VOYAGER AT 45

Q&A WITH THE MISSION TEAM

1
00:00:00,410 --> 00:00:07,990
[Music]

2
00:00:12,150 --> 00:00:10,310
hello and welcome to nasa's jet

3
00:00:13,430 --> 00:00:12,160
propulsion laboratory in southern

4
00:00:16,230 --> 00:00:13,440
california

5
00:00:18,390 --> 00:00:16,240
jpl is the home of nasa's longest

6
00:00:19,910 --> 00:00:18,400
continuously operating mission the

7
00:00:25,029 --> 00:00:19,920
voyager mission

8
00:00:26,950 --> 00:00:25,039
historic milestone right now 45 years of

9
00:00:29,269 --> 00:00:26,960
flying through space and collecting

10
00:00:31,669 --> 00:00:29,279
science data along the way and since

11
00:00:33,990 --> 00:00:31,679
it's been on this 45 year old

12
00:00:36,549 --> 00:00:34,000
45 year old journey

13
00:00:39,590 --> 00:00:36,559

the voyagers are actually also the most

14
00:00:42,310 --> 00:00:39,600
distant human-made objects out there

15
00:00:44,950 --> 00:00:42,320
i'm jari cook with jpl's digital news

16
00:00:47,910 --> 00:00:44,960
and media office and i'm here

17
00:00:50,630 --> 00:00:47,920
with a full-size model of voyager so

18
00:00:52,790 --> 00:00:50,640
there are two voyager spacecraft and

19
00:00:55,350 --> 00:00:52,800
they look just like this

20
00:00:57,189 --> 00:00:55,360
so right now we're right in between the

21
00:00:59,670 --> 00:00:57,199
two launch anniversaries the first

22
00:01:02,229 --> 00:00:59,680
voyager launched on august 20th and the

23
00:01:04,390 --> 00:01:02,239
second voyager launched on september 5th

24
00:01:06,550 --> 00:01:04,400
and so we're here today to talk to you

25
00:01:08,789 --> 00:01:06,560
some more about voyager and i've got two

26
00:01:09,750 --> 00:01:08,799
extremely knowledgeable guests about the

27
00:01:11,910 --> 00:01:09,760
mission

28
00:01:14,550 --> 00:01:11,920
the first speaker is going to be linda

29
00:01:15,990 --> 00:01:14,560
spilker the deputy project scientist and

30
00:01:18,149 --> 00:01:16,000
then we're going to have a propulsion

31
00:01:19,990 --> 00:01:18,159
engineer todd barber to talk to you

32
00:01:23,429 --> 00:01:20,000
today so we are going to take your

33
00:01:25,510 --> 00:01:23,439
questions um so if you're online now you

34
00:01:27,590 --> 00:01:25,520
can drop your questions in the chat or

35
00:01:29,749 --> 00:01:27,600
in the comments box and we will try to

36
00:01:31,270 --> 00:01:29,759
get to as many as we can

37
00:01:32,870 --> 00:01:31,280
all right so let's start with linda come

38
00:01:34,550 --> 00:01:32,880

on over here linda

39
00:01:36,390 --> 00:01:34,560
i'm really excited to talk to linda

40
00:01:38,789 --> 00:01:36,400
because she's been with the mission a

41
00:01:41,270 --> 00:01:38,799
long time actually got her start in her

42
00:01:43,190 --> 00:01:41,280
career with the mission so welcome linda

43
00:01:44,469 --> 00:01:43,200
it's great to be here jari yeah i'm

44
00:01:45,749 --> 00:01:44,479
excited to have you here so why don't

45
00:01:47,510 --> 00:01:45,759
you catch us up

46
00:01:49,510 --> 00:01:47,520
where have the voyagers been and where

47
00:01:50,200 --> 00:01:49,520
are they going or actually where are

48
00:01:51,670 --> 00:01:50,210
they right now

49
00:01:53,990 --> 00:01:51,680
[Laughter]

