way to test different

722
00:28:35,669 --> 00:28:33,760
things out this is a very complex rover

723
00:28:37,669 --> 00:28:35,679
so we actually had planned

724
00:28:39,590 --> 00:28:37,679
sort of uh breaks in the science

725
00:28:41,430 --> 00:28:39,600
campaign where we would stop for two

726
00:28:44,070 --> 00:28:41,440
weeks test the arm out stop for two

727
00:28:46,149 --> 00:28:44,080
weeks test the scooping out stop for a

728
00:28:48,070 --> 00:28:46,159
month test the drill out so it kind of

729
00:28:49,430 --> 00:28:48,080
extended things and we got over there by

730
00:28:53,590 --> 00:28:49,440
about

731
00:28:55,510 --> 00:28:53,600
three months into the mission

732
00:28:57,350 --> 00:28:55,520
along the way though we started seeing

733
00:28:59,830 --> 00:28:57,360
more of this stuff

734
00:29:01,430 --> 00:28:59,840
we started seeing more slabs now this

735
00:29:03,669 --> 00:29:01,440
wasn't even buried this was just sort of

736
00:29:05,750 --> 00:29:03,679
sticking up we were driving we took some

737
00:29:07,590 --> 00:29:05,760
pictures one day and here was this thing

738
00:29:09,190 --> 00:29:07,600

coming out of the gravelly ground that

739
00:29:12,870 --> 00:29:09,200
looks you know looks a lot like a

740
00:29:15,110 --> 00:29:12,880
sidewalk you know broken sidewalk um

741
00:29:17,830 --> 00:29:15,120
there's no trees there's no bad you know

742
00:29:18,549 --> 00:29:17,840
city maintenance around here

743
00:29:20,070 --> 00:29:18,559
but

744
00:29:21,350 --> 00:29:20,080
it was very exciting because now we

745
00:29:23,590 --> 00:29:21,360
could sort of see

746
00:29:26,310 --> 00:29:23,600
in cross section you know

747
00:29:28,549 --> 00:29:26,320
what the the stuff we saw exposed by the

748
00:29:31,110 --> 00:29:28,559
landing engines we looked at in detail

749
00:29:33,110 --> 00:29:31,120
it's a rock made up of a lot of other

750
00:29:35,269 --> 00:29:33,120
rocks and geologists call this a

751
00:29:37,029 --> 00:29:35,279
conglomerate when rock a rock made up of

752
00:29:38,230 --> 00:29:37,039
a bunch of smaller rocks cemented

753
00:29:39,830 --> 00:29:38,240
together

754
00:29:42,149 --> 00:29:39,840
and what's even more

755
00:29:44,149 --> 00:29:42,159
interesting is that when you looked in

756
00:29:45,909 --> 00:29:44,159
detail at the rocks in here and then the

757
00:29:47,909 --> 00:29:45,919
ones that have presumably eroded out of

758
00:29:49,669 --> 00:29:47,919
it they were rounded

759
00:29:51,430 --> 00:29:49,679
now we've never seen rounded rocks on

760
00:29:53,029 --> 00:29:51,440
mars before you see these jagged things

761
00:29:55,350 --> 00:29:53,039
that come when an impact

762
00:29:57,590 --> 00:29:55,360
hits and you shatter rock

763
00:30:00,149 --> 00:29:57,600

you see we saw all these little rounded

764
00:30:01,990 --> 00:30:00,159
one centimeter-ish stones

765
00:30:03,909 --> 00:30:02,000
that was you know to the geologists on

766
00:30:05,750 --> 00:30:03,919
the team there's only one pro the number

767
00:30:08,389 --> 00:30:05,760
one process you'd go to on earth to form

768
00:30:09,590 --> 00:30:08,399
that you could probably guess

769
00:30:10,870 --> 00:30:09,600
right i mean you're probably reading my

770
00:30:12,630 --> 00:30:10,880
caption

771
00:30:15,029 --> 00:30:12,640
but um

772
00:30:17,110 --> 00:30:15,039
but yeah um when you go to a stream or a

773
00:30:19,750 --> 00:30:17,120
river on earth and the water is

774
00:30:21,110 --> 00:30:19,760
transporting rocks for several miles and

775
00:30:22,549 --> 00:30:21,120
they're all sort of rolling along the

776
00:30:23,909 --> 00:30:22,559
bottom and

777
00:30:25,990 --> 00:30:23,919
and

778
00:30:28,149 --> 00:30:26,000
hitting each other you end up getting a

779
00:30:29,750 --> 00:30:28,159
lot of rounded pebbles and by the

780
00:30:31,750 --> 00:30:29,760
roundedness of these pebbles and then

781
00:30:33,750 --> 00:30:31,760
the size of them the size of them tells

782
00:30:35,590 --> 00:30:33,760
you how much water was there because the

783
00:30:36,470 --> 00:30:35,600
more water the bigger things you can

784
00:30:38,710 --> 00:30:36,480
carry

785
00:30:39,669 --> 00:30:38,720
so by looking at the the total picture

786
00:30:42,230 --> 00:30:39,679
here

787
00:30:45,110 --> 00:30:42,240
they they were able to conclude that we

788
00:30:47,190 --> 00:30:45,120

were actually driving over a stream bed

789
00:30:49,190 --> 00:30:47,200
we were the curiosity's wheels would

790
00:30:50,630 --> 00:30:49,200
have been

791
00:30:52,710 --> 00:30:50,640
you know buried or whatever you call it

792
00:30:54,630 --> 00:30:52,720
uh you know underwater

793
00:30:55,590 --> 00:30:54,640
um if we were there a couple billion

794
00:30:57,669 --> 00:30:55,600
years ago

795
00:30:59,590 --> 00:30:57,679
uh and so uh based on all these

796
00:31:01,430 --> 00:30:59,600
measurements the scientists uh science

797
00:31:02,230 --> 00:31:01,440
team came up with the uh the conclusion

798
00:31:02,950 --> 00:31:02,240
that

799
00:31:04,710 --> 00:31:02,960
the

800
00:31:06,549 --> 00:31:04,720
this indicates a streambed environment

801
00:31:09,350 --> 00:31:06,559
where water once flowed ankle to hip

802
00:31:10,789 --> 00:31:09,360
deep about um several miles which is

803
00:31:12,230 --> 00:31:10,799
consistent with that river coming from

804
00:31:14,870 --> 00:31:12,240
the crater rim that i pointed out

805
00:31:19,430 --> 00:31:17,669
and flowing a few miles per hour so it's

806
00:31:21,269 --> 00:31:19,440
a real kind of gentle stream the kind of

807
00:31:23,269 --> 00:31:21,279
thing you might go fishing in

808
00:31:26,230 --> 00:31:23,279
and here here we are seeing the first

809
00:31:28,549 --> 00:31:26,240
real evidence for flowing water

810
00:31:30,310 --> 00:31:28,559
on mars

811
00:31:32,870 --> 00:31:30,320
and just to remind you we this is where

812
00:31:34,870 --> 00:31:32,880
we aimed we landed about here

813
00:31:36,950 --> 00:31:34,880

and then this fan was coming down and it

814
00:31:40,549 --> 00:31:36,960
kind of goes to about here and we drove

815
00:31:44,389 --> 00:31:42,789
all right so the hunt for habitable

816
00:31:46,630 --> 00:31:44,399
environments was on

817
00:31:48,630 --> 00:31:46,640
but meanwhile we did some other stuff so

818
00:31:49,909 --> 00:31:48,640
for the next few minutes i just want to

819
00:31:52,549 --> 00:31:49,919
walk you through

820
00:31:54,070 --> 00:31:52,559
four different little mini vignettes um

821
00:31:55,830 --> 00:31:54,080
one of the challenges now even after a

822
00:31:57,110 --> 00:31:55,840
year is that this rover with all of its

823
00:31:57,909 --> 00:31:57,120
instruments is doing so many different

824
00:32:00,070 --> 00:31:57,919
things

825
00:32:01,909 --> 00:32:00,080
i'm going to offend half the team by not

826
00:32:03,269 --> 00:32:01,919
talking about their discoveries and the

827
00:32:06,389 --> 00:32:03,279
other half the team will be delighted

828
00:32:08,149 --> 00:32:06,399
but that's the way it goes

829
00:32:11,350 --> 00:32:08,159
so meanwhile

830
00:32:16,230 --> 00:32:12,950
so one thing that's pretty cool is we

831
00:32:17,669 --> 00:32:16,240
have a camera at the end of our arm

832
00:32:19,590 --> 00:32:17,679
and

833
00:32:21,669 --> 00:32:19,600
the camera team

834
00:32:23,430 --> 00:32:21,679
had a lot of insight actually

835
00:32:25,909 --> 00:32:23,440
i didn't even see this coming really as

836
00:32:27,509 --> 00:32:25,919
we were developing it the camera team

837
00:32:29,350 --> 00:32:27,519
was designing of course

838
00:32:31,350 --> 00:32:29,360

something that you put on a rock and

839
00:32:33,350 --> 00:32:31,360
take microscopic pictures so that the

840
00:32:34,789 --> 00:32:33,360
geologists and mineralogists on our team

841
00:32:36,950 --> 00:32:34,799
could look at the image individual

842
00:32:38,710 --> 00:32:36,960
grains of the rock in detail and figure

843
00:32:40,310 --> 00:32:38,720
out where that rock came from

844
00:32:42,310 --> 00:32:40,320
but what they did is they put a focus

845
00:32:44,070 --> 00:32:42,320
mechanism on that camera as well so that

846
00:32:46,630 --> 00:32:44,080
they couldn't only focus they could

847
00:32:48,789 --> 00:32:46,640
focus not only on a rock a centimeter

848
00:32:50,950 --> 00:32:48,799
away from the lens but they could focus

849
00:32:52,630 --> 00:32:50,960
like any camera and so now we had a

850
00:32:54,149 --> 00:32:52,640
camera at the end of the arm we could

851
00:32:55,669 --> 00:32:54,159
point anywhere we could point on top of

852
00:32:57,909 --> 00:32:55,679
us we could look behind us we could look

853
00:33:00,470 --> 00:32:57,919
between our legs

854
00:33:02,870 --> 00:33:00,480
and this was uh you know it was actually

855
00:33:04,710 --> 00:33:02,880
a really neat thing but this particular

856
00:33:06,870 --> 00:33:04,720
one is the first one we did before we

857
00:33:08,630 --> 00:33:06,880
even drove the first time i think not

858
00:33:11,190 --> 00:33:08,640
the first time before we drove we wanted

859
00:33:12,789 --> 00:33:11,200
to check out uh to make sure that the

860
00:33:14,310 --> 00:33:12,799
rover was clear of obstacles and we do

861
00:33:16,149 --> 00:33:14,320
this regularly now we can actually peer

862
00:33:17,269 --> 00:33:16,159
under the rover if there's any danger

863
00:33:17,990 --> 00:33:17,279

that we might

864
00:33:19,430 --> 00:33:18,000
be

865
00:33:22,630 --> 00:33:19,440
you know high centered

866
00:33:24,630 --> 00:33:22,640
like a bad four-wheel driver

867
00:33:26,070 --> 00:33:24,640
so yeah um

868
00:33:27,669 --> 00:33:26,080
another thing though is that they kind

869
00:33:28,710 --> 00:33:27,679
of surprised us again this team is very

870
00:33:31,110 --> 00:33:28,720
creative and sometimes a little

871
00:33:31,990 --> 00:33:31,120
secretive they went off and they figured

872
00:33:34,710 --> 00:33:32,000
out

873
00:33:35,909 --> 00:33:34,720
an incredibly complex series of moves

874
00:33:39,909 --> 00:33:35,919
with the arm

875
00:33:43,269 --> 00:33:39,919
to take a full portrait of the rover now

876
00:33:45,269 --> 00:33:43,279
this sounds probably easier than it was

877
00:33:47,509 --> 00:33:45,279
we don't have an arm as beautiful as a

878
00:33:49,430 --> 00:33:47,519
human arm you know roboticists are still

879
00:33:50,789 --> 00:33:49,440
trying to invent things as good as we

880
00:33:52,070 --> 00:33:50,799
came out

881
00:33:53,110 --> 00:33:52,080
and you know our arm can do amazing

882
00:33:54,310 --> 00:33:53,120
things if you're trying to do it it'd be

883
00:33:56,789 --> 00:33:54,320
pretty easy you could do it in 20

884
00:33:58,149 --> 00:33:56,799
seconds but it's sort of i couldn't

885
00:33:59,909 --> 00:33:58,159
think of a good analogy for this but

886
00:34:01,990 --> 00:33:59,919
it's sort of like scratching an itch on

887
00:34:03,909 --> 00:34:02,000
your back when you start to kind of go

888
00:34:05,509 --> 00:34:03,919

like this you know

889
00:34:07,669 --> 00:34:05,519
you have to like figure out the right

890
00:34:09,909 --> 00:34:07,679
way to get to any particular itch and to

891
00:34:10,869 --> 00:34:09,919
take this portrait of curiosity they had

892
00:34:13,190 --> 00:34:10,879
to do that they had to go through

893
00:34:14,550 --> 00:34:13,200
hundreds of different you know ideas of

894
00:34:16,710 --> 00:34:14,560
how to move the arm around to take the

895
00:34:17,589 --> 00:34:16,720
self-portrait and they did it one day on

896
00:34:19,109 --> 00:34:17,599
mars

897
00:34:21,030 --> 00:34:19,119
and it's just one of the most iconic

898
00:34:22,869 --> 00:34:21,040
images of the mission

899
00:34:26,869 --> 00:34:22,879
and where's the arm well of course

900
00:34:30,230 --> 00:34:29,109
but yeah now now we regularly do this

901
00:34:32,869 --> 00:34:30,240
it's it's

902
00:34:34,230 --> 00:34:32,879
it's good for kind of a documentation so

903
00:34:36,389 --> 00:34:34,240
every time we do a major thing like

904
00:34:38,230 --> 00:34:36,399
drill this is where we first drilled and

905
00:34:39,909 --> 00:34:38,240
we took this self-portrait we also did

906
00:34:41,669 --> 00:34:39,919
it where we first scooped and we do it

907
00:34:43,109 --> 00:34:41,679
at every major milestone of the mission

908
00:34:45,430 --> 00:34:43,119
it's a wonderful thing it only takes

909
00:34:47,270 --> 00:34:45,440
like an hour or something on mars to do

910
00:34:52,710 --> 00:34:47,280
but it probably took them months to to

911
00:34:57,190 --> 00:34:54,310
so

912
00:34:58,550 --> 00:34:57,200
the next kind of scientific story um

913
00:34:59,750 --> 00:34:58,560

doesn't really have that much to do with

914
00:35:01,190 --> 00:34:59,760
cows

915
00:35:02,710 --> 00:35:01,200
but only in the sense that it's about

916
00:35:04,870 --> 00:35:02,720
methane

917
00:35:05,589 --> 00:35:04,880
and

918
00:35:08,870 --> 00:35:05,599
so

919
00:35:10,630 --> 00:35:08,880
methane of course is a gas that on earth

920
00:35:13,190 --> 00:35:10,640
a lot of it in the atmosphere comes from

921
00:35:15,589 --> 00:35:13,200
things like agriculture and then comes

922
00:35:17,430 --> 00:35:15,599
from the insides of cows

923
00:35:19,430 --> 00:35:17,440
their stomachs produce a lot of methane

924
00:35:21,109 --> 00:35:19,440
as they digest their food and actually

925
00:35:22,950 --> 00:35:21,119
it's one of the greenhouse gases it's

926
00:35:24,230 --> 00:35:22,960
you know it gets a lot of notoriety on

927
00:35:26,710 --> 00:35:24,240
earth

928
00:35:28,230 --> 00:35:26,720
on mars it was

929
00:35:29,829 --> 00:35:28,240
it was claimed to be detected in the

930
00:35:32,069 --> 00:35:29,839
last decade by a few different groups of

931
00:35:34,470 --> 00:35:32,079
people one was a european orbiter

932
00:35:35,589 --> 00:35:34,480
mission at mars another were several

933
00:35:37,190 --> 00:35:35,599
telescopes from earth that looked

934
00:35:38,310 --> 00:35:37,200
through the earth's atmosphere

935
00:35:40,790 --> 00:35:38,320
and this would be pretty exciting

936
00:35:42,390 --> 00:35:40,800
because if methane was on mars

937
00:35:44,390 --> 00:35:42,400
although there are different natural

938
00:35:46,390 --> 00:35:44,400

ways of forming it through

939
00:35:47,510 --> 00:35:46,400
mineral reactions deep in the ground for

940
00:35:49,589 --> 00:35:47,520
example

941
00:35:50,950 --> 00:35:49,599
delivery by comets and other other

942
00:35:52,710 --> 00:35:50,960
things like that

943
00:35:54,550 --> 00:35:52,720
one of the possible sources of methane

944
00:35:55,750 --> 00:35:54,560
on mars would be

945
00:35:58,870 --> 00:35:55,760
biology

946
00:36:00,150 --> 00:35:58,880
so we took a look at it and i won't walk

947
00:36:01,670 --> 00:36:00,160
you through this whole thing but this is

948
00:36:03,030 --> 00:36:01,680
just to say that the discovery of

949
00:36:04,790 --> 00:36:03,040
methane on mars caused a lot of

950
00:36:06,630 --> 00:36:04,800
scientists to go do their homework

951
00:36:07,829 --> 00:36:06,640
figure out how much might be produced by

952
00:36:09,510 --> 00:36:07,839
a lot of different sources where it

953
00:36:11,109 --> 00:36:09,520
might be stored on mars

954
00:36:13,270 --> 00:36:11,119
and one of the answers they came up with

955
00:36:15,349 --> 00:36:13,280
is that if methane is produced on mars

956
00:36:16,790 --> 00:36:15,359
today it would only last a few hundred

957
00:36:17,990 --> 00:36:16,800
years

958
00:36:19,750 --> 00:36:18,000
that sounds like a long time but in

959
00:36:21,349 --> 00:36:19,760
geologic time it's nothing so that

960
00:36:22,630 --> 00:36:21,359
basically means if you found methane on

961
00:36:25,109 --> 00:36:22,640
mars today

962
00:36:27,589 --> 00:36:25,119
it's being actively supplied made the

963
00:36:28,790 --> 00:36:27,599

the idea of biology uh producing it even

964
00:36:31,670 --> 00:36:28,800
better

965
00:36:33,829 --> 00:36:31,680
but unfortunately we we took this

966
00:36:36,550 --> 00:36:33,839
beautiful instrument that shoots lasers

967
00:36:38,829 --> 00:36:36,560
between two mirrors and uses the very

968
00:36:41,430 --> 00:36:38,839
subtle absorption of light by

