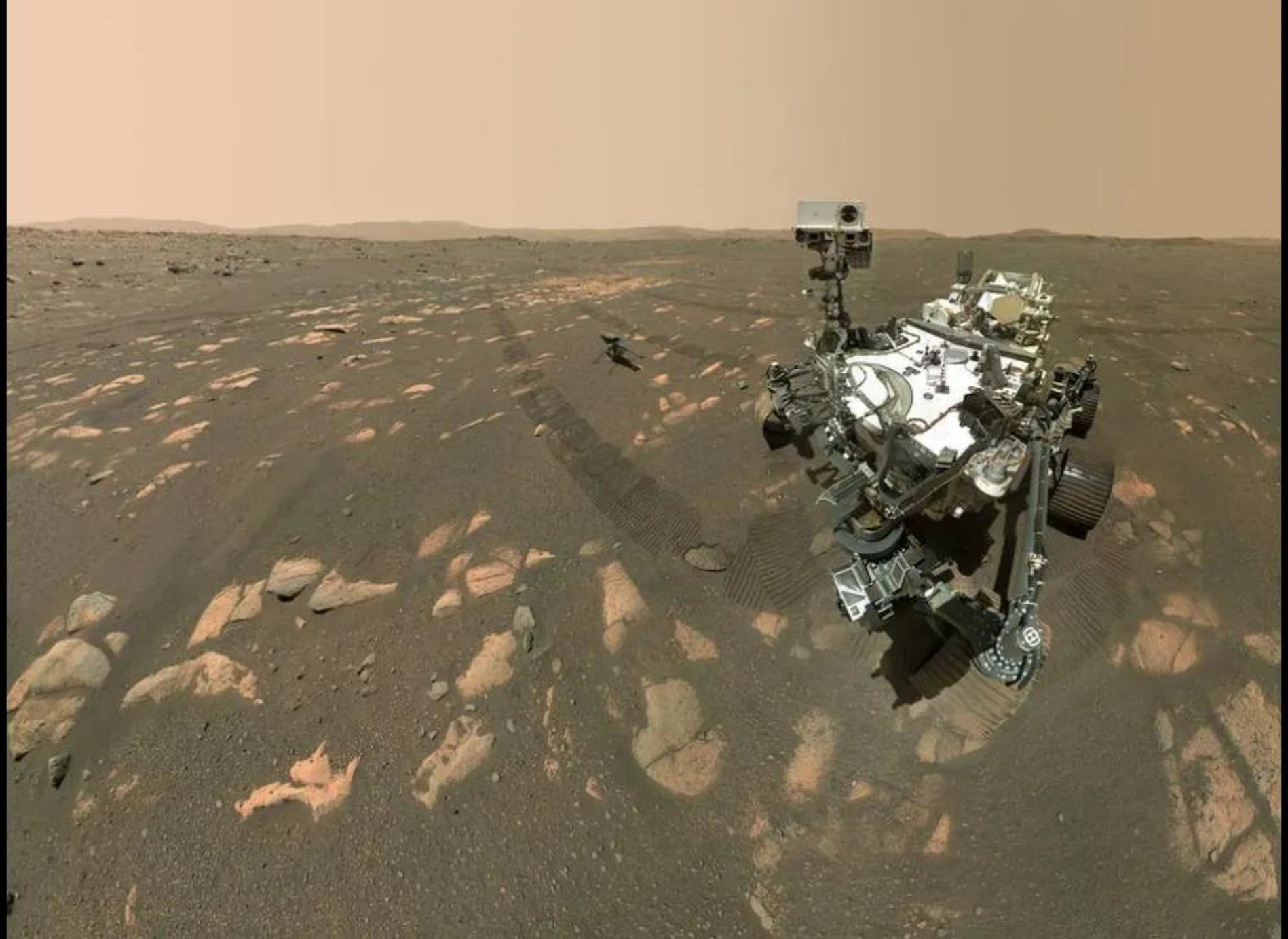

1
00:00:03,110 --> 00:00:01,189
[Music]

2
00:00:04,710 --> 00:00:03,120
nasa's jet propulsion laboratory

3
00:00:07,349 --> 00:00:04,720
presents

4
00:00:09,430 --> 00:00:07,359
the von carmen lecture a series of talks

5
00:00:10,070 --> 00:00:09,440
by scientists and engineers who are

6
00:00:13,509 --> 00:00:10,080
exploring

7
00:00:17,800 --> 00:00:13,519
our planet our solar system and all that

8
00:00:23,269 --> 00:00:17,810
lies beyond

9
00:00:26,950 --> 00:00:25,429
good evening everybody my name is mark

10
00:00:29,109 --> 00:00:26,960
razzie from jpl's office of

11
00:00:30,630 --> 00:00:29,119
communications and education

12
00:00:32,069 --> 00:00:30,640
and i want to thank all of you for

13
00:00:33,910 --> 00:00:32,079

joining us for tonight's edition of the

14
00:00:35,590 --> 00:00:33,920
von carmen lecture series

15
00:00:37,590 --> 00:00:35,600
tonight we'll be talking about cameras

16
00:00:39,110 --> 00:00:37,600
and pictures but being that this is jpl

17
00:00:40,389 --> 00:00:39,120
of course we'll be focusing on space

18
00:00:43,030 --> 00:00:40,399
cameras and pictures

19
00:00:44,549 --> 00:00:43,040
and primarily those of mars from the

20
00:00:45,029 --> 00:00:44,559
first picture taken on the surface of

21
00:00:48,150 --> 00:00:45,039
mars

22
00:00:49,750 --> 00:00:48,160
by the viking one lander in 1976

23
00:00:51,750 --> 00:00:49,760
to the incredible images we're seeing

24
00:00:53,510 --> 00:00:51,760
today from the perseverance rover

25
00:00:55,590 --> 00:00:53,520
it's evident the technology has come a

26
00:00:56,709 --> 00:00:55,600
long way in 40 plus years

27
00:00:58,790 --> 00:00:56,719
tonight we'll take a look at the

28
00:00:59,990 --> 00:00:58,800
evolution of technologies that led us to

29
00:01:01,189 --> 00:01:00,000
the incredible images we're seeing

30
00:01:03,750 --> 00:01:01,199
tonight

31
00:01:05,270 --> 00:01:03,760
our co-host this evening is my friend

32
00:01:06,789 --> 00:01:05,280
and colleague brian white

33
00:01:08,789 --> 00:01:06,799
also from the office of communications

34
00:01:09,750 --> 00:01:08,799
and education he'll be taking questions

35
00:01:13,270 --> 00:01:09,760
from the chat

36
00:01:15,670 --> 00:01:13,280
say hi brian hi brian

37
00:01:16,950 --> 00:01:15,680
hi mark thanks for having me today i

38
00:01:18,070 --> 00:01:16,960

want to remind everybody out there in

39
00:01:19,990 --> 00:01:18,080
the audience that this is

40
00:01:21,990 --> 00:01:20,000
their space program so we want you to

41
00:01:23,270 --> 00:01:22,000
ask questions we want you to be involved

42
00:01:24,870 --> 00:01:23,280
in this conversation

43
00:01:26,230 --> 00:01:24,880
our amazing social media team is going

44
00:01:27,670 --> 00:01:26,240
to take all these questions that you

45
00:01:29,510 --> 00:01:27,680
have in the chats

46
00:01:31,990 --> 00:01:29,520
we're going to try to ask as many as we

47
00:01:33,670 --> 00:01:32,000
possibly can keep that curiosity going

48
00:01:35,270 --> 00:01:33,680
now if you don't see the chat

49
00:01:37,109 --> 00:01:35,280
go ahead and refresh your pages and it

50
00:01:40,469 --> 00:01:37,119
should be right there

51
00:01:43,190 --> 00:01:40,479
looking forward to this talk tonight

52
00:01:44,469 --> 00:01:43,200
thank you very much brian so to take us

53
00:01:45,429 --> 00:01:44,479
on our journey tonight we actually have

54
00:01:47,030 --> 00:01:45,439
two guests

55
00:01:49,510 --> 00:01:47,040
both of whom are members of the mars

56
00:01:52,230 --> 00:01:49,520
2020 project imaging team

57
00:01:54,389 --> 00:01:52,240
to start us off please say hello to

58
00:01:57,030 --> 00:01:54,399
imaging scientist and mast cam z

59
00:01:57,749 --> 00:01:57,040
deputy principal investigator dr justin

60
00:02:01,030 --> 00:01:57,759
mackey

61
00:02:03,670 --> 00:02:01,040
hey justin how's it going tonight

62
00:02:05,030 --> 00:02:03,680
hi how are you doing great to be here

63
00:02:06,469 --> 00:02:05,040

well thank you so much for giving us

64
00:02:08,309 --> 00:02:06,479
your time tonight

65
00:02:10,150 --> 00:02:08,319
so first of all tell us a little bit

66
00:02:12,470 --> 00:02:10,160
about yourself and how you came to be at

67
00:02:16,550 --> 00:02:12,480
jpl

68
00:02:19,110 --> 00:02:16,560
and i design

69
00:02:22,229 --> 00:02:19,120
uh develop and operate imaging systems

70
00:02:24,150 --> 00:02:22,239
mostly for mars rovers but also landers

71
00:02:25,750 --> 00:02:24,160
an imaging system in this context

72
00:02:28,070 --> 00:02:25,760
includes the camera hardware

73
00:02:29,350 --> 00:02:28,080
the software that controls the cameras

74
00:02:31,990 --> 00:02:29,360
compresses the data and sends it to

75
00:02:33,830 --> 00:02:32,000
earth and processes it on the ground

76
00:02:35,509 --> 00:02:33,840
i came into the field as a physics

77
00:02:36,070 --> 00:02:35,519
undergraduate student at the university

78
00:02:37,830 --> 00:02:36,080
of colorado

79
00:02:39,270 --> 00:02:37,840
in boulder uh where i worked at the

80
00:02:41,030 --> 00:02:39,280
laboratory for atmospheric and space

81
00:02:42,710 --> 00:02:41,040
physics for larry esposito and george

82
00:02:43,830 --> 00:02:42,720
lawrence i was working on the cassini

83
00:02:45,430 --> 00:02:43,840
mission

84
00:02:47,430 --> 00:02:45,440
and i was part of the hardware team that

85
00:02:50,390 --> 00:02:47,440
developed the ultra

86
00:02:50,790 --> 00:02:50,400
violet imaging spectrograph or uvis and

87
00:02:53,589 --> 00:02:50,800
then

88
00:02:54,949 --> 00:02:53,599

after that i and i received my phd at

89
00:02:56,790 --> 00:02:54,959
the university of colorado

90
00:02:58,949 --> 00:02:56,800
after that i went to the university of

91
00:03:00,630 --> 00:02:58,959
arizona at the lunar and planetary lab

92
00:03:01,270 --> 00:03:00,640
where i worked as a postdoc for peter

93
00:03:03,910 --> 00:03:01,280
smith

94
00:03:05,190 --> 00:03:03,920
on the mars pathfinder mission uh and

95
00:03:07,830 --> 00:03:05,200
that was um

96
00:03:08,229 --> 00:03:07,840
our first return to mars since viking uh

97
00:03:11,830 --> 00:03:08,239
and then

98
00:03:14,949 --> 00:03:11,840
after that i came to jpl in 1997.