50
00:01:56,630 --> 00:01:54,000
well both voyager spacecraft have been

51
00:01:59,190 --> 00:01:56,640
out in space since 1977

52
00:02:01,270 --> 00:01:59,200
and they flew by the four outer planets

53
00:02:03,990 --> 00:02:01,280
voyager 1 and 2 flew by jupiter and

54
00:02:06,149 --> 00:02:04,000
saturn and then voyager 2 continued on

55
00:02:08,949 --> 00:02:06,159
alone to uranus and neptune

56
00:02:11,510 --> 00:02:08,959
and only voyager 2 has flown close to

57
00:02:13,350 --> 00:02:11,520
uranus and neptune so far

58
00:02:15,670 --> 00:02:13,360
and then there are about two decades

59
00:02:18,550 --> 00:02:15,680
where the voyagers continued on

60
00:02:20,949 --> 00:02:18,560
past the planets toward the edge of this

61
00:02:23,190 --> 00:02:20,959
bubble this bubble where the solar wind

62
00:02:24,790 --> 00:02:23,200
pushes out meets with the interstellar

63
00:02:27,110 --> 00:02:24,800

wind and forms what we call the

64
00:02:28,949 --> 00:02:27,120
heliosphere in fact if you look at this

65
00:02:31,030 --> 00:02:28,959
graphic jar you can see that giant

66
00:02:32,790 --> 00:02:31,040
bubble it's moving through space like a

67
00:02:34,710 --> 00:02:32,800
comet you can see the two voyager

68
00:02:37,589 --> 00:02:34,720
spacecraft toward the nose of that

69
00:02:39,589 --> 00:02:37,599
bubble with a tail going out behind and

70
00:02:42,229 --> 00:02:39,599
in interstellar space they're measuring

71
00:02:46,630 --> 00:02:42,239
what you would see from explosions from

72
00:02:49,589 --> 00:02:46,640
supernova and voyager 1 is about 15

73
00:02:51,910 --> 00:02:49,599
billion miles away from the sun and for

74
00:02:54,070 --> 00:02:51,920
comparison that's about 150 times

75
00:02:57,030 --> 00:02:54,080
further away from the sun than the earth

76
00:02:58,630 --> 00:02:57,040
and voyager 2 is about 12 billion miles

77
00:03:02,710 --> 00:02:58,640
away

78
00:03:04,710 --> 00:03:02,720
yet they're still operating so why are

79
00:03:07,350 --> 00:03:04,720
scientists so excited that the voyagers

80
00:03:09,270 --> 00:03:07,360
are still operating after 45 years well

81
00:03:11,030 --> 00:03:09,280
jaree with this spacecraft let me just

82
00:03:13,190 --> 00:03:11,040
point out there are three

83
00:03:15,110 --> 00:03:13,200
instruments here covered in their black

84
00:03:17,030 --> 00:03:15,120
thermal blankets these are the particle

85
00:03:18,949 --> 00:03:17,040
instruments and that's part of the

86
00:03:21,270 --> 00:03:18,959
package and so the particle instruments

87
00:03:23,509 --> 00:03:21,280
are measuring the cosmic rays those

88
00:03:25,670 --> 00:03:23,519

high-energy particles that are out in

89
00:03:27,670 --> 00:03:25,680
space and that shield that heliospheric

90
00:03:29,910 --> 00:03:27,680
bubble protects us from a lot of those

91
00:03:32,390 --> 00:03:29,920
cosmic rays we're also looking at the

92
00:03:34,470 --> 00:03:32,400
magnetic field so far the sun is

93
00:03:36,390 --> 00:03:34,480
controlling the direction of the field

94
00:03:39,350 --> 00:03:36,400
we're waiting for it to turn into the

95
00:03:41,750 --> 00:03:39,360
direction of interstellar space and even

96
00:03:43,910 --> 00:03:41,760
some of the biggest storms on the sun

97
00:03:46,229 --> 00:03:43,920
produce waves that cross through that

98
00:03:48,470 --> 00:03:46,239
boundary and can be measured by voyager

99
00:03:50,149 --> 00:03:48,480
so it's a very exciting time for the

100
00:03:51,990 --> 00:03:50,159
scientists

101
00:03:54,149 --> 00:03:52,000
yeah so it's exciting now but it's also

102
00:03:55,509 --> 00:03:54,159
been uh exciting throughout its journey

103
00:03:57,270 --> 00:03:55,519
i know you have a long history with

104
00:03:59,589 --> 00:03:57,280
voyager so could you tell us about some

105
00:04:01,350 --> 00:03:59,599
of your most meaningful moments

106
00:04:03,190 --> 00:04:01,360
well i think for me on voyager one of

107
00:04:05,750 --> 00:04:03,200
the most meaningful moments was to be

108
00:04:07,190 --> 00:04:05,760
there on august 20th for the launch of

109
00:04:09,190 --> 00:04:07,200
voyager 2.