969
00:36:43,430 --> 00:36:41,440
methane to calculate how much methane

970
00:36:44,390 --> 00:36:43,440
was in mars atmosphere

971
00:36:46,069 --> 00:36:44,400
and we

972
00:36:48,550 --> 00:36:46,079
we brought this specifically to look at

973
00:36:50,230 --> 00:36:48,560
methane on mars and it turned out that

974
00:36:51,829 --> 00:36:50,240
we found nothing

975
00:36:53,750 --> 00:36:51,839
so this was a little bit

976
00:36:55,510 --> 00:36:53,760
i guess disappointing but as a scientist

977
00:36:56,870 --> 00:36:55,520
i'm supposed to not let emotion play

978
00:36:59,589 --> 00:36:56,880
into it

979
00:37:00,630 --> 00:36:59,599
we found no methane

980
00:37:03,109 --> 00:37:00,640
but you know that's actually an

981
00:37:05,190 --> 00:37:03,119
important result it kind of puts

982
00:37:06,470 --> 00:37:05,200
at least temporarily puts to rest this

983
00:37:08,470 --> 00:37:06,480
question of methane we're going to keep

984
00:37:10,470 --> 00:37:08,480
looking as the seasons change because

985
00:37:12,950 --> 00:37:10,480
maybe it actually changes with season

986
00:37:14,710 --> 00:37:12,960
but so far that's one of the

987
00:37:16,230 --> 00:37:14,720
i've got to be fair and tell you the the

988
00:37:19,270 --> 00:37:16,240

bad scientific results as well as the

989
00:37:23,270 --> 00:37:21,430
okay the internet's wrong

990
00:37:26,150 --> 00:37:23,280
and now that should be

991
00:37:27,510 --> 00:37:26,160
surprising to nobody

992
00:37:29,589 --> 00:37:27,520
but if you were to wikipedia the

993
00:37:32,550 --> 00:37:29,599
composition of mars atmosphere

994
00:37:33,910 --> 00:37:32,560
today you'd actually find that 96 of it

995
00:37:36,150 --> 00:37:33,920
is co2

996
00:37:38,870 --> 00:37:36,160
or maybe 95 point something a couple

997
00:37:40,870 --> 00:37:38,880
percent is uh nitrogen and then maybe a

998
00:37:42,950 --> 00:37:40,880
little over one percent are gone

999
00:37:45,510 --> 00:37:42,960
well we have this wonderful instrument

1000
00:37:46,870 --> 00:37:45,520
uh the the one the gold plating

1001
00:37:48,790 --> 00:37:46,880
that actually can measure the

1002
00:37:52,390 --> 00:37:48,800
atmospheric composition as well

1003
00:37:54,470 --> 00:37:52,400
and we found that argon with a lot more

1004
00:37:55,910 --> 00:37:54,480
accuracy than anybody could do before

1005
00:37:58,710 --> 00:37:55,920
curiosity got there

1006
00:38:00,150 --> 00:37:58,720
argon's actually the next most abundant

1007
00:38:01,270 --> 00:38:00,160
thing in the atmosphere after carbon

1008
00:38:03,670 --> 00:38:01,280
dioxide

1009
00:38:05,030 --> 00:38:03,680
so it's it's not you know life-changing

1010
00:38:07,510 --> 00:38:05,040
but on the other hand it's rewriting the

1011
00:38:09,589 --> 00:38:07,520
textbooks and it's uh someone needs to

1012
00:38:11,109 --> 00:38:09,599
update that wikipedia page so

1013
00:38:12,470 --> 00:38:11,119

so get on it

1014
00:38:14,790 --> 00:38:12,480
the other thing we found probably

1015
00:38:16,790 --> 00:38:14,800
probably more fundamental is measuring

1016
00:38:18,710 --> 00:38:16,800
what we call the isotopic composition of

1017
00:38:22,310 --> 00:38:18,720
mars atmosphere

1018
00:38:23,589 --> 00:38:22,320
isotopes are versions of molecules

1019
00:38:25,990 --> 00:38:23,599
that have

1020
00:38:28,310 --> 00:38:26,000
more neutrons than

1021
00:38:31,190 --> 00:38:28,320
than others so it's still the same

1022
00:38:34,069 --> 00:38:31,200
element for example hydrogen here most

1023
00:38:34,870 --> 00:38:34,079
of the hydrogen in the universe

1024
00:38:35,750 --> 00:38:34,880
is

1025
00:38:37,990 --> 00:38:35,760
uh

1026
00:38:41,030 --> 00:38:38,000
has one proton and one electron

1027
00:38:42,870 --> 00:38:41,040
but sometimes there's actually a neutron

1028
00:38:43,750 --> 00:38:42,880
and that's called deuterium and if you

1029
00:38:45,829 --> 00:38:43,760
were to

1030
00:38:48,230 --> 00:38:45,839
hold a glass of water on earth that you

1031
00:38:49,589 --> 00:38:48,240
got from the tap one out of every six

1032
00:38:50,630 --> 00:38:49,599
thousand or so

1033
00:38:53,510 --> 00:38:50,640
atoms

1034
00:38:55,270 --> 00:38:53,520
of hydrogen would be deuterium and not

1035
00:38:57,270 --> 00:38:55,280
uh what's called protium which we

1036
00:38:59,910 --> 00:38:57,280
normally call hydrogen one out of six

1037
00:39:02,710 --> 00:38:59,920
thousand on mars when we measured this

1038
00:39:05,030 --> 00:39:02,720

uh the same number of deuterium and as

1039
00:39:06,069 --> 00:39:05,040
well as as the isotopes of carbon and

1040
00:39:08,150 --> 00:39:06,079
argon

1041
00:39:11,030 --> 00:39:08,160
we found that there's a lot more of the

1042
00:39:13,510 --> 00:39:11,040
heavy isotope than the light one

1043
00:39:15,109 --> 00:39:13,520
relative to earth and relative to what

1044
00:39:16,230 --> 00:39:15,119
we think is sort of what the planet's

1045
00:39:18,630 --> 00:39:16,240
formed out of

1046
00:39:20,470 --> 00:39:18,640
so that means something is getting rid

1047
00:39:24,150 --> 00:39:20,480
of the light versions of the atmospheric

1048
00:39:26,230 --> 00:39:24,160
gases and retaining the the heavy ones

1049
00:39:28,870 --> 00:39:26,240
and one of the main theories about how

1050
00:39:31,030 --> 00:39:28,880
mars went from a wet planet to a dry

1051
00:39:33,589 --> 00:39:31,040
planet involves the loss of its

1052
00:39:35,430 --> 00:39:33,599
atmosphere early in its history

1053
00:39:36,870 --> 00:39:35,440
and the mechanisms for losing the

1054
00:39:39,349 --> 00:39:36,880
atmosphere over time

1055
00:39:42,550 --> 00:39:39,359
one of the favored ones is that

1056
00:39:44,069 --> 00:39:42,560
the atmosphere is lost by the sun slowly

1057
00:39:45,589 --> 00:39:44,079
stripping away slowly eroding the

1058
00:39:47,990 --> 00:39:45,599
particles that are shot out by the sun

1059
00:39:50,550 --> 00:39:48,000
into space slowly erode mars atmosphere

1060
00:39:52,230 --> 00:39:50,560
over time and that would preferentially

1061
00:39:54,310 --> 00:39:52,240
take out those light elements and leave

1062
00:39:56,550 --> 00:39:54,320
the heavy ones behind so by measuring

1063
00:39:58,870 --> 00:39:56,560

these isotopic ratios we've really

1064
00:40:00,230 --> 00:39:58,880
helped confirm one of the theories

1065
00:40:02,470 --> 00:40:00,240
that's been around for a while now but

1066
00:40:04,790 --> 00:40:02,480
we've we've added a lot more sort of

1067
00:40:06,150 --> 00:40:04,800
evidence to the theory that mars lost a

1068
00:40:08,630 --> 00:40:06,160
lot of its atmosphere early in its

1069
00:40:12,550 --> 00:40:10,790
okay houston we have a problem

1070
00:40:14,230 --> 00:40:12,560
but nasa can solve it

1071
00:40:17,349 --> 00:40:14,240
um

1072
00:40:23,270 --> 00:40:17,359
so uh the problem is not the lack of

1073
00:40:27,589 --> 00:40:25,430
and in fact uh i thought i'd show you

1074
00:40:29,510 --> 00:40:27,599
some of the fantastic uh

1075
00:40:30,950 --> 00:40:29,520
women that i work with every day who run

1076
00:40:33,109 --> 00:40:30,960
the rover basically

1077
00:40:34,069 --> 00:40:33,119
and uh this is some event they did to

1078
00:40:35,990 --> 00:40:34,079
get

1079
00:40:36,950 --> 00:40:36,000
women into science and engineering

1080
00:40:38,950 --> 00:40:36,960
careers

1081
00:40:41,109 --> 00:40:38,960
and they do a fantastic job but the

1082
00:40:43,510 --> 00:40:41,119
problem that nasa needs to solve

1083
00:40:44,870 --> 00:40:43,520
actually is about radiation

1084
00:40:46,710 --> 00:40:44,880
so when we

1085
00:40:48,470 --> 00:40:46,720
flew from earth to mars we actually

1086
00:40:50,790 --> 00:40:48,480
turned on our radiation experiment right

1087
00:40:52,790 --> 00:40:50,800
after launch and it measured radiation

1088
00:40:54,550 --> 00:40:52,800

all the way to mars

1089
00:40:56,790 --> 00:40:54,560
and there's a couple different sources

1090
00:40:57,910 --> 00:40:56,800
of harmful radiation flying around in

1091
00:41:00,069 --> 00:40:57,920
space

1092
00:41:01,910 --> 00:41:00,079
one is galactic cosmic rays these are

1093
00:41:03,349 --> 00:41:01,920
sort of things flying around from

1094
00:41:05,270 --> 00:41:03,359
galaxies

1095
00:41:06,630 --> 00:41:05,280
and they're all over the place in space

1096
00:41:08,870 --> 00:41:06,640
and they could they

1097
00:41:11,190 --> 00:41:08,880
not not a huge amount of them but

1098
00:41:14,790 --> 00:41:11,200
there's but there's very high energy and

1099
00:41:17,190 --> 00:41:14,800
harmful uh cancer causing etc

1100
00:41:18,950 --> 00:41:17,200
much worse for humans one day in space

1101
00:41:20,630 --> 00:41:18,960
will be the particles that

1102
00:41:22,870 --> 00:41:20,640
intermittently come from the sun from

1103
00:41:25,030 --> 00:41:22,880
coronal mass ejections these big flares

1104
00:41:25,910 --> 00:41:25,040
from the sun that spew particles into

1105
00:41:28,230 --> 00:41:25,920
space

1106
00:41:29,990 --> 00:41:28,240
so we were the first uh

1107
00:41:31,670 --> 00:41:30,000
time we were able to provide the first

1108
00:41:34,230 --> 00:41:31,680
measurements of these two sources of

1109
00:41:37,270 --> 00:41:34,240
radiation from earth to mars and then

1110
00:41:39,510 --> 00:41:37,280
also uh even even kind of uniquely from

1111
00:41:41,430 --> 00:41:39,520
within a spacecraft just the kind of

1112
00:41:43,510 --> 00:41:41,440
spacecraft that humans will one day fly

1113
00:41:44,950 --> 00:41:43,520

from earth to mars within and the the

1114
00:41:46,230 --> 00:41:44,960
shielding of the spacecraft the metal

1115
00:41:48,790 --> 00:41:46,240
the spacecraft's made out of actually

1116
00:41:50,710 --> 00:41:48,800
changes that radiation in both good ways

1117
00:41:52,790 --> 00:41:50,720
and harmful ways so being able to

1118
00:41:54,710 --> 00:41:52,800
measure it curiosity being in its little

1119
00:41:56,710 --> 00:41:54,720
spacecraft it could actually its giant

1120
00:41:58,069 --> 00:41:56,720
spacecraft it could measure that

1121
00:41:59,750 --> 00:41:58,079
radiation and so this is what we

1122
00:42:01,829 --> 00:41:59,760
measured from earth to mars here's the

1123
00:42:04,550 --> 00:42:01,839
galactic cosmic rays here are the little

1124
00:42:05,750 --> 00:42:04,560
spikes of solar events

1125
00:42:07,829 --> 00:42:05,760
and the reason it's a problem for

1126
00:42:09,670 --> 00:42:07,839
houston is that what we measured on

1127
00:42:11,030 --> 00:42:09,680
earth to mars when you calculate what an

1128
00:42:14,069 --> 00:42:11,040
astronaut would take to go to earth and

1129
00:42:15,670 --> 00:42:14,079
mars and back it's more than the

1130
00:42:18,390 --> 00:42:15,680
lifetime dose that nasa allows

1131
00:42:20,710 --> 00:42:18,400
astronauts to get which isn't a problem

1132
00:42:22,309 --> 00:42:20,720
it just means that nasa has to solve it

1133
00:42:25,190 --> 00:42:22,319
i mean it is a problem but nasa has to

1134
00:42:27,109 --> 00:42:25,200
solve it it's not a fatal problem um

1135
00:42:28,710 --> 00:42:27,119
they have to just design spacecraft to

1136
00:42:30,710 --> 00:42:28,720
shield their astronauts that much better

1137
00:42:34,309 --> 00:42:30,720
so we're contributing to future human

1138
00:42:38,950 --> 00:42:35,190

okay

1139
00:42:41,990 --> 00:42:40,069
we had

1140
00:42:44,069 --> 00:42:42,000
headed for bradbury landing

1141
00:42:45,910 --> 00:42:44,079
over to yellowknife bay and actually

1142
00:42:47,270 --> 00:42:45,920
this is a picture pretty awesome picture

1143
00:42:48,470 --> 00:42:47,280
from what's called the mars

1144
00:42:50,150 --> 00:42:48,480
reconnaissance orbiter one of our

1145
00:42:51,349 --> 00:42:50,160
orbiters at mars

1146
00:42:54,630 --> 00:42:51,359
i think it's actually back in that

1147
00:42:55,430 --> 00:42:54,640
corner over there not the real one

1148
00:42:57,109 --> 00:42:55,440
um

1149
00:42:58,550 --> 00:42:57,119
and and you see that giant telescope on

1150
00:43:00,309 --> 00:42:58,560
that thing

1151
00:43:01,589 --> 00:43:00,319
that's that's kind of like

1152
00:43:03,829 --> 00:43:01,599
launching half of the hubble space

1153
00:43:06,069 --> 00:43:03,839
telescope in orbit around mars takes

1154
00:43:07,829 --> 00:43:06,079
these fantastic images for us here

1155
00:43:09,750 --> 00:43:07,839
here's where we drove over to this edge

1156
00:43:11,750 --> 00:43:09,760
of the fan which we call yellowknife bay

1157
00:43:13,270 --> 00:43:11,760
and that actually is curiosity as seen

1158
00:43:17,270 --> 00:43:13,280
from an orbiter around mars and you can

1159
00:43:20,630 --> 00:43:18,870
yeah so we can we can look at each other

1160
00:43:24,550 --> 00:43:20,640
too

1161
00:43:28,470 --> 00:43:26,550
what we found as we got closer and

1162
00:43:30,069 --> 00:43:28,480
closer to yellowknife just got more and

1163
00:43:31,750 --> 00:43:30,079

more exciting for us

1164
00:43:34,069 --> 00:43:31,760
we started going through this whole

1165
00:43:36,230 --> 00:43:34,079
variety of rock layers that we didn't

1166
00:43:38,870 --> 00:43:36,240
anticipate we just hoped to find

1167
00:43:40,790 --> 00:43:38,880
something unique in the fan material but

1168
00:43:43,109 --> 00:43:40,800
we actually found four different rock

1169
00:43:44,870 --> 00:43:43,119
layers before that each very unique in

1170
00:43:46,710 --> 00:43:44,880
their in their texture and and the

1171
00:43:47,990 --> 00:43:46,720
environment they formed in i can't go

1172
00:43:49,109 --> 00:43:48,000
through all of them but this is one of

1173
00:43:51,670 --> 00:43:49,119
the more interesting ones we started

1174
00:43:53,910 --> 00:43:51,680
seeing these very thin platy rocks

1175
00:43:55,670 --> 00:43:53,920
if you've ever been to somewhere in the

1176
00:43:57,510 --> 00:43:55,680
southwest where there's a lot of sand

1177
00:43:59,030 --> 00:43:57,520
dunes you see things like this

1178
00:44:01,270 --> 00:43:59,040
especially

1179
00:44:03,109 --> 00:44:01,280
in like zion national park has a

1180
00:44:05,750 --> 00:44:03,119
beautiful

1181
00:44:07,829 --> 00:44:05,760
hillside full of rock that's etched with

1182
00:44:09,910 --> 00:44:07,839
these fine lines and that's actually a

1183
00:44:11,829 --> 00:44:09,920
sand dune that traversed through there

1184
00:44:13,910 --> 00:44:11,839
then stopped and then got turned into

1185
00:44:15,990 --> 00:44:13,920
rock and so we actually are seeing

1186
00:44:18,870 --> 00:44:16,000
evidence of sand dunes on mars

1187
00:44:20,150 --> 00:44:18,880
highly eroded now but ancient sand dunes

1188
00:44:21,589 --> 00:44:20,160

when we actually went up to these sand

1189
00:44:23,030 --> 00:44:21,599
dunes and looked with our microscopic

1190
00:44:25,430 --> 00:44:23,040
camera

1191
00:44:28,069 --> 00:44:25,440
it turned out that the sand grains are

1192
00:44:29,990 --> 00:44:28,079
much too big to be transported by even

1193
00:44:31,190 --> 00:44:30,000
earth's thick atmosphere they're

1194
00:44:33,670 --> 00:44:31,200
actually

1195
00:44:35,430 --> 00:44:33,680
very large sand grains that and require

1196
00:44:37,430 --> 00:44:35,440
something more like water to transport

1197
00:44:39,030 --> 00:44:37,440
them so we think we're seeing here

1198
00:44:40,710 --> 00:44:39,040
is some other part of that river and

1199
00:44:42,870 --> 00:44:40,720
stream system that was able to transport

1200
00:44:44,710 --> 00:44:42,880
a large amount of sand and create

1201
00:44:46,870 --> 00:44:44,720
ripples as it went

1202
00:44:48,950 --> 00:44:46,880
and so here is another piece of evidence

1203
00:44:50,790 --> 00:44:48,960
for water

1204
00:44:52,870 --> 00:44:50,800
here's what yellowknife bay looked like

1205
00:44:54,870 --> 00:44:52,880
this is the gravel we landed on and then

1206
00:44:57,829 --> 00:44:54,880
it all of a sudden it turned into this

1207
00:44:59,990 --> 00:44:57,839
much different terrain these platy flat

1208
00:45:02,390 --> 00:45:00,000
rocks that were associated with this fan

1209
00:45:04,710 --> 00:45:02,400
and river system we saw

1210
00:45:06,230 --> 00:45:04,720
we got deeper in there we started seeing

1211
00:45:07,430 --> 00:45:06,240
that the the rocks were indeed made up

1212