99
00:03:15,830 --> 00:03:14,959
well that's a that's a cool story um was

100
00:03:17,430 --> 00:03:15,840
there a

101
00:03:19,509 --> 00:03:17,440
like what made you focus on imaging was

102
00:03:21,990 --> 00:03:19,519
there's an image you saw at some point

103
00:03:23,430 --> 00:03:22,000
or some particular moment or something

104
00:03:25,589 --> 00:03:23,440
that you know kind of made you want to

105
00:03:27,350 --> 00:03:25,599
focus on imaging

106
00:03:29,589 --> 00:03:27,360
well yes i've always been interested in

107
00:03:31,990 --> 00:03:29,599
physics and the physics of route sensing

108
00:03:33,190 --> 00:03:32,000
and certainly growing up i saw the

109
00:03:35,110 --> 00:03:33,200
voyager missions

110
00:03:37,670 --> 00:03:35,120
uh those fantastic pictures returned

111
00:03:39,030 --> 00:03:37,680
from voyager but i also saw the viking

112
00:03:41,910 --> 00:03:39,040
mission and when i was a graduate

113
00:03:44,390 --> 00:03:41,920

student i had a uh i wanted a picture

114
00:03:46,149 --> 00:03:44,400
printed photograph above my desk of the

115
00:03:48,869 --> 00:03:46,159
surface of mars now let's thought

116
00:03:50,470 --> 00:03:48,879
that's pretty amazing that we can land

117
00:03:51,990 --> 00:03:50,480
landers on another surface of another

118
00:03:53,670 --> 00:03:52,000
planet at the surface of another world

119
00:03:55,350 --> 00:03:53,680
and return images from it

120
00:03:56,789 --> 00:03:55,360
and so that really was something i

121
00:03:58,309 --> 00:03:56,799
always had my eye on is like that would

122
00:03:59,589 --> 00:03:58,319
be really great to work on

123
00:04:01,509 --> 00:03:59,599
projects like that and then i find

124
00:04:04,869 --> 00:04:01,519
myself doing it for my career

125
00:04:06,630 --> 00:04:04,879
so it's great so then in your career

126
00:04:08,630 --> 00:04:06,640
you've certainly seen and helped evolve

127
00:04:10,789 --> 00:04:08,640
the camera technologies

128
00:04:11,830 --> 00:04:10,799
i'm used in a bunch of these missions um

129
00:04:13,589 --> 00:04:11,840
can you give us something of like a

130
00:04:15,670 --> 00:04:13,599
historical review of these technologies

131
00:04:18,310 --> 00:04:15,680
and capabilities

132
00:04:19,030 --> 00:04:18,320
sure so uh as you mentioned in the

133
00:04:21,590 --> 00:04:19,040
opening

134
00:04:23,510 --> 00:04:21,600
the surface of mars or mars surface

135
00:04:23,909 --> 00:04:23,520
imaging started with viking and so the

136
00:04:26,550 --> 00:04:23,919
first

137
00:04:27,110 --> 00:04:26,560
slide actually shows a picture of the

138
00:04:30,070 --> 00:04:27,120

viking

139
00:04:31,749 --> 00:04:30,080
cameras that they flew and this is

140
00:04:33,990 --> 00:04:31,759
really

141
00:04:34,790 --> 00:04:34,000
like old school technology it's it's a

142
00:04:36,870 --> 00:04:34,800
it's basically

143
00:04:38,790 --> 00:04:36,880
a scanning radiometer and there's a

144
00:04:41,590 --> 00:04:38,800
picture in this slide that you can see

145
00:04:43,030 --> 00:04:41,600
that shows uh how it worked it basically

146
00:04:44,310 --> 00:04:43,040
had a scanning mirror

147
00:04:45,830 --> 00:04:44,320
and it would scan up and down and left

148
00:04:46,870 --> 00:04:45,840
to right and take pictures it was it was

149
00:04:48,310 --> 00:04:46,880
um

150
00:04:50,310 --> 00:04:48,320
it was actually quite heavy too it

151
00:04:52,150 --> 00:04:50,320
weighed 17 pounds

152
00:04:54,230 --> 00:04:52,160
so it was not what you would think of as

153
00:04:56,150 --> 00:04:54,240
a as a typical camera but it took great

154
00:04:58,790 --> 00:04:56,160
pictures and the next slide shows uh

155
00:05:00,390 --> 00:04:58,800
an image from viking showing the

156
00:05:00,870 --> 00:05:00,400
fantastic pictures the first pictures

157
00:05:02,629 --> 00:05:00,880
ever

158
00:05:04,230 --> 00:05:02,639
from the surface of mars it was really a

159
00:05:05,590 --> 00:05:04,240
historic mission

160
00:05:07,270 --> 00:05:05,600
uh so that was the state of cameron

161
00:05:09,909 --> 00:05:07,280
technology when i came into the field in

162
00:05:12,870 --> 00:05:09,919
1997 and worked for peter smith

163
00:05:14,070 --> 00:05:12,880

on the next slide you could see what his

164
00:05:15,590 --> 00:05:14,080
camera

165
00:05:17,909 --> 00:05:15,600
basically was all about this was

166
00:05:19,430 --> 00:05:17,919
actually kind of revolutionary this was

167
00:05:21,430 --> 00:05:19,440
similar resolution to viking but much

168
00:05:23,430 --> 00:05:21,440
more compact and lighter it had two eyes

169
00:05:25,270 --> 00:05:23,440
sort of in that classic robot head

170
00:05:27,749 --> 00:05:25,280
look there you can see on the right had

171
00:05:28,870 --> 00:05:27,759
a full 360 degree range of motion and it

172
00:05:31,029 --> 00:05:28,880
used uh

173
00:05:32,390 --> 00:05:31,039
ccds it was a typical frame it was like

174
00:05:33,590 --> 00:05:32,400
a framing camera like you would think of

175
00:05:35,510 --> 00:05:33,600
as a modern camera

176
00:05:37,110 --> 00:05:35,520
and the next slide shows that it also

177
00:05:38,710 --> 00:05:37,120
was capable of taking

178
00:05:40,710 --> 00:05:38,720
fantastic pictures from the surface of

179
00:05:41,590 --> 00:05:40,720
mars again at about the same resolution

180
00:05:43,909 --> 00:05:41,600
as viking

181
00:05:44,710 --> 00:05:43,919
which is about three times worse than

182
00:05:46,469 --> 00:05:44,720
the human

183
00:05:47,990 --> 00:05:46,479
human vision but still pretty good and

184
00:05:49,430 --> 00:05:48,000
you can see that picture there

185
00:05:51,749 --> 00:05:49,440
and one of the unique things about mars

186
00:05:53,670 --> 00:05:51,759
pathfinder is shown on the next slide

187
00:05:55,029 --> 00:05:53,680
is that we had a rover and this was a

188
00:05:57,510 --> 00:05:55,039

technology demonstration

189
00:05:58,629 --> 00:05:57,520
of the sojourner rover and you can see

190
00:06:00,629 --> 00:05:58,639
there the little outline

191
00:06:02,790 --> 00:06:00,639
that it drove around and we had to take

192
00:06:05,029 --> 00:06:02,800
pictures of it to find out where it was

193
00:06:06,870 --> 00:06:05,039
and how to command it and just sort of

194
00:06:08,469 --> 00:06:06,880
learn about how to operate a

195
00:06:10,469 --> 00:06:08,479
robot on the surface of another planet

196
00:06:12,550 --> 00:06:10,479
and it was a real popular mission the

197
00:06:13,909 --> 00:06:12,560
next slide shows they even made a stamp

198
00:06:16,150 --> 00:06:13,919
out of some of the images that we did

199
00:06:18,550 --> 00:06:16,160
take uh and you can see the the surgeon

200
00:06:20,309 --> 00:06:18,560
over there sitting on the lander and

201
00:06:21,350 --> 00:06:20,319
then the other new part about this

202
00:06:23,430 --> 00:06:21,360
technology is the next

203
00:06:24,710 --> 00:06:23,440
you can see in the next slide the rover

204
00:06:27,189 --> 00:06:24,720
itself had cameras

205
00:06:29,430 --> 00:06:27,199
and there there was a picture of the

206
00:06:31,510 --> 00:06:29,440
lander that the rover was delivered on

207
00:06:32,870 --> 00:06:31,520
uh which was kind of you know a view of

208
00:06:35,270 --> 00:06:32,880
things to come so to speak

209
00:06:36,790 --> 00:06:35,280
where we now add a new platform to put

210
00:06:39,029 --> 00:06:36,800
these cameras on

211
00:06:41,189 --> 00:06:39,039
um and then on the next slide you can

212
00:06:41,990 --> 00:06:41,199
see that uh the mars exploration rover

213
00:06:44,309 --> 00:06:42,000

mission

214
00:06:45,110 --> 00:06:44,319
uh which was a pi with steve squires was

215
00:06:48,230 --> 00:06:45,120
a mission that we

216
00:06:49,749 --> 00:06:48,240
rover we built at jpl and

217
00:06:52,150 --> 00:06:49,759
we kind of standardized sort of the

218
00:06:53,909 --> 00:06:52,160
modern rover imaging system you can see

219
00:06:54,870 --> 00:06:53,919
the cameras there attached to the body

220
00:06:57,110 --> 00:06:54,880
the has cam

221
00:06:58,390 --> 00:06:57,120
cams or the hazard avoidance cameras and

222
00:07:00,390 --> 00:06:58,400
then you can see the

223
00:07:02,550 --> 00:07:00,400
cameras up on the mast so the nav cams

224
00:07:04,950 --> 00:07:02,560
and the pan cams and

225
00:07:06,870 --> 00:07:04,960
the next slide shows that the cameras

226
00:07:08,469 --> 00:07:06,880
themselves advanced quite a bit and only

227
00:07:11,029 --> 00:07:08,479
a few years where we had

228
00:07:12,870 --> 00:07:11,039
four cameras up on the mast this time

229
00:07:14,070 --> 00:07:12,880
about the same resolution for the color

230
00:07:15,990 --> 00:07:14,080
cameras

231
00:07:18,070 --> 00:07:16,000
but the next slide shows the real

232
00:07:19,749 --> 00:07:18,080
difference was that we were able to

233
00:07:21,430 --> 00:07:19,759
drive around so this is a picture that

234
00:07:22,629 --> 00:07:21,440
we took of one of the landers this is

235
00:07:24,870 --> 00:07:22,639
the opportunity lander

236
00:07:26,390 --> 00:07:24,880
where we drove away and we said goodbye

237
00:07:27,430 --> 00:07:26,400
to the lander and we kept on driving and

238
00:07:28,870 --> 00:07:27,440

the next slide

239
00:07:31,350 --> 00:07:28,880
shows that we just kept driving and

240
00:07:33,830 --> 00:07:31,360
driving and these cameras now could go

241
00:07:35,749 --> 00:07:33,840
really anywhere in the local vicinity so

242
00:07:37,350 --> 00:07:35,759
that was a real advance that was

243
00:07:40,070 --> 00:07:37,360
we proved that we could take these kinds

244
00:07:41,749 --> 00:07:40,080
of pictures and keep going and exploring

245
00:07:43,670 --> 00:07:41,759
uh and then the next slide after that is

246
00:07:45,670 --> 00:07:43,680
a picture from the pan cam

247
00:07:47,029 --> 00:07:45,680
this is now one of the first pictures

248
00:07:49,670 --> 00:07:47,039
where we had

249
00:07:51,589 --> 00:07:49,680
human eye resolution so it's color and

250
00:07:54,710 --> 00:07:51,599
you could see we were driving up and up

251
00:07:55,510 --> 00:07:54,720
down hills and things then in addition

252
00:07:57,189 --> 00:07:55,520
to that

253
00:07:58,550 --> 00:07:57,199
the next slide shows we also carry a

254
00:08:00,629 --> 00:07:58,560
microscopic imager

255
00:08:01,749 --> 00:08:00,639
which is capable of taking really close

256
00:08:03,670 --> 00:08:01,759
up high resolution

257
00:08:05,350 --> 00:08:03,680
photos this is about 30 microns per

258
00:08:06,629 --> 00:08:05,360
pixel it's about the size of a stamp

259
00:08:07,749 --> 00:08:06,639
actually smaller than that stamp i

260
00:08:09,270 --> 00:08:07,759
showed earlier

261
00:08:11,589 --> 00:08:09,280
so we could take a robot arm and put it

262
00:08:12,790 --> 00:08:11,599
up to something and take high resolution

263
00:08:14,869 --> 00:08:12,800

pictures of it

264
00:08:16,950 --> 00:08:14,879
so then after that the next mission the

265
00:08:20,390 --> 00:08:16,960
msl mars science laboratory

266
00:08:21,589 --> 00:08:20,400
curiosity rover much bigger rover uh we

267
00:08:23,110 --> 00:08:21,599
kept some of the same camera

268
00:08:24,869 --> 00:08:23,120
technologies on that one but we also

269
00:08:27,589 --> 00:08:24,879
upgraded them and the next slide

270
00:08:29,189 --> 00:08:27,599
shows the next real advance in mars

271
00:08:32,469 --> 00:08:29,199
surface imaging

272
00:08:34,310 --> 00:08:32,479
on the next slide built by the mainland

273
00:08:35,589 --> 00:08:34,320
space science systems group down in san

274
00:08:38,230 --> 00:08:35,599
diego

275
00:08:38,870 --> 00:08:38,240
now this is really the first time we had

276
00:08:40,310 --> 00:08:38,880
cameras

277
00:08:42,230 --> 00:08:40,320
that were really like a modern camera

278
00:08:44,070 --> 00:08:42,240
with focus mechanisms

279
00:08:45,269 --> 00:08:44,080
uh color sensors like the kind that you

280
00:08:46,630 --> 00:08:45,279
would get in your phones your

281
00:08:49,190 --> 00:08:46,640
smartphones

282
00:08:51,190 --> 00:08:49,200
but in addition um the resolution on

283
00:08:53,269 --> 00:08:51,200
these cameras especially the one on the

284
00:08:54,389 --> 00:08:53,279
top right uh was about three times

285
00:08:56,949 --> 00:08:54,399
better than human

286
00:08:59,269 --> 00:08:56,959
human vision so uh and then a little

287
00:09:01,269 --> 00:08:59,279
video camera down there in the panel c

288
00:09:02,550 --> 00:09:01,279

so that was a real advancement uh and

289
00:09:03,590 --> 00:09:02,560
you can see on the next slide just the

290
00:09:05,110 --> 00:09:03,600
pictures that came

291
00:09:08,389 --> 00:09:05,120
that are and are still coming from this

292
00:09:10,470 --> 00:09:08,399
imaging system are really spectacular

293
00:09:12,470 --> 00:09:10,480
high resolution photos uh the next slide

294
00:09:14,150 --> 00:09:12,480
shows the kinds of

295
00:09:15,990 --> 00:09:14,160
photos of the geology that really

296
00:09:18,470 --> 00:09:16,000
advance our understanding of the planet

297
00:09:21,190 --> 00:09:18,480
so that was a real advancement and in

298
00:09:23,910 --> 00:09:21,200
addition to that the next slide

299
00:09:25,670 --> 00:09:23,920
shows the improvements that were made in

300
00:09:28,470 --> 00:09:25,680
uh kind of the hand lens imaging the

301
00:09:30,470 --> 00:09:28,480
microscopic type imagers um this is

302
00:09:32,230 --> 00:09:30,480
the instrument uh pi was ken edgett down

303
00:09:34,949 --> 00:09:32,240
in san diego works with the mainland

304
00:09:36,550 --> 00:09:34,959
group was also quite an advancement had

305
00:09:38,470 --> 00:09:36,560
to focus mechanisms and just take

306
00:09:39,509 --> 00:09:38,480
spectacular photos and those cameras are

307
00:09:41,350 --> 00:09:39,519
still active

308
00:09:43,350 --> 00:09:41,360
uh and one other thing that it brought

309
00:09:45,269 --> 00:09:43,360
to us in the next slide is one of the

310
00:09:46,230 --> 00:09:45,279
first real high-resolution rover selfies

311
00:09:47,509 --> 00:09:46,240
and these are

312
00:09:49,190 --> 00:09:47,519
you've probably seen these on the

313
00:09:49,990 --> 00:09:49,200