110
00:04:11,350 --> 00:04:09,200
and that launched my career i was just

111
00:04:13,190 --> 00:04:11,360
fresh out of college and it was great to

112
00:04:15,830 --> 00:04:13,200
start my career and start the voyager

113
00:04:17,670 --> 00:04:15,840

mission at the same time and if you look

114
00:04:21,030 --> 00:04:17,680
at this next picture here the person

115
00:04:23,189 --> 00:04:21,040
seated that's me back in 1979 talking

116
00:04:25,350 --> 00:04:23,199
about what we were going to do with the

117
00:04:27,830 --> 00:04:25,360
jupiter flyby in particular the voyager

118
00:04:29,909 --> 00:04:27,840
2 jupiter flyby and one of the things i

119
00:04:33,430 --> 00:04:29,919
really liked also was that at jupiter

120
00:04:36,310 --> 00:04:33,440
one of those tiny moons io had active

121
00:04:38,950 --> 00:04:36,320
volcanoes going off in fact i have a

122
00:04:41,990 --> 00:04:38,960
button here from the voyager 2 flyby and

123
00:04:44,310 --> 00:04:42,000
you can see a volcano in blue going off

124
00:04:45,990 --> 00:04:44,320
on the surface of io

125
00:04:47,590 --> 00:04:46,000
yeah and you were mentioning to me

126
00:04:49,590 --> 00:04:47,600
before that you would bring your

127
00:04:51,430 --> 00:04:49,600
sleeping bag in i mean what was it like

128
00:04:53,670 --> 00:04:51,440
you know waiting for all that data to

129
00:04:55,350 --> 00:04:53,680
come back well it seems like some of the

130
00:04:57,189 --> 00:04:55,360
best data would come back in the middle

131
00:04:59,749 --> 00:04:57,199
of the night and we'd have a list of

132
00:05:01,590 --> 00:04:59,759
when those pictures would come back and

133
00:05:04,230 --> 00:05:01,600
so we'd bring our sleeping bags and get

134
00:05:06,390 --> 00:05:04,240
a couple of hours sleep in between some

135
00:05:08,629 --> 00:05:06,400
of the best and newest pictures i

136
00:05:11,590 --> 00:05:08,639
remember staring at the screen watching

137
00:05:12,790 --> 00:05:11,600
line by line as each of those pictures

138
00:05:15,749 --> 00:05:12,800

came back

139
00:05:17,670 --> 00:05:15,759
knowing i was seeing for the first time

140
00:05:20,150 --> 00:05:17,680
some of these worlds that were pinpoints

141
00:05:22,310 --> 00:05:20,160
of light and telescopes and now were

142
00:05:24,950 --> 00:05:22,320
worlds in their own right so exciting

143
00:05:26,710 --> 00:05:24,960
didn't want to miss a moment of it

144
00:05:28,390 --> 00:05:26,720
thank you linda for sharing what it was

145
00:05:30,150 --> 00:05:28,400
like to be in the room where it happened

146
00:05:32,070 --> 00:05:30,160
right it sounded really exciting so i'm

147
00:05:34,550 --> 00:05:32,080
gonna thank you and i'm gonna bring on

148
00:05:36,390 --> 00:05:34,560
our second guest over here so todd won't

149
00:05:37,830 --> 00:05:36,400
you come over thank you linda we'll

150
00:05:39,510 --> 00:05:37,840
we'll come back to linda in a little bit

151
00:05:41,670 --> 00:05:39,520
with some questions and i want to remind

152
00:05:43,670 --> 00:05:41,680
you if you've got questions now drop

153
00:05:45,990 --> 00:05:43,680
them in the chat or in the comments box

154
00:05:48,230 --> 00:05:46,000
and we'll get to as many as we can so

155
00:05:49,749 --> 00:05:48,240
todd i'm excited to talk to you because

156
00:05:51,350 --> 00:05:49,759
for linda and the other scientists to

157
00:05:53,270 --> 00:05:51,360
get their data we have to have a team of

158
00:05:55,749 --> 00:05:53,280
engineers flying the spacecraft taking

159
00:05:57,430 --> 00:05:55,759
care of it so um i know you're a

160
00:06:00,070 --> 00:05:57,440
relative newbie

161
00:06:02,150 --> 00:06:00,080
to the gym so what does it mean for you

162
00:06:03,590 --> 00:06:02,160
to join the voyager team oh it means the

163
00:06:06,710 --> 00:06:03,600

world to me jari and thanks for having

164
00:06:09,830 --> 00:06:06,720
me today uh i remember being a nerdy

165
00:06:13,029 --> 00:06:09,840
little kid in kansas 13 or 14 years old

166
00:06:15,189 --> 00:06:13,039
and uh seeing the pictures that uh from

167
00:06:17,830 --> 00:06:15,199
the mission that linda was describing

168
00:06:19,350 --> 00:06:17,840
when she was there doing the real work i

169
00:06:21,350 --> 00:06:19,360
got to see these images in national

170
00:06:23,350 --> 00:06:21,360
geographic magazine which you can see on

171
00:06:25,270 --> 00:06:23,360
your screen now and i remember those

172
00:06:27,350 --> 00:06:25,280
covers just like it was yesterday even

173
00:06:29,830 --> 00:06:27,360
though that's been some some time ago

174
00:06:32,390 --> 00:06:29,840
and i dreamt of one day

175
00:06:33,990 --> 00:06:32,400
i became hooked for life in the lure of

176
00:06:36,070 --> 00:06:34,000
planetary science i knew it was my

177
00:06:38,390 --> 00:06:36,080
destiny i never dreamed that i'd get to

178
00:06:43,029 --> 00:06:38,400
work now 32 years and counting my only

179
00:06:44,710 --> 00:06:43,039
job at jpl but let alone in 2022 if you

180
00:06:47,909 --> 00:06:44,720
if you'd have told that kid in kansas in

181
00:06:50,390 --> 00:06:47,919
1981 that in 2022 he'd be one of about a

182
00:06:52,550 --> 00:06:50,400
dozen engineers getting to fly these two

183
00:06:54,230 --> 00:06:52,560
45-year-old spacecraft he would never

184
00:06:55,430 --> 00:06:54,240
believe it so just delighted to be here

185
00:06:57,510 --> 00:06:55,440
today and try to keep the spacecraft

186
00:06:59,430 --> 00:06:57,520
alive yeah and so it's been great that

187
00:07:01,510 --> 00:06:59,440
you've been able to personally come full

188
00:07:03,430 --> 00:07:01,520

circle but you know the the spacecraft

189
00:07:04,629 --> 00:07:03,440
are vintage as you say and so i was

190
00:07:06,070 --> 00:07:04,639
wondering if you could talk to us a

191
00:07:07,749 --> 00:07:06,080
little bit about the challenges of

192
00:07:09,909 --> 00:07:07,759
flying these spacecraft that have been

193
00:07:11,909 --> 00:07:09,919
through so much already how much time do

194
00:07:13,749 --> 00:07:11,919
we have just half an hour well it is

195
00:07:15,749 --> 00:07:13,759
it's kind of like a fly keeping an old

196
00:07:18,469 --> 00:07:15,759
car running uh they are geriatrics

197
00:07:20,070 --> 00:07:18,479
spacecraft by by nasa standards and it's

198
00:07:21,909 --> 00:07:20,080
been the hardest engineering i've ever

199
00:07:23,189 --> 00:07:21,919
done in my entire career and all but

200
00:07:25,029 --> 00:07:23,199
also that means it's the most fun

201
00:07:26,550 --> 00:07:25,039
because engineers love a challenge

202
00:07:28,870 --> 00:07:26,560
we lose four watts a year on the

203
00:07:30,550 --> 00:07:28,880
spacecraft things are insanely cold the

204
00:07:34,150 --> 00:07:30,560
propellant lines are about to freeze

205
00:07:36,309 --> 00:07:34,160
we've had computer chip issues and

206
00:07:38,629 --> 00:07:36,319
i'm delighted to report we we had a

207
00:07:40,790 --> 00:07:38,639
problem with the spacecraft

208
00:07:43,430 --> 00:07:40,800
in march or april it really flummoxed us

209
00:07:45,510 --> 00:07:43,440
our attitude control telemetry was

210
00:07:47,589 --> 00:07:45,520
nonsensical we couldn't get any health

211
00:07:49,430 --> 00:07:47,599
and safety information about uh the

212
00:07:52,309 --> 00:07:49,440
point of the spacecraft or any of the

213
00:07:54,629 --> 00:07:52,319

thruster operation and we just announced

214
00:07:57,670 --> 00:07:54,639
today we've fixed that problem so it's

215
00:07:59,430 --> 00:07:57,680
it's just a tremendous testament to the

216
00:08:01,990 --> 00:07:59,440
brilliant engineers i work with yeah

217
00:08:04,150 --> 00:08:02,000
fixing it from 15 billion miles away

218
00:08:05,430 --> 00:08:04,160
exactly the ultimate telesurgery there

219
00:08:07,510 --> 00:08:05,440
yeah

220
00:08:09,110 --> 00:08:07,520
okay well we're going to now turn to

221
00:08:12,710 --> 00:08:09,120
some questions and so i'm going to

222
00:08:14,469 --> 00:08:12,720
invite linda back up here on the stage

223
00:08:16,150 --> 00:08:14,479
all right so again if you've got

224
00:08:17,749 --> 00:08:16,160
questions you can drop them in the chat

225
00:08:20,710 --> 00:08:17,759
and we'll get to as many as we can

226
00:08:23,670 --> 00:08:20,720
they're coming in right now so i am

227
00:08:26,070 --> 00:08:23,680
going to ask todd the first question

228
00:08:27,990 --> 00:08:26,080
electrobard on twitter asks did you

229
00:08:29,830 --> 00:08:28,000
design the probe to last this long what

230
00:08:31,990 --> 00:08:29,840
subsystems surprised you at their

231
00:08:33,909 --> 00:08:32,000
longevity and which failed before you

232
00:08:36,630 --> 00:08:33,919
expected them to lecture that's a great

233
00:08:38,790 --> 00:08:36,640
question thank you so we actually

234
00:08:40,389 --> 00:08:38,800
barely were able to design this mission

235
00:08:42,630 --> 00:08:40,399
to last five years which was the

236
00:08:44,470 --> 00:08:42,640
requirement to get to jupiter and saturn

237
00:08:46,150 --> 00:08:44,480
and get the data played back and at the

238
00:08:48,870 --> 00:08:46,160

time that was already a stretch goal for

239
00:08:50,790 --> 00:08:48,880
nasa but when people had a chance to use

240
00:08:53,350 --> 00:08:50,800
that slightly better part or build the

241
00:08:55,430 --> 00:08:53,360
mission for longevity they did so in the

242
00:08:56,870 --> 00:08:55,440
hopes that maybe we'd get to 12 years

243
00:08:59,350 --> 00:08:56,880
because then you could get the uranus

244
00:09:01,110 --> 00:08:59,360
and neptune flybys with voyager 2.

245
00:09:03,990 --> 00:09:01,120
i don't think anyone could have possibly

246
00:09:06,470 --> 00:09:04,000
dreamt we'd be here in 2022 with a 245

247
00:09:07,829 --> 00:09:06,480
year old spacecraft still going um i've

248
00:09:09,670 --> 00:09:07,839
mentioned some of the problems we've had

249
00:09:11,190 --> 00:09:09,680
along the way we had some early failures

250
00:09:13,269 --> 00:09:11,200
the radio receiver on one of the

251
00:09:15,590 --> 00:09:13,279
spacecraft failed within the first day

252
00:09:17,110 --> 00:09:15,600
so we've had to use a few backup systems

253
00:09:19,750 --> 00:09:17,120
here and there

254
00:09:21,910 --> 00:09:19,760
personally i'm most excited about the

255
00:09:24,389 --> 00:09:21,920
thrusters we have a prime branch a

256
00:09:26,470 --> 00:09:24,399
backup branch and both of those have

257
00:09:28,310 --> 00:09:26,480
seen degradation and ordinarily that

258
00:09:29,910 --> 00:09:28,320
would be the end of any mission

259
00:09:32,230 --> 00:09:29,920
good old voyager had another trick up

260
00:09:34,070 --> 00:09:32,240
its sleeve underneath the spacecraft

261
00:09:36,070 --> 00:09:34,080
there's a third set of thrusters called

262
00:09:38,470 --> 00:09:36,080
tcm thrusters trajectory correction

263
00:09:40,710 --> 00:09:38,480

maneuver thrusters and we've actually

264
00:09:43,350 --> 00:09:40,720
been able to use those to control pitch

265
00:09:46,230 --> 00:09:43,360
and yaw on voyager

266
00:09:47,750 --> 00:09:46,240
since about 2018 2019 for both voyager 1

267
00:09:49,670 --> 00:09:47,760
and voyager 2.