00:45:10,069 --> 00:45:07,440
of these plates

1213
00:45:11,670 --> 00:45:10,079

about a meter across usually

1214
00:45:13,510 --> 00:45:11,680
and you can see different layers this is

1215
00:45:15,589 --> 00:45:13,520
the bottom layer there's another unique

1216
00:45:16,550 --> 00:45:15,599
layer here those sand dunes are kind of

1217
00:45:17,829 --> 00:45:16,560
up here

1218
00:45:20,150 --> 00:45:17,839
and so we were seeing a whole

1219
00:45:21,670 --> 00:45:20,160
stratigraphy a whole set of rock layers

1220
00:45:25,349 --> 00:45:21,680
each of which formed in a different

1221
00:45:29,430 --> 00:45:27,190
when we got closer we used some of our

1222
00:45:31,910 --> 00:45:29,440
other instruments like our arm mounted

1223
00:45:33,829 --> 00:45:31,920
spectrometer and that laser that shoots

1224
00:45:36,470 --> 00:45:33,839
the little spots on the rocks

1225
00:45:38,550 --> 00:45:36,480
and we found that the rock was heavily

1226
00:45:40,150 --> 00:45:38,560
fractured with these tiny little cracks

1227
00:45:42,390 --> 00:45:40,160
but the cracks were filled with white

1228
00:45:44,710 --> 00:45:42,400
minerals and the white minerals when we

1229
00:45:46,470 --> 00:45:44,720
looked at it with our chemcam that laser

1230
00:45:48,230 --> 00:45:46,480
it turned out to be made of calcium

1231
00:45:49,589 --> 00:45:48,240
sulfate this is a mineral that can

1232
00:45:51,829 --> 00:45:49,599
dissolve in water and then if you run

1233
00:45:53,829 --> 00:45:51,839
that water through rock

1234
00:45:55,910 --> 00:45:53,839
for a long time it'll build up and sort

1235
00:45:58,150 --> 00:45:55,920
of fill the cracks with mineral deposits

1236
00:46:01,030 --> 00:45:58,160
and that's an example of that on earth

1237
00:46:02,870 --> 00:46:01,040
so we found yet another

1238
00:46:07,990 --> 00:46:02,880

way that water has interacted with these

1239
00:46:12,870 --> 00:46:09,670
leaving these calcium sulfate deposits

1240
00:46:16,230 --> 00:46:14,870
another one are these little pimples so

1241
00:46:18,550 --> 00:46:16,240
some of the rocks have these things

1242
00:46:20,630 --> 00:46:18,560
called concretions which are other kinds

1243
00:46:22,470 --> 00:46:20,640
of minerals that form in rock that's

1244
00:46:23,750 --> 00:46:22,480
saturated with water and water is

1245
00:46:24,870 --> 00:46:23,760
flowing through and leaving minerals

1246
00:46:27,349 --> 00:46:24,880
behind

1247
00:46:29,109 --> 00:46:27,359
so this sheep bed rock is the one that

1248
00:46:30,630 --> 00:46:29,119
forms the bottom of yellowknife bay the

1249
00:46:32,390 --> 00:46:30,640
one that really we think is associated

1250
00:46:34,390 --> 00:46:32,400
with this fan and that's where we got

1251
00:46:35,670 --> 00:46:34,400
very excited about seeing uh what we

1252
00:46:38,069 --> 00:46:35,680
could find out

1253
00:46:39,990 --> 00:46:38,079
with our big laboratory instruments that

1254
00:46:42,470 --> 00:46:40,000
really we hadn't used yet for the first

1255
00:46:44,950 --> 00:46:42,480
time on mars in in one of our main

1256
00:46:46,710 --> 00:46:44,960
scientific questions

1257
00:46:49,109 --> 00:46:46,720
this is a gorgeous image taken by our

1258
00:46:51,190 --> 00:46:49,119
black and white navigation cameras

1259
00:46:54,069 --> 00:46:51,200
of mount sharp in the background

1260
00:46:55,910 --> 00:46:54,079
the transition from the the dunes to

1261
00:46:57,670 --> 00:46:55,920
this upper unit to the sheet bed rocks

1262
00:46:59,990 --> 00:46:57,680
of yellowknife bay

1263
00:47:01,510 --> 00:47:00,000

and the arm deployed with the drill in

1264
00:47:02,870 --> 00:47:01,520
the ground ready to do our first

1265
00:47:05,109 --> 00:47:02,880
drilling

1266
00:47:07,750 --> 00:47:05,119
and we named this feature john klein

1267
00:47:10,150 --> 00:47:07,760
after one of our former deputy project

1268
00:47:12,550 --> 00:47:10,160
managers who passed away shortly before

1269
00:47:14,309 --> 00:47:12,560
we landed

1270
00:47:15,990 --> 00:47:14,319
so this is our drill holes

1271
00:47:16,950 --> 00:47:16,000
this is a little test hole this is our

1272
00:47:19,990 --> 00:47:16,960
main one

1273
00:47:21,750 --> 00:47:20,000
a dime will fit just around there so we

1274
00:47:23,990 --> 00:47:21,760
have a drill bit that's about a dime in

1275
00:47:25,190 --> 00:47:24,000
diameter we drilled in this is the drill

1276
00:47:26,550 --> 00:47:25,200
bit

1277
00:47:28,790 --> 00:47:26,560
and we uh

1278
00:47:31,030 --> 00:47:28,800
we were pleasantly surprised really to

1279
00:47:33,910 --> 00:47:31,040
find that for the first time

1280
00:47:36,309 --> 00:47:33,920
that any mission has eroded or scraped

1281
00:47:39,750 --> 00:47:36,319
or drilled into rocks on mars

1282
00:47:41,750 --> 00:47:39,760
the powder wasn't red but it was gray

1283
00:47:43,750 --> 00:47:41,760
the interior of the rock

1284
00:47:47,270 --> 00:47:43,760
actually had been protected

1285
00:47:49,510 --> 00:47:47,280
from the oxidation that turns mars red

1286
00:47:51,589 --> 00:47:49,520
and that's pretty key that's the reason

1287
00:47:53,270 --> 00:47:51,599
we brought a drill with us honestly i

1288
00:47:55,670 --> 00:47:53,280

mean we wanted to we were hoping that

1289
00:47:57,750 --> 00:47:55,680
the oxidation that's that's harmful to

1290
00:48:00,630 --> 00:47:57,760
life actually and has turned most of

1291
00:48:02,870 --> 00:48:00,640
mars red wouldn't have penetrated

1292
00:48:04,630 --> 00:48:02,880
so deeply into the interiors of rocks

1293
00:48:06,390 --> 00:48:04,640
and we could find if there's any

1294
00:48:07,990 --> 00:48:06,400
evidence of life or the ingredients for

1295
00:48:10,390 --> 00:48:08,000
life that would be destroyed by

1296
00:48:12,390 --> 00:48:10,400
oxidation by drilling into the rocks we

1297
00:48:14,470 --> 00:48:12,400
might be free from that and so the fact

1298
00:48:16,950 --> 00:48:14,480
that we got a scoop full of nice gray

1299
00:48:18,630 --> 00:48:16,960
sand was a real wonderful moment for the

1300
00:48:20,470 --> 00:48:18,640
team

1301
00:48:22,950 --> 00:48:20,480
we then of course needed to shoot it

1302
00:48:24,470 --> 00:48:22,960
with a laser because that's just fun

1303
00:48:26,390 --> 00:48:24,480
so um

1304
00:48:28,069 --> 00:48:26,400
this is the drill hole these are the

1305
00:48:30,630 --> 00:48:28,079
tailings that came out and we kind of

1306
00:48:31,589 --> 00:48:30,640
just zapped across and and we could get

1307
00:48:33,589 --> 00:48:31,599
a nice

1308
00:48:36,230 --> 00:48:33,599
chemical record of how the composition

1309
00:48:37,990 --> 00:48:36,240
of the rock changes between the rock and

1310
00:48:40,150 --> 00:48:38,000
the inside of the rock and then here's

1311
00:48:41,750 --> 00:48:40,160
another little what we call a raster

1312
00:48:43,910 --> 00:48:41,760
pattern we can shoot with the laser as

1313
00:48:46,790 --> 00:48:43,920

well

1314
00:48:49,030 --> 00:48:46,800
i got to tell you what we found now

1315
00:48:50,950 --> 00:48:49,040
because this is sort of the biggest

1316
00:48:52,710 --> 00:48:50,960
discovery of the year

1317
00:48:56,069 --> 00:48:52,720
and really the the main reason we went

1318
00:48:59,990 --> 00:48:58,230
the lab instrument that's not the

1319
00:49:02,390 --> 00:49:00,000
gold-plated one the one that of the guy

1320
00:49:03,670 --> 00:49:02,400
who was in the field using it

1321
00:49:06,230 --> 00:49:03,680
is called an x-ray diffraction

1322
00:49:07,190 --> 00:49:06,240
experiment it shoots an x-ray beam

1323
00:49:09,589 --> 00:49:07,200
through

1324
00:49:11,349 --> 00:49:09,599
a little sleeve of rock powder that we

1325
00:49:13,829 --> 00:49:11,359
feed it after we drill

1326
00:49:15,910 --> 00:49:13,839
and the x-rays are sort of like light

1327
00:49:17,670 --> 00:49:15,920
scattering in a prism they form rainbow

1328
00:49:18,790 --> 00:49:17,680
patterns because rocks are made out of

1329
00:49:21,030 --> 00:49:18,800
crystals

1330
00:49:22,630 --> 00:49:21,040
and the unique rainbow pattern

1331
00:49:24,390 --> 00:49:22,640
there's a unique rainbow pattern for

1332
00:49:26,630 --> 00:49:24,400
every type of mineral

1333
00:49:29,109 --> 00:49:26,640
so by doing this experiment on mars we

1334
00:49:31,510 --> 00:49:29,119
can send back this pattern to earth and

1335
00:49:32,870 --> 00:49:31,520
figure out exactly what the minerals are

1336
00:49:34,870 --> 00:49:32,880
in the rock sample

1337
00:49:37,190 --> 00:49:34,880
and when we did that for typical mars

1338
00:49:38,790 --> 00:49:37,200

sand as sort of a test we got this

1339
00:49:41,030 --> 00:49:38,800
beautiful set of rings which turned out

1340
00:49:42,790 --> 00:49:41,040
to be typical mars basalt

1341
00:49:44,470 --> 00:49:42,800
typical mars rock

1342
00:49:45,349 --> 00:49:44,480
when we did it on the john klein drill

1343
00:49:47,670 --> 00:49:45,359
powder

1344
00:49:49,349 --> 00:49:47,680
we got a very similar signature except

1345
00:49:53,349 --> 00:49:49,359
this bright inner ring

1346
00:49:55,829 --> 00:49:53,359
believe it or not you know grown men cry

1347
00:49:57,910 --> 00:49:55,839
over this no joking but

1348
00:50:00,069 --> 00:49:57,920
it really was the thing that we uh we

1349
00:50:02,309 --> 00:50:00,079
were hoping to find it's a what we call

1350
00:50:04,549 --> 00:50:02,319
phylosilicates which are basically a

1351
00:50:06,790 --> 00:50:04,559
fancy word for clay minerals and so

1352
00:50:08,390 --> 00:50:06,800
finding these clay minerals and uh and

1353
00:50:09,510 --> 00:50:08,400
definitively detecting them with the

1354
00:50:11,510 --> 00:50:09,520
state-of-the-art technique that

1355
00:50:13,510 --> 00:50:11,520
geologists use on earth was a big deal

1356
00:50:15,990 --> 00:50:13,520
this meant that water did interact with

1357
00:50:17,349 --> 00:50:16,000
these primitive rocks and in a long

1358
00:50:19,270 --> 00:50:17,359
enough time

1359
00:50:21,030 --> 00:50:19,280
and the kind of fresh water that you

1360
00:50:23,190 --> 00:50:21,040
heard dr grotzinger mentioned in the

1361
00:50:25,589 --> 00:50:23,200
intro video the kind of fresh water

1362
00:50:28,549 --> 00:50:25,599
required to form clays out of these

1363
00:50:30,790 --> 00:50:28,559

rocks so this was a huge discovery

1364
00:50:31,589 --> 00:50:30,800
and that leads to the story i'll wrap up

1365
00:50:33,990 --> 00:50:31,599
with

1366
00:50:36,150 --> 00:50:34,000
when we put it inside the sam instrument

1367
00:50:37,990 --> 00:50:36,160
the big mass spectrometer

1368
00:50:40,870 --> 00:50:38,000
it works a little differently you put

1369
00:50:41,990 --> 00:50:40,880
the dirt in an oven and the oven slowly

1370
00:50:47,109 --> 00:50:42,000
heats up

1371
00:50:48,549 --> 00:50:47,119
rock minerals begin to disintegrate and

1372
00:50:49,670 --> 00:50:48,559
they sort of let off vapor as they

1373
00:50:51,270 --> 00:50:49,680
disintegrate

1374
00:50:53,030 --> 00:50:51,280
so by this is another technique that's

1375
00:50:55,190 --> 00:50:53,040
used very commonly on earth you heat up

1376
00:50:58,549 --> 00:50:55,200
your rock sample and you watch it

1377
00:50:59,829 --> 00:50:58,559
disintegrate and as you as it does and

1378
00:51:01,990 --> 00:50:59,839
and you make a little chart of what

1379
00:51:03,510 --> 00:51:02,000
comes off at every temperature

1380
00:51:05,349 --> 00:51:03,520
you can back out

1381
00:51:06,950 --> 00:51:05,359
what it was made out of

1382
00:51:08,470 --> 00:51:06,960
and so that's what this is

1383
00:51:11,030 --> 00:51:08,480
i mean you don't really have to know

1384
00:51:12,630 --> 00:51:11,040
much more than that's what that is and

1385
00:51:15,750 --> 00:51:12,640
oxygen came off at one point carbon

1386
00:51:18,549 --> 00:51:15,760
dioxide sulfur water

1387
00:51:21,109 --> 00:51:18,559
and putting this all together it it

1388
00:51:22,790 --> 00:51:21,119

revealed that the inside of that rock

1389
00:51:24,950 --> 00:51:22,800
had both

1390
00:51:26,870 --> 00:51:24,960
water sort of on the on the surface of

1391
00:51:28,790 --> 00:51:26,880
it just the thin amount of water that's

1392
00:51:29,990 --> 00:51:28,800
in the atmosphere today but also those

1393
00:51:34,150 --> 00:51:30,000
clays

1394
00:51:36,230 --> 00:51:34,160
very specific temperature and then you

1395
00:51:38,309 --> 00:51:36,240
see the water come off and so the sam

1396
00:51:39,829 --> 00:51:38,319
experiment confirmed what chemin saw

1397
00:51:41,510 --> 00:51:39,839
that these rocks were full of clay

1398
00:51:43,910 --> 00:51:41,520
minerals

1399
00:51:45,829 --> 00:51:43,920
and actually detected sulfur and other

1400
00:51:48,630 --> 00:51:45,839
things as well

1401
00:51:52,309 --> 00:51:48,640
so putting that all together

1402
00:51:54,549 --> 00:51:52,319
what did it mean it meant that the team

1403
00:51:57,190 --> 00:51:54,559
after a lot of discussion and vigorous

1404
00:51:58,150 --> 00:51:57,200
scientific debate was ready to declare

1405
00:51:59,990 --> 00:51:58,160
that

1406
00:52:01,990 --> 00:52:00,000
yellowknife bay at one point in mars

1407
00:52:03,510 --> 00:52:02,000
history was indeed a habitable

1408
00:52:06,870 --> 00:52:03,520
environment to the best of our ability

1409
00:52:08,870 --> 00:52:06,880
to find it with these instruments

1410
00:52:11,030 --> 00:52:08,880
how do we make that

1411
00:52:13,589 --> 00:52:11,040
that conclusion will the regional

1412
00:52:15,109 --> 00:52:13,599
geology and the fine-grained rock of the

1413
00:52:16,870 --> 00:52:15,119

sheep bedrock

1414
00:52:18,870 --> 00:52:16,880
suggest that john klein was at the end

1415
00:52:21,190 --> 00:52:18,880
of an ancient river system

1416
00:52:22,309 --> 00:52:21,200
or within an intermittently like wet

1417
00:52:24,069 --> 00:52:22,319
lake bed

1418
00:52:26,230 --> 00:52:24,079
we know that the river came down we know

1419
00:52:28,390 --> 00:52:26,240
that these rocks are the kind of rocks

1420
00:52:30,390 --> 00:52:28,400
that very fine green rocks that form in

1421
00:52:31,990 --> 00:52:30,400
a lake environment when sediment being

1422
00:52:34,069 --> 00:52:32,000
transported by a river has the

1423
00:52:36,069 --> 00:52:34,079
opportunity to just settle down and then

1424
00:52:37,510 --> 00:52:36,079
form into rock

1425
00:52:39,190 --> 00:52:37,520
the mineralogy

1426
00:52:40,390 --> 00:52:39,200
indicates sustained interaction with

1427
00:52:42,069 --> 00:52:40,400
liquid water

1428
00:52:43,589 --> 00:52:42,079
and based on all the different evidence

1429
00:52:46,309 --> 00:52:43,599
of water i described it wasn't too

1430
00:52:47,910 --> 00:52:46,319
acidic or alkaline and it wasn't too

1431
00:52:49,030 --> 00:52:47,920
saline there wasn't too much dissolved

1432
00:52:51,109 --> 00:52:49,040
in it

1433
00:52:54,470 --> 00:52:51,119
further the big one the conditions were

1434
00:52:56,870 --> 00:52:55,349
sam

1435
00:52:58,630 --> 00:52:56,880
is able to look at a lot of different

1436
00:53:00,390 --> 00:52:58,640
chemical elements and found a lot of the

1437
00:53:02,710 --> 00:53:00,400
ingredients of life

1438
00:53:05,190 --> 00:53:02,720

that life requires carbon hydrogen

1439
00:53:07,589 --> 00:53:05,200
oxygen phosphorus and sulfur

1440
00:53:09,589 --> 00:53:07,599
these are sort of on the top

1441
00:53:11,030 --> 00:53:09,599
10 list of what any

1442
00:53:12,390 --> 00:53:11,040
biologist would tell you all of our

1443
00:53:14,309 --> 00:53:12,400
cells are made out of and what life

1444
00:53:15,589 --> 00:53:14,319
needs to survive

1445
00:53:17,990 --> 00:53:15,599
and finally

1446
00:53:20,309 --> 00:53:18,000
we're not 100 sure on this one yet we're

1447
00:53:22,309 --> 00:53:20,319
still working on it but it appeared to

1448
00:53:24,630 --> 00:53:22,319
be the presence of minerals in various

1449
00:53:26,390 --> 00:53:24,640
oxidation states that would provide a

1450
00:53:27,750 --> 00:53:26,400
source of energy let me break that one

1451
00:53:30,790 --> 00:53:27,760
down for you because that's a lot of

1452
00:53:31,750 --> 00:53:30,800
jargon but what it means is uh when

1453
00:53:33,430 --> 00:53:31,760
you're looking for a habitable

1454
00:53:35,349 --> 00:53:33,440
environment