internet they're um they're popular and

314
00:09:51,190 --> 00:09:50,000
they're actually a great way of

315
00:09:53,190 --> 00:09:51,200
documenting

316
00:09:54,389 --> 00:09:53,200
where the rover is in in the mission and

317
00:09:56,949 --> 00:09:54,399
here it is uh near

318
00:09:58,630 --> 00:09:56,959
uh one of its first first places that

319
00:10:01,590 --> 00:09:58,640
had examined rock nest

320
00:10:02,069 --> 00:10:01,600
um so um those were the advancements

321
00:10:04,710 --> 00:10:02,079
then the

322
00:10:06,470 --> 00:10:04,720
the insight mission which uh was just

323
00:10:06,949 --> 00:10:06,480
launched a few years ago uh the next

324
00:10:08,550 --> 00:10:06,959
slide

325
00:10:10,310 --> 00:10:08,560
uh we actually upgraded the cameras that

326
00:10:11,990 --> 00:10:10,320
we had at jpl to color now we're

327
00:10:13,190 --> 00:10:12,000
catching up on the engineering camera

328
00:10:14,710 --> 00:10:13,200
side of things and we were able to take

329
00:10:17,030 --> 00:10:14,720
some fantastic photos

330
00:10:19,590 --> 00:10:17,040
on insight but the real next advancement

331
00:10:22,150 --> 00:10:19,600
came um on the 2020 mission so the next

332
00:10:25,110 --> 00:10:22,160
slide for the for that shows um

333
00:10:26,710 --> 00:10:25,120
we now have 20 megapixel color imagers

334
00:10:28,230 --> 00:10:26,720
on the surface of mars so now these are

335
00:10:29,670 --> 00:10:28,240
these are cameras that would

336
00:10:31,350 --> 00:10:29,680
be comparable to something like viewer

337
00:10:32,790 --> 00:10:31,360
real camera buff and you went to

338
00:10:35,509 --> 00:10:32,800

spend a lot of money on a camera in this

339
00:10:37,990 --> 00:10:35,519
store you would get high resolution

340
00:10:39,269 --> 00:10:38,000
images cameras like this and then in

341
00:10:41,269 --> 00:10:39,279
addition to that

342
00:10:43,190 --> 00:10:41,279
we also advanced the state of the art on

343
00:10:45,590 --> 00:10:43,200
the science cameras and the next slide

344
00:10:47,430 --> 00:10:45,600
after that shows cameras with zoom

345
00:10:48,069 --> 00:10:47,440
lenses so now we have the capability to

346
00:10:50,949 --> 00:10:48,079
zoom on

347
00:10:52,710 --> 00:10:50,959
zoom in on things from far away uh so

348
00:10:54,069 --> 00:10:52,720
this next slide here shows

349
00:10:55,590 --> 00:10:54,079
in addition we had a whole bunch of

350
00:10:55,990 --> 00:10:55,600
other cameras way too much to talk about

351
00:10:58,630 --> 00:10:56,000
now

352
00:11:00,310 --> 00:10:58,640
but we had 23 we have 23 cameras on the

353
00:11:01,430 --> 00:11:00,320
perseverance mission plus two on the

354
00:11:03,350 --> 00:11:01,440
helicopter

355
00:11:05,030 --> 00:11:03,360
and we won't get into too much of that

356
00:11:06,790 --> 00:11:05,040
but there this is all documented you can

357
00:11:09,590 --> 00:11:06,800
find it on the internet and the next

358
00:11:12,150 --> 00:11:09,600
uh next slide shows just a list of all

359
00:11:14,230 --> 00:11:12,160
the cameras we have there's a lot

360
00:11:16,949 --> 00:11:14,240
a lot of technology advancements that

361
00:11:19,110 --> 00:11:16,959
have allowed us to take pictures and um

362
00:11:20,389 --> 00:11:19,120
this next slide shows the the rover and

363
00:11:23,269 --> 00:11:20,399

the cameras before we

364
00:11:24,470 --> 00:11:23,279
launched we were testing them out at jpl

365
00:11:25,990 --> 00:11:24,480
and then i always like to compare that

366
00:11:27,190 --> 00:11:26,000
with the next picture which is

367
00:11:29,110 --> 00:11:27,200
one of the first pictures that we

368
00:11:30,389 --> 00:11:29,120
received from the surface of mars

369
00:11:32,710 --> 00:11:30,399
showing that everything made it there

370
00:11:34,470 --> 00:11:32,720
safely this is a 20 megapixel nav cam

371
00:11:36,949 --> 00:11:34,480
image a single image

372
00:11:38,710 --> 00:11:36,959
uh of the whole rover and then uh you

373
00:11:41,509 --> 00:11:38,720
remember down on the underneath the

374
00:11:42,550 --> 00:11:41,519
on the rotary body their hash cams i'll

375
00:11:45,350 --> 00:11:42,560
take pictures

376
00:11:45,990 --> 00:11:45,360
and the next slide shows a picture from

377
00:11:49,030 --> 00:11:46,000
the hass cam

378
00:11:52,470 --> 00:11:49,040
so nice view of the terrain full color

379
00:11:54,389 --> 00:11:52,480
uh full 20 megapixel uh imaging

380
00:11:56,150 --> 00:11:54,399
and then the next slide shows an example

381
00:11:57,670 --> 00:11:56,160
of what we can get from our zoom lens

382
00:11:59,990 --> 00:11:57,680
system the mass cam z

383
00:12:02,790 --> 00:12:00,000
system uh jim bell's the pi on that i'm

384
00:12:04,470 --> 00:12:02,800
the deputy pi on that jim bill's at asu

385
00:12:06,310 --> 00:12:04,480
a collaboration with the mainland folks

386
00:12:07,430 --> 00:12:06,320
down in san diego again advancing the

387
00:12:09,430 --> 00:12:07,440
technology

388
00:12:10,470 --> 00:12:09,440

fully zoomed photo of something like two

389
00:12:13,910 --> 00:12:10,480
kilometers away

390
00:12:15,430 --> 00:12:13,920
so um really capable imaging systems

391
00:12:18,069 --> 00:12:15,440
uh and it's just been exciting to be a

392
00:12:21,030 --> 00:12:18,079
part of all this over the years

393
00:12:21,829 --> 00:12:21,040
yeah it's been crazy exciting to like

394
00:12:23,430 --> 00:12:21,839
just

395
00:12:25,509 --> 00:12:23,440
look at these things the pictures are

396
00:12:27,590 --> 00:12:25,519
stunning but

397
00:12:30,069 --> 00:12:27,600
now we have video capabilities too which

398
00:12:31,670 --> 00:12:30,079
is kind of new right can you tell us a

399
00:12:34,150 --> 00:12:31,680
little bit about that

400
00:12:35,750 --> 00:12:34,160
we do we do have video capabilities and

401
00:12:37,829 --> 00:12:35,760
it all kind of started

402
00:12:39,590 --> 00:12:37,839
the modern era started with what i call

403
00:12:41,190 --> 00:12:39,600
time lapse video which is just what you

404
00:12:43,030 --> 00:12:41,200
think it is it's a picture some time

405
00:12:44,870 --> 00:12:43,040
goes by in another picture and so the

406
00:12:45,910 --> 00:12:44,880
first example of that is shown on the

407
00:12:48,389 --> 00:12:45,920
next uh

408
00:12:49,670 --> 00:12:48,399
slide where the sojourner rover was

409
00:12:51,350 --> 00:12:49,680
about to

410
00:12:53,030 --> 00:12:51,360
drive onto the surface so we had this

411
00:12:53,670 --> 00:12:53,040
idea that if we maybe did some time

412
00:12:55,829 --> 00:12:53,680
lapse

413
00:12:57,990 --> 00:12:55,839

imagery we could make make a video out

414
00:12:59,269 --> 00:12:58,000
of it turn it into an animated gif

415
00:13:01,350 --> 00:12:59,279
and put it on the internet which was

416
00:13:02,230 --> 00:13:01,360
this new thing at the time of these

417
00:13:03,670 --> 00:13:02,240
animated

418
00:13:05,590 --> 00:13:03,680
images it's hard to believe that that

419
00:13:06,069 --> 00:13:05,600
the internet was in its early stages in

420
00:13:08,230 --> 00:13:06,079
the 90s

421
00:13:09,910 --> 00:13:08,240
but so we did this with these uh

422
00:13:11,590 --> 00:13:09,920
animations here and we managed to

423
00:13:13,670 --> 00:13:11,600
capture it coming onto the surface

424
00:13:15,509 --> 00:13:13,680
and as part of my work as a postdoc i

425
00:13:15,990 --> 00:13:15,519
helped develop that technique and refine

426
00:13:18,389 --> 00:13:16,000
it

427
00:13:19,990 --> 00:13:18,399
and the next slide shows uh kind of the

428
00:13:21,829 --> 00:13:20,000
full volume of work for that

429
00:13:23,670 --> 00:13:21,839
for that which is basically little

430
00:13:25,110 --> 00:13:23,680
movies of sojourner rovers

431
00:13:26,710 --> 00:13:25,120
scooting around on the surface and these

432
00:13:29,269 --> 00:13:26,720
these were very popular and

433
00:13:31,509 --> 00:13:29,279
this really showed us that wow we could

434
00:13:33,190 --> 00:13:31,519
we could drive a rover around on mars

435
00:13:34,629 --> 00:13:33,200
imaging systems are a really important

436
00:13:36,470 --> 00:13:34,639
part of that and

437
00:13:38,230 --> 00:13:36,480
we were really developing the technique

438
00:13:40,389 --> 00:13:38,240

techniques and sort of you know mars

439
00:13:42,150 --> 00:13:40,399
pathfinder it's a great name it really

440
00:13:43,430 --> 00:13:42,160
gave us the path to on how to do these

441
00:13:46,310 --> 00:13:43,440
missions so

442
00:13:48,470 --> 00:13:46,320
uh moving forward on the next real

443
00:13:50,230 --> 00:13:48,480
change in video we did time lapse on mer

444
00:13:52,310 --> 00:13:50,240
but the next change was for this uh this

445
00:13:55,590 --> 00:13:52,320
video here the msl marty instrument

446
00:13:58,230 --> 00:13:55,600
again diego which took

447
00:14:00,310 --> 00:13:58,240
uh video during descent again it's a

448
00:14:01,750 --> 00:14:00,320
little faster than time lapse

449
00:14:04,230 --> 00:14:01,760
three and a half frames per second uh

450
00:14:05,990 --> 00:14:04,240
but it's it's video and it was um

451
00:14:07,430 --> 00:14:06,000
our first view of how what it's like to

452
00:14:10,069 --> 00:14:07,440
land on mars

453
00:14:12,230 --> 00:14:10,079
um and then on the surface we took the

454
00:14:14,150 --> 00:14:12,240
same capability with the mast cam and we

455
00:14:15,750 --> 00:14:14,160
managed to do videos of the scoop and

456
00:14:18,870 --> 00:14:15,760
the next slide shows

457
00:14:21,189 --> 00:14:18,880
the uh scoop being shaken

458
00:14:22,310 --> 00:14:21,199
um the next slide yeah there we go shows

459
00:14:24,069 --> 00:14:22,320
the um

460
00:14:25,750 --> 00:14:24,079
scoop shaking some sand and we were able

461
00:14:28,069 --> 00:14:25,760
to document a little bit of that

462
00:14:28,870 --> 00:14:28,079
that was kind of it for msl the next big

463
00:14:31,829 --> 00:14:28,880

advance

464
00:14:32,150 --> 00:14:31,839
was mars 2020 and the next slide we have

465
00:14:34,310 --> 00:14:32,160
this

466
00:14:35,910 --> 00:14:34,320
we have a system now that's designed to

467
00:14:38,389 --> 00:14:35,920
do high-speed video

468
00:14:40,150 --> 00:14:38,399
and this is the edl camera system a

469
00:14:41,670 --> 00:14:40,160
specific task to do high-speed video

470
00:14:43,590 --> 00:14:41,680
during edl and so the first

471
00:14:45,829 --> 00:14:43,600
slide after the next slide after this

472
00:14:47,670 --> 00:14:45,839
shows the parachute uplift camera

473
00:14:49,189 --> 00:14:47,680
and this was the first time ever we were

474
00:14:51,509 --> 00:14:49,199
able to get video of

475
00:14:52,710 --> 00:14:51,519
a parachute deploying above the surface

476
00:14:54,389 --> 00:14:52,720
of another planet

477
00:14:55,750 --> 00:14:54,399
and it was just spectacular we were all

478
00:14:57,829 --> 00:14:55,760
very happy to see this

479
00:14:58,870 --> 00:14:57,839
video come back it's a real great

480
00:15:00,870 --> 00:14:58,880
documentation

481
00:15:02,790 --> 00:15:00,880
to show what it's like and the parachute

482
00:15:04,069 --> 00:15:02,800
team also really likes to see this

483
00:15:06,629 --> 00:15:04,079
as well for how their parachute

484
00:15:09,350 --> 00:15:06,639
performed the next slide after this

485
00:15:10,790 --> 00:15:09,360
shows the view from the descent stage

486
00:15:12,389 --> 00:15:10,800
looking down at the rover now if you

487
00:15:14,470 --> 00:15:12,399
watch it happens pretty quickly but the

488
00:15:17,030 --> 00:15:14,480

rover itself now is being

489
00:15:18,470 --> 00:15:17,040
lowered on the sky crane above the

490
00:15:20,230 --> 00:15:18,480
surface of mars

491
00:15:21,590 --> 00:15:20,240
and the rockets are firing and all the

492
00:15:23,430 --> 00:15:21,600
dust and we were capturing all those

493
00:15:25,430 --> 00:15:23,440
dynamics as part of this video

494
00:15:27,269 --> 00:15:25,440
uh showing the rover for the first time

495
00:15:28,629 --> 00:15:27,279
ever landing on the surface of mars and

496
00:15:31,030 --> 00:15:28,639
it was pretty spectacular

497
00:15:32,550 --> 00:15:31,040
uh and then the sky crank cut away and

498
00:15:34,949 --> 00:15:32,560
the next slide shows the view

499
00:15:35,829 --> 00:15:34,959
of the sky crane as seen from the rover

500
00:15:37,670 --> 00:15:35,839
so now we're looking

501
00:15:38,949 --> 00:15:37,680
up and this is what it was like if you

502
00:15:40,550 --> 00:15:38,959
were on a rover and you were looking up

503
00:15:41,910 --> 00:15:40,560
there's the sky crane pulling away and

504
00:15:42,550 --> 00:15:41,920
you're being lowered down on the surface

505
00:15:43,910 --> 00:15:42,560
of mars

506
00:15:46,310 --> 00:15:43,920
and then if you watch carefully it gets

507
00:15:47,829 --> 00:15:46,320
a little dusty but then the sky crane

508
00:15:49,749 --> 00:15:47,839
itself will fly away

509
00:15:51,110 --> 00:15:49,759
after it cuts the cord and flies out of

510
00:15:51,910 --> 00:15:51,120
the field you can watch it fly away it

511
00:15:53,670 --> 00:15:51,920
looks like

512
00:15:55,189 --> 00:15:53,680
kind of an alien spacecraft that's about

513
00:15:57,509 --> 00:15:55,199

to happen right now

514
00:15:58,629 --> 00:15:57,519
and keep watching and it's really quick

515
00:16:00,069 --> 00:15:58,639
and there it goes

516
00:16:01,910 --> 00:16:00,079
and so now we're on mars and so we

517
00:16:05,110 --> 00:16:01,920
documented that with our video system

518
00:16:08,150 --> 00:16:05,120
um it's it's just amazing video um

519
00:16:10,230 --> 00:16:08,160
a real first and then the last slide to

520
00:16:11,990 --> 00:16:10,240
talk about video is recently acquired

521
00:16:13,990 --> 00:16:12,000
images of the mars helicopter

522
00:16:15,509 --> 00:16:14,000
and if you listen carefully we actually

523
00:16:16,870 --> 00:16:15,519
combine the video with audio and you can

524
00:16:18,870 --> 00:16:16,880
hear the helicopter

525
00:16:19,990 --> 00:16:18,880
humming so listen carefully you might be

526
00:16:21,430 --> 00:16:20,000
able to hear you might need headphones

527
00:16:28,310 --> 00:16:21,440
for this so

528
00:16:28,320 --> 00:16:35,030
[Music]