268
00:09:52,070 --> 00:09:49,680
never really designed to do that but

269
00:09:54,150 --> 00:09:52,080
some genius let's write the software

270
00:09:55,670 --> 00:09:54,160
just in case we have to do that we

271
00:09:58,870 --> 00:09:55,680
turned on those thrusters for the first

272
00:10:01,590 --> 00:09:58,880
time in 30 years in voyager 2's case in

273
00:10:02,630 --> 00:10:01,600
37 years in voyager 1's case and they

274
00:10:04,949 --> 00:10:02,640
started right up and have been

275
00:10:06,870 --> 00:10:04,959
controlling pitch and yaw ever since

276
00:10:09,350 --> 00:10:06,880
yeah and so the tcm thrusters they were

277
00:10:11,990 --> 00:10:09,360
actually used for the planetary part of

278
00:10:14,949 --> 00:10:12,000
the mission right yeah long before i

279
00:10:16,870 --> 00:10:14,959
joined jpl or even dreamed about the uh

280
00:10:18,550 --> 00:10:16,880
the chance of working on voyager those

281
00:10:19,670 --> 00:10:18,560
thrusters did the lion's share of the

282
00:10:22,389 --> 00:10:19,680
work to

283
00:10:25,030 --> 00:10:22,399
we took advantage of this 176-year

284
00:10:27,509 --> 00:10:25,040
extremely rare cosmic alignment to get

285
00:10:29,590 --> 00:10:27,519
all four gas giant outer planets uh but

286
00:10:32,630 --> 00:10:29,600
even then you needed those thrusters to

287
00:10:34,389 --> 00:10:32,640
fine-tune the trajectory to patch the uh

288
00:10:36,630 --> 00:10:34,399

sections together to get from jupiter

289
00:10:38,710 --> 00:10:36,640
saturn uranus and neptune so they they

290
00:10:41,430 --> 00:10:38,720
had their heyday and were basically done

291
00:10:42,870 --> 00:10:41,440
by 1989. but of course

292
00:10:44,310 --> 00:10:42,880
you know never count them out we need

293
00:10:45,509 --> 00:10:44,320
them here in the 2020s to keep going

294
00:10:47,430 --> 00:10:45,519
with the mission

295
00:10:49,829 --> 00:10:47,440
yeah i know that sometimes you've said

296
00:10:52,069 --> 00:10:49,839
linda expect the unexpected with voyager

297
00:10:53,509 --> 00:10:52,079
right absolutely there are always

298
00:10:55,190 --> 00:10:53,519
surprises around the corner when you

299
00:10:57,350 --> 00:10:55,200
think you have all the answers that's

300
00:10:59,269 --> 00:10:57,360
when you get your biggest surprise

301
00:11:01,430 --> 00:10:59,279
well i have a question for you now linda

302
00:11:03,509 --> 00:11:01,440
okay so c of stars on twitter asks and

303
00:11:05,829 --> 00:11:03,519
we get this question quite a bit

304
00:11:08,069 --> 00:11:05,839
is there a possibility of either probe

305
00:11:10,389 --> 00:11:08,079
turning its cameras back on

306
00:11:12,150 --> 00:11:10,399
after all that time and take one last

307
00:11:14,550 --> 00:11:12,160
image of our solar system again before

308
00:11:16,310 --> 00:11:14,560
they can no longer produce enough power

309
00:11:18,470 --> 00:11:16,320
and what would that view of the solar

310
00:11:20,150 --> 00:11:18,480
system even look like

311
00:11:22,710 --> 00:11:20,160
well it turns out we just don't have

312
00:11:24,710 --> 00:11:22,720
enough power to turn the cameras back on

313
00:11:27,509 --> 00:11:24,720

in fact the voyager 1 cameras went off

314
00:11:29,509 --> 00:11:27,519
in 1990 but before they did on

315
00:11:31,670 --> 00:11:29,519
valentine's day they took this wonderful

316
00:11:34,150 --> 00:11:31,680
portrait of the solar system with

317
00:11:36,069 --> 00:11:34,160
individual shots of planets including a

318
00:11:38,550 --> 00:11:36,079
view of earth if we could turn the

319
00:11:40,550 --> 00:11:38,560
cameras back on now and look back at our

320
00:11:42,550 --> 00:11:40,560
solar system it would have shrunk down

321
00:11:45,269 --> 00:11:42,560
to something that's quite small

322
00:11:47,190 --> 00:11:45,279
and our sun is starting to look like one

323
00:11:48,790 --> 00:11:47,200
of the ordinary stars you might see at

324
00:11:50,790 --> 00:11:48,800
night it's still brighter but it's

325
00:11:52,790 --> 00:11:50,800
getting close

326
00:11:54,470 --> 00:11:52,800
thank you yeah and i know that you know

327
00:11:57,190 --> 00:11:54,480
one of the last pictures it took was

328
00:11:58,870 --> 00:11:57,200
that pale blue dot image of earth do you

329
00:12:00,310 --> 00:11:58,880
want to talk about that

330
00:12:02,470 --> 00:12:00,320
it was really an interesting and

331
00:12:03,590 --> 00:12:02,480
spectacular picture there's

332
00:12:05,670 --> 00:12:03,600
looking at the pictures it was kind of

333
00:12:07,190 --> 00:12:05,680
hard to find some of the planets and

334
00:12:09,110 --> 00:12:07,200
there was the earth in what looked like

335
00:12:11,910 --> 00:12:09,120
a sun beam some scattered light from

336
00:12:14,310 --> 00:12:11,920
inside the cameras and carl sagan coined

337
00:12:16,629 --> 00:12:14,320
it a pale blue dot because it's all the

338
00:12:18,790 --> 00:12:16,639

life that we know of in our solar system

339
00:12:21,269 --> 00:12:18,800
is on that one tiny world and how

340
00:12:23,509 --> 00:12:21,279
special that world is

341
00:12:25,269 --> 00:12:23,519
thank you all right i'm going to turn to

342
00:12:27,829 --> 00:12:25,279
todd again because todd i know you love

343
00:12:31,670 --> 00:12:29,750
so we have a question about a light day

344
00:12:33,670 --> 00:12:31,680
so a light day for you know explain that

345
00:12:36,150 --> 00:12:33,680
to our audience here but mad mark on

346
00:12:38,069 --> 00:12:36,160
twitter asks when will you be a light

347
00:12:41,269 --> 00:12:38,079
day away from earth that's a great

348
00:12:42,870 --> 00:12:41,279
question and uh so we've talked so far

349
00:12:44,790 --> 00:12:42,880
about billions of miles and that's a

350
00:12:46,949 --> 00:12:44,800
great way to realize just how far away

351
00:12:49,110 --> 00:12:46,959
these spacecraft are another way to talk

352
00:12:51,509 --> 00:12:49,120
about is in terms of the communication

353
00:12:53,430 --> 00:12:51,519
delay in either sending a command to

354
00:12:55,590 --> 00:12:53,440
voyager or getting something back and

355
00:12:58,150 --> 00:12:55,600
that's using radio waves that move at a

356
00:13:00,550 --> 00:12:58,160
zippy 186 000 miles per second the speed

357
00:13:02,230 --> 00:13:00,560
of light so this the

358
00:13:04,389 --> 00:13:02,240
moon is about a second and a half mars a

359
00:13:07,670 --> 00:13:04,399
few tens of minutes uh saturn maybe an

360
00:13:10,389 --> 00:13:07,680
hour and a half voyager 1 is 22 light

361
00:13:13,910 --> 00:13:10,399
hours away so if we sen the data from