1455
00:53:37,589 --> 00:53:35,359
you really you know what life requires

1456
00:53:39,829 --> 00:53:37,599
is the key to ingredients for life

1457
00:53:43,190 --> 00:53:39,839
carbon especially water

1458
00:53:45,190 --> 00:53:43,200
and food a source of energy and sunlight

1459
00:53:47,270 --> 00:53:45,200
of course is there on mars but one of

1460
00:53:49,430 --> 00:53:47,280
the ways that primitive bacteria on

1461
00:53:51,750 --> 00:53:49,440
earth survive when they're buried miles

1462
00:53:54,710 --> 00:53:51,760
down beneath the surface is by using

1463
00:53:56,790 --> 00:53:54,720

chemistry to generate their their food

1464
00:53:59,270 --> 00:53:56,800
and the chemistry

1465
00:54:01,349 --> 00:53:59,280
they use is when different minerals have

1466
00:54:03,030 --> 00:54:01,359
these different states of oxidation they

1467
00:54:04,950 --> 00:54:03,040
can sort of use that difference to

1468
00:54:07,430 --> 00:54:04,960
generate their their energy they need to

1469
00:54:08,470 --> 00:54:07,440
live so finding that these two different

1470
00:54:09,990 --> 00:54:08,480
minerals

1471
00:54:12,069 --> 00:54:10,000
are these two different types of

1472
00:54:14,390 --> 00:54:12,079
oxidation states exist together could

1473
00:54:16,710 --> 00:54:14,400
have provided that food source so we had

1474
00:54:17,589 --> 00:54:16,720
our checklist of ingredients of life

1475
00:54:18,549 --> 00:54:17,599
water

1476
00:54:20,870 --> 00:54:18,559
and

1477
00:54:22,069 --> 00:54:20,880
source of energy we could check each box

1478
00:54:24,230 --> 00:54:22,079
and that's what

1479
00:54:27,670 --> 00:54:24,240
led the team to think that this was a

1480
00:54:30,549 --> 00:54:27,680
potentially habitable environment

1481
00:54:32,150 --> 00:54:30,559
so finally i'll just end with um

1482
00:54:34,950 --> 00:54:32,160
with where we are now because we need to

1483
00:54:36,950 --> 00:54:34,960
kind of wrap it up soon

1484
00:54:39,430 --> 00:54:36,960
mission's going great we did turn around

1485
00:54:42,470 --> 00:54:39,440
finally on july 3rd

1486
00:54:45,030 --> 00:54:42,480
the team spent months at yellowknife bay

1487
00:54:46,950 --> 00:54:45,040
uh months longer than we had planned

1488
00:54:48,069 --> 00:54:46,960

partly because

1489
00:54:50,390 --> 00:54:48,079
it was

1490
00:54:53,430 --> 00:54:50,400
so fantastic and every time we every

1491
00:54:55,349 --> 00:54:53,440
every layer we uncovered

1492
00:54:56,950 --> 00:54:55,359
you know in every every more detailed

1493
00:54:59,190 --> 00:54:56,960
study we did it got more and more

1494
00:55:00,470 --> 00:54:59,200
interesting so we wanted to stay there

1495
00:55:02,309 --> 00:55:00,480
and it was worth it

1496
00:55:04,390 --> 00:55:02,319
and then of course the other aspect is

1497
00:55:05,430 --> 00:55:04,400
that this rover is just kind of hard to

1498
00:55:08,870 --> 00:55:05,440
operate

1499
00:55:11,349 --> 00:55:08,880
it's a beast and it's very complex and

1500
00:55:12,950 --> 00:55:11,359
our sort of pre-landing notions of how

1501
00:55:15,030 --> 00:55:12,960
long it would take to drill the first

1502
00:55:17,109 --> 00:55:15,040
time and and that sort of thing

1503
00:55:19,430 --> 00:55:17,119
probably everything doubled and that's

1504
00:55:20,390 --> 00:55:19,440
fine that's uh that's just how these

1505
00:55:22,309 --> 00:55:20,400
things work

1506
00:55:25,190 --> 00:55:22,319
and and yet now you know we're ready to

1507
00:55:26,790 --> 00:55:25,200
do it um a lot faster in the future

1508
00:55:29,510 --> 00:55:26,800
but it's been an incredible learning

1509
00:55:32,230 --> 00:55:29,520
experience that's why it's exhausting

1510
00:55:34,549 --> 00:55:32,240
we troubleshoot a lot we we really ask

1511
00:55:37,109 --> 00:55:34,559
this rover a lot and the rover always

1512
00:55:39,030 --> 00:55:37,119
pays off in the end

1513
00:55:41,270 --> 00:55:39,040

so what are we doing now here's where we

1514
00:55:43,190 --> 00:55:41,280
are now bradbury landing

1515
00:55:45,750 --> 00:55:43,200
we drove over to yellowknife bay now

1516
00:55:47,670 --> 00:55:45,760
we've driven well past our landing site

1517
00:55:50,309 --> 00:55:47,680
and are headed towards mount sharp

1518
00:55:52,309 --> 00:55:50,319
so we're about um

1519
00:55:53,990 --> 00:55:52,319
we're about we're just a little ways

1520
00:55:55,990 --> 00:55:54,000
into a long journey

1521
00:55:57,510 --> 00:55:56,000
to be frank

1522
00:55:58,950 --> 00:55:57,520
we're probably going to arrive there

1523
00:55:59,910 --> 00:55:58,960
around next summer

1524
00:56:01,589 --> 00:55:59,920
so

1525
00:56:04,150 --> 00:56:01,599
it's still a ways off and then we'll

1526
00:56:06,470 --> 00:56:04,160
spend the next you know years after that

1527
00:56:07,829 --> 00:56:06,480
hopefully uh climbing the foothills of

1528
00:56:09,430 --> 00:56:07,839
mount sharp going through those clays

1529
00:56:11,510 --> 00:56:09,440
and going through those sulfates looking

1530
00:56:13,589 --> 00:56:11,520
for how this environment we saw

1531
00:56:14,829 --> 00:56:13,599
yellowknife fits into the bigger picture

1532
00:56:17,829 --> 00:56:14,839
of

1533
00:56:20,230 --> 00:56:17,839
mars the way we take a few pictures this

1534
00:56:22,390 --> 00:56:20,240
is a picture we took with that that

1535
00:56:23,829 --> 00:56:22,400
wonderful arm mounted camera

1536
00:56:25,030 --> 00:56:23,839
without even deploying the arm the arm

1537
00:56:26,789 --> 00:56:25,040
just kind of sits on the rover deck and

1538
00:56:29,589 --> 00:56:26,799

we snap a picture every once in a while

1539
00:56:31,670 --> 00:56:29,599
post cards along the way

1540
00:56:33,349 --> 00:56:31,680
look at that i mean this is like

1541
00:56:35,030 --> 00:56:33,359
mind-blowing

1542
00:56:36,630 --> 00:56:35,040
these are fantastic pictures of the

1543
00:56:41,589 --> 00:56:36,640
foothills of mount sharp taken by our

1544
00:56:45,109 --> 00:56:43,109
here's where we're going to go we're

1545
00:56:46,630 --> 00:56:45,119
going to drive a clock across across

1546
00:56:48,390 --> 00:56:46,640
these dark dunes

1547
00:56:49,990 --> 00:56:48,400
and then begin driving up one of these

1548
00:56:52,230 --> 00:56:50,000
canyons

1549
00:56:53,510 --> 00:56:52,240
the the clays are down here the sulfates

1550
00:56:55,510 --> 00:56:53,520
are in these buttes

1551
00:56:58,230 --> 00:56:55,520
and then this is that dust layer on the

1552
00:56:59,270 --> 00:56:58,240
top

1553
00:57:00,950 --> 00:56:59,280
and then

1554
00:57:02,870 --> 00:57:00,960
this is uh this is actually where we're

1555
00:57:04,150 --> 00:57:02,880
going uh we're going to this part of the

1556
00:57:05,910 --> 00:57:04,160
mountain and we'll drive up one of these

1557
00:57:08,950 --> 00:57:05,920
canyons

1558
00:57:11,030 --> 00:57:08,960
up to about maybe here and in fact

1559
00:57:12,870 --> 00:57:11,040
if you can see it but there's a sort of

1560
00:57:15,589 --> 00:57:12,880
a boulder over here

1561
00:57:17,589 --> 00:57:15,599
and that'll be the size of curiosity so

1562
00:57:18,390 --> 00:57:17,599
this will be unlike anything we've ever

1563
00:57:19,990 --> 00:57:18,400

done

1564
00:57:21,829 --> 00:57:20,000
on another planet you know we'll be

1565
00:57:23,430 --> 00:57:21,839
driving through these mountains and

1566
00:57:25,349 --> 00:57:23,440
foothills and seeing walls of rock on

1567
00:57:28,390 --> 00:57:25,359
either side of us

1568
00:57:29,829 --> 00:57:28,400
is going to be fantastic

1569
00:57:32,950 --> 00:57:29,839
so i'll just end

1570
00:57:36,789 --> 00:57:34,870
you realize uh

1571
00:57:38,390 --> 00:57:36,799
how many people contributed to

1572
00:57:42,069 --> 00:57:38,400
everything that i

1573
00:58:03,829 --> 00:57:45,440
and thank you for your support

1574
00:58:08,789 --> 00:58:06,150
so there's a microphone here

1575
00:58:10,309 --> 00:58:08,799
we can answer a couple questions live

1576
00:58:12,069 --> 00:58:10,319
and then we're going to shut down all

1577
00:58:13,750 --> 00:58:12,079
the the the taping that's going on for

1578
00:58:15,270 --> 00:58:13,760
everybody to watch it then i'll feel

1579
00:58:15,990 --> 00:58:15,280
free to answer more questions afterwards

1580
00:58:17,349 --> 00:58:16,000
so

1581
00:58:27,030 --> 00:58:17,359
a couple questions from the mic now

1582
00:58:30,470 --> 00:58:29,190
you talk a lot about how you've shown

1583
00:58:33,430 --> 00:58:30,480
that there's

1584
00:58:36,870 --> 00:58:33,440
uh a habitable environment what was

1585
00:58:39,190 --> 00:58:36,880
there in the past

1586
00:58:40,870 --> 00:58:39,200
i think my question is a little a little

1587
00:58:42,309 --> 00:58:40,880
different than that i'm

1588
00:58:44,470 --> 00:58:42,319

if

1589
00:58:45,750 --> 00:58:44,480
to what extent has the major analysis

1590
00:58:47,349 --> 00:58:45,760
you've done

1591
00:58:49,910 --> 00:58:47,359
show that

1592
00:58:51,910 --> 00:58:49,920
you have soil there maybe some of the

1593
00:58:55,109 --> 00:58:51,920
some of what you found is soil that you

1594
00:58:56,710 --> 00:58:55,119
could you could uh that would support

1595
00:58:59,829 --> 00:58:56,720
life brought from earth you could you

1596
00:59:02,789 --> 00:58:59,839
could bring the bacteria earth bacteria

1597
00:59:04,630 --> 00:59:02,799
and seeds and and grow a crop

1598
00:59:06,630 --> 00:59:04,640
right right how close are you to showing

1599
00:59:08,789 --> 00:59:06,640
that that is possible i mean you'd have

1600
00:59:11,430 --> 00:59:08,799
to have like a greenhouse and right and

1601
00:59:12,549 --> 00:59:11,440
keep the water from escaping and so on

1602
00:59:14,069 --> 00:59:12,559
yeah um

1603
00:59:15,430 --> 00:59:14,079
that's not something we directly have

1604
00:59:16,309 --> 00:59:15,440
thought about

1605
00:59:17,430 --> 00:59:16,319
but

1606
00:59:19,670 --> 00:59:17,440
finding

1607
00:59:21,589 --> 00:59:19,680
the extent of that heavily oxidized

1608
00:59:23,910 --> 00:59:21,599
layer on mars the fact that if you dig

1609
00:59:26,470 --> 00:59:23,920
down even into the insides of rocks you

1610
00:59:27,990 --> 00:59:26,480
can get soil that's a lot less toxic to

1611
00:59:30,630 --> 00:59:28,000
life is a big

1612
00:59:31,910 --> 00:59:30,640
conclusion of curiosity what future

1613
00:59:34,230 --> 00:59:31,920

missions are going to do is actually try

1614
00:59:36,230 --> 00:59:34,240
to drill one or two meters down to get

1615
00:59:37,990 --> 00:59:36,240
even further away from the destructive

1616
00:59:39,349 --> 00:59:38,000
environment at the surface so i think

1617
00:59:41,750 --> 00:59:39,359
we're learning that there is raw

1618
00:59:43,750 --> 00:59:41,760
material on mars that could provide a

1619
00:59:46,549 --> 00:59:43,760
less toxic environment than the surface

1620
00:59:48,630 --> 00:59:46,559
so the surface is toxic

1621
00:59:50,870 --> 00:59:48,640
because of not just because of the the

1622
00:59:52,390 --> 00:59:50,880
radiation coming in but because of the

1623
00:59:53,829 --> 00:59:52,400
chemicals you have that's right the

1624
01:00:00,390 --> 00:59:53,839
chemicals that are formed by the

1625
01:00:06,630 --> 01:00:02,950
i have a two-part question

1626
01:00:08,069 --> 01:00:06,640
uh first off uh regarding marty

1627
01:00:10,950 --> 01:00:08,079
uh

1628
01:00:13,190 --> 01:00:10,960
were there any fluctuations noted in the

1629
01:00:15,910 --> 01:00:13,200
descent imager

1630
01:00:18,789 --> 01:00:15,920
when it reached its proximity

1631
01:00:20,150 --> 01:00:18,799
and secondly uh regarding solar

1632
01:00:23,910 --> 01:00:20,160
conjunction

1633
01:00:25,270 --> 01:00:23,920
uh is the rover able to receive uh

1634
01:00:27,670 --> 01:00:25,280
any uh

1635
01:00:30,150 --> 01:00:27,680
information regarding the instruments on

1636
01:00:32,150 --> 01:00:30,160
it at the current time

1637
01:00:33,990 --> 01:00:32,160
right um so we went through solar

1638
01:00:36,870 --> 01:00:34,000

conjunction i think in about

1639
01:00:38,789 --> 01:00:36,880
april or may so we actually had to

1640
01:00:41,510 --> 01:00:38,799
not operate the rover for about i think

1641
01:00:43,670 --> 01:00:41,520
it was about 20 28 days or something

1642
01:00:46,069 --> 01:00:43,680
where we were not in communication with

1643
01:00:47,510 --> 01:00:46,079
it from earth or from the orbiters

1644
01:00:49,510 --> 01:00:47,520
well the orbiters actually did talk to

1645
01:00:52,069 --> 01:00:49,520
the rover but the earth could not talk

1646
01:00:53,910 --> 01:00:52,079
to either the orbiters or the rover so

1647
01:00:55,349 --> 01:00:53,920
that was a nerve-wracking time earlier

1648
01:00:58,230 --> 01:00:55,359
this year when and what conjunction

1649
01:01:00,230 --> 01:00:58,240
means is that mars goes behind the sun

1650
01:01:01,990 --> 01:01:00,240
as seen from earth and that disrupts our

1651
01:01:04,470 --> 01:01:02,000
ability to communicate so we gave the

1652
01:01:06,870 --> 01:01:04,480
rover 28 days of things to do actually

1653
01:01:09,030 --> 01:01:06,880
uh simple things didn't ask too much and

1654
01:01:10,870 --> 01:01:09,040
it did them every day and we recovered

1655
01:01:12,549 --> 01:01:10,880
it afterwards and with marty the descent

1656
01:01:14,789 --> 01:01:12,559
imager um

1657
01:01:16,950 --> 01:01:14,799
i don't know exactly what fluctuations

1658
01:01:17,990 --> 01:01:16,960
you you are asking about but we did

1659
01:01:19,910 --> 01:01:18,000
record

1660
01:01:21,750 --> 01:01:19,920
all the different you know sways of the

1661
01:01:23,670 --> 01:01:21,760
rover as we're driving as we were flying

1662
01:01:25,349 --> 01:01:23,680
down and then the rockets came on and it

1663
01:01:26,390 --> 01:01:25,359

got very smooth

1664
01:01:28,549 --> 01:01:26,400
while we're on the parachute in other

1665
01:01:30,150 --> 01:01:28,559
words we we swung a little bit once the

1666
01:01:31,270 --> 01:01:30,160
rockets fired it was a very smooth

1667
01:01:38,309 --> 01:01:31,280
descent

1668
01:01:41,990 --> 01:01:38,319
on a proximity that was very smooth and

1669
01:01:42,950 --> 01:01:42,000
eliminated uh perhaps other proximity is

1670
01:01:45,109 --> 01:01:42,960
the word

1671
01:01:47,829 --> 01:01:45,119
oh i see what you mean

1672
01:01:50,069 --> 01:01:47,839
you can consider this flight of marty as

1673
01:01:52,470 --> 01:01:50,079
sort of a test run for that so we ran

1674
01:01:54,950 --> 01:01:52,480
marty we just turned it on and recorded

1675
01:01:56,710 --> 01:01:54,960
a movie but we didn't use the movie in

1676
01:01:59,670 --> 01:01:56,720
real time to aim for a better landing

1677
01:02:01,990 --> 01:01:59,680
site uh future missions will do that um

1678
01:02:03,750 --> 01:02:02,000
for sure and marty is sort of a good

1679
01:02:06,390 --> 01:02:03,760
test run to do it without putting the

1680
01:02:09,510 --> 01:02:06,400
mission you know online for that

1681
01:02:12,789 --> 01:02:11,190
okay thanks for the presentation so i

1682
01:02:15,030 --> 01:02:12,799
have two questions and then one question

1683
01:02:18,069 --> 01:02:15,040
is so what's the like the best theory so

1684
01:02:20,470 --> 01:02:18,079
far that explains the like how water

1685
01:02:22,150 --> 01:02:20,480
like disappeared on mars and the second

1686
01:02:24,710 --> 01:02:22,160
question is so how can you actually

1687
01:02:26,390 --> 01:02:24,720
control the curiosity of the mars so

1688
01:02:29,109 --> 01:02:26,400

specifically the look i mean

1689
01:02:31,030 --> 01:02:29,119
localization and also some sort of path

1690
01:02:33,190 --> 01:02:31,040
planning method they use for the

1691
01:02:35,190 --> 01:02:33,200
curiosity to explore the mars yeah

1692
01:02:36,950 --> 01:02:35,200
that's my question okay i'll answer the

1693
01:02:38,309 --> 01:02:36,960
second one i'm just realizing it's eight

1694
01:02:40,150 --> 01:02:38,319
and i have sort of a hard cut off but

1695
01:02:43,670 --> 01:02:40,160
then i'll stick around like i said

1696
01:02:45,829 --> 01:02:43,680
but the second one is um we

1697
01:02:49,190 --> 01:02:45,839
okay

1698
01:02:51,270 --> 01:02:49,200
have more time

1699
01:02:52,950 --> 01:02:51,280
[Laughter]