529
00:16:40,949 --> 00:16:39,030
so that's one of the first videos of an

530
00:16:42,949 --> 00:16:40,959
aircraft a rotorcraft flying on the

531
00:16:45,509 --> 00:16:42,959
surface another planet with sound

532
00:16:46,870 --> 00:16:45,519
so this was the masscam z video system

533
00:16:49,509 --> 00:16:46,880
that i talked about earlier

534
00:16:50,150 --> 00:16:49,519
along with the supercam microphone which

535
00:16:52,230 --> 00:16:50,160
is brought

536
00:16:54,150 --> 00:16:52,240
brought by our colleagues in france and

537
00:16:56,069 --> 00:16:54,160
it was just a fantastic collaboration

538
00:16:58,150 --> 00:16:56,079

and so this is kind of the the whirlwind

539
00:17:00,710 --> 00:16:58,160
tour of imaging systems on mars as it

540
00:17:04,630 --> 00:17:00,720
stands right now

541
00:17:07,110 --> 00:17:04,640
thank you justin those videos like still

542
00:17:08,470 --> 00:17:07,120
give me goosebumps they're just amazing

543
00:17:10,309 --> 00:17:08,480
um so this is probably a good

544
00:17:12,069 --> 00:17:10,319
opportunity to take some questions so

545
00:17:14,870 --> 00:17:12,079
brian let's hop over to you and see how

546
00:17:17,829 --> 00:17:14,880
things are going out there

547
00:17:18,710 --> 00:17:17,839
so many great questions i i mean it's

548
00:17:21,189 --> 00:17:18,720
hard to pick

549
00:17:23,189 --> 00:17:21,199
um but we're we're going to start with

550
00:17:25,590 --> 00:17:23,199
uh 1224 chris

551
00:17:27,270 --> 00:17:25,600
on youtube they actually wanted to know

552
00:17:30,310 --> 00:17:27,280
why you still use black and white

553
00:17:34,390 --> 00:17:32,950
well that's a good question so more

554
00:17:36,870 --> 00:17:34,400
recently with 2020

555
00:17:38,870 --> 00:17:36,880
most of our cameras are color we've done

556
00:17:40,470 --> 00:17:38,880
a lot of upgrades as i talked about

557
00:17:42,630 --> 00:17:40,480
there still are some black and white

558
00:17:43,909 --> 00:17:42,640
imagers and typically the reason that we

559
00:17:46,230 --> 00:17:43,919
use black and white those are much

560
00:17:47,909 --> 00:17:46,240
simpler systems and sometimes

561
00:17:49,430 --> 00:17:47,919
all that's required is a measure of what

562
00:17:51,190 --> 00:17:49,440
we call luminance which is basically

563
00:17:52,549 --> 00:17:51,200

brightness

564
00:17:55,350 --> 00:17:52,559
some of the navigation cameras for

565
00:17:56,630 --> 00:17:55,360
example on msl are are grayscale only

566
00:17:59,110 --> 00:17:56,640
they're black and white so it's a

567
00:17:59,990 --> 00:17:59,120
broadband filter which captures all the

568
00:18:01,750 --> 00:18:00,000
visible range

569
00:18:03,830 --> 00:18:01,760
as is a single brightness value and

570
00:18:04,549 --> 00:18:03,840
those are sometimes useful for machine

571
00:18:07,029 --> 00:18:04,559
vision

572
00:18:08,950 --> 00:18:07,039
where color isn't as critical but for

573
00:18:11,110 --> 00:18:08,960
science cameras for example

574
00:18:12,630 --> 00:18:11,120
particularly science cameras science

575
00:18:13,270 --> 00:18:12,640
teams very interested in the color of

576
00:18:15,110 --> 00:18:13,280
things

577
00:18:17,350 --> 00:18:15,120
and so that's why for the most part

578
00:18:20,870 --> 00:18:17,360
we've been mostly using color

579
00:18:23,270 --> 00:18:20,880
especially in 2020 very cool

580
00:18:25,110 --> 00:18:23,280
um something that kind of follows up

581
00:18:25,430 --> 00:18:25,120
with being on mars and knowing what's

582
00:18:27,510 --> 00:18:25,440
there

583
00:18:29,830 --> 00:18:27,520
dennis on facebook wants to know how you

584
00:18:33,430 --> 00:18:29,840
mitigate dust accumulation on the winds

585
00:18:35,990 --> 00:18:33,440
on the lens or the viewport

586
00:18:39,190 --> 00:18:36,000
well dust is an interesting problem on

587
00:18:42,470 --> 00:18:39,200
mars mars is a very dusty place

588
00:18:45,510 --> 00:18:42,480

really dusty and so dust gets everywhere

589
00:18:47,990 --> 00:18:45,520
it gets on everything um

590
00:18:49,350 --> 00:18:48,000
we do have on one of our calibration

591
00:18:52,230 --> 00:18:49,360
targets for mass cam z

592
00:18:53,190 --> 00:18:52,240
uh provided by our danish colleagues in

593
00:18:56,070 --> 00:18:53,200
denmark

594
00:18:57,750 --> 00:18:56,080
they do have magnets uh strategically

595
00:18:58,950 --> 00:18:57,760
placed that sweep away the dust most of

596
00:19:01,110 --> 00:18:58,960
its metallic

597
00:19:02,230 --> 00:19:01,120
so when the dust lands on it it gets

598
00:19:03,590 --> 00:19:02,240
swept away by the magnet those are

599
00:19:05,029 --> 00:19:03,600
called sweep magnets

600
00:19:06,310 --> 00:19:05,039
but if you don't have those kinds of

601
00:19:07,430 --> 00:19:06,320
systems and we don't have anything like

602
00:19:10,390 --> 00:19:07,440
that on the cameras

603
00:19:11,190 --> 00:19:10,400
you just get dust the good news is um

604
00:19:13,510 --> 00:19:11,200
obviously

605
00:19:14,789 --> 00:19:13,520
it only accumulates a certain amount

606
00:19:16,630 --> 00:19:14,799
just like you think about

607
00:19:18,390 --> 00:19:16,640
your patio you know you get a layer of

608
00:19:19,590 --> 00:19:18,400
dust but you don't get a foot of dust

609
00:19:20,390 --> 00:19:19,600
you just get this teeny layer because

610
00:19:21,990 --> 00:19:20,400
the wind

611
00:19:23,750 --> 00:19:22,000
keeps blowing it and so that happens

612
00:19:24,230 --> 00:19:23,760
with our cameras too we get a little

613
00:19:26,310 --> 00:19:24,240

dust

614
00:19:28,470 --> 00:19:26,320
and then the wind blows it off and it

615
00:19:30,549 --> 00:19:28,480
does reduce contrast a little bit

616
00:19:32,070 --> 00:19:30,559
but it's not so much that we can't we

617
00:19:33,909 --> 00:19:32,080
can't handle it so um

618
00:19:35,430 --> 00:19:33,919
we don't do anything in particular to

619
00:19:35,990 --> 00:19:35,440
get rid of the dust the viking camera

620
00:19:40,150 --> 00:19:36,000
actually

621
00:19:41,669 --> 00:19:40,160
the dust

622
00:19:42,950 --> 00:19:41,679
um and everybody that i talked to that

623
00:19:44,230 --> 00:19:42,960
worked on that mission i did not work on

624
00:19:45,590 --> 00:19:44,240
that mission but everyone i talked to

625
00:19:47,350 --> 00:19:45,600
they they don't think they think they

626
00:19:48,950 --> 00:19:47,360
tested it out but it wasn't

627
00:19:50,950 --> 00:19:48,960
wasn't a big deal and so most of our

628
00:19:53,270 --> 00:19:50,960
cameras don't have any active

629
00:19:54,950 --> 00:19:53,280
dust rejection systems except the arm

630
00:19:57,430 --> 00:19:54,960
camera sorry there's a long answer

631
00:19:58,390 --> 00:19:57,440
uh we have covers on some of the cameras

632
00:19:59,909 --> 00:19:58,400
on the arm

633
00:20:01,669 --> 00:19:59,919
because we put the camera so close to

634
00:20:03,270 --> 00:20:01,679
the surface that

635
00:20:04,830 --> 00:20:03,280
it gets really dusty down there so we

636
00:20:06,470 --> 00:20:04,840
tend to have covers on those kinds of

637
00:20:08,310 --> 00:20:06,480
cameras

638
00:20:09,669 --> 00:20:08,320

it's a great answer and the last

639
00:20:11,909 --> 00:20:09,679
question we'll ask for the moment

640
00:20:16,149 --> 00:20:11,919
is nick on linkedin wants to know what's

641
00:20:18,710 --> 00:20:16,159
the human eye resolution in megapixels

642
00:20:20,230 --> 00:20:18,720
well you know it's a great question we

643
00:20:22,149 --> 00:20:20,240
don't measure the resolution

644
00:20:23,510 --> 00:20:22,159
in megapixels or you can but then you

645
00:20:25,110 --> 00:20:23,520
need to know the size of the pixel and

646
00:20:27,350 --> 00:20:25,120
do some calculations and things

647
00:20:28,789 --> 00:20:27,360
so what we um what we instead we measure

648
00:20:31,669 --> 00:20:28,799
the angular

649
00:20:32,310 --> 00:20:31,679
resolution and that is basically an

650
00:20:33,750 --> 00:20:32,320
angle

651
00:20:36,070 --> 00:20:33,760
and we typically do those in in

652
00:20:37,350 --> 00:20:36,080
milliradians uh you can convert those

653
00:20:38,310 --> 00:20:37,360
two degrees and i don't want to try to

654
00:20:40,549 --> 00:20:38,320
do that

655
00:20:42,070 --> 00:20:40,559
in my head right now but it's about 0.2

656
00:20:43,430 --> 00:20:42,080
milliradians

657
00:20:46,710 --> 00:20:43,440
per pixel now your eye doesn't have

658
00:20:47,190 --> 00:20:46,720
pixels so it's it's a resolution test

659
00:20:49,830 --> 00:20:47,200
and it

660
00:20:50,470 --> 00:20:49,840
gets you can get pretty detailed but

661
00:20:53,029 --> 00:20:50,480
basically

662
00:20:54,870 --> 00:20:53,039
um you know the the people that market

663
00:20:56,390 --> 00:20:54,880

uh screens and everything

664
00:20:57,909 --> 00:20:56,400
and they call you know you've heard

665
00:20:59,110 --> 00:20:57,919
about you know retina displays and

666
00:21:00,149 --> 00:20:59,120
things like that that's essentially the

667
00:21:03,909 --> 00:21:00,159
resolution of your

668
00:21:04,390 --> 00:21:03,919
eye at some distance and the uh the

669
00:21:07,750 --> 00:21:04,400
number

670
00:21:10,710 --> 00:21:07,760
is 0.2 milliradians per per

671
00:21:13,029 --> 00:21:10,720
resolution element in your eye and those

672
00:21:17,350 --> 00:21:13,039
are like for example the pan cam

673
00:21:20,789 --> 00:21:17,360
from mer or the mass cam 34 millimeter

674
00:21:23,909 --> 00:21:20,799
and then um with the 100 millimeter

675
00:21:25,990 --> 00:21:23,919
mass cam on on msl and the cameras on on

676
00:21:27,350 --> 00:21:26,000
2020 we're now above human resolution

677
00:21:28,310 --> 00:21:27,360
eyes we're taking pictures that are

678
00:21:30,549 --> 00:21:28,320
sharper

679
00:21:31,590 --> 00:21:30,559
than you would get if you were there uh

680
00:21:33,029 --> 00:21:31,600
so that's the

681
00:21:34,310 --> 00:21:33,039
that's a real advance so that's why some

682
00:21:34,950 --> 00:21:34,320
of these pic some of these pictures are

683
00:21:39,110 --> 00:21:34,960
just

684
00:21:42,470 --> 00:21:39,120
amazing in terms of resolution very cool

685
00:21:44,950 --> 00:21:42,480
indeed thank you very much so

686
00:21:46,390 --> 00:21:44,960
now as much as the imaging and imagers

687
00:21:48,710 --> 00:21:46,400
have evolved over the years

688
00:21:49,669 --> 00:21:48,720

so has how we produce and process the

689
00:21:52,470 --> 00:21:49,679
images

690
00:21:53,350 --> 00:21:52,480
to talk more about that let's welcome in

691
00:21:56,230 --> 00:21:53,360
our next guest

692
00:21:58,549 --> 00:21:56,240
mrs haley abarca who is the mars 2020

693
00:21:59,110 --> 00:21:58,559
image and data processing operations

694
00:22:02,070 --> 00:21:59,120
lead

695
00:22:03,590 --> 00:22:02,080
hi hallie how are you tonight hey mark

696
00:22:07,190 --> 00:22:03,600
thanks for having me tonight

697
00:22:08,230 --> 00:22:07,200
of course so like we did with justin um

698
00:22:11,669 --> 00:22:08,240
tell us a little bit about your

699
00:22:14,310 --> 00:22:11,679
background and how you got to jpl

700
00:22:15,750 --> 00:22:14,320
yeah um i was definitely one of those

701
00:22:17,990 --> 00:22:15,760
kids who uh

702
00:22:18,950 --> 00:22:18,000
came to jpl's open house that they do

703
00:22:21,590 --> 00:22:18,960
every year

704
00:22:23,190 --> 00:22:21,600
and when i was a ninth grade freshman in

705
00:22:25,350 --> 00:22:23,200
high school i immediately

706
00:22:27,270 --> 00:22:25,360
went to the jpl open house not knowing

707
00:22:29,510 --> 00:22:27,280
really what to expect and then decided i

708
00:22:31,990 --> 00:22:29,520
was going to work on mars when i grow up

709
00:22:33,350 --> 00:22:32,000
and so i have actually stuck on that

710
00:22:36,070 --> 00:22:33,360
path

711
00:22:38,070 --> 00:22:36,080
and now work on mars while i grow up you

712
00:22:39,430 --> 00:22:38,080
know i was really fortunate to

713
00:22:40,630 --> 00:22:39,440

be able to go to arizona state

714
00:22:42,230 --> 00:22:40,640
university they have a really good

715
00:22:43,990 --> 00:22:42,240
program that's a joint

716
00:22:45,510 --> 00:22:44,000
planetary science engineering degree

717
00:22:47,750 --> 00:22:45,520
earth and space exploration

718
00:22:48,710 --> 00:22:47,760
and got the opportunity to work for mark

719
00:22:50,310 --> 00:22:48,720
robinson

720
00:22:51,990 --> 00:22:50,320
working on the lunar reconnaissance

721
00:22:53,990 --> 00:22:52,000
orbiter cameras

722
00:22:55,190 --> 00:22:54,000