362
00:13:15,350 --> 00:13:13,920
voyager 1 is 22 hours old and to send a

363
00:13:17,430 --> 00:13:15,360

fix if there's a problem for example

364
00:13:19,509 --> 00:13:17,440
would take another 22 hours so voyage

365
00:13:22,550 --> 00:13:19,519
take care of itself for two days that

366
00:13:25,430 --> 00:13:22,560
number keeps increasing and i did the

367
00:13:28,710 --> 00:13:25,440
math and it's november of 2026 when

368
00:13:30,790 --> 00:13:28,720
voyager 1 reaches one light day from

369
00:13:32,310 --> 00:13:30,800
earth so that's a i think we should

370
00:13:34,150 --> 00:13:32,320
celebrate that right before the golden

371
00:13:36,710 --> 00:13:34,160
anniversary in august and september of

372
00:13:39,110 --> 00:13:36,720
2027. but lest we think we've gone a

373
00:13:41,590 --> 00:13:39,120
long way the nearest star is four light

374
00:13:43,430 --> 00:13:41,600
years away so even after 50 years we're

375
00:13:45,590 --> 00:13:43,440
only one fifteen hundredth of the way to

376
00:13:47,189 --> 00:13:45,600
the nearest star yeah that's amazing the

377
00:13:49,670 --> 00:13:47,199
sense of scale is a little different

378
00:13:52,230 --> 00:13:49,680
where the voyagers are than here

379
00:13:53,269 --> 00:13:52,240
okay got another question for you todd

380
00:13:55,030 --> 00:13:53,279
okay so

381
00:13:58,150 --> 00:13:55,040
aka psy

382
00:14:00,150 --> 00:13:58,160
oops aka sci on twitter asks what would

383
00:14:02,629 --> 00:14:00,160
you do differently for a next-gen

384
00:14:05,430 --> 00:14:02,639
voyager mission to make the spacecraft

385
00:14:07,269 --> 00:14:05,440
last longer go faster and further and

386
00:14:09,189 --> 00:14:07,279
collect new types of planetary and

387
00:14:11,110 --> 00:14:09,199
interstellar data wow that's a great

388
00:14:13,590 --> 00:14:11,120

question i don't think i'd change much

389
00:14:15,110 --> 00:14:13,600
of anything as far as the longevity goes

390
00:14:17,350 --> 00:14:15,120
you know maybe a few more redundant

391
00:14:20,150 --> 00:14:17,360
systems if you could afford the mass to

392
00:14:21,590 --> 00:14:20,160
do so uh i would leave to linda as far

393
00:14:24,150 --> 00:14:21,600
as which science instruments she would

394
00:14:26,550 --> 00:14:24,160
like the next generation voyager by the

395
00:14:27,910 --> 00:14:26,560
way the planets will align again in 2153

396
00:14:28,829 --> 00:14:27,920
so i hope we do at least a voyager

397
00:14:31,750 --> 00:14:28,839
tribute

398
00:14:33,189 --> 00:14:31,760
mission another chance uh and as far as

399
00:14:34,629 --> 00:14:33,199
the um

400
00:14:35,829 --> 00:14:34,639
what was the third part of the middle

401
00:14:38,790 --> 00:14:35,839
part of that question

402
00:14:41,110 --> 00:14:38,800
to go faster and farther faster yeah so

403
00:14:42,870 --> 00:14:41,120
we you know this again the cosmic

404
00:14:45,670 --> 00:14:42,880
alignment of the planets there is

405
00:14:47,590 --> 00:14:45,680
extremely rare the 176 years there are

406
00:14:49,590 --> 00:14:47,600
other exotic more exotic forms of

407
00:14:51,750 --> 00:14:49,600
propulsion that in theory could get us

408
00:14:53,430 --> 00:14:51,760
to the outer solar system faster i know

409
00:14:55,269 --> 00:14:53,440
nasa is looking at that and i would love

410
00:14:56,790 --> 00:14:55,279
to see that within my lifetime too it

411
00:14:59,350 --> 00:14:56,800
just otherwise it takes a really long

412
00:15:02,470 --> 00:14:59,360
time to get to the outer solar system

413
00:15:04,150 --> 00:15:02,480

yeah an entire lifetime in fact

414
00:15:06,150 --> 00:15:04,160
okay well i'm going to ask a question to

415
00:15:08,670 --> 00:15:06,160
linda here okay and i'm going to ask you

416
00:15:12,069 --> 00:15:08,680
this because you were actually around in

417
00:15:14,949 --> 00:15:12,079
1977 when voyager launched so coyote

418
00:15:17,509 --> 00:15:14,959
siege 92 on twitter asks did anyone

419
00:15:20,710 --> 00:15:17,519
think in 1977 that you'd still be

420
00:15:23,990 --> 00:15:20,720
hearing from voyager 45 years later

421
00:15:26,550 --> 00:15:24,000
i can say in 1977 at the launch no one

422
00:15:28,629 --> 00:15:26,560
was talking about where voyager would be

423
00:15:30,790 --> 00:15:28,639
in 45 years and in fact when you look at

424
00:15:32,470 --> 00:15:30,800
where the voyagers went out the nose

425
00:15:34,949 --> 00:15:32,480
that's the closest point to the

426
00:15:37,829 --> 00:15:34,959
heliopause and it was just luck we

427
00:15:39,509 --> 00:15:37,839
happened to go out that direction

428
00:15:41,910 --> 00:15:39,519
okay well yeah because it could have

429
00:15:43,990 --> 00:15:41,920
gone out the tail and then maybe we'd

430
00:15:45,269 --> 00:15:44,000
still be in the heliopause

431
00:15:46,710 --> 00:15:45,279
yeah

432
00:15:49,110 --> 00:15:46,720
okay well i'm gonna ask this first to

433
00:15:52,629 --> 00:15:49,120
you linda and then i'll ask you todd so

434
00:15:54,870 --> 00:15:52,639
henry on youtube asks what college major

435
00:15:57,189 --> 00:15:54,880
do you guys personally think gets us the

436
00:15:59,590 --> 00:15:57,199
best chance at earning a job in the in

437
00:16:00,870 --> 00:15:59,600
these fields and what majors did you

438
00:16:02,949 --> 00:16:00,880

study

439
00:16:05,189 --> 00:16:02,959
well henry that's a good question i was

440
00:16:07,269 --> 00:16:05,199
a physics major pretty much through for

441
00:16:09,430 --> 00:16:07,279
my bachelor's and master's and then got

442
00:16:11,670 --> 00:16:09,440
a geophysics and space physics degree

443
00:16:12,790 --> 00:16:11,680
but certainly to be a scientist or an

444
00:16:14,870 --> 00:16:12,800
engineer

445
00:16:17,829 --> 00:16:14,880
science classes are great physics is

446
00:16:19,910 --> 00:16:17,839
really great advanced math those are the

447
00:16:22,470 --> 00:16:19,920
kinds of classes that would prepare you

448
00:16:24,310 --> 00:16:22,480
say for a job at jpl

449
00:16:26,470 --> 00:16:24,320
great and what about you todd yeah i

450
00:16:29,030 --> 00:16:26,480
have a bachelor's and master's degrees

451
00:16:31,590 --> 00:16:29,040
in aerospace engineering from mit and

452
00:16:33,189 --> 00:16:31,600
what i found though at jpl if if it's a

453
00:16:35,189 --> 00:16:33,199
science degree or an engineering degree

454
00:16:36,949 --> 00:16:35,199
of any sort we probably have a place for

455
00:16:38,870 --> 00:16:36,959
you here i mean as an example might be

456
00:16:41,670 --> 00:16:38,880
civil engineers that learn how to build