1700
01:02:53,990 --> 01:02:52,960
which is great uh

1701
01:02:55,750 --> 01:02:54,000
now i have to remember your first

1702
01:02:56,789 --> 01:02:55,760
question um but the second one i'll get

1703
01:02:59,589 --> 01:02:56,799
to

1704
01:03:01,990 --> 01:02:59,599
uh we we do path planning based on what

1705
01:03:04,630 --> 01:03:02,000
we call our navigation cameras so we

1706
01:03:06,470 --> 01:03:04,640
have a set of stereo cameras that take

1707
01:03:07,510 --> 01:03:06,480
three-dimensional images in black and

1708
01:03:09,750 --> 01:03:07,520
white because that's all the rover

1709
01:03:10,870 --> 01:03:09,760
really needs and they're mounted up on

1710
01:03:12,710 --> 01:03:10,880
that mast

1711
01:03:14,470 --> 01:03:12,720
we also have what are called hazard

1712
01:03:16,549 --> 01:03:14,480
cameras which are much more fisheye

1713
01:03:18,549 --> 01:03:16,559

cameras that are mounted down low so

1714
01:03:21,270 --> 01:03:18,559
every day the rover sends back those

1715
01:03:23,029 --> 01:03:21,280
images and engineers here on on earth

1716
01:03:25,349 --> 01:03:23,039
put on their 3d goggles and they choose

1717
01:03:27,990 --> 01:03:25,359
a path and the current way we drive is

1718
01:03:30,069 --> 01:03:28,000
actually we drive to the edge of that 3d

1719
01:03:31,990 --> 01:03:30,079
map that we can make on earth and then

1720
01:03:33,270 --> 01:03:32,000
we stop the rover and we do it again the

1721
01:03:34,789 --> 01:03:33,280
next day

1722
01:03:37,029 --> 01:03:34,799
pretty soon we're going to bring online

1723
01:03:38,870 --> 01:03:37,039
a capability called auto navigation

1724
01:03:41,270 --> 01:03:38,880
where the rover will actually take those

1725
01:03:42,789 --> 01:03:41,280
images every few meters and figure out

1726
01:03:43,750 --> 01:03:42,799
its own path

1727
01:03:45,270 --> 01:03:43,760
where

1728
01:03:46,789 --> 01:03:45,280
with this rover there's so much to do

1729
01:03:48,470 --> 01:03:46,799
and so much complexity we sort of ramp

1730
01:03:50,789 --> 01:03:48,480
up and we're not there yet with the auto

1731
01:03:52,950 --> 01:03:50,799
nav the first question about how fresh

1732
01:03:55,190 --> 01:03:52,960
the water is oh yeah so how water

1733
01:03:57,430 --> 01:03:55,200
disappeared on mars oh the best theory

1734
01:03:59,029 --> 01:03:57,440
we have so far yeah i mean the main

1735
01:04:01,190 --> 01:03:59,039
theory is the one i mentioned where the

1736
01:04:03,270 --> 01:04:01,200
solar wind particles from the sun slowly

1737
01:04:05,510 --> 01:04:03,280
strip away mars atmosphere as the

1738
01:04:07,910 --> 01:04:05,520

atmosphere shrinks both carbon dioxide

1739
01:04:09,349 --> 01:04:07,920
is being lost and water but also more

1740
01:04:11,589 --> 01:04:09,359
importantly

1741
01:04:13,510 --> 01:04:11,599
once you get too thin of an atmosphere

1742
01:04:15,270 --> 01:04:13,520
you no longer can support liquid water

1743
01:04:16,950 --> 01:04:15,280
the water water starts going directly

1744
01:04:18,549 --> 01:04:16,960
it's like dry ice on earth it goes

1745
01:04:19,990 --> 01:04:18,559
directly from the frozen state to the

1746
01:04:20,789 --> 01:04:20,000
gas state

1747
01:04:22,470 --> 01:04:20,799
and

1748
01:04:24,309 --> 01:04:22,480
once that happens it gets locked up in

1749
01:04:26,549 --> 01:04:24,319
the polar caps if you're actually to

1750
01:04:28,789 --> 01:04:26,559
melt mars polar caps you'd get several

1751
01:04:30,789 --> 01:04:28,799
meters of water around the planet you

1752
01:04:33,270 --> 01:04:30,799
get an ocean basically but right now all

1753
01:04:36,069 --> 01:04:33,280
that water is locked up at the poles

1754
01:04:40,950 --> 01:04:38,870
hi this isn't a very scientific question

1755
01:04:42,950 --> 01:04:40,960
but i heard on the other day that the

1756
01:04:45,510 --> 01:04:42,960
budget of jpl is going to be less on

1757
01:04:47,270 --> 01:04:45,520
space exploration and more

1758
01:04:48,630 --> 01:04:47,280
earth sciences and

1759
01:04:50,390 --> 01:04:48,640
i was wondering if that's going to

1760
01:04:51,270 --> 01:04:50,400
affect you and if the

1761
01:04:53,829 --> 01:04:51,280
um

1762
01:04:55,750 --> 01:04:53,839
i mean the project and the sequester has

1763
01:04:57,750 --> 01:04:55,760

affected the project

1764
01:05:01,750 --> 01:04:57,760
um

1765
01:05:03,670 --> 01:05:01,760
i don't think that there's going to be a

1766
01:05:05,510 --> 01:05:03,680
decrease in in what jpl does in terms of

1767
01:05:06,390 --> 01:05:05,520
planetary exploration i mean we're still

1768
01:05:07,670 --> 01:05:06,400
waiting

1769
01:05:09,270 --> 01:05:07,680
for some

1770
01:05:11,349 --> 01:05:09,280
guidance there on what the big missions

1771
01:05:13,029 --> 01:05:11,359
will be in the future uh we we of course

1772
01:05:15,910 --> 01:05:13,039
have the 2020 rover mission that was

1773
01:05:17,829 --> 01:05:15,920
announced so follow on to curiosity uh

1774
01:05:19,829 --> 01:05:17,839
hopefully we'll see an outer planets

1775
01:05:23,270 --> 01:05:19,839
mission come pretty soon um hopefully to

1776
01:05:24,630 --> 01:05:23,280
jpl and then uh um and then of course we

1777
01:05:26,309 --> 01:05:24,640
do have a really vigorous earth

1778
01:05:28,549 --> 01:05:26,319
exploration program here as well which

1779
01:05:29,910 --> 01:05:28,559
uh i think you know it will be the the

1780
01:05:31,190 --> 01:05:29,920
near-term emphasis just because there's

1781
01:05:33,430 --> 01:05:31,200
sort of a gap in

1782
01:05:35,029 --> 01:05:33,440
uh we just got curiosity there uh but i

1783
01:05:36,549 --> 01:05:35,039
think the overall we're

1784
01:05:38,069 --> 01:05:36,559
things are pretty healthy and there's a

1785
01:05:41,190 --> 01:05:38,079
sequester

1786
01:05:46,230 --> 01:05:42,950
it's a pain for everybody in the country

1787
01:05:49,670 --> 01:05:48,150
congratulations it was just so i wanted

1788
01:05:51,109 --> 01:05:49,680

to jump up and cheer many times during

1789
01:05:53,829 --> 01:05:51,119
that movie and other things you've said

1790
01:05:56,069 --> 01:05:53,839
thanks again and to everybody involved

1791
01:05:57,750 --> 01:05:56,079
so the selection of mount sharp again

1792
01:05:59,270 --> 01:05:57,760
it's because it has the most sedimentary

1793
01:06:01,190 --> 01:05:59,280
record which would be the most useful

1794
01:06:02,309 --> 01:06:01,200
thing to try to

1795
01:06:05,109 --> 01:06:02,319
read

1796
01:06:07,029 --> 01:06:05,119
i see and um i know the

1797
01:06:09,510 --> 01:06:07,039
main thing you said was to see whether

1798
01:06:11,670 --> 01:06:09,520
mars was ever inhabitable but can you

1799
01:06:13,270 --> 01:06:11,680
foresee that any kind of discovery here

1800
01:06:15,109 --> 01:06:13,280
or understanding could also contribute

1801
01:06:17,829 --> 01:06:15,119
to our understanding of the origins of

1802
01:06:23,349 --> 01:06:19,589
any processes or

1803
01:06:24,950 --> 01:06:23,359
elements or anything like that yeah um

1804
01:06:27,670 --> 01:06:24,960
it's an interesting one i i think our

1805
01:06:29,910 --> 01:06:27,680
instruments have are capable of

1806
01:06:31,270 --> 01:06:29,920
of studying the more primitive rocks of

1807
01:06:33,029 --> 01:06:31,280
mars which would be the kind of thing

1808
01:06:35,510 --> 01:06:33,039
that would tell you more about how the

1809
01:06:37,109 --> 01:06:35,520
solar system formed for example

1810
01:06:38,549 --> 01:06:37,119
we are

1811
01:06:40,630 --> 01:06:38,559
this the interesting part of is we're

1812
01:06:42,230 --> 01:06:40,640
sort of avoiding those rocks because the

1813
01:06:43,910 --> 01:06:42,240

more interesting rocks to us are the

1814
01:06:46,230 --> 01:06:43,920
ones that have been

1815
01:06:48,069 --> 01:06:46,240
taken from their primitive state and

1816
01:06:49,430 --> 01:06:48,079
trans you know other minerals have

1817
01:06:51,349 --> 01:06:49,440
formed from them because of their

1818
01:06:53,750 --> 01:06:51,359
interaction with water and other

1819
01:06:55,510 --> 01:06:53,760
processes so you know we actually

1820
01:06:57,750 --> 01:06:55,520
if we were to see

1821
01:06:58,950 --> 01:06:57,760
a chunk of primitive mars basalt we

1822
01:07:00,549 --> 01:06:58,960
would probably

1823
01:07:02,710 --> 01:07:00,559
skirt around the outside

1824
01:07:03,750 --> 01:07:02,720
to keep the people on our team who are

1825
01:07:06,630 --> 01:07:03,760
interested in those questions from

1826
01:07:09,510 --> 01:07:07,750
but you never know what you're going to

1827
01:07:10,630 --> 01:07:09,520
find on the long track to my sharp

1828
01:07:11,750 --> 01:07:10,640
either right that is true because all

1829
01:07:13,670 --> 01:07:11,760
you have so far

1830
01:07:15,750 --> 01:07:13,680
is

1831
01:07:17,589 --> 01:07:15,760
observed from higher up yeah i mean in

1832
01:07:19,670 --> 01:07:17,599
about a half a kilometer we saw five

1833
01:07:21,670 --> 01:07:19,680
different rock layers only two of which

1834
01:07:23,910 --> 01:07:21,680
we expected to see and you know there's

1835
01:07:25,029 --> 01:07:23,920
so much more left to go to mount sharp

1836
01:07:26,950 --> 01:07:25,039
that's actually one of the biggest

1837
01:07:28,710 --> 01:07:26,960
problems on the mission right now is

1838
01:07:30,950 --> 01:07:28,720

keeping our blinders on

1839
01:07:32,549 --> 01:07:30,960
you know we want to get there and like i

1840
01:07:34,870 --> 01:07:32,559
said it's a year away

1841
01:07:37,109 --> 01:07:34,880
and the more we stop to look at stuff

1842
01:07:38,390 --> 01:07:37,119
along the way you're never gonna yeah we

1843
01:07:40,390 --> 01:07:38,400
make all these analogies all the time

1844
01:07:42,549 --> 01:07:40,400
like you got to keep kids inside because

1845
01:07:43,349 --> 01:07:42,559
you want to get to disneyland eventually

1846
01:07:44,870 --> 01:07:43,359
yeah

1847
01:07:49,829 --> 01:07:44,880
you can't stop at the dinosaur on the

1848
01:07:53,750 --> 01:07:51,270
yeah again that was a really great video

1849
01:07:55,750 --> 01:07:53,760
i really enjoyed it um so we found all

1850
01:07:56,789 --> 01:07:55,760
this evidence for liquid water on mars

1851
01:07:58,309 --> 01:07:56,799
and

1852
01:08:00,150 --> 01:07:58,319
you know i'm pretty sure i don't know if

1853
01:08:02,789 --> 01:08:00,160
it's the same on or different on other

1854
01:08:05,270 --> 01:08:02,799
planets but different environments but

1855
01:08:08,630 --> 01:08:05,280
water freezes at 32 degrees

1856
01:08:10,390 --> 01:08:08,640
so do we have any idea what temperature

1857
01:08:11,349 --> 01:08:10,400
mars would have been to host liquid

1858
01:08:12,710 --> 01:08:11,359
water

1859
01:08:14,710 --> 01:08:12,720
right

1860
01:08:15,670 --> 01:08:14,720
yeah so that turns out to be a pretty

1861
01:08:18,309 --> 01:08:15,680
hard

1862
01:08:20,630 --> 01:08:18,319
lower bound on on water freezing at zero

1863
01:08:23,030 --> 01:08:20,640

degrees celsius or 32 fahrenheit and

1864
01:08:24,709 --> 01:08:23,040
that would have been true on mars

1865
01:08:26,709 --> 01:08:24,719
and really independent of how thick the

1866
01:08:29,510 --> 01:08:26,719
atmosphere was what changes is actually

1867
01:08:31,990 --> 01:08:29,520
the the boiling point uh and so on earth

1868
01:08:34,149 --> 01:08:32,000
it's 100 c or 212 fahrenheit when you

1869
01:08:36,470 --> 01:08:34,159
get a very thin atmosphere it goes all

1870
01:08:37,910 --> 01:08:36,480
the way close to zero and like i

1871
01:08:40,550 --> 01:08:37,920
mentioned it behaves like dry ice at

1872
01:08:42,870 --> 01:08:40,560
that point it goes from solid to boiling

1873
01:08:45,030 --> 01:08:42,880
right away so if you were to throw out

1874
01:08:46,709 --> 01:08:45,040
a bucket of water on mars surface today

1875
01:08:48,149 --> 01:08:46,719
it would sort of freeze and boil away at

1876
01:08:50,070 --> 01:08:48,159
the same time

1877
01:08:51,829 --> 01:08:50,080
kind of interesting

1878
01:08:53,349 --> 01:08:51,839
and and rivers won't flow very long

1879
01:08:56,309 --> 01:08:53,359
because they will freeze and and

1880
01:08:58,149 --> 01:08:56,319
evaporate at the same time uh

1881
01:09:00,309 --> 01:08:58,159
so to answer your question uh yeah you

1882
01:09:01,430 --> 01:09:00,319
would have had to have parts of mars

1883
01:09:04,870 --> 01:09:01,440
above

1884
01:09:07,030 --> 01:09:04,880
zero c or 32 f to um to have liquid

1885
01:09:09,030 --> 01:09:07,040
water okay and the second question if

1886
01:09:09,749 --> 01:09:09,040
you don't mind um in one of your prior

1887
01:09:11,910 --> 01:09:09,759
uh

1888
01:09:13,749 --> 01:09:11,920

the previous slides the snapshots from

1889
01:09:15,990 --> 01:09:13,759
mars uh the one where you showed

1890
01:09:18,149 --> 01:09:16,000
curiosity would be the size of this how

1891
01:09:19,590 --> 01:09:18,159
far away is that and how far up mount

1892
01:09:21,510 --> 01:09:19,600
sharp is that

1893
01:09:22,950 --> 01:09:21,520
oh um

1894
01:09:23,749 --> 01:09:22,960
this guy

1895
01:09:25,910 --> 01:09:23,759
so

1896
01:09:27,510 --> 01:09:25,920
we're well we what i mentioned about

1897
01:09:29,669 --> 01:09:27,520
where we'll be in a year

1898
01:09:30,950 --> 01:09:29,679
is to what we call the mount sharp entry

1899
01:09:32,149 --> 01:09:30,960
point which is sort of over here

1900
01:09:35,110 --> 01:09:32,159
somewhere

1901
01:09:36,550 --> 01:09:35,120
and that's about um you know roughly

1902
01:09:37,269 --> 01:09:36,560
five or six miles

1903
01:09:43,110 --> 01:09:37,279
so

1904
01:09:45,189 --> 01:09:43,120
five or six miles in a year come on um

1905
01:09:48,309 --> 01:09:45,199
but yeah it's uh

1906
01:09:50,709 --> 01:09:48,319
there's no road

1907
01:09:52,149 --> 01:09:50,719
and then it'll probably take us you know

1908
01:09:53,430 --> 01:09:52,159
then we're gonna actually start drilling

1909
01:09:55,830 --> 01:09:53,440
again and things like that as we go to

1910
01:09:57,350 --> 01:09:55,840
these layers so if we were to just uh

1911
01:10:00,470 --> 01:09:57,360
okay and then this is probably another

1912
01:10:02,470 --> 01:10:00,480
few miles to get from the entry point up

1913
01:10:03,830 --> 01:10:02,480

to the dusty layer

1914
01:10:06,149 --> 01:10:03,840
but of course this part's going to be

1915
01:10:07,669 --> 01:10:06,159
much slower because we're going to do

1916
01:10:09,350 --> 01:10:07,679
a clay

1917
01:10:11,910 --> 01:10:09,360
drill you know at least one probably a

1918
01:10:14,630 --> 01:10:11,920
lot sulfates and then get up here

1919
01:10:17,110 --> 01:10:14,640
so yeah how far up the mountain is that

1920
01:10:19,270 --> 01:10:17,120
um up to the dusty layer is actually

1921
01:10:21,669 --> 01:10:19,280
it's it's only a few hundred meters up

1922
01:10:22,950 --> 01:10:21,679
uh at its lowest extent so

1923
01:10:24,070 --> 01:10:22,960
we don't have to actually climb that

1924
01:10:25,350 --> 01:10:24,080
high

1925
01:10:27,189 --> 01:10:25,360
but it's a lot of

1926
01:10:28,950 --> 01:10:27,199
lateral driving i mean i didn't really

1927
01:10:31,030 --> 01:10:28,960
mention this but you know being three

1928
01:10:33,270 --> 01:10:31,040
miles high mount sharp is higher than

1929
01:10:36,149 --> 01:10:33,280
any mountain in the united states except

1930
01:10:38,149 --> 01:10:36,159
for alaska so it's a high mountain you

1931
01:10:40,709 --> 01:10:38,159
know and we're even going up the

1932
01:10:44,070 --> 01:10:40,719
foothills of it is uh challenging cool

1933
01:10:46,070 --> 01:10:44,080
thank you very much

1934
01:10:46,950 --> 01:10:46,080
hi congratulations and thanks for

1935
01:10:49,270 --> 01:10:46,960
sharing

1936