while all my all my four years that i

723
00:22:57,750 --> 00:22:55,200
was there

724
00:22:58,710 --> 00:22:57,760
um during that time i got to do amazing

725
00:23:00,870 --> 00:22:58,720
things and actually

726
00:23:02,710 --> 00:23:00,880
work with image data products and you

727
00:23:04,230 --> 00:23:02,720
know being 17 in college you don't

728
00:23:04,950 --> 00:23:04,240
really know what to expect and so i've

729
00:23:07,029 --> 00:23:04,960
kind of then

730
00:23:08,870 --> 00:23:07,039
kind of grown up with image processing

731
00:23:10,230 --> 00:23:08,880
and doing terrain modeling and things

732
00:23:13,590 --> 00:23:10,240
like that

733
00:23:15,350 --> 00:23:13,600
for a long time now and uh when i was uh

734
00:23:16,950 --> 00:23:15,360
getting ready to graduate i was able to

735
00:23:20,230 --> 00:23:16,960
get an internship at jpl

736
00:23:21,750 --> 00:23:20,240
the summer before i uh my last year and

737
00:23:24,149 --> 00:23:21,760
got to do

738
00:23:25,750 --> 00:23:24,159

landing site analysis for upcoming

739
00:23:28,789 --> 00:23:25,760
missions like mars 2020

740
00:23:30,789 --> 00:23:28,799
and gems which is now insight and

741
00:23:32,710 --> 00:23:30,799
that was a really amazing experience and

742
00:23:35,190 --> 00:23:32,720
i knew i wanted to be at jpl

743
00:23:36,950 --> 00:23:35,200
and uh when somebody offered me a job to

744
00:23:40,070 --> 00:23:36,960
come work on curiosity and

745
00:23:40,870 --> 00:23:40,080
mer doing image processing i immediately

746
00:23:43,430 --> 00:23:40,880
said yes

747
00:23:45,909 --> 00:23:43,440
and uh and here i am almost 10 years

748
00:23:51,510 --> 00:23:48,470
so that transition from college to jpl

749
00:23:53,269 --> 00:23:51,520
was pretty smooth no doubt then right

750
00:23:54,630 --> 00:23:53,279
yeah you know i was really fortunate um

751
00:23:56,070 --> 00:23:54,640
you know not everybody definitely gets

752
00:23:57,029 --> 00:23:56,080
the opportunity to work on a flight

753
00:23:59,029 --> 00:23:57,039
project

754
00:24:00,549 --> 00:23:59,039
before coming to a nasa center and so i

755
00:24:02,070 --> 00:24:00,559
was really fortunate to have that

756
00:24:02,950 --> 00:24:02,080
experience so it's pretty natural to

757
00:24:05,510 --> 00:24:02,960
roll in

758
00:24:07,190 --> 00:24:05,520
to mer and you know while i've been here

759
00:24:09,510 --> 00:24:07,200
working up to march 2020

760
00:24:10,549 --> 00:24:09,520
i've been privileged to work on image

761
00:24:13,750 --> 00:24:10,559
processing for

762
00:24:14,710 --> 00:24:13,760
mer and msl and actually led the image

763
00:24:17,909 --> 00:24:14,720

processing team

764
00:24:20,230 --> 00:24:17,919
on insight lander i've been able to do

765
00:24:21,590 --> 00:24:20,240
uplink for the engineering cameras

766
00:24:24,070 --> 00:24:21,600
um i was fortunate enough to actually

767
00:24:24,789 --> 00:24:24,080
get to drive opportunity rover for a few

768
00:24:26,870 --> 00:24:24,799
years

769
00:24:28,230 --> 00:24:26,880
which is something kind of just

770
00:24:29,430 --> 00:24:28,240
mind-boggling it still mind-boggles me

771
00:24:30,950 --> 00:24:29,440
that i had the opportunity to do

772
00:24:33,269 --> 00:24:30,960
something like that

773
00:24:34,870 --> 00:24:33,279
and have you know worked on the the 2020

774
00:24:35,430 --> 00:24:34,880
robotic arm for a bit when we were doing

775
00:24:39,190 --> 00:24:35,440
testing

776
00:24:41,350 --> 00:24:39,200
leading up to launch um and then uh

777
00:24:43,590 --> 00:24:41,360
working on targeting software for mars

778
00:24:45,269 --> 00:24:43,600
2020 and then rolled into this and it's

779
00:24:46,549 --> 00:24:45,279
really excited to get back into image

780
00:24:49,990 --> 00:24:46,559
processing

781
00:24:52,630 --> 00:24:50,000
it's been really great oh that's so cool

782
00:24:54,070 --> 00:24:52,640
so if you've been paying attention to

783
00:24:55,510 --> 00:24:54,080
the mars websites from you know the

784
00:24:57,269 --> 00:24:55,520
public's point of view we're

785
00:24:58,710 --> 00:24:57,279
we're getting just thousands and

786
00:25:01,269 --> 00:24:58,720
thousands of images from

787
00:25:02,710 --> 00:25:01,279
perseverance and ingenuity how do you

788
00:25:05,830 --> 00:25:02,720

even begin to process

789
00:25:07,750 --> 00:25:05,840
all these raw images

790
00:25:09,350 --> 00:25:07,760
yeah um you know it's kind of a crazy

791
00:25:10,950 --> 00:25:09,360
thing if you actually take a step back

792
00:25:13,269 --> 00:25:10,960
for a second and how do we even

793
00:25:14,549 --> 00:25:13,279
get all of these images so many things

794
00:25:16,390 --> 00:25:14,559
have to happen and there's so many

795
00:25:19,110 --> 00:25:16,400
people involved to make all this happen

796
00:25:19,750 --> 00:25:19,120
i mean we start by we make a plan on the

797
00:25:22,149 --> 00:25:19,760
ground

798
00:25:22,789 --> 00:25:22,159
we uplink a plan to the rover the rover

799
00:25:25,269 --> 00:25:22,799
then takes

800
00:25:26,630 --> 00:25:25,279
these incredible images the rover then

801
00:25:27,190 --> 00:25:26,640
at the end of the day has to send this

802
00:25:29,430 --> 00:25:27,200
data

803
00:25:30,789 --> 00:25:29,440
to one of the mars orbiters which we

804
00:25:32,390 --> 00:25:30,799
then have to get back through into the

805
00:25:33,510 --> 00:25:32,400
deep states network

806
00:25:35,669 --> 00:25:33,520
and then that data has to get

807
00:25:36,470 --> 00:25:35,679
transferred to jpl and then eventually

808
00:25:39,590 --> 00:25:36,480
it makes its way

809
00:25:41,590 --> 00:25:39,600
to our cloud computing and we then

810
00:25:42,870 --> 00:25:41,600
process the data and we have that last

811
00:25:44,390 --> 00:25:42,880
five minutes and that's what

812
00:25:45,909 --> 00:25:44,400
you know the team that i'm on that last

813
00:25:48,390 --> 00:25:45,919

five minutes is where we then try to get

814
00:25:51,269 --> 00:25:48,400
these images out as quickly as possible

815
00:25:52,470 --> 00:25:51,279
to the public and you know that's been

816
00:25:54,149 --> 00:25:52,480
something that

817
00:25:56,149 --> 00:25:54,159
has taken many people to work on we've

818
00:25:58,310 --> 00:25:56,159
had more than 50 people work on

819
00:26:00,230 --> 00:25:58,320
our image and data processing team in

820
00:26:02,070 --> 00:26:00,240
development over the last six years

821
00:26:04,070 --> 00:26:02,080
and we have 10 people right now

822
00:26:04,950 --> 00:26:04,080
currently doing operations for this so

823
00:26:06,470 --> 00:26:04,960
it's a huge

824
00:26:07,990 --> 00:26:06,480
effort and when we're talking about

825
00:26:12,390 --> 00:26:08,000
thousands of images we've

826
00:26:15,430 --> 00:26:12,400
actually released 72 over 72 000 images

827
00:26:17,269 --> 00:26:15,440
as of today and 33 000 of those are

828
00:26:20,310 --> 00:26:17,279
video from the mastcam

829
00:26:22,310 --> 00:26:20,320
and the edl cameras so it's it's in a

830
00:26:23,750 --> 00:26:22,320
really amazing amount of data that we've

831
00:26:25,590 --> 00:26:23,760
been able to process

832
00:26:27,750 --> 00:26:25,600
in such a short time on the surface of

833
00:26:30,070 --> 00:26:27,760
mars

834
00:26:30,870 --> 00:26:30,080
and you've had like the panoramas too do

835
00:26:34,950 --> 00:26:30,880
they add any

836
00:26:37,269 --> 00:26:34,960
complexity to putting this all together

837
00:26:38,070 --> 00:26:37,279
yeah exactly um if you pull up graphic

838
00:26:40,710 --> 00:26:38,080

839
00:26:42,549 --> 00:26:40,720
you know something about going back

840
00:26:45,750 --> 00:26:42,559
about the panoramas a little bit um

841
00:26:47,269 --> 00:26:45,760
so jpl actually um you know

842
00:26:48,950 --> 00:26:47,279
has created our own image processing

843
00:26:51,830 --> 00:26:48,960
software back in uh

844
00:26:52,950 --> 00:26:51,840
66 is the first record that we've had

845
00:26:56,390 --> 00:26:52,960
bicker around

846
00:26:57,110 --> 00:26:56,400
and so we actually have been decades of

847
00:26:58,950 --> 00:26:57,120
heritage

848
00:27:00,390 --> 00:26:58,960
working on all of our image processing

849
00:27:01,990 --> 00:27:00,400
software here at jpl

850
00:27:03,909 --> 00:27:02,000
and you know some of my favorites i just

851
00:27:06,630 --> 00:27:03,919
wanted to pull up really quick

852
00:27:07,990 --> 00:27:06,640
are some of these two from mer just to

853
00:27:09,029 --> 00:27:08,000
kind of show you the evolution of those

854
00:27:11,750 --> 00:27:09,039
mosaics

855
00:27:12,390 --> 00:27:11,760
so we have these two mer panoramas from

856
00:27:15,269 --> 00:27:12,400
the

857
00:27:17,190 --> 00:27:15,279
navigation cameras right before we were

858
00:27:18,549 --> 00:27:17,200
dropping into perseverance valley on the

859
00:27:20,789 --> 00:27:18,559
top and then right as we got into

860
00:27:24,310 --> 00:27:20,799
perseverance valley on the bottom

861
00:27:26,870 --> 00:27:24,320
and then transitioning into msl

862
00:27:28,149 --> 00:27:26,880
is going to look very similar for our

863
00:27:30,470 --> 00:27:28,159

navigation cameras

864
00:27:32,149 --> 00:27:30,480
on the top of this graphic again here's

865
00:27:37,110 --> 00:27:32,159
a five frame mosaic

866
00:27:38,470 --> 00:27:37,120
of this outcrop uh back from 2015

867
00:27:39,750 --> 00:27:38,480
and you know it's it's definitely a

868
00:27:40,470 --> 00:27:39,760
little different than what we're seeing

869
00:27:41,990 --> 00:27:40,480
today

870
00:27:43,510 --> 00:27:42,000
so just kind of transitioning to that

871
00:27:45,510 --> 00:27:43,520
here's the msl

872
00:27:46,789 --> 00:27:45,520
mosaic that uh male and space science

873
00:27:48,950 --> 00:27:46,799
owners worked on

874
00:27:50,710 --> 00:27:48,960
after we had our global dust storm so

875
00:27:53,029 --> 00:27:50,720
you can see that nice layer of dirt that

876
00:27:56,070 --> 00:27:53,039
justin was referring to or dust that

877
00:27:58,310 --> 00:27:56,080
justin was referring to earlier that's

878
00:28:00,389 --> 00:27:58,320
you know coding all of our hardware and

879
00:28:03,110 --> 00:28:00,399
then getting into the next

880
00:28:04,710 --> 00:28:03,120
frame for the next graphic we have here

881
00:28:06,950 --> 00:28:04,720
uh we can actually see

882
00:28:07,750 --> 00:28:06,960
uh insights lander so what was really

883
00:28:11,750 --> 00:28:07,760
cool about this

884
00:28:15,750 --> 00:28:11,760
is um we actually had uh the same

885
00:28:18,230 --> 00:28:15,760
hardware for these cameras as murren msl

886
00:28:19,269 --> 00:28:18,240
but now we have color imaging and this

887
00:28:20,710 --> 00:28:19,279
is one of the things that justin

888
00:28:22,070 --> 00:28:20,720

actually had worked on and was a lead

889
00:28:25,830 --> 00:28:22,080
for that i believe

890
00:28:28,310 --> 00:28:25,840
so here we have the before and after

891
00:28:29,590 --> 00:28:28,320
so this is as we landed and then 100

892
00:28:32,230 --> 00:28:29,600
days later you can again

893
00:28:34,389 --> 00:28:32,240
see that dust accumulation on the solar

894
00:28:35,830 --> 00:28:34,399
panels and on the deck of the lander

895
00:28:37,830 --> 00:28:35,840
so what's really cool about how we

896
00:28:38,950 --> 00:28:37,840
actually made these panoramas is before

897
00:28:41,350 --> 00:28:38,960
you know we have

898
00:28:42,549 --> 00:28:41,360
a mask that turns around and we can take

899
00:28:44,389 --> 00:28:42,559
a panorama

900
00:28:45,909 --> 00:28:44,399
where this one we actually had on inside

901
00:28:48,310 --> 00:28:45,919
a robotic arm on

902
00:28:50,470 --> 00:28:48,320
and a camera on the robotic arm and

903
00:28:52,870 --> 00:28:50,480
actually swung the robotic arm around

904
00:28:54,789 --> 00:28:52,880
taking these pictures and so we were

905
00:28:57,029 --> 00:28:54,799
able to kind of piecemeal together

906
00:28:58,710 --> 00:28:57,039
and figure out where they all fit and

907
00:29:00,789 --> 00:28:58,720
this is all command line based

908
00:29:02,950 --> 00:29:00,799
so this isn't quite like photoshop where

909
00:29:04,310 --> 00:29:02,960
you have this gui interface we're doing

910
00:29:07,350 --> 00:29:04,320
all of this processing

911
00:29:08,950 --> 00:29:07,360
with unix command line tools just really

912
00:29:12,230 --> 00:29:08,960
it's a really cool heritage to

913
00:29:15,430 --> 00:29:12,240

to be part of and so transitioning into

914
00:29:17,029 --> 00:29:15,440