457
00:16:43,829 --> 00:16:41,680
martian habitats using martian soil uh

458
00:16:45,269 --> 00:16:43,839
so i you know we have navigators and

459
00:16:47,269 --> 00:16:45,279
mathematicians

460
00:16:49,269 --> 00:16:47,279
biology is a big thing looking for life

461
00:16:50,949 --> 00:16:49,279
outside of planet earth so you wouldn't

462
00:16:52,870 --> 00:16:50,959
think necessarily space travel and would

463
00:16:55,749 --> 00:16:52,880

involve the biological sciences but

464
00:16:58,790 --> 00:16:55,759
really any stem kind of background there

465
00:17:01,430 --> 00:16:58,800
could be a position here at jpl

466
00:17:03,509 --> 00:17:01,440
yeah there's been lots of different

467
00:17:05,350 --> 00:17:03,519
i've met so many people who've started

468
00:17:06,789 --> 00:17:05,360
one way and did other things i know

469
00:17:08,630 --> 00:17:06,799
there's people who worked in even

470
00:17:11,350 --> 00:17:08,640
pharmaceuticals and then they came and

471
00:17:12,870 --> 00:17:11,360
did sort of astrobiology here so okay

472
00:17:14,470 --> 00:17:12,880
let me ask you another question todd and

473
00:17:16,150 --> 00:17:14,480
if you don't know this then i might i

474
00:17:18,870 --> 00:17:16,160
might ask you linda

475
00:17:21,110 --> 00:17:18,880
how many years did it take nasa to build

476
00:17:23,189 --> 00:17:21,120
voyager oh and this is priyanka on

477
00:17:24,309 --> 00:17:23,199
youtube okay yeah i will defer that to

478
00:17:26,309 --> 00:17:24,319
linda okay

479
00:17:28,710 --> 00:17:26,319
yeah i'm not sure exactly how many years

480
00:17:31,270 --> 00:17:28,720
i think the concept really got started

481
00:17:32,710 --> 00:17:31,280
sort of in the late 60s the opportunity

482
00:17:34,630 --> 00:17:32,720
was available

483
00:17:37,750 --> 00:17:34,640
and i know that ed stone became project

484
00:17:41,590 --> 00:17:37,760
scientist in 1972 so i'm sure they were

485
00:17:43,510 --> 00:17:41,600
hard at work building voyager in the 70s

486
00:17:45,909 --> 00:17:43,520
it's safe to say that the

487
00:17:48,150 --> 00:17:45,919
we were lucky extremely lucky because

488
00:17:49,430 --> 00:17:48,160

probably five years earlier 10 years

489
00:17:51,150 --> 00:17:49,440
earlier we wouldn't have had the

490
00:17:54,390 --> 00:17:51,160
technology to take advantage of this

491
00:17:55,909 --> 00:17:54,400
176-year opportunity so uh we'll we'll

492
00:17:57,990 --> 00:17:55,919
take a bit of luck whenever we can get

493
00:18:00,150 --> 00:17:58,000
it too yeah and one of the things that

494
00:18:01,909 --> 00:18:00,160
made voyager last so long was that you

495
00:18:04,070 --> 00:18:01,919
guys did a lot of redundant systems

496
00:18:05,270 --> 00:18:04,080
right so that you had backups so i

497
00:18:07,029 --> 00:18:05,280
imagine that you know you wouldn't just

498
00:18:09,270 --> 00:18:07,039
build one thing but you had to build two

499
00:18:12,230 --> 00:18:09,280
right right all of the computers are

500
00:18:14,070 --> 00:18:12,240
redundant on voyager and we knew from an

501
00:18:15,909 --> 00:18:14,080
earlier flyby of pioneer going by

502
00:18:18,070 --> 00:18:15,919
jupiter that jupiter's radiation

503
00:18:20,230 --> 00:18:18,080
environment was quite harsh so we did a

504
00:18:22,310 --> 00:18:20,240
lot of things to radiation harden the

505
00:18:24,310 --> 00:18:22,320
two voyagers and that stood them in good

506
00:18:26,549 --> 00:18:24,320
stead not just for their jupiter flybys

507
00:18:28,310 --> 00:18:26,559
but now an interstellar space where

508
00:18:30,710 --> 00:18:28,320
those cosmic rays or high energy

509
00:18:33,750 --> 00:18:30,720
radiation is greater that extra little

510
00:18:35,110 --> 00:18:33,760
protection is at work still

511
00:18:37,430 --> 00:18:35,120
okay i'm going to ask you another

512
00:18:40,230 --> 00:18:37,440
question linda uh so spiderweb on

513
00:18:42,150 --> 00:18:40,240

twitter asks how much further will each

514
00:18:44,310 --> 00:18:42,160
of the voyagers have to travel on their

515
00:18:46,549 --> 00:18:44,320
present trajectory until they're closer

516
00:18:47,990 --> 00:18:46,559
to another star than our sun and how

517
00:18:49,669 --> 00:18:48,000
long would that take we mentioned that

518
00:18:51,190 --> 00:18:49,679
the other the closest star is about four

519
00:18:53,190 --> 00:18:51,200
light years away but of course things

520
00:18:54,950 --> 00:18:53,200
are moving in space so

521
00:18:56,710 --> 00:18:54,960
how much farther is it that's right

522
00:18:58,789 --> 00:18:56,720
things are moving in space so in about

523
00:19:00,470 --> 00:18:58,799
forty thousand years each of the

524
00:19:01,830 --> 00:19:00,480
voyagers will become

525
00:19:03,590 --> 00:19:01,840
in about forty thousand years each

526
00:19:05,590 --> 00:19:03,600
voyager will come within about two light

527
00:19:07,669 --> 00:19:05,600
years of another star

528
00:19:09,590 --> 00:19:07,679
and so that's like half the way to alpha

529
00:19:12,150 --> 00:19:09,600
centauri now but things are moving in

530
00:19:14,230 --> 00:19:12,160
space and so 40 000 years if there's

531
00:19:16,549 --> 00:19:14,240
anybody around maybe they'll take a look

532
00:19:18,070 --> 00:19:16,559
and find the golden record

533
00:19:19,750 --> 00:19:18,080
well since you mentioned the golden

534
00:19:22,230 --> 00:19:19,760
record let's actually talk about it i

535
00:19:24,630 --> 00:19:22,240
know we have a picture up close of its

536
00:19:27,270 --> 00:19:24,640
cover and so the golden record is this

537
00:19:31,029 --> 00:19:27,280
kind of time capsule of sounds and

538
00:19:33,190 --> 00:19:31,039

images uh you know from basically 1977

539
00:19:35,110 --> 00:19:33,200
or thereabouts as a way to kind of you

540
00:19:37,270 --> 00:19:35,120
know share with whoever finds voyager

541
00:19:40,230 --> 00:19:37,280
someday you know what where did it come

542
00:19:41,830 --> 00:19:40,240
from so i wanted to ask you both

543
00:19:42,870 --> 00:19:41,840
what's your favorite sound on the golden

544
00:19:44,390 --> 00:19:42,880
record

545
00:19:46,789 --> 00:19:44,400
well i think my favorite sound on the

546
00:19:48,950 --> 00:19:46,799
golden record is chuck berry singing

547
00:19:50,950 --> 00:19:48,960
johnny be good and the reason i really

548
00:19:53,590 --> 00:19:50,960
like that is that after the neptune

549
00:19:56,150 --> 00:19:53,600
flyby all the planetary flybys are over

550
00:19:59,350 --> 00:19:56,160
we had a great big party out here in the

551
00:20:00,950 --> 00:19:59,360