01:10:51,990 --> 01:10:49,280
um i wanted to know a little bit about

1937
01:10:53,669 --> 01:10:52,000
the communication with with curiosity

1938
01:10:56,870 --> 01:10:53,679

how do you guys communicate how long

1939
01:11:00,070 --> 01:10:56,880
does it take to get it to answer and do

1940
01:11:02,149 --> 01:11:00,080
things sure no it's um

1941
01:11:03,669 --> 01:11:02,159
that's a fun one

1942
01:11:06,310 --> 01:11:03,679
so uh

1943
01:11:08,550 --> 01:11:06,320
we have um what's called the deep space

1944
01:11:09,750 --> 01:11:08,560
network here on earth these big antennas

1945
01:11:12,390 --> 01:11:09,760
i'm looking for one around the room i

1946
01:11:14,390 --> 01:11:12,400
think it's in the museum you can see it

1947
01:11:16,470 --> 01:11:14,400
but they're these giant antenna dishes

1948
01:11:19,030 --> 01:11:16,480
and there's one in australia one in

1949
01:11:21,030 --> 01:11:19,040
spain one in the u.s so no matter where

1950
01:11:22,550 --> 01:11:21,040
earth is rotating mars is always in the

1951
01:11:24,470 --> 01:11:22,560
view of one of them

1952
01:11:26,070 --> 01:11:24,480
but then of course mars is rotating also

1953
01:11:27,270 --> 01:11:26,080
so the rover comes in and out of you

1954
01:11:29,669 --> 01:11:27,280
from earth

1955
01:11:32,550 --> 01:11:29,679
so we use the deep space network to give

1956
01:11:35,750 --> 01:11:32,560
the rover a set of commands once a day

1957
01:11:38,709 --> 01:11:35,760
as as mars just comes into view and

1958
01:11:40,470 --> 01:11:38,719
earth is rising on mars we give it a set

1959
01:11:43,110 --> 01:11:40,480
of commands and actually it's really

1960
01:11:46,630 --> 01:11:43,120
when when the sun is rising on mars

1961
01:11:48,709 --> 01:11:46,640
at about 10 a.m or so on mars and mars

1962
01:11:50,149 --> 01:11:48,719
has a 24 and a half hour day

1963
01:11:52,310 --> 01:11:50,159

so it's very similar to earth in that

1964
01:11:54,149 --> 01:11:52,320
respect about 10 a.m on mars we send up

1965
01:11:55,110 --> 01:11:54,159
a day's worth of commands the rover does

1966
01:11:56,550 --> 01:11:55,120
that day's worth of commands

1967
01:11:58,550 --> 01:11:56,560
autonomously

1968
01:12:01,030 --> 01:11:58,560
we can't really joystick it from earth

1969
01:12:03,110 --> 01:12:01,040
because it's about a half hour

1970
01:12:05,030 --> 01:12:03,120
round trip time if we were to try to

1971
01:12:06,310 --> 01:12:05,040
turn left and then wait half an hour

1972
01:12:08,229 --> 01:12:06,320
turn you know

1973
01:12:09,590 --> 01:12:08,239
we don't do that so it does a day's

1974
01:12:11,430 --> 01:12:09,600
worth of commands and then at three

1975
01:12:13,990 --> 01:12:11,440
o'clock in the afternoon or so

1976
01:12:16,550 --> 01:12:14,000
um mars reconnaissance orbiter

1977
01:12:18,550 --> 01:12:16,560
flies overhead and for about 15 minutes

1978
01:12:20,630 --> 01:12:18,560
uh the rover communicates with it and

1979
01:12:22,229 --> 01:12:20,640
sends the data back so once a day we

1980
01:12:25,590 --> 01:12:22,239
command it once a day we get the data

1981
01:12:27,270 --> 01:12:25,600
back and we can do that every day

1982
01:12:29,669 --> 01:12:27,280
for about this is where it gets a little

1983
01:12:32,550 --> 01:12:29,679
tricky for about half the month because

1984
01:12:34,790 --> 01:12:32,560
that's when our 24 hour cycle is lined

1985
01:12:36,470 --> 01:12:34,800
up with mars 24 and a half hour cycle

1986
01:12:38,470 --> 01:12:36,480
the other half of the month

1987
01:12:40,550 --> 01:12:38,480
that timing no longer works out so you

1988
01:12:42,709 --> 01:12:40,560

have two options you either start living

1989
01:12:45,830 --> 01:12:42,719
on 24 and a half hour days

1990
01:12:50,310 --> 01:12:45,840
which we did for three months

1991
01:12:55,189 --> 01:12:52,709
um about this many people lived on what

1992
01:12:57,510 --> 01:12:55,199
we call mars time for three months i did

1993
01:13:00,149 --> 01:12:57,520
two it was horrible um

1994
01:13:01,669 --> 01:13:00,159
but very productive and then uh we got

1995
01:13:03,750 --> 01:13:01,679
off of mars time which means that for

1996
01:13:05,830 --> 01:13:03,760
half of the month we can sort of do

1997
01:13:09,830 --> 01:13:05,840
things every other day

1998
01:13:12,470 --> 01:13:11,110
thank you

1999
01:13:13,910 --> 01:13:12,480
follow up actually to a previous

2000
01:13:16,229 --> 01:13:13,920
question

2001
01:13:17,350 --> 01:13:16,239
what can you really say about the

2002
01:13:20,229 --> 01:13:17,360
climate

2003
01:13:21,990 --> 01:13:20,239
that would have been present

2004
01:13:25,590 --> 01:13:22,000
three billion years ago to produce that

2005
01:13:28,630 --> 01:13:25,600
kind of uh of a river uh you know would

2006
01:13:29,669 --> 01:13:28,640
have been snow melt snow run off would

2007
01:13:32,550 --> 01:13:29,679
it have been

2008
01:13:34,470 --> 01:13:32,560
rain would uh where did the water flow

2009
01:13:37,910 --> 01:13:34,480
where's the ocean or lake that it flowed

2010
01:13:40,709 --> 01:13:37,920
to right what kind of climate was there

2011
01:13:46,550 --> 01:13:40,719
and if you if you can uh

2012
01:13:50,070 --> 01:13:48,870
that is one of the other than life on

2013
01:13:51,750 --> 01:13:50,080

mars

2014
01:13:53,830 --> 01:13:51,760
i i'd say that that's probably the

2015
01:13:55,910 --> 01:13:53,840
number one question you know about mars

2016
01:13:58,070 --> 01:13:55,920
exploration is

2017
01:14:00,790 --> 01:13:58,080
how did it get from a planet that could

2018
01:14:03,430 --> 01:14:00,800
have had these big rivers and even

2019
01:14:05,189 --> 01:14:03,440
catastrophic floods and this stream bed

2020
01:14:06,790 --> 01:14:05,199
to the planet that is today that you

2021
01:14:08,950 --> 01:14:06,800
can't even support a drop of liquid

2022
01:14:10,310 --> 01:14:08,960
water on the surface and you know we

2023
01:14:11,669 --> 01:14:10,320
have these theories about the atmosphere

2024
01:14:13,189 --> 01:14:11,679
being lost

2025
01:14:14,950 --> 01:14:13,199
but we don't really know much more of

2026
01:14:16,870 --> 01:14:14,960
the picture then you know say you had a

2027
01:14:18,790 --> 01:14:16,880
thicker atmosphere if it wasn't warm

2028
01:14:19,510 --> 01:14:18,800
enough like the other gentleman pointed

2029
01:14:21,510 --> 01:14:19,520
out

2030
01:14:23,350 --> 01:14:21,520
you still would have a lot of a lot of

2031
01:14:25,510 --> 01:14:23,360
frozen water and a very limited

2032
01:14:26,709 --> 01:14:25,520
hydrologic cycle perhaps

2033
01:14:29,830 --> 01:14:26,719
there could be

2034
01:14:31,510 --> 01:14:29,840
some kind of climate where it may be you

2035
01:14:33,110 --> 01:14:31,520
know one thing is co2 is a greenhouse

2036
01:14:34,470 --> 01:14:33,120
gas so some theories involve getting a

2037
01:14:36,390 --> 01:14:34,480
thicker atmosphere

2038
01:14:38,070 --> 01:14:36,400

getting more warmth

2039
01:14:40,310 --> 01:14:38,080
and then having that allowing it to be

2040
01:14:41,910 --> 01:14:40,320
warm enough for liquid water

2041
01:14:43,590 --> 01:14:41,920
that's not a home run it turns out

2042
01:14:47,430 --> 01:14:43,600
there's there's issues that come up when

2043
01:14:48,390 --> 01:14:47,440
you have so much carbon dioxide um

2044
01:14:50,470 --> 01:14:48,400
but

2045
01:14:52,070 --> 01:14:50,480
um the other things are the ones you

2046
01:14:53,990 --> 01:14:52,080
mentioned you know in order to have a

2047
01:14:55,510 --> 01:14:54,000
hydrologic cycle with like rain you

2048
01:14:57,669 --> 01:14:55,520
really have to have a big body of water

2049
01:14:59,430 --> 01:14:57,679
somewhere for it to evaporate and then

2050
01:15:00,790 --> 01:14:59,440
be transported and then rain somewhere

2051
01:15:02,470 --> 01:15:00,800
else

2052
01:15:04,470 --> 01:15:02,480
that could have happened although

2053
01:15:05,830 --> 01:15:04,480
there's not a lot of evidence for the

2054
01:15:08,390 --> 01:15:05,840
kinds of

2055
01:15:11,189 --> 01:15:08,400
really finely braided streams like on

2056
01:15:13,030 --> 01:15:11,199
earth that happen when when rain falls

2057
01:15:15,510 --> 01:15:13,040
instead we see a lot of rivers that seem

2058
01:15:17,270 --> 01:15:15,520
to start out of nowhere and and flow

2059
01:15:19,270 --> 01:15:17,280
vigorously and then end

2060
01:15:20,630 --> 01:15:19,280
very mysterious uh but another option

2061
01:15:23,350 --> 01:15:20,640
like you said is snow

2062
01:15:25,270 --> 01:15:23,360
so even today the water vapor

2063
01:15:27,510 --> 01:15:25,280

does go from the water does go from the

2064
01:15:29,189 --> 01:15:27,520
vapor to the snow phase

2065
01:15:30,470 --> 01:15:29,199
and back and forth and it could have

2066
01:15:32,630 --> 01:15:30,480
done that in the past in a much more

2067
01:15:34,709 --> 01:15:32,640
vigorous way it could have had big snow

2068
01:15:36,630 --> 01:15:34,719
packs and the bottom of those snow packs

2069
01:15:38,950 --> 01:15:36,640
might maybe melted and formed the start

2070
01:15:40,310 --> 01:15:38,960
of these rivers we don't really know

2071
01:15:42,870 --> 01:15:40,320
we're going to hope to find some of that

2072
01:15:45,110 --> 01:15:42,880
in these layers of mount sharp

2073
01:15:48,229 --> 01:15:45,120
thank you

2074
01:15:49,910 --> 01:15:48,239
presentation

2075
01:15:52,310 --> 01:15:49,920
what's the future of this particular

2076
01:15:54,310 --> 01:15:52,320
curiosity where does it end up how long

2077
01:15:55,189 --> 01:15:54,320
will it last yeah and what happens in

2078
01:15:57,590 --> 01:15:55,199
the end

2079
01:16:00,390 --> 01:15:57,600
we hope it lasts

2080
01:16:02,149 --> 01:16:00,400
up to that dust layer

2081
01:16:04,390 --> 01:16:02,159
now spirit and opportunity

2082
01:16:06,630 --> 01:16:04,400
were also built here of course and built

2083
01:16:09,110 --> 01:16:06,640
to a lot of the same standards as

2084
01:16:11,430 --> 01:16:09,120
curiosity and use a lot of similar parts

2085
01:16:12,870 --> 01:16:11,440
so you know we can go off of their

2086
01:16:14,390 --> 01:16:12,880
lifetimes a little bit and when we're

2087
01:16:15,430 --> 01:16:14,400
thinking about this and

2088
01:16:17,590 --> 01:16:15,440

i think their

2089
01:16:19,110 --> 01:16:17,600
spirit lasted at least seven years maybe

2090
01:16:21,350 --> 01:16:19,120
eight and curiosity's i mean

2091
01:16:22,709 --> 01:16:21,360
opportunities going on to 10 years

2092
01:16:24,149 --> 01:16:22,719
it's still alive today so there's two

2093
01:16:27,270 --> 01:16:24,159
rovers on mars

2094
01:16:30,630 --> 01:16:27,280
today on opposite sides of the planet

2095
01:16:32,070 --> 01:16:30,640
so we hope we can last that long we have

2096
01:16:34,310 --> 01:16:32,080
some advantages

2097
01:16:36,070 --> 01:16:34,320
in the sense that we were built to last

2098
01:16:37,669 --> 01:16:36,080
to be even a little bit more robust than

2099
01:16:38,870 --> 01:16:37,679
spirit opportunity

2100
01:16:39,830 --> 01:16:38,880
we were built with a little better

2101
01:16:42,149 --> 01:16:39,840
warranty

2102
01:16:43,910 --> 01:16:42,159
in that respect

2103
01:16:45,750 --> 01:16:43,920
but we also are subject to all the same

2104
01:16:47,430 --> 01:16:45,760
things that destroy

2105
01:16:51,270 --> 01:16:47,440
beautiful mechanisms once you put them

2106
01:16:55,350 --> 01:16:54,310
um he kind of took my question okay but

2107
01:16:58,310 --> 01:16:55,360
uh

2108
01:17:00,870 --> 01:16:58,320
do you guys have any specific plans to

2109
01:17:02,390 --> 01:17:00,880
as where curiosity is going to go after

2110
01:17:04,550 --> 01:17:02,400
mount sharp

2111
01:17:05,270 --> 01:17:04,560
yeah um

2112
01:17:08,470 --> 01:17:05,280
i

2113
01:17:12,390 --> 01:17:08,480

after

2114
01:17:16,950 --> 01:17:14,950
so actually you know what we hope to do

2115
01:17:18,709 --> 01:17:16,960
i mean this is going to be a gold mine

2116
01:17:20,390 --> 01:17:18,719
from everything we believe

2117
01:17:22,149 --> 01:17:20,400
this is going to really

2118
01:17:26,390 --> 01:17:22,159
tell us a lot about the environment of

2119
01:17:27,189 --> 01:17:26,400
ancient mars we found this one specific

2120
01:17:29,830 --> 01:17:27,199
lake

2121
01:17:31,189 --> 01:17:29,840
we think you know at yellowknife bay

2122
01:17:34,470 --> 01:17:31,199
there could be

2123
01:17:36,470 --> 01:17:34,480
a similar habitable environment at

2124
01:17:38,310 --> 01:17:36,480
many different levels of this mountain

2125
01:17:40,550 --> 01:17:38,320
and each slightly different and maybe

2126
01:17:42,229 --> 01:17:40,560
even a story of better ones at the

2127
01:17:44,550 --> 01:17:42,239
bottom getting worse as you go up all

2128
01:17:45,990 --> 01:17:44,560
those things could happen uh so you know

2129
01:17:46,950 --> 01:17:46,000
not only are we going to be here several

2130
01:17:48,630 --> 01:17:46,960
years

2131
01:17:50,070 --> 01:17:48,640
but say we we

2132
01:17:52,310 --> 01:17:50,080
sample all these layers and go all the

2133
01:17:53,910 --> 01:17:52,320
way up to the dust and we create a story

2134
01:17:55,669 --> 01:17:53,920
i guarantee the first thing scientists

2135
01:17:57,030 --> 01:17:55,679
want to do is make sure they're right so

2136
01:18:00,550 --> 01:17:57,040
they'll drive over here and do it in

2137
01:18:04,630 --> 01:18:01,830
and actually that's the right thing to

2138
01:18:06,950 --> 01:18:04,640

do scientifically so you know we plan to

2139
01:18:08,470 --> 01:18:06,960
to explore this as long as the rover

2140
01:18:10,070 --> 01:18:08,480
talks to us

2141
01:18:14,229 --> 01:18:10,080
thank you and good luck

2142
01:18:20,950 --> 01:18:17,110
so my question is related to what if

2143
01:18:22,550 --> 01:18:20,960
something breaks on curiosity

2144
01:18:25,110 --> 01:18:22,560
okay yeah

2145
01:18:27,110 --> 01:18:25,120
we worry about that all the time

2146
01:18:28,229 --> 01:18:27,120
one thing that's pretty cool is that the

2147
01:18:29,110 --> 01:18:28,239
rover

2148
01:18:31,510 --> 01:18:29,120
is

2149
01:18:33,270 --> 01:18:31,520
smart and protects itself and it even

2150
01:18:35,189 --> 01:18:33,280
protects itself from us

2151
01:18:38,070 --> 01:18:35,199
so the rover has

2152
01:18:40,630 --> 01:18:38,080
a lot of software i think it's over 500

2153
01:18:42,630 --> 01:18:40,640
000 lines of computer code

2154
01:18:44,709 --> 01:18:42,640
so more than any one person and even

2155
01:18:46,709 --> 01:18:44,719
hundreds of people can write

2156
01:18:49,270 --> 01:18:46,719
and a lot of that software that's on the

2157
01:18:51,510 --> 01:18:49,280
rover is what we call fault protection

2158
01:18:52,709 --> 01:18:51,520
we want to keep it from we want to keep

2159
01:18:54,630 --> 01:18:52,719
it from

2160
01:18:56,390 --> 01:18:54,640
faulting and a fault could be anything

2161
01:18:58,070 --> 01:18:56,400
it could mean bumping into a rock it

2162
01:18:59,189 --> 01:18:58,080
could mean using its arm and hitting

2163
01:19:01,510 --> 01:18:59,199

itself

2164
01:19:03,189 --> 01:19:01,520
or it can mean running one of the ovens

2165
01:19:04,149 --> 01:19:03,199
in the sam experiment too hot so it

2166
01:19:05,189 --> 01:19:04,159
melts

2167
01:19:07,430 --> 01:19:05,199
and

2168
01:19:09,030 --> 01:19:07,440
to protect the rover from us that

2169
01:19:11,270 --> 01:19:09,040
software on board

2170
01:19:13,350 --> 01:19:11,280
checks everything we ask it to do and

2171
01:19:15,270 --> 01:19:13,360
you know um yeah you probably won't know

2172
01:19:17,360 --> 01:19:15,280
but your parents will know you know i'm

2173
01:19:19,590 --> 01:19:17,370
sorry dave i can't do that you know

2174
01:19:21,510 --> 01:19:19,600
[Laughter]