mars 2020 on the next graphic

915
00:29:18,549 --> 00:29:17,039
um i just kind of want to talk a little

916
00:29:20,149 --> 00:29:18,559
bit about how we actually put these

917
00:29:23,350 --> 00:29:20,159
panoramas together in a very

918
00:29:24,870 --> 00:29:23,360
simplified example um this is it's a

919
00:29:27,590 --> 00:29:24,880
little bit more complicated uh

920
00:29:29,990 --> 00:29:27,600
on our day-to-day basis um so this is

921
00:29:31,669 --> 00:29:30,000
actually the six frames that we have

922
00:29:33,269 --> 00:29:31,679
that make up this panorama that's on the

923
00:29:35,110 --> 00:29:33,279
bottom and this is our

924
00:29:36,630 --> 00:29:35,120
panorama right when we landed so i

925
00:29:39,110 --> 00:29:36,640
believe this is solved four

926
00:29:39,990 --> 00:29:39,120
where we took these color panoramas but

927
00:29:41,750 --> 00:29:40,000
if you look on top

928
00:29:43,110 --> 00:29:41,760
we actually have uh you know their

929
00:29:44,389 --> 00:29:43,120
grayscale images that we were talking

930
00:29:47,750 --> 00:29:44,399
about before

931
00:29:50,470 --> 00:29:47,760
so if we go to the next slide

932
00:29:52,070 --> 00:29:50,480
these actually are all separate red

933
00:29:54,149 --> 00:29:52,080
green blue exposures

934
00:29:55,190 --> 00:29:54,159
so we actually then can turn these into

935
00:29:56,549 --> 00:29:55,200
color images

936
00:29:57,990 --> 00:29:56,559
and so if you look at you know on the

937
00:29:59,269 --> 00:29:58,000
raw images site you'll see a lot of

938
00:30:01,029 --> 00:29:59,279

black and white images

939
00:30:02,870 --> 00:30:01,039
from early on in the mission where we

940
00:30:05,029 --> 00:30:02,880
were actually in some of these cases

941
00:30:07,430 --> 00:30:05,039
taking these separate bands um when we

942
00:30:10,389 --> 00:30:07,440
were still on our cruise flight software

943
00:30:11,510 --> 00:30:10,399
so into the next graphic we can then

944
00:30:14,149 --> 00:30:11,520
transition back

945
00:30:15,909 --> 00:30:14,159
and now you can see the raw color if you

946
00:30:18,149 --> 00:30:15,919
just combine the rgb bands

947
00:30:19,430 --> 00:30:18,159
for these six frames and that sixth

948
00:30:20,710 --> 00:30:19,440
frame you can kind of slide it down now

949
00:30:22,630 --> 00:30:20,720
you can kind of see that we actually had

950
00:30:25,669 --> 00:30:22,640
two tiers when the

951
00:30:27,590 --> 00:30:25,679
ecamm team acquired this panorama

952
00:30:29,350 --> 00:30:27,600
and you can actually see on the bottom

953
00:30:30,870 --> 00:30:29,360
where these all fit as we start putting

954
00:30:32,950 --> 00:30:30,880
these panoramas together

955
00:30:34,389 --> 00:30:32,960
and a lot has to happen for it to get to

956
00:30:36,389 --> 00:30:34,399
look like this if you notice that you

957
00:30:38,710 --> 00:30:36,399
know there's different brightnesses

958
00:30:40,630 --> 00:30:38,720
and you can actually see these are you

959
00:30:42,710 --> 00:30:40,640
know fisheye lenses where you see the

960
00:30:43,990 --> 00:30:42,720
the horizon actually curve on each one

961
00:30:46,389 --> 00:30:44,000
of these images

962
00:30:47,510 --> 00:30:46,399
so um there's a series of processing so

963
00:30:50,549 --> 00:30:47,520

we make these

964
00:30:52,870 --> 00:30:50,559
into a panorama as well as

965
00:30:53,750 --> 00:30:52,880
actually do brightness correction on all

966
00:30:56,549 --> 00:30:53,760
of these

967
00:30:59,509 --> 00:30:56,559
radiometric calibration and then going

968
00:31:03,110 --> 00:31:01,909
you can see the seamless mosaics that

969
00:31:05,190 --> 00:31:03,120
we're able to do

970
00:31:07,669 --> 00:31:05,200
what's really cool in mars 2020 in terms

971
00:31:09,750 --> 00:31:07,679
of the changing

972
00:31:11,990 --> 00:31:09,760
software is we're actually generating

973
00:31:13,590 --> 00:31:12,000
all of these automatically now

974
00:31:15,350 --> 00:31:13,600
it used to be before on previous

975
00:31:17,110 --> 00:31:15,360
missions that this would take a lot of

976
00:31:18,630 --> 00:31:17,120
time to get these beautiful seam

977
00:31:20,950 --> 00:31:18,640
corrected mosaics out

978
00:31:21,909 --> 00:31:20,960
and you know there's been a lot of um a

979
00:31:23,509 --> 00:31:21,919
lot of

980
00:31:24,950 --> 00:31:23,519
focus on making sure that we could get

981
00:31:26,710 --> 00:31:24,960
these out faster and that was one of the

982
00:31:27,110 --> 00:31:26,720
things that mars 2020 wanted to focus on

983
00:31:28,710 --> 00:31:27,120
is

984
00:31:29,990 --> 00:31:28,720
making sure how do we do operations

985
00:31:31,350 --> 00:31:30,000
faster and how do we get our data

986
00:31:34,389 --> 00:31:31,360
products out faster and

987
00:31:35,750 --> 00:31:34,399
spending hours hand assembling these you

988
00:31:36,470 --> 00:31:35,760

know really just wasn't an option

989
00:31:38,149 --> 00:31:36,480
anymore

990
00:31:41,509 --> 00:31:38,159
so it's been really incredible to see

991
00:31:43,990 --> 00:31:41,519
this uh change over time

992
00:31:45,269 --> 00:31:44,000
so uh going on the next slide just kind

993
00:31:47,909 --> 00:31:45,279
of wanted to talk about you know we were

994
00:31:49,909 --> 00:31:47,919
talking about these high resolution

995
00:31:51,909 --> 00:31:49,919
images so this is a single tile so you

996
00:31:52,789 --> 00:31:51,919
can find this image out on the raw

997
00:31:55,830 --> 00:31:52,799
images site

998
00:31:58,549 --> 00:31:55,840
so this is a single color tile that we

999
00:31:59,509 --> 00:31:58,559
acquired overlapping these original

1000
00:32:01,190 --> 00:31:59,519
images

1001
00:32:02,630 --> 00:32:01,200
and what's really cool about these is

1002
00:32:05,990 --> 00:32:02,640
they're actually stereo

1003
00:32:07,350 --> 00:32:06,000
so if you look on the next graphic

1004
00:32:09,110 --> 00:32:07,360
now you can actually see that there is

1005
00:32:10,310 --> 00:32:09,120
actually a left and a right eye and

1006
00:32:11,909 --> 00:32:10,320
again these are all out on the raw

1007
00:32:13,029 --> 00:32:11,919
images website you can go find these and

1008
00:32:14,310 --> 00:32:13,039
you'll notice that you know they all

1009
00:32:15,509 --> 00:32:14,320
make stereo pairs

1010
00:32:16,549 --> 00:32:15,519
and what that means is basically you

1011
00:32:17,669 --> 00:32:16,559
know like we're talking about we have a

1012
00:32:18,950 --> 00:32:17,679
left and right eye

1013
00:32:20,870 --> 00:32:18,960

and then we put all these frames

1014
00:32:22,149 --> 00:32:20,880
together and if you go to the next

1015
00:32:24,310 --> 00:32:22,159
graphic

1016
00:32:26,149 --> 00:32:24,320
you can kind of start to see how we use

1017
00:32:28,149 --> 00:32:26,159
these as stereo so one of the most

1018
00:32:29,990 --> 00:32:28,159
important things of our jobs is making

1019
00:32:31,029 --> 00:32:30,000
sure we have terrains and all the data

1020
00:32:33,509 --> 00:32:31,039
products that

1021
00:32:34,149 --> 00:32:33,519
the robotic operations team can use to

1022
00:32:36,389 --> 00:32:34,159
actually

1023
00:32:38,470 --> 00:32:36,399
drive this rover and so now you can see

1024
00:32:41,590 --> 00:32:38,480
that this is a simulation of

1025
00:32:43,830 --> 00:32:41,600
the actual i believe itself 14 drive out

1026
00:32:47,430 --> 00:32:43,840
onto one of the terrain meshes

1027
00:32:49,669 --> 00:32:47,440
that our team produces and on the lower

1028
00:32:51,590 --> 00:32:49,679
right corner you can basically see the

1029
00:32:53,750 --> 00:32:51,600
images that it was being it was taking

1030
00:32:55,190 --> 00:32:53,760
during the drive and you know we were

1031
00:32:57,750 --> 00:32:55,200
talking about earlier about the

1032
00:32:59,350 --> 00:32:57,760
you know machine vision liking these uh

1033
00:33:02,149 --> 00:32:59,360
grayscale images so this is a perfect

1034
00:33:04,950 --> 00:33:02,159
example of these are basically the auto

1035
00:33:05,509 --> 00:33:04,960
images kicking off for visual odometry

1036
00:33:09,509 --> 00:33:05,519
uh

1037
00:33:13,350 --> 00:33:12,230
very very cool very cool those are

1038
00:33:16,549 --> 00:33:13,360

amazing

1039
00:33:20,310 --> 00:33:16,559
information yeah there's so much stuff

1040
00:33:21,830 --> 00:33:20,320
um so brian let me cut to you

1041
00:33:24,950 --> 00:33:21,840
and see if we have any questions for

1042
00:33:26,549 --> 00:33:24,960
hallie oh we have so many questions for

1043
00:33:28,070 --> 00:33:26,559
hallie that we won't get to all of them

1044
00:33:30,710 --> 00:33:28,080
but aaron on linkedin

1045
00:33:32,549 --> 00:33:30,720
asks what kind of frequency band is used

1046
00:33:34,549 --> 00:33:32,559
for transmitting the imaging data and

1047
00:33:36,630 --> 00:33:34,559
there's been a lot of questions about

1048
00:33:38,070 --> 00:33:36,640
i mean compression and all of that in

1049
00:33:41,350 --> 00:33:38,080
the transmission of back and forth

1050
00:33:43,990 --> 00:33:41,360
and how well you do that oh gosh

1051
00:33:45,350 --> 00:33:44,000
um that is a bit outside of my job scope

1052
00:33:46,310 --> 00:33:45,360
but justin's been doing this a lot

1053
00:33:51,029 --> 00:33:46,320
longer than i have

1054
00:33:54,070 --> 00:33:52,630
yeah boy that one's an interesting one

1055
00:33:55,830 --> 00:33:54,080
you know we use uh

1056
00:33:58,310 --> 00:33:55,840
we have two ways of talking to the

1057
00:34:01,669 --> 00:33:58,320
rovers we have um

1058
00:34:05,190 --> 00:34:01,679
x-band communications um which are

1059
00:34:07,029 --> 00:34:05,200
directly between mars and earth

1060
00:34:08,310 --> 00:34:07,039
i don't have the exact frequency off the

1061
00:34:10,550 --> 00:34:08,320
top of my head

1062
00:34:11,430 --> 00:34:10,560
but then the other the main frequencies

1063
00:34:13,589 --> 00:34:11,440

that we use

1064
00:34:15,349 --> 00:34:13,599
uh are talking to orbiters so we have

1065
00:34:19,109 --> 00:34:15,359
com lengths and those are uhf

1066
00:34:21,109 --> 00:34:19,119
frequencies ultra high frequencies

1067
00:34:22,310 --> 00:34:21,119
and again i don't know the exact

1068
00:34:24,389 --> 00:34:22,320
frequencies but

1069
00:34:25,510 --> 00:34:24,399
uh it's x-band and uhf those are the two

1070
00:34:27,669 --> 00:34:25,520
major bands that we use

1071
00:34:30,550 --> 00:34:27,679
mostly uhf for the images it's mostly

1072
00:34:33,909 --> 00:34:32,230
very cool all that coming from the deep

1073
00:34:34,950 --> 00:34:33,919
space network and the last one for now

1074
00:34:37,510 --> 00:34:34,960
and i know there's because there's more

1075
00:34:39,510 --> 00:34:37,520
that you want to get to

1076
00:34:40,790 --> 00:34:39,520
this is one of the most important

1077
00:34:42,389 --> 00:34:40,800
questions we've been getting

1078
00:34:43,990 --> 00:34:42,399
matt on twitter wants to know how the

1079
00:34:48,310 --> 00:34:44,000
rover selfies get taken

1080
00:34:50,230 --> 00:34:48,320
when they don't see the arm

1081
00:34:51,909 --> 00:34:50,240
um yeah so it's it's fairly

1082
00:34:53,349 --> 00:34:51,919
straightforward um just like when you

1083
00:34:54,629 --> 00:34:53,359
take a selfie you see like you know a

1084
00:34:56,470 --> 00:34:54,639
piece of your arm and then it just kind

1085
00:34:58,310 --> 00:34:56,480
of disappears off the image um what

1086
00:35:00,630 --> 00:34:58,320
happens when we take these selfies

1087
00:35:02,230 --> 00:35:00,640
on whether it's you know insights lander

1088
00:35:05,030 --> 00:35:02,240

um you also notice in that one we don't

1089
00:35:07,750 --> 00:35:05,040
have a robotic arm or any of the rovers

1090
00:35:09,109 --> 00:35:07,760
we actually are taking the images with

1091
00:35:11,109 --> 00:35:09,119
the robotic arm out at all different

1092
00:35:11,670 --> 00:35:11,119
angles so every time we move the robotic

1093
00:35:13,349 --> 00:35:11,680
arm

1094
00:35:14,790 --> 00:35:13,359
is actually where you're then filling in

1095
00:35:16,790 --> 00:35:14,800
you know the terrain below

1096
00:35:18,310 --> 00:35:16,800
or you know the rover hardware below so

1097
00:35:20,630 --> 00:35:18,320
you're never actually seeing

1098
00:35:22,230 --> 00:35:20,640
the robotic arm in those images and

1099
00:35:23,670 --> 00:35:22,240
you're basically filling in all the

1100
00:35:26,950 --> 00:35:23,680
holes around it

1101
00:35:28,230 --> 00:35:26,960
it's actually pretty cool there's a lot

1102
00:35:30,230 --> 00:35:28,240