mall at jpl and chuck berry came and he

552
00:20:03,750 --> 00:20:00,960
played that song and i think it's been

553
00:20:06,549 --> 00:20:03,760
my favorite on the record ever since

554
00:20:09,029 --> 00:20:06,559
that sounds like an amazing party

555
00:20:10,470 --> 00:20:09,039
and what about you todd well i i love

556
00:20:12,630 --> 00:20:10,480
the golden record very much it's the

557
00:20:14,789 --> 00:20:12,640
most eclectic set of music you'll hear

558
00:20:16,070 --> 00:20:14,799
from every corner planet earth

559
00:20:18,390 --> 00:20:16,080
but i think my favorite would have to be

560
00:20:20,149 --> 00:20:18,400
any of the beethoven works on the uh on

561
00:20:22,230 --> 00:20:20,159
the record he's the most represented

562
00:20:24,230 --> 00:20:22,240
composer if you will and i'm a pianist

563
00:20:25,990 --> 00:20:24,240

and my piano teachers teachers teachers

564
00:20:28,230 --> 00:20:26,000
teacher was beethoven so we played a lot

565
00:20:30,149 --> 00:20:28,240
of ludwig and it's nice to see we're

566
00:20:32,710 --> 00:20:30,159
sharing them with interstellar space too

567
00:20:34,470 --> 00:20:32,720
yeah i hope i hope they uh appreciate

568
00:20:37,830 --> 00:20:34,480
the piano there okay

569
00:20:39,830 --> 00:20:37,840
um i have a question for you todd and

570
00:20:41,909 --> 00:20:39,840
greg on youtube asks

571
00:20:45,110 --> 00:20:41,919
how are you and the voyagers able to

572
00:20:47,270 --> 00:20:45,120
communicate is it a pinpoint signal

573
00:20:49,190 --> 00:20:47,280
or are you casting a wide net in both

574
00:20:52,070 --> 00:20:49,200
directions oh that's a great question

575
00:20:55,190 --> 00:20:52,080
well at these distances uh the radio

576
00:20:57,430 --> 00:20:55,200
transmitter on voyager is about 18 watts

577
00:20:59,029 --> 00:20:57,440
so it's less power than the light bulb

578
00:21:01,830 --> 00:20:59,039
in your refrigerator so if you can

579
00:21:04,870 --> 00:21:01,840
imagine how that signal is attenuated

580
00:21:07,270 --> 00:21:04,880
how much tinier and fainter it is once

581
00:21:09,590 --> 00:21:07,280
it reaches 15 billion miles away we need

582
00:21:11,830 --> 00:21:09,600
giant antenna on earth as part of nasa's

583
00:21:13,990 --> 00:21:11,840
deep space network to pick up that faint

584
00:21:16,870 --> 00:21:14,000
whisper of a signal now because of that

585
00:21:18,789 --> 00:21:16,880
we need a very directed signal within

586
00:21:21,029 --> 00:21:18,799
you know fractions of a degree our high

587
00:21:23,430 --> 00:21:21,039
gain antenna needs to be pointed right

588
00:21:25,190 --> 00:21:23,440

at the earth to be able to receive data

589
00:21:27,029 --> 00:21:25,200
and to transmit it back to earth and

590
00:21:29,029 --> 00:21:27,039
that's where we were so flummoxed with

591
00:21:30,390 --> 00:21:29,039
losing our attitude control telemetry

592
00:21:31,750 --> 00:21:30,400
because we had no

593
00:21:33,750 --> 00:21:31,760
information on the pointing of that

594
00:21:35,510 --> 00:21:33,760
antenna but we we knew things were

595
00:21:37,110 --> 00:21:35,520
working because we were still getting a

596
00:21:39,430 --> 00:21:37,120
signal we just we didn't have the

597
00:21:40,870 --> 00:21:39,440
details and i'm happy for linda's sake

598
00:21:42,710 --> 00:21:40,880
and her fellow scientists that the

599
00:21:44,470 --> 00:21:42,720
science data kept flowing that whole

600
00:21:47,190 --> 00:21:44,480
time it just was very frustrating to the

601
00:21:48,470 --> 00:21:47,200
engineers not having that data until now

602
00:21:50,149 --> 00:21:48,480
yeah and i've heard that the signal

603
00:21:52,950 --> 00:21:50,159
coming back from voyager is really weak

604
00:21:54,789 --> 00:21:52,960
too right it is and that's uh that's why

605
00:21:57,669 --> 00:21:54,799
one reason we need these a huge antenna

606
00:21:59,110 --> 00:21:57,679
they're up to 230 feet in diameter just

607
00:22:01,669 --> 00:21:59,120
to pick up that faint whisper of a

608
00:22:03,909 --> 00:22:01,679
signal from space so it's both the size

609
00:22:05,990 --> 00:22:03,919
and the power of the antennas on earth

610
00:22:08,630 --> 00:22:06,000
and the precise pointing that allows us

611
00:22:11,029 --> 00:22:08,640
to continue to monitor and talk to a

612
00:22:12,630 --> 00:22:11,039
vehicle so so far away

613
00:22:15,590 --> 00:22:12,640

yeah well okay i've got another question

614
00:22:18,149 --> 00:22:15,600
now this time for linda so uh david

615
00:22:20,070 --> 00:22:18,159
johnson on youtube asks

616
00:22:22,390 --> 00:22:20,080
what were the most surprising results

617
00:22:24,070 --> 00:22:22,400
you received from either or both of the

618
00:22:26,149 --> 00:22:24,080
voyagers

619
00:22:27,430 --> 00:22:26,159
well i think surprising results for the

620
00:22:29,029 --> 00:22:27,440
interstellar mission being an

621
00:22:30,870 --> 00:22:29,039
interstellar space

622
00:22:32,870 --> 00:22:30,880
have to do with directly measuring the

623
00:22:34,950 --> 00:22:32,880
cosmic ray abundance and and seeing how

624
00:22:37,350 --> 00:22:34,960
they change and as i mentioned earlier

625
00:22:38,950 --> 00:22:37,360
the fact that the magnetic field hasn't

626
00:22:41,190 --> 00:22:38,960
rotated into the direction of

627
00:22:43,110 --> 00:22:41,200
interstellar magnetic field yet

628
00:22:45,909 --> 00:22:43,120
the fact that the waves from the sun

629
00:22:47,510 --> 00:22:45,919
actually go out into space and beyond

630
00:22:50,549 --> 00:22:47,520
but if you look back on the planetary

631
00:22:53,190 --> 00:22:50,559
flybys i think voyager really reshaped

632
00:22:54,789 --> 00:22:53,200
how we think about the moons themselves

633
00:22:56,870 --> 00:22:54,799
and perhaps that some of these worlds

634
00:22:58,950 --> 00:22:56,880
might have liquid water oceans

635
00:23:00,789 --> 00:22:58,960
underneath their icy crusts that might

636
00:23:03,110 --> 00:23:00,799
be habitable and so it's really to

637
00:23:05,430 --> 00:23:03,120
voyager's credit that we found that

638
00:23:07,510 --> 00:23:05,440

moons don't just look like our moon they

639
00:23:09,590 --> 00:23:07,520
can look like all sorts of different

640
00:23:11,510 --> 00:23:09,600
objects

641
00:23:13,669 --> 00:23:11,520
yeah and you know i think the the i o

642
00:23:14,549 --> 00:23:13,679
thing was a surprise too uh when you

643
00:23:16,470 --> 00:23:14,559
when you found it because it was

644
00:23:18,870 --> 00:23:16,480
actually in the navigation data right i

645