2175
01:19:23,350 --> 01:19:21,520
right

2176
01:19:25,189 --> 01:19:23,360
there's a computer that tells a human

2177
01:19:27,270 --> 01:19:25,199
that um and the rover will tell us that

2178
01:19:28,630 --> 01:19:27,280
sometimes um that's sort of the good

2179
01:19:30,070 --> 01:19:28,640
news is that

2180
01:19:31,910 --> 01:19:30,080
it's it's a little hard to break the

2181
01:19:33,350 --> 01:19:31,920
rover because the rover is smart enough

2182
01:19:35,189 --> 01:19:33,360
to keep us from breaking

2183
01:19:36,470 --> 01:19:35,199
um the bad news is that things will

2184
01:19:37,910 --> 01:19:36,480
break just because

2185
01:19:39,990 --> 01:19:37,920
there's so many moving parts all the

2186
01:19:42,070 --> 01:19:40,000
wheels have motors and they were

2187
01:19:43,750 --> 01:19:42,080
lubricated before launch

2188
01:19:45,910 --> 01:19:43,760

you can't lubricate them anymore you

2189
01:19:48,709 --> 01:19:45,920
know so once those things start wearing

2190
01:19:50,870 --> 01:19:48,719
out a wheel might stop so we've designed

2191
01:19:52,870 --> 01:19:50,880
a few things to sort of extend the life

2192
01:19:53,990 --> 01:19:52,880
um we can drive with only five wheels

2193
01:19:57,189 --> 01:19:54,000
for example

2194
01:19:59,030 --> 01:19:57,199
um and in fact uh opportunity and spirit

2195
01:20:01,430 --> 01:19:59,040
i think both ended up losing a wheel and

2196
01:20:03,030 --> 01:20:01,440
dragging a wheel we actually learned

2197
01:20:05,350 --> 01:20:03,040
from that and made it so the wheels

2198
01:20:07,510 --> 01:20:05,360
don't freeze um we won't have to drag it

2199
01:20:09,030 --> 01:20:07,520
in other words it'll just rotate

2200
01:20:11,430 --> 01:20:09,040
part of the fun of having six wheels is

2201
01:20:12,709 --> 01:20:11,440
you can still drive with five of them

2202
01:20:14,229 --> 01:20:12,719
and so there's things like that but one

2203
01:20:15,350 --> 01:20:14,239
thing we can never do

2204
01:20:17,030 --> 01:20:15,360
oh i gotta tell you one more thing one

2205
01:20:18,950 --> 01:20:17,040
thing we never do is replace anything of

2206
01:20:20,229 --> 01:20:18,960
course but the other thing we do is we

2207
01:20:26,229 --> 01:20:20,239
have two

2208
01:20:27,990 --> 01:20:26,239
of navigation cameras we use one now we

2209
01:20:28,870 --> 01:20:28,000
have a backup in case the prime one

2210
01:20:30,229 --> 01:20:28,880
fails

2211
01:20:32,310 --> 01:20:30,239
and we have two

2212
01:20:34,070 --> 01:20:32,320
computers on the spacecraft so the

2213
01:20:36,310 --> 01:20:34,080

entire computer the entire brain of the

2214
01:20:37,669 --> 01:20:36,320
rover can get fried and we can switch to

2215
01:20:39,110 --> 01:20:37,679
the other one and in fact we did that

2216
01:20:41,189 --> 01:20:39,120
once already

2217
01:20:46,470 --> 01:20:41,199
during this mission so those are all the

2218
01:20:51,189 --> 01:20:48,950
so i love these pictures um during the

2219
01:20:52,709 --> 01:20:51,199
daytime like everybody else but

2220
01:20:54,149 --> 01:20:52,719
something that i didn't expect and i

2221
01:20:56,950 --> 01:20:54,159
really enjoyed is

2222
01:20:57,750 --> 01:20:56,960
um seeing the pictures of of mars moons

2223
01:21:00,470 --> 01:20:57,760
right

2224
01:21:01,669 --> 01:21:00,480
and pictures of the sun taken from mars

2225
01:21:02,790 --> 01:21:01,679
and i didn't even realize that was

2226
01:21:03,750 --> 01:21:02,800
something that you guys were going to

2227
01:21:05,430 --> 01:21:03,760
study

2228
01:21:06,630 --> 01:21:05,440
and i just saw recently you guys took a

2229
01:21:08,550 --> 01:21:06,640
night picture

2230
01:21:10,229 --> 01:21:08,560
in ultraviolet light and i was just

2231
01:21:12,390 --> 01:21:10,239
wondering if you had any plans to take

2232
01:21:15,750 --> 01:21:12,400
maybe like a long exposure of the

2233
01:21:16,790 --> 01:21:15,760
martian landscape at night time like i

2234
01:21:18,870 --> 01:21:16,800
potentially

2235
01:21:20,709 --> 01:21:18,880
get public interest to see that like

2236
01:21:22,070 --> 01:21:20,719
star trails and right just something

2237
01:21:23,750 --> 01:21:22,080
that i personally would like but i was

2238
01:21:28,070 --> 01:21:23,760

just wondering if there were any

2239
01:21:30,470 --> 01:21:28,080
scientific merit to something like that

2240
01:21:31,830 --> 01:21:30,480
that's the key actually you gotta

2241
01:21:32,870 --> 01:21:31,840
find the science reason to sneak the

2242
01:21:34,470 --> 01:21:32,880
cool thing in

2243
01:21:37,350 --> 01:21:34,480
um

2244
01:21:39,669 --> 01:21:37,360
but yeah if you look at jpl's homepage

2245
01:21:42,070 --> 01:21:39,679
today just today we

2246
01:21:44,070 --> 01:21:42,080
we released some images of mars two

2247
01:21:46,149 --> 01:21:44,080
moons phobos and deimos as taken from

2248
01:21:48,149 --> 01:21:46,159
curiosity and they are actually

2249
01:21:49,750 --> 01:21:48,159
scientifically valuable because those

2250
01:21:52,390 --> 01:21:49,760
moons orbit very closely and are

2251
01:21:54,870 --> 01:21:52,400
affected by the shape of mars and and

2252
01:21:57,189 --> 01:21:54,880
actually what mars is made of the like

2253
01:21:59,830 --> 01:21:57,199
whether it has a you know how what the

2254
01:22:01,669 --> 01:21:59,840
distribution of stuff inside mars is

2255
01:22:02,470 --> 01:22:01,679
affects the gravity that those moons

2256
01:22:04,310 --> 01:22:02,480
feel

2257
01:22:06,390 --> 01:22:04,320
so by by tracking those orbits very

2258
01:22:08,709 --> 01:22:06,400
precisely of phobos and demos

2259
01:22:11,350 --> 01:22:08,719
they kind of trace out the shape of mars

2260
01:22:12,709 --> 01:22:11,360
internally and so we take these cool

2261
01:22:14,550 --> 01:22:12,719
pictures but they're good for science as

2262
01:22:16,790 --> 01:22:14,560
well and the one that's on the homepage

2263
01:22:19,350 --> 01:22:16,800

today is the first time we ever saw

2264
01:22:21,110 --> 01:22:19,360
phobos the big moon pass in front of

2265
01:22:22,870 --> 01:22:21,120
deimos the small moon

2266
01:22:24,229 --> 01:22:22,880
so it's a it's called a mutual

2267
01:22:26,310 --> 01:22:24,239
occultation or something like that i'm

2268
01:22:27,669 --> 01:22:26,320
not an astronomer um

2269
01:22:29,750 --> 01:22:27,679
but uh so those are useful

2270
01:22:32,149 --> 01:22:29,760
scientifically the images of the sun we

2271
01:22:34,390 --> 01:22:32,159
take uh once a week or so are actually

2272
01:22:36,790 --> 01:22:34,400
um very useful because

2273
01:22:39,590 --> 01:22:36,800
that's how we tell how much dust is in

2274
01:22:41,350 --> 01:22:39,600
the atmosphere so on on earth when you

2275
01:22:44,470 --> 01:22:41,360
think of weather you think of sort of

2276
01:22:45,830 --> 01:22:44,480
wind and water on mars you think of wind

2277
01:22:48,149 --> 01:22:45,840
water and dust

2278
01:22:49,910 --> 01:22:48,159
there's always some level of dust in the

2279
01:22:52,229 --> 01:22:49,920
atmosphere and by studying the amount of

2280
01:22:54,310 --> 01:22:52,239
dust you can sort of figure out how

2281
01:22:55,189 --> 01:22:54,320
storms are working and that sort of

2282
01:22:57,110 --> 01:22:55,199
thing

2283
01:22:58,870 --> 01:22:57,120
and so we take pictures of the sun

2284
01:22:59,910 --> 01:22:58,880
because we know how bright the sun is

2285
01:23:02,070 --> 01:22:59,920
and when there's a dust in the

2286
01:23:03,830 --> 01:23:02,080
atmosphere we can very precisely measure

2287
01:23:06,709 --> 01:23:03,840
uh how much dust there is by the

2288
01:23:09,669 --> 01:23:06,719

decrease in sunlight um i think that's

2289
01:23:11,110 --> 01:23:09,679
oh the star trails one um i just heard

2290
01:23:13,030 --> 01:23:11,120
that um

2291
01:23:15,270 --> 01:23:13,040
i heard our camera team talking about

2292
01:23:16,470 --> 01:23:15,280
that it's it's hard because there's not

2293
01:23:18,070 --> 01:23:16,480
like moonlight

2294
01:23:19,990 --> 01:23:18,080
so to take the landscape image this

2295
01:23:21,590 --> 01:23:20,000
night it's too dark you know there's

2296
01:23:22,709 --> 01:23:21,600
really nothing lighting up phobos is not

2297
01:23:25,189 --> 01:23:22,719
big enough

2298
01:23:26,390 --> 01:23:25,199
but star trails we might be able to do

2299
01:23:27,990 --> 01:23:26,400
there isn't really good science for that

2300
01:23:32,790 --> 01:23:28,000
though

2301
01:23:38,149 --> 01:23:35,669
hi you kept talking about this theory in

2302
01:23:40,070 --> 01:23:38,159
which there was an ocean on mars at one

2303
01:23:41,750 --> 01:23:40,080
point where did that come from what's

2304
01:23:43,110 --> 01:23:41,760
the reasoning that you might discover

2305
01:23:45,590 --> 01:23:43,120
something like that

2306
01:23:46,550 --> 01:23:45,600
now like where did that come from um

2307
01:23:48,310 --> 01:23:46,560
it's

2308
01:23:50,229 --> 01:23:48,320
a few different things um there are

2309
01:23:52,870 --> 01:23:50,239
actually some uh

2310
01:23:55,189 --> 01:23:52,880
well okay i think one of the

2311
01:23:56,550 --> 01:23:55,199
the two two sort of things that really

2312
01:23:58,470 --> 01:23:56,560
hint at it are

2313
01:24:01,669 --> 01:23:58,480

there's a whole lot of

2314
01:24:04,070 --> 01:24:01,679
huge rivers and even floods that start

2315
01:24:05,430 --> 01:24:04,080
up high and end up low

2316
01:24:07,510 --> 01:24:05,440
and then you can't really see where they

2317
01:24:09,910 --> 01:24:07,520
end it's almost as if they went into a

2318
01:24:11,590 --> 01:24:09,920
larger body of water

2319
01:24:13,990 --> 01:24:11,600
couple that with the fact that mars has

2320
01:24:15,669 --> 01:24:14,000
this very interesting shape

2321
01:24:17,750 --> 01:24:15,679
where the most of the southern

2322
01:24:19,510 --> 01:24:17,760
hemisphere of the planet is a few miles

2323
01:24:21,350 --> 01:24:19,520
higher elevation than the north so the

2324
01:24:22,790 --> 01:24:21,360
north is a big basin

2325
01:24:25,110 --> 01:24:22,800
and there are actually some scientists

2326
01:24:27,830 --> 01:24:25,120
who who tried to trace around what they

2327
01:24:29,350 --> 01:24:27,840
think are shorelines of an ancient ocean

2328
01:24:30,709 --> 01:24:29,360
so it's all kind of circumstantial

2329
01:24:32,550 --> 01:24:30,719
evidence at this point we don't know for

2330
01:24:33,910 --> 01:24:32,560
sure there was an ocean but there's a

2331
01:24:35,350 --> 01:24:33,920
lot of reasons to think there could have

2332
01:24:37,350 --> 01:24:35,360
been because we see

2333
01:24:39,110 --> 01:24:37,360
a lot of water that must have moved from

2334
01:24:41,510 --> 01:24:39,120
the high elevations into something in

2335
01:24:42,950 --> 01:24:41,520
the low elevations that's in a closed

2336
01:24:45,750 --> 01:24:42,960
basin that could have filled up with

2337
01:24:48,229 --> 01:24:45,760
water and um do you ever think another

2338
01:24:49,510 --> 01:24:48,239

rover might may join curiosity in this

2339
01:24:50,390 --> 01:24:49,520
mission or not

2340
01:24:54,629 --> 01:24:50,400
um

2341
01:24:56,390 --> 01:24:54,639
we only do these things every decade or

2342
01:24:57,910 --> 01:24:56,400
so because they're so complex and takes

2343
01:25:00,149 --> 01:24:57,920
a lot of time to kind of get the next

2344
01:25:02,550 --> 01:25:00,159
generation of of rover and instruments

2345
01:25:05,430 --> 01:25:02,560
and everything so in 2020 there's plans

2346
01:25:07,430 --> 01:25:05,440
to launch a curiosity like rover but to

2347
01:25:10,070 --> 01:25:07,440
actually have it go around and collect

2348
01:25:11,510 --> 01:25:10,080
samples of rock that would actually

2349
01:25:12,950 --> 01:25:11,520
get brought back to earth at some point

2350
01:25:16,390 --> 01:25:12,960
by a future mission

2351
01:25:18,070 --> 01:25:16,400
and if we continue to find that this

2352
01:25:19,750 --> 01:25:18,080
uh that that this is not only a

2353
01:25:22,390 --> 01:25:19,760
habitable environment at yellowknife bay

2354
01:25:24,470 --> 01:25:22,400
but this is the place the best place to

2355
01:25:26,870 --> 01:25:24,480
to take those samples back to earth and

2356
01:25:29,110 --> 01:25:26,880
use an even better experiments

2357
01:25:31,750 --> 01:25:29,120
the 2020 mission might come here

2358
01:25:36,950 --> 01:25:33,590
all right so in my opinion one of the

2359
01:25:38,870 --> 01:25:36,960
cooler things about this rover is the uh

2360
01:25:41,430 --> 01:25:38,880
the power source so what what kind of

2361
01:25:43,430 --> 01:25:41,440
went into the decision to not have solar

2362
01:25:45,270 --> 01:25:43,440
panels like all the previous rovers and

2363
01:25:47,750 --> 01:25:45,280

how does it work out in terms of cost

2364
01:25:50,390 --> 01:25:47,760
versus longevity and that sort of thing

2365
01:25:53,430 --> 01:25:52,470
interesting because we've learned over

2366
01:25:55,030 --> 01:25:53,440
time

2367
01:25:56,550 --> 01:25:55,040
and i think 10 years ago you would have

2368
01:25:58,070 --> 01:25:56,560
gotten a different answer so 10 years

2369
01:26:00,149 --> 01:25:58,080
ago the idea was that spirit opportunity

2370
01:26:03,590 --> 01:26:00,159
were built to last um

2371
01:26:05,110 --> 01:26:03,600
six months maybe you know and

2372
01:26:06,550 --> 01:26:05,120
so their prime mission was thought to be

2373
01:26:09,030 --> 01:26:06,560
able to be accomplished in that amount

2374
01:26:11,990 --> 01:26:09,040
of time so all they had a requirement

2375
01:26:13,830 --> 01:26:12,000
for was to last six months so solar

2376
01:26:15,430 --> 01:26:13,840
panels for six months work great they

2377
01:26:17,270 --> 01:26:15,440
provide a lot of power

2378
01:26:18,229 --> 01:26:17,280
and then as they slowly get covered by

2379
01:26:20,870 --> 01:26:18,239
dust

2380
01:26:22,629 --> 01:26:20,880