that goes into that and you know the

1103
00:35:33,030 --> 00:35:30,240
ones that are really cool um on

1104
00:35:34,069 --> 00:35:33,040
mer and 2020 is they're able to

1105
00:35:35,990 --> 00:35:34,079
basically

1106
00:35:37,510 --> 00:35:36,000
set up a point so they can actually take

1107
00:35:41,349 --> 00:35:37,520
these images and not have

1108
00:35:42,710 --> 00:35:41,359
any seams in them the insight lander was

1109
00:35:44,150 --> 00:35:42,720
not quite so easy so you'll

1110
00:35:45,910 --> 00:35:44,160
start to see a lot of seams in there

1111
00:35:47,670 --> 00:35:45,920
basically you know the images from being

1112
00:35:49,030 --> 00:35:47,680
taken at such different views just kind

1113
00:35:50,470 --> 00:35:49,040

of like if you did that with your phone

1114
00:35:51,750 --> 00:35:50,480
and try to put those images together

1115
00:35:52,790 --> 00:35:51,760
you'll get a lot of different views and

1116
00:35:58,230 --> 00:35:52,800
parallax

1117
00:36:01,589 --> 00:35:58,240
around different items

1118
00:36:04,390 --> 00:36:01,599
we'll get to more questions in a bit but

1119
00:36:06,470 --> 00:36:04,400
all right in fact um justin let's bring

1120
00:36:08,470 --> 00:36:06,480
you back into the conversation but

1121
00:36:09,670 --> 00:36:08,480
for q a but before we go to the public

1122
00:36:12,630 --> 00:36:09,680
for more

1123
00:36:14,630 --> 00:36:12,640
um i have one and that is as compelling

1124
00:36:16,069 --> 00:36:14,640
as these images are for the public and

1125
00:36:18,790 --> 00:36:16,079
of course the science teams

1126
00:36:21,829 --> 00:36:18,800
um are they also useful useful for uh

1127
00:36:24,870 --> 00:36:23,510
they definitely are useful for mission

1128
00:36:25,510 --> 00:36:24,880
planning in fact i talked a little bit

1129
00:36:28,150 --> 00:36:25,520
about

1130
00:36:29,270 --> 00:36:28,160
uh this idea that we have these rovers

1131
00:36:30,630 --> 00:36:29,280
driving around and

1132
00:36:32,710 --> 00:36:30,640
and that's really where we kind of

1133
00:36:34,310 --> 00:36:32,720
demonstrated that imaging and imaging

1134
00:36:36,310 --> 00:36:34,320
systems play a

1135
00:36:37,829 --> 00:36:36,320
huge role in the operation of these

1136
00:36:39,190 --> 00:36:37,839
vehicles

1137
00:36:41,589 --> 00:36:39,200
and so we talked a little bit about

1138
00:36:43,990 --> 00:36:41,599

machine vision and what we do

1139
00:36:45,750 --> 00:36:44,000
uh to make that possible or what i do

1140
00:36:48,150 --> 00:36:45,760
it's part of my job uh

1141
00:36:49,829 --> 00:36:48,160
a lot of calibration of the cameras

1142
00:36:51,510 --> 00:36:49,839
knowing exactly how they're

1143
00:36:53,190 --> 00:36:51,520
this is not just a picture but knowing

1144
00:36:55,270 --> 00:36:53,200
how they're lined up

1145
00:36:56,790 --> 00:36:55,280
relative to each other the boresight

1146
00:36:58,950 --> 00:36:56,800
pointing

1147
00:37:00,310 --> 00:36:58,960
and the you know the real detailed

1148
00:37:02,390 --> 00:37:00,320
measurements of

1149
00:37:04,069 --> 00:37:02,400
um all the cameras and how they're all

1150
00:37:06,230 --> 00:37:04,079
positioned relative to each other

1151
00:37:08,310 --> 00:37:06,240
and once we build that sort of database

1152
00:37:10,310 --> 00:37:08,320
of camera positions

1153
00:37:11,589 --> 00:37:10,320
we then can take uh fairly accurate

1154
00:37:13,750 --> 00:37:11,599
stereo data

1155
00:37:15,270 --> 00:37:13,760
which build these 3d trains that uh

1156
00:37:17,589 --> 00:37:15,280
hallie was showing

1157
00:37:18,390 --> 00:37:17,599
and then that's the world that we use to

1158
00:37:20,870 --> 00:37:18,400
operate in

1159
00:37:21,670 --> 00:37:20,880
and so the rover drivers the arm

1160
00:37:24,230 --> 00:37:21,680
operators

1161
00:37:25,589 --> 00:37:24,240
the scientists that are targeting that

1162
00:37:27,589 --> 00:37:25,599
rock over there and that rock over there

1163
00:37:29,670 --> 00:37:27,599

we know exactly how are very close

1164
00:37:30,950 --> 00:37:29,680
uh to the exact positions of where those

1165
00:37:33,589 --> 00:37:30,960
rocks are

1166
00:37:35,270 --> 00:37:33,599
that's all enabling all of the

1167
00:37:37,109 --> 00:37:35,280
additional instruments that we operate

1168
00:37:38,390 --> 00:37:37,119
to point you know laser beams at

1169
00:37:41,829 --> 00:37:38,400
specific targets

1170
00:37:43,750 --> 00:37:41,839
seven meters away and it's also used for

1171
00:37:45,430 --> 00:37:43,760
the road by the rover itself

1172
00:37:48,150 --> 00:37:45,440
where it takes it takes the pictures

1173
00:37:50,150 --> 00:37:48,160
itself uses the detailed machine vision

1174
00:37:52,550 --> 00:37:50,160
calibration to figure out you know how

1175
00:37:55,030 --> 00:37:52,560
far away that rock is and then avoid it

1176
00:37:56,390 --> 00:37:55,040
uh so that's kind of the broad class of

1177
00:37:58,470 --> 00:37:56,400
the ways we use those

1178
00:37:59,430 --> 00:37:58,480
but then it's just really you see the

1179
00:38:01,190 --> 00:37:59,440
picture

1180
00:38:02,150 --> 00:38:01,200
from the surface of another planet and

1181
00:38:03,510 --> 00:38:02,160
you know everyone could look at the

1182
00:38:06,550 --> 00:38:03,520
picture and say yeah that

1183
00:38:08,069 --> 00:38:06,560
looks like you know a desert or that's a

1184
00:38:10,069 --> 00:38:08,079
canyon or a hillside

1185
00:38:11,510 --> 00:38:10,079
or that's a rock and you get that

1186
00:38:13,910 --> 00:38:11,520
feeling that you're really there

1187
00:38:14,550 --> 00:38:13,920
um it's an amazing experience to be able

1188
00:38:15,990 --> 00:38:14,560

to

1189
00:38:18,150 --> 00:38:16,000
take these pictures and for the first

1190
00:38:19,829 --> 00:38:18,160
time see what it's like to be on the

1191
00:38:21,430 --> 00:38:19,839
surface of another world

1192
00:38:22,950 --> 00:38:21,440
and that's what we do with the cameras

1193
00:38:25,670 --> 00:38:22,960
and so it really enables a lot

1194
00:38:29,349 --> 00:38:25,680
of just operations and people's

1195
00:38:33,430 --> 00:38:31,990
well thank you for putting us there what

1196
00:38:35,670 --> 00:38:33,440
needless to say

1197
00:38:37,109 --> 00:38:35,680
um so brian do we have any questions for

1198
00:38:39,990 --> 00:38:37,119
the two of them

1199
00:38:40,310 --> 00:38:40,000
uh yeah i think hallie's got one about

1200
00:38:42,069 --> 00:38:40,320
or

1201
00:38:43,510 --> 00:38:42,079
haley has something about the next

1202
00:38:46,790 --> 00:38:43,520
generation of that too

1203
00:38:50,630 --> 00:38:46,800
with astro correct

1204
00:38:51,829 --> 00:38:50,640
yeah uh we have a new software on mars

1205
00:38:54,790 --> 00:38:51,839
2020 called

1206
00:38:56,470 --> 00:38:54,800
astro uh and i think we'll just let this

1207
00:38:57,829 --> 00:38:56,480
video roll in the background

1208
00:38:59,270 --> 00:38:57,839
so one of the really cool things you

1209
00:39:00,069 --> 00:38:59,280
know when talking about mission planning

1210
00:39:02,550 --> 00:39:00,079
is

1211
00:39:04,230 --> 00:39:02,560
for all of our different team members we

1212
00:39:05,030 --> 00:39:04,240
have people all over the world right now

1213
00:39:08,870 --> 00:39:05,040

you know

1214
00:39:11,190 --> 00:39:08,880
just and i are both working from home

1215
00:39:13,190 --> 00:39:11,200
pretty much full time and one of the

1216
00:39:16,230 --> 00:39:13,200
really cool things is we can actually

1217
00:39:19,589 --> 00:39:16,240
on our web browser have available to

1218
00:39:21,349 --> 00:39:19,599
the entire team all of this information

1219
00:39:22,870 --> 00:39:21,359
so what's showing on right in the screen

1220
00:39:26,950 --> 00:39:22,880
right now is the

1221
00:39:30,390 --> 00:39:26,960
rover in one of its positions on sol

1222
00:39:32,950 --> 00:39:30,400
28 i think that says um and

1223
00:39:34,870 --> 00:39:32,960
this is actually the 3d reconstruction

1224
00:39:37,430 --> 00:39:34,880
of the

1225
00:39:38,470 --> 00:39:37,440
local data with the orbital data and

1226
00:39:40,230 --> 00:39:38,480
then the horizon

1227
00:39:42,390 --> 00:39:40,240
actually used from the panorama that we

1228
00:39:44,230 --> 00:39:42,400
acquired so now you actually get a sense

1229
00:39:45,670 --> 00:39:44,240
of what's around the rover

1230
00:39:47,109 --> 00:39:45,680
and you know we were talking about you

1231
00:39:48,630 --> 00:39:47,119
know that sense of being there but

1232
00:39:50,390 --> 00:39:48,640
something that's really difficult

1233
00:39:52,150 --> 00:39:50,400
is you know an example when i was a

1234
00:39:54,390 --> 00:39:52,160
rover driver um

1235
00:39:56,390 --> 00:39:54,400
you'd get questions about like oh i want

1236
00:39:56,950 --> 00:39:56,400
to you know maybe put the robotic arm

1237
00:39:59,750 --> 00:39:56,960
down

1238
00:40:00,310 --> 00:39:59,760

on a rock and that rock may be the size

1239
00:40:02,870 --> 00:40:00,320
of

1240
00:40:03,349 --> 00:40:02,880
like a small pebble or a large boulder

1241
00:40:04,710 --> 00:40:03,359
and

1242
00:40:06,630 --> 00:40:04,720
it's really hard to just tell when an

1243
00:40:07,910 --> 00:40:06,640
image if you see an image of a rock what

1244
00:40:10,069 --> 00:40:07,920
that scale is

1245
00:40:11,750 --> 00:40:10,079
and now we have the ability to actually

1246
00:40:13,430 --> 00:40:11,760
give to our science team

1247
00:40:15,270 --> 00:40:13,440
tools that they can actually figure out

1248
00:40:16,710 --> 00:40:15,280
what are the sizes of things how far is

1249
00:40:17,990 --> 00:40:16,720
it actually from the rover that was

1250
00:40:20,230 --> 00:40:18,000
another one of my favorites

1251
00:40:22,550 --> 00:40:20,240
is it's so hard to understand from an

1252
00:40:24,150 --> 00:40:22,560
image how far something really is away

1253
00:40:25,750 --> 00:40:24,160
unless you have that stereo data that

1254
00:40:27,270 --> 00:40:25,760
justin was mentioning and now we're

1255
00:40:28,550 --> 00:40:27,280
basically able to make this into a very

1256
00:40:30,950 --> 00:40:28,560
user-friendly way

1257
00:40:32,630 --> 00:40:30,960
for the entire science team to decide

1258
00:40:33,990 --> 00:40:32,640
and figure out what their observations

1259
00:40:35,030 --> 00:40:34,000
are so one of the things right now it's

1260
00:40:36,870 --> 00:40:35,040
showing what the uh

1261
00:40:38,309 --> 00:40:36,880
i think what the surface normals are for

1262
00:40:41,670 --> 00:40:38,319
the terrain so

1263
00:40:43,829 --> 00:40:41,680

um and it's it's really going to help

1264
00:40:46,309 --> 00:40:43,839
the targeting for the mission oh sorry

1265
00:40:49,190 --> 00:40:47,750
i was just going to add um when you're

1266
00:40:51,270 --> 00:40:49,200
if you're done i was going to we had

1267
00:40:53,030 --> 00:40:51,280
talked about this before

1268
00:40:55,349 --> 00:40:53,040
when we first started these rover

1269
00:40:57,190 --> 00:40:55,359
missions this is this is so advanced

1270
00:40:59,589 --> 00:40:57,200
compared to what we had

1271
00:41:01,190 --> 00:40:59,599
and when we started uh on mars

1272
00:41:01,589 --> 00:41:01,200
pathfinder again this was during the

1273
00:41:06,150 --> 00:41:01,599
print

1274
00:41:07,430 --> 00:41:06,160
the photographs and then people would

1275
00:41:08,950 --> 00:41:07,440
stick post-it notes

1276
00:41:10,710 --> 00:41:08,960
on things like okay this is where we

1277
00:41:13,349 --> 00:41:10,720
want to point the next

1278
00:41:14,870 --> 00:41:13,359
observation and so on and this this tool

1279
00:41:17,190 --> 00:41:14,880
that hallie uh

1280
00:41:18,870 --> 00:41:17,200
worked on with with parker abercrombie

1281
00:41:21,270 --> 00:41:18,880
and folks at jpl

1282
00:41:23,510 --> 00:41:21,280
is just such an advancement over what we

1283
00:41:25,589 --> 00:41:23,520
even had 24 years ago so

1284
00:41:27,190 --> 00:41:25,599
it's just really incredible um the the

1285
00:41:28,230 --> 00:41:27,200
virtual world and then it's also shared

1286
00:41:31,829 --> 00:41:28,240
on the internet

1287
00:41:33,990 --> 00:41:31,839
so uh people can follow along uh in

1288
00:41:37,750 --> 00:41:34,000

using this these great visualization

1289
00:41:43,670 --> 00:41:40,309
yeah it really is compelling to get that

1290
00:41:47,349 --> 00:41:45,990
anymore go ahead i was gonna say one

1291
00:41:48,790 --> 00:41:47,359
thing that's actually really amazing

1292
00:41:50,470 --> 00:41:48,800