it's okay because in six months you'd

2381
01:26:24,149 --> 01:26:22,639
still have enough power

2382
01:26:26,470 --> 01:26:24,159
of course i just told you opportunity is

2383
01:26:28,870 --> 01:26:26,480
now going on 10 years

2384
01:26:31,110 --> 01:26:28,880
so two things happen you know one

2385
01:26:33,030 --> 01:26:31,120
opportunity is living on a lot less

2386
01:26:35,189 --> 01:26:33,040
power than it had in its heyday so it's

2387
01:26:37,910 --> 01:26:35,199
eeking by you know but the the better

2388
01:26:39,669 --> 01:26:37,920

news is that there's been

2389
01:26:41,430 --> 01:26:39,679
what we call you know scientific term

2390
01:26:42,629 --> 01:26:41,440
wind events you know because we don't

2391
01:26:44,550 --> 01:26:42,639
really know what they are are they dust

2392
01:26:46,550 --> 01:26:44,560
devils are they gusts or well you know

2393
01:26:48,390 --> 01:26:46,560
what are they there are wind events that

2394
01:26:50,229 --> 01:26:48,400
have cleared off the solar panels of

2395
01:26:52,709 --> 01:26:50,239
spirit and opportunity many times and

2396
01:26:54,310 --> 01:26:52,719
given them sort of a new lease on life

2397
01:26:56,870 --> 01:26:54,320
so we didn't know that and so by the

2398
01:26:59,430 --> 01:26:56,880
time curiosity was already well into its

2399
01:27:01,830 --> 01:26:59,440
design phase you know we had already

2400
01:27:04,950 --> 01:27:01,840
decided for a two-year mission which is

2401
01:27:06,790 --> 01:27:04,960
what curiosity's warranty is

2402
01:27:09,270 --> 01:27:06,800
we didn't want to do solar panels you

2403
01:27:11,830 --> 01:27:09,280
know two reasons one is that we have a

2404
01:27:13,669 --> 01:27:11,840
much bigger rover a lot hungrier power

2405
01:27:15,189 --> 01:27:13,679
wise so we would have to carry these

2406
01:27:17,030 --> 01:27:15,199
enormous solar panels that would have

2407
01:27:18,950 --> 01:27:17,040
made it hard for us to drive

2408
01:27:20,390 --> 01:27:18,960
we would need a lot more area than

2409
01:27:21,430 --> 01:27:20,400
spirit opportunity because we're so much

2410
01:27:23,189 --> 01:27:21,440
bigger

2411
01:27:24,870 --> 01:27:23,199
the second one is

2412
01:27:27,189 --> 01:27:24,880
for two year mission we didn't think we

2413
01:27:28,870 --> 01:27:27,199

could last on solar panels

2414
01:27:30,310 --> 01:27:28,880
but we didn't know about the wind events

2415
01:27:31,590 --> 01:27:30,320
yet and we couldn't guarantee them at

2416
01:27:33,110 --> 01:27:31,600
gale crater

2417
01:27:35,110 --> 01:27:33,120
so that's why we ended up with what we

2418
01:27:36,790 --> 01:27:35,120
call a radio isotope thermoelectric

2419
01:27:38,950 --> 01:27:36,800
generator

2420
01:27:40,229 --> 01:27:38,960
okay i don't want to harm these nice

2421
01:27:41,830 --> 01:27:40,239
people here so i'm not going to use my

2422
01:27:43,189 --> 01:27:41,840
laser pointer but behind these guys over

2423
01:27:44,870 --> 01:27:43,199
here

2424
01:27:45,669 --> 01:27:44,880
you can see these little garbage can

2425
01:27:47,510 --> 01:27:45,679
things

2426
01:27:50,390 --> 01:27:47,520
on the end of voyager

2427
01:27:52,070 --> 01:27:50,400
right in front of the couple there

2428
01:27:53,910 --> 01:27:52,080
and they are actually

2429
01:27:55,910 --> 01:27:53,920
i can see three of them i think three of

2430
01:27:57,750 --> 01:27:55,920
them kind of strapped together powering

2431
01:27:59,510 --> 01:27:57,760
voyager and voyager still talking to

2432
01:28:01,430 --> 01:27:59,520
earth today so when you use

2433
01:28:03,750 --> 01:28:01,440
radioisotopes naturally decaying

2434
01:28:05,990 --> 01:28:03,760
radioactive material that you put in a

2435
01:28:08,310 --> 01:28:06,000
in a in a well i shouldn't you say

2436
01:28:09,830 --> 01:28:08,320
garbage can but you know that kind of a

2437
01:28:11,189 --> 01:28:09,840
that kind of structure and then you

2438
01:28:12,310 --> 01:28:11,199

generate electricity from the heat it

2439
01:28:14,870 --> 01:28:12,320
gives out

2440
01:28:16,390 --> 01:28:14,880
they can last uh a long time they'll

2441
01:28:19,270 --> 01:28:16,400
outlive voyager and they'll outlive

2442
01:28:21,189 --> 01:28:19,280
curiosity as well all right so for the

2443
01:28:23,189 --> 01:28:21,199
for example for the 2020 rover that

2444
01:28:25,990 --> 01:28:23,199
might do something like storing samples

2445
01:28:28,229 --> 01:28:26,000
for sample return um would you be

2446
01:28:29,990 --> 01:28:28,239
considering making a like a replaceable

2447
01:28:31,669 --> 01:28:30,000
power source so whatever comes in to do

2448
01:28:33,430 --> 01:28:31,679
the sample return could give it a sort

2449
01:28:35,830 --> 01:28:33,440
of longer lease on life

2450
01:28:37,669 --> 01:28:35,840
or would that just be too expensive yeah

2451
01:28:38,629 --> 01:28:37,679
i hadn't thought of that um i don't

2452
01:28:40,709 --> 01:28:38,639
think

2453
01:28:42,390 --> 01:28:40,719
that rover needs to necessarily be alive

2454
01:28:43,590 --> 01:28:42,400
you know they can just store the samples

2455
01:28:44,310 --> 01:28:43,600
and the next one comes and takes it you

2456
01:28:45,830 --> 01:28:44,320
know

2457
01:28:46,950 --> 01:28:45,840
but i'm sure they're thinking about all

2458
01:28:48,629 --> 01:28:46,960
these options

2459
01:28:50,950 --> 01:28:48,639
the rtg the radioactive thermal

2460
01:28:52,470 --> 01:28:50,960
generators worked great for us um and i

2461
01:28:54,149 --> 01:28:52,480
think it you know it's going to be flown

2462
01:28:58,390 --> 01:28:54,159
on future missions as well you do

2463
01:29:01,110 --> 01:28:59,510

okay

2464
01:29:02,790 --> 01:29:01,120
great

2465
01:29:04,950 --> 01:29:02,800
oh um

2466
01:29:06,870 --> 01:29:04,960
pardon me i want to take one from the

2467
01:29:08,950 --> 01:29:06,880
people watching online

2468
01:29:11,669 --> 01:29:08,960
or through social media have you ever

2469
01:29:13,350 --> 01:29:11,679
found any more hematite blueberries in

2470
01:29:14,390 --> 01:29:13,360
this area similar to those found by

2471
01:29:19,750 --> 01:29:14,400
opportunity

2472
01:29:24,870 --> 01:29:21,510
what they call

2473
01:29:27,030 --> 01:29:24,880
blueberries which a little round

2474
01:29:29,110 --> 01:29:27,040
stones i guess you'd call them made of a

2475
01:29:30,149 --> 01:29:29,120
mineral called hematite and that's what

2476
01:29:32,310 --> 01:29:30,159
attracted

2477
01:29:33,430 --> 01:29:32,320
them opportunity to that landing site it

2478
01:29:35,350 --> 01:29:33,440
was a place where there's a big

2479
01:29:37,350 --> 01:29:35,360
signature from orbit of this mineral

2480
01:29:39,590 --> 01:29:37,360
called hematite which could form in the

2481
01:29:41,830 --> 01:29:39,600
interaction with water with rock

2482
01:29:44,470 --> 01:29:41,840
we haven't found those specific hematite

2483
01:29:45,990 --> 01:29:44,480
minerals but we did find these nodules i

2484
01:29:47,669 --> 01:29:46,000
briefly mentioned the pimples that were

2485
01:29:49,350 --> 01:29:47,679
covering the rock it's a kind of a

2486
01:29:51,910 --> 01:29:49,360
similar thing where water flows through

2487
01:29:53,750 --> 01:29:51,920
rock leaves hard minerals behind and

2488
01:29:55,189 --> 01:29:53,760

then as the rock erodes

2489
01:29:57,590 --> 01:29:55,199
these pimples sort of come out because

2490
01:29:58,950 --> 01:29:57,600
they erode less uh well than the the

2491
01:30:00,550 --> 01:29:58,960
rock around it

2492
01:30:02,229 --> 01:30:00,560
so that's that one well i'm gonna knock

2493
01:30:04,310 --> 01:30:02,239
off this other one really quickly you

2494
01:30:06,229 --> 01:30:04,320
mentioned that argon was found to be the

2495
01:30:08,790 --> 01:30:06,239
second most abundant gas what are the

2496
01:30:10,390 --> 01:30:08,800
chances of it being found planet-wide

2497
01:30:13,030 --> 01:30:10,400
that's an easy one because the

2498
01:30:14,870 --> 01:30:13,040
atmosphere like on earth blows around so

2499
01:30:16,470 --> 01:30:14,880
anything we would measure at curiosity

2500
01:30:17,830 --> 01:30:16,480
is at least

2501
01:30:19,910 --> 01:30:17,840
regional

2502
01:30:22,149 --> 01:30:19,920
it's definitely not restricted to just

2503
01:30:24,149 --> 01:30:22,159
where curiosity is unless we happen to

2504
01:30:26,229 --> 01:30:24,159
find a volcano going on right next door

2505
01:30:28,310 --> 01:30:26,239
which isn't the case so we believe the

2506
01:30:30,149 --> 01:30:28,320
argon and nitrogen that we're measuring

2507
01:30:33,510 --> 01:30:30,159
are indicative of the composition

2508
01:30:37,990 --> 01:30:35,750
hi so you pointed out few times that

2509
01:30:39,430 --> 01:30:38,000
curiosity moves very slow

2510
01:30:41,990 --> 01:30:39,440
so what is the speed and what was the

2511
01:30:43,350 --> 01:30:42,000
biggest limitation that you had from the

2512
01:30:45,669 --> 01:30:43,360
engineering point of view that you had

2513
01:30:48,229 --> 01:30:45,679

to limit the speed

2514
01:30:49,430 --> 01:30:48,239
sure um limiting the speed is really uh

2515
01:30:51,510 --> 01:30:49,440
safety

2516
01:30:54,070 --> 01:30:51,520
um so we drive

2517
01:30:55,590 --> 01:30:54,080
so that we we don't

2518
01:30:57,110 --> 01:30:55,600
uh put any

2519
01:30:58,790 --> 01:30:57,120
um you know

2520
01:31:00,550 --> 01:30:58,800
forces on the rover that the rover can't

2521
01:31:02,149 --> 01:31:00,560
handle the faster you drive the harder

2522
01:31:03,590 --> 01:31:02,159
you hit something that sort of thing and

2523
01:31:05,189 --> 01:31:03,600
the harder your wheel might fall off a

2524
01:31:07,590 --> 01:31:05,199
rock if you're driving over a rock and

2525
01:31:09,030 --> 01:31:07,600
the wheel slips off it so we drive slow

2526
01:31:10,709 --> 01:31:09,040
for that reason we also drive slow

2527
01:31:13,270 --> 01:31:10,719
because we're taking images every now

2528
01:31:14,709 --> 01:31:13,280
and then to create new maps of the

2529
01:31:17,030 --> 01:31:14,719
hazards around us especially when we go

2530
01:31:19,189 --> 01:31:17,040
into this auto navigation mode

2531
01:31:21,270 --> 01:31:19,199
so those are the reasons we drive slow

2532
01:31:23,910 --> 01:31:21,280
and the driving slow means

2533
01:31:27,669 --> 01:31:23,920
much less than one mile an hour

2534
01:31:30,070 --> 01:31:27,679
so we drive about a football field a day

2535
01:31:32,550 --> 01:31:30,080
and you know it sounds horrible and it

2536
01:31:34,310 --> 01:31:32,560
kind of is when you're doing it um but

2537
01:31:36,149 --> 01:31:34,320
when you uh

2538
01:31:38,310 --> 01:31:36,159

uh

2539
01:31:39,830 --> 01:31:38,320
when you consider that if you were at

2540
01:31:41,669 --> 01:31:39,840
the end of a football field and you were

2541
01:31:43,590 --> 01:31:41,679
had binoculars at eye level and you were

2542
01:31:45,350 --> 01:31:43,600
trying to see if there was any hazards

2543
01:31:47,189 --> 01:31:45,360
you can imagine by the end of the other

2544
01:31:49,430 --> 01:31:47,199
you know the end zone you wouldn't be

2545
01:31:50,629 --> 01:31:49,440
very confident that your quarterback

2546
01:31:52,229 --> 01:31:50,639
isn't going to hit a sprinkler head you

2547
01:31:53,830 --> 01:31:52,239
know

2548
01:31:55,510 --> 01:31:53,840
so we we drive to the end of those

2549
01:31:57,270 --> 01:31:55,520
images at about a hundred meters away

2550
01:31:59,030 --> 01:31:57,280
one more question then i that's still

2551
01:32:01,110 --> 01:31:59,040
one leading question is it possible to

2552
01:32:02,550 --> 01:32:01,120
make it go faster based on the terrain

2553
01:32:04,390 --> 01:32:02,560
that you observe

2554
01:32:06,870 --> 01:32:04,400
yeah i mean we don't make it go faster

2555
01:32:08,629 --> 01:32:06,880
but we we interrupt it less so when it's

2556
01:32:10,709 --> 01:32:08,639
smooth sailing we actually do what's

2557
01:32:12,709 --> 01:32:10,719
called blind driving we just tell the

2558
01:32:14,790 --> 01:32:12,719
rover go put the pedal to the metal

2559
01:32:16,229 --> 01:32:14,800
don't even like check for obstacles

2560
01:32:18,229 --> 01:32:16,239
because we've already certified the

2561
01:32:19,350 --> 01:32:18,239
terrain's flat so that's the fastest we

2562
01:32:21,590 --> 01:32:19,360
can drive

2563
01:32:23,910 --> 01:32:21,600

last one so about the comet that's

2564
01:32:25,669 --> 01:32:23,920
supposed to um that mike

2565
01:32:27,110 --> 01:32:25,679
hit mars

2566
01:32:29,189 --> 01:32:27,120
next year

2567
01:32:30,310 --> 01:32:29,199
how are you guys preparing for that or

2568
01:32:31,350 --> 01:32:30,320
is that something you're even worried

2569
01:32:32,870 --> 01:32:31,360
about

2570
01:32:34,229 --> 01:32:32,880
um

2571
01:32:34,480 --> 01:32:34,239
it was interesting when we heard about

2572
01:32:36,390 --> 01:32:34,490
it

2573
01:32:38,229 --> 01:32:36,400
[Laughter]

2574
01:32:40,870 --> 01:32:38,239
but it turns out that this comment

2575
01:32:42,390 --> 01:32:40,880
called ison ison no idea what that

2576
01:32:44,310 --> 01:32:42,400
stands for

2577
01:32:46,629 --> 01:32:44,320
it's not going to hit mars so now that

2578
01:32:49,750 --> 01:32:46,639
we are tracking it more we being the

2579
01:32:51,669 --> 01:32:49,760
global we not me

2580
01:32:53,750 --> 01:32:51,679
we know that it's not going to hit mars

2581
01:32:55,910 --> 01:32:53,760
any longer in fact i kind of heard

2582
01:32:57,910 --> 01:32:55,920
depressing news that it's fizzing out

2583
01:32:59,910 --> 01:32:57,920
but hopefully it won't fizz out and then

2584
01:33:01,830 --> 01:32:59,920
we will actually attempt to image it

2585
01:33:05,510 --> 01:33:01,840
both opportunity and curiosity will

2586
01:33:07,830 --> 01:33:05,520
image it hopefully from the surface

2587
01:33:26,350 --> 01:33:07,840
that's it