again is it's we're actually giving the

1293
00:41:50,950 --> 00:41:50,480
ability to the science team to actually

1294
00:41:54,230 --> 00:41:50,960
kind of

1295
00:41:55,829 --> 00:41:54,240
act like uh you know knowledgeable

1296
00:41:57,030 --> 00:41:55,839
scientist team members who can actually

1297
00:41:58,950 --> 00:41:57,040
figure out and model

1298
00:42:00,550 --> 00:41:58,960
where the rover is so they can actually

1299
00:42:02,790 --> 00:42:00,560
see what's actually playing right now is

1300
00:42:04,790 --> 00:42:02,800
where the robotic arm is planned to be

1301
00:42:06,790 --> 00:42:04,800
and then basically plan their imaging

1302
00:42:07,589 --> 00:42:06,800
and have all of this come together and

1303
00:42:09,430 --> 00:42:07,599
part of this is

1304
00:42:11,030 --> 00:42:09,440
also to to do this faster right now

1305
00:42:13,030 --> 00:42:11,040
we're doing uh seven day a week

1306
00:42:14,150 --> 00:42:13,040
operations on mars 2020

1307
00:42:16,309 --> 00:42:14,160
and you know eventually we want to make

1308
00:42:17,030 --> 00:42:16,319
it these shorter days less amount of

1309
00:42:18,470 --> 00:42:17,040
time

1310
00:42:20,309 --> 00:42:18,480
and you know eventually hopefully get to

1311
00:42:22,550 --> 00:42:20,319
you know like maybe a five hours

1312
00:42:24,150 --> 00:42:22,560
uh of a planning day and now we can

1313
00:42:25,910 --> 00:42:24,160

basically just streamline this entire

1314
00:42:27,589 --> 00:42:25,920
process and have all of our teams really

1315
00:42:29,670 --> 00:42:27,599
work together and integrate in a way

1316
00:42:33,109 --> 00:42:29,680
that we haven't been able to before

1317
00:42:36,069 --> 00:42:33,119
i just think that's really really cool

1318
00:42:37,670 --> 00:42:36,079
very cool indeed that's great and what's

1319
00:42:39,270 --> 00:42:37,680
amazing about the questions is a lot of

1320
00:42:40,950 --> 00:42:39,280
times though i'll get these questions in

1321
00:42:42,550 --> 00:42:40,960
and you will have both answered them

1322
00:42:43,030 --> 00:42:42,560
right before we even get a chance to ask

1323
00:42:44,630 --> 00:42:43,040
them

1324
00:42:46,950 --> 00:42:44,640
so that's wonderful right now but we'll

1325
00:42:49,750 --> 00:42:46,960
finish with two final questions

1326
00:42:50,309 --> 00:42:49,760
um sorry if your question didn't get

1327
00:42:52,309 --> 00:42:50,319
asked

1328
00:42:54,470 --> 00:42:52,319
today keep asking questions keep that

1329
00:42:57,829 --> 00:42:54,480
curiosity coming but nick on linkedin

1330
00:43:03,030 --> 00:42:57,839
asks has your work on image processing

1331
00:43:07,829 --> 00:43:05,190
well i guess i could take that one uh i

1332
00:43:11,510 --> 00:43:07,839
think with each mission

1333
00:43:13,829 --> 00:43:11,520
we learn a little bit more about

1334
00:43:15,430 --> 00:43:13,839
mars for one so we're certainly learning

1335
00:43:16,630 --> 00:43:15,440
about mars itself and it's certainly

1336
00:43:18,069 --> 00:43:16,640
informing

1337
00:43:19,990 --> 00:43:18,079
how to do things on the next mission and

1338
00:43:22,950 --> 00:43:20,000

you sort of saw that progression

1339
00:43:24,470 --> 00:43:22,960
of learning better ways to build cameras

1340
00:43:25,349 --> 00:43:24,480
taking advantage of a lot of commercial

1341
00:43:27,990 --> 00:43:25,359
technology

1342
00:43:29,510 --> 00:43:28,000
to improve our imaging systems um and it

1343
00:43:31,349 --> 00:43:29,520
dates all the way back you know into the

1344
00:43:32,230 --> 00:43:31,359
60s as hallie mentioned you know we

1345
00:43:35,589 --> 00:43:32,240
started

1346
00:43:38,710 --> 00:43:35,599
but

1347
00:43:41,430 --> 00:43:38,720
folks before us where the word pixel

1348
00:43:45,109 --> 00:43:41,440
actually was first popularized by

1349
00:43:46,870 --> 00:43:45,119
a group at jpl so just

1350
00:43:49,030 --> 00:43:46,880
understanding picture element you know

1351
00:43:50,630 --> 00:43:49,040
the needing to understand that

1352
00:43:52,150 --> 00:43:50,640
which led to a lot of detector

1353
00:43:53,430 --> 00:43:52,160
development which occurred at jpl and

1354
00:43:54,950 --> 00:43:53,440
now the imaging system

1355
00:43:56,870 --> 00:43:54,960
and now the commercial industry is

1356
00:43:58,710 --> 00:43:56,880
really taking over with you know

1357
00:44:01,670 --> 00:43:58,720
smartphone cameras and

1358
00:44:02,309 --> 00:44:01,680
video systems and so we we're always

1359
00:44:06,069 --> 00:44:02,319
pushing the

1360
00:44:07,430 --> 00:44:06,079
technology developing and then sort of

1361
00:44:09,109 --> 00:44:07,440
the synergistic

1362
00:44:10,950 --> 00:44:09,119
relationship where maybe jpl will

1363
00:44:11,270 --> 00:44:10,960

pioneer something then industry takes

1364
00:44:13,430 --> 00:44:11,280
and

1365
00:44:14,790 --> 00:44:13,440
improves beyond what we could ever do

1366
00:44:15,750 --> 00:44:14,800
you're kind of seeing that happening now

1367
00:44:17,510 --> 00:44:15,760
actually with

1368
00:44:19,190 --> 00:44:17,520
self-driving cars you know some of the

1369
00:44:21,910 --> 00:44:19,200
first self-driving cars

1370
00:44:22,470 --> 00:44:21,920
were rovers mars rivers and we have a

1371
00:44:24,309 --> 00:44:22,480
lot of the

1372
00:44:25,670 --> 00:44:24,319
robotics people coming in from the

1373
00:44:28,550 --> 00:44:25,680
university systems

1374
00:44:29,990 --> 00:44:28,560
developing technologies at jpl and now

1375
00:44:32,870 --> 00:44:30,000
you see there are self-driving car

1376
00:44:34,630 --> 00:44:32,880
companies all over the country and so

1377
00:44:36,069 --> 00:44:34,640
we learn a lot from every mission and we

1378
00:44:36,950 --> 00:44:36,079
learn from industry and we keep

1379
00:44:40,950 --> 00:44:36,960
advancing

1380
00:44:44,950 --> 00:44:43,589
very cool um that kind of sets us up for

1381
00:44:47,670 --> 00:44:44,960
the last question

1382
00:44:49,270 --> 00:44:47,680
which is from kia on linkedin and this

1383
00:44:50,069 --> 00:44:49,280
is for both of you and what has helped

1384
00:44:53,670 --> 00:44:50,079
you set yourself

1385
00:44:56,309 --> 00:44:53,680
apart do you recommend

1386
00:45:01,270 --> 00:44:56,319
how somebody could get to do the amazing

1387
00:45:04,390 --> 00:45:03,030
ellie you want to go first yeah i'll go

1388
00:45:06,309 --> 00:45:04,400

first um

1389
00:45:09,030 --> 00:45:06,319
so one of the things that i always

1390
00:45:11,990 --> 00:45:09,040
recommend is

1391
00:45:13,510 --> 00:45:12,000
starting as early as possible to do

1392
00:45:15,109 --> 00:45:13,520
something with your interests

1393
00:45:17,589 --> 00:45:15,119
you know if your interests are image

1394
00:45:19,829 --> 00:45:17,599
processing you know

1395
00:45:21,270 --> 00:45:19,839
be pulling down raw images from all

1396
00:45:23,030 --> 00:45:21,280
these amazing missions and you know

1397
00:45:24,630 --> 00:45:23,040
there's not even just mars images

1398
00:45:25,589 --> 00:45:24,640
there's missions we're releasing all of

1399
00:45:28,470 --> 00:45:25,599
our data

1400
00:45:29,510 --> 00:45:28,480
um every you know few months to the

1401
00:45:32,150 --> 00:45:29,520
planetary

1402
00:45:33,670 --> 00:45:32,160
data archive and we are actually coming

1403
00:45:34,150 --> 00:45:33,680
up and we're going to deliver all of our

1404
00:45:37,030 --> 00:45:34,160
data

1405
00:45:38,390 --> 00:45:37,040
on august 20th that we process for the

1406
00:45:40,309 --> 00:45:38,400
first 90 days

1407
00:45:41,829 --> 00:45:40,319
um you know jump in and actually get

1408
00:45:42,870 --> 00:45:41,839
familiar with these data products we

1409
00:45:45,589 --> 00:45:42,880
even actually

1410
00:45:46,790 --> 00:45:45,599
you know we have vicar is actually

1411
00:45:49,109 --> 00:45:46,800
accessible to the public

1412
00:45:50,230 --> 00:45:49,119
you can google it it's on github you

1413
00:45:52,630 --> 00:45:50,240

know just really learning

1414
00:45:53,750 --> 00:45:52,640
things you know it's so much easier to

1415
00:45:55,589 --> 00:45:53,760
come in and get a job

1416
00:45:57,109 --> 00:45:55,599
if they don't have to train you from

1417
00:45:58,390 --> 00:45:57,119
scratch right if you have an interest

1418
00:45:59,829 --> 00:45:58,400
image processing and you say hey i

1419
00:46:01,589 --> 00:45:59,839
actually know a lot about

1420
00:46:03,349 --> 00:46:01,599
this mission whatever mission that is

1421
00:46:05,990 --> 00:46:03,359
and i understand what the tools are

1422
00:46:06,630 --> 00:46:06,000
you're so valuable to whatever that

1423
00:46:09,109 --> 00:46:06,640
project

1424
00:46:10,790 --> 00:46:09,119
is and that you can really just you know

1425
00:46:12,069 --> 00:46:10,800
we're really trying to get all of this

1426
00:46:14,710 --> 00:46:12,079
information out there we have

1427
00:46:16,710 --> 00:46:14,720
amateur scientists who are doing amazing

1428
00:46:18,870 --> 00:46:16,720
work making their own panoramas

1429
00:46:20,790 --> 00:46:18,880
you know that's it's such a a gift that

1430
00:46:22,710 --> 00:46:20,800
you can actually bring back to jpl or

1431
00:46:24,390 --> 00:46:22,720
any nasa center or any mission

1432
00:46:27,190 --> 00:46:24,400
to be able to provide something to them

1433
00:46:31,589 --> 00:46:29,829
and i'll just add i think definitely

1434
00:46:33,030 --> 00:46:31,599
pursue things that you're interested in

1435
00:46:34,390 --> 00:46:33,040
uh if you're a student out there and

1436
00:46:35,670 --> 00:46:34,400
you're trying to figure out what to

1437
00:46:37,349 --> 00:46:35,680
major in

1438
00:46:39,829 --> 00:46:37,359

follow your passions i think that's

1439
00:46:41,270 --> 00:46:39,839
really a secret in life you know do

1440
00:46:42,870 --> 00:46:41,280
things that you enjoy doing

1441
00:46:43,990 --> 00:46:42,880
and i think there's it's so many

1442
00:46:45,670 --> 00:46:44,000
interesting things out there that

1443
00:46:49,190 --> 00:46:45,680
there's something for everyone

1444
00:46:50,230 --> 00:46:49,200
i would also advise uh i'm all uh to go

1445
00:46:52,309 --> 00:46:50,240
to school

1446
00:46:53,670 --> 00:46:52,319
study hard i'm a big proponent of

1447
00:46:56,230 --> 00:46:53,680
education a lot of

1448
00:46:57,109 --> 00:46:56,240
obviously you need a lot of training to

1449
00:46:59,349 --> 00:46:57,119
take on

1450
00:47:00,710 --> 00:46:59,359
jobs like this and so study hard uh

1451
00:47:02,630 --> 00:47:00,720
listen to your teachers listen to your

1452
00:47:04,390 --> 00:47:02,640
parents

1453
00:47:05,670 --> 00:47:04,400
and just be curious about the world

1454
00:47:07,589 --> 00:47:05,680
there's so much out there and with the

1455
00:47:10,550 --> 00:47:07,599
internet these days you can learn about

1456
00:47:11,829 --> 00:47:10,560
all kinds of things you know technology

1457
00:47:13,990 --> 00:47:11,839
science

1458
00:47:15,589 --> 00:47:14,000
i'm also a physics guy so i recommend

1459
00:47:16,790 --> 00:47:15,599
majoring in physics is a great thing i

1460
00:47:18,309 --> 00:47:16,800
highly recommend that

1461
00:47:19,910 --> 00:47:18,319
but any of the fundamental sciences

1462
00:47:22,390 --> 00:47:19,920
chemistry

1463
00:47:23,910 --> 00:47:22,400

or engineering mathematics i mean

1464
00:47:24,790 --> 00:47:23,920
there's just so much out there to learn

1465
00:47:27,030 --> 00:47:24,800
and so

1466
00:47:28,390 --> 00:47:27,040
enjoy it and uh study hard and you can

1467
00:47:30,549 --> 00:47:28,400
get jobs uh like

1468
00:47:32,309 --> 00:47:30,559
like we have there are just interesting

1469
00:47:33,589 --> 00:47:32,319
jobs everywhere all over the country and

1470
00:47:35,430 --> 00:47:33,599
all over the world

1471
00:47:37,270 --> 00:47:35,440
uh and just learn about something and

1472
00:47:41,990 --> 00:47:37,280
try to improve things and

1473
00:47:47,670 --> 00:47:44,950
education it is indeed a never-ending

1474
00:47:49,910 --> 00:47:47,680
adventure isn't it

1475
00:47:51,190 --> 00:47:49,920
well that's about all the time we

1476
00:47:54,470 --> 00:47:51,200
actually have tonight folks

1477
00:47:57,510 --> 00:47:54,480
so i want to thank brian halle

1478
00:47:59,670 --> 00:47:57,520
justin our crew of course all of you out

1479
00:48:01,589 --> 00:47:59,680
there for watching tonight

1480
00:48:03,109 --> 00:48:01,599
stay safe and we'll see you next month

1481
00:48:06,150 --> 00:48:03,119
when we talk about perhaps our

1482
00:48:23,590 --> 00:48:06,160
favorite solar system enigma jupiter