00:23:20,630 --> 00:23:18,880
mean it wasn't even necessary it was i

646
00:23:22,070 --> 00:23:20,640
you know was at the end of a day or

647
00:23:23,830 --> 00:23:22,080
something do you want to tell us a story

648
00:23:25,430 --> 00:23:23,840
about how those i o volcanoes were

649
00:23:26,789 --> 00:23:25,440
discovered right well it turns out we

650
00:23:28,310 --> 00:23:26,799
needed to take what we called optical

651
00:23:30,549 --> 00:23:28,320
navigation frames where you would get

652
00:23:32,710 --> 00:23:30,559
sort of stars in the background to help

653
00:23:35,350 --> 00:23:32,720
your with your pointing at these targets

654
00:23:36,470 --> 00:23:35,360
one of those frames had this fuzzy bump

655
00:23:38,710 --> 00:23:36,480
on the limb

656
00:23:40,950 --> 00:23:38,720
and so had to rule out could it be like

657
00:23:43,190 --> 00:23:40,960
a bright galaxy could it be another moon

658
00:23:44,789 --> 00:23:43,200
peeking out from behind io

659
00:23:46,390 --> 00:23:44,799
and it turned out you rule out all those

660
00:23:49,430 --> 00:23:46,400
probabilities that it's suddenly

661
00:23:51,190 --> 00:23:49,440
something coming from the surface of io

662
00:23:53,430 --> 00:23:51,200
as we started to look more closely we

663
00:23:55,590 --> 00:23:53,440

noticed areas that look like

664
00:23:56,950 --> 00:23:55,600
volcanoes and they were erupting even as

665
00:23:59,350 --> 00:23:56,960
we could see them in the voyager

666
00:24:01,350 --> 00:23:59,360
pictures and forming this ring of where

667
00:24:03,990 --> 00:24:01,360
that lava came back down it was it was

668
00:24:07,190 --> 00:24:04,000
just incredible and then neptune's most

669
00:24:09,750 --> 00:24:07,200
distant moon triton it also had geysers

670
00:24:10,870 --> 00:24:09,760
and that was a complete surprise so far

671
00:24:13,830 --> 00:24:10,880
from the sun

672
00:24:16,230 --> 00:24:13,840
so cold and yet these little tiny black

673
00:24:20,310 --> 00:24:16,240
wisps coming up from the surface of

674
00:24:21,269 --> 00:24:20,320
triton so so many surprises with voyager

675
00:24:23,029 --> 00:24:21,279
all right well i'm going to ask you

676
00:24:24,470 --> 00:24:23,039
another question

677
00:24:26,549 --> 00:24:24,480
and maybe you can take this as a more

678
00:24:28,310 --> 00:24:26,559
general one even to just explain you

679
00:24:31,110 --> 00:24:28,320
know the directions the voyagers are

680
00:24:33,750 --> 00:24:31,120
heading but bruce mcninch on youtube

681
00:24:36,070 --> 00:24:33,760
asks have there been any unexplained

682
00:24:37,430 --> 00:24:36,080
changes in speed or direction for either

683
00:24:39,510 --> 00:24:37,440
of the voyagers

684
00:24:41,430 --> 00:24:39,520
aha in other words have we flown close

685
00:24:43,669 --> 00:24:41,440
to something that perturbed us a little

686
00:24:45,269 --> 00:24:43,679
bit well so far to the best of our

687
00:24:47,430 --> 00:24:45,279
knowledge no there's nothing that's

688
00:24:49,510 --> 00:24:47,440

happened to the voyagers that have

689
00:24:51,110 --> 00:24:49,520
changed their speed or direction in an

690
00:24:52,789 --> 00:24:51,120
unexpected way

691
00:24:55,029 --> 00:24:52,799
if you fly close to a large

692
00:24:56,789 --> 00:24:55,039
gravitational mass like a planet that

693
00:24:59,029 --> 00:24:56,799
would bend your trajectory and that's

694
00:25:01,029 --> 00:24:59,039
what we did early on in the mission so

695
00:25:03,510 --> 00:25:01,039
so far we haven't seen anything but who

696
00:25:05,110 --> 00:25:03,520
knows what's out there

697
00:25:07,430 --> 00:25:05,120
yeah and the reason that we kind of bent

698
00:25:09,029 --> 00:25:07,440
upwards and bent lower is because there

699
00:25:11,350 --> 00:25:09,039
were certain things you guys wanted to

700
00:25:13,990 --> 00:25:11,360
see on the planetary voyage

701
00:25:16,310 --> 00:25:14,000
right with voyager 1 we wanted to go

702
00:25:18,870 --> 00:25:16,320
close to saturn's moon titan and in

703
00:25:20,630 --> 00:25:18,880
doing that it bent us out of the plane

704
00:25:23,590 --> 00:25:20,640
of the planets bent us upward and with

705
00:25:25,510 --> 00:25:23,600
voyager 2 we wanted to fly very close to

706
00:25:27,669 --> 00:25:25,520
neptune's moon triton and so to do that

707
00:25:30,149 --> 00:25:27,679
we flew over the pole of neptune and

708
00:25:32,950 --> 00:25:30,159
down to catch triton and then kept going

709
00:25:34,470 --> 00:25:32,960
out of the solar system that way

710
00:25:36,310 --> 00:25:34,480
great okay i'm going to ask one last

711
00:25:37,190 --> 00:25:36,320
question to you todd

712
00:25:39,510 --> 00:25:37,200
okay

713
00:25:41,430 --> 00:25:39,520

travis winch on youtube asks keeping the

714
00:25:43,269 --> 00:25:41,440
probes online is one thing but how do

715
00:25:45,669 --> 00:25:43,279
you maintain the ground systems that

716
00:25:47,669 --> 00:25:45,679
could be as old as the probes or are all

717
00:25:49,990 --> 00:25:47,679
the ground systems completely modern oh

718
00:25:52,630 --> 00:25:50,000
travis that's a great question and it is

719
00:25:54,310 --> 00:25:52,640
a real struggle uh you know as you can

720
00:25:56,630 --> 00:25:54,320
imagine back in the days when voyager

721
00:25:59,029 --> 00:25:56,640
was launched it's punch cards and tape

722
00:26:00,870 --> 00:25:59,039
drives and things like that so we have

723
00:26:02,710 --> 00:26:00,880
we have struggled with that we've also

724
00:26:05,750 --> 00:26:02,720
done a number of spacecraft moves you

725
00:26:07,909 --> 00:26:05,760
know from off the jpl facility back on

726
00:26:10,230 --> 00:26:07,919
and inevitably some problems might pop

727
00:26:12,549 --> 00:26:10,240
up during these transitions just to keep

728
00:26:13,590 --> 00:26:12,559
these old systems running it's useful to

729
00:26:15,669 --> 00:26:13,600
have some people that understand

730
00:26:17,669 --> 00:26:15,679
assembly language and the old code too

731
00:26:19,750 --> 00:26:17,679
but yeah it's definitely one of the uh

732
00:26:21,669 --> 00:26:19,760
the major problems here that we have to

733
00:26:24,470 --> 00:26:21,679
deal with on voyager to keep getting

734
00:26:27,110 --> 00:26:24,480
data in the 21st century

735
00:26:28,950 --> 00:26:27,120
okay all right well let's see i think

736
00:26:30,470 --> 00:26:28,960
we're going to wrap it up here because i

737
00:26:31,909 --> 00:26:30,480
think this is basically all the time

738
00:26:33,990 --> 00:26:31,919

that we have and i wanted to say thank

739
00:26:35,909 --> 00:26:34,000
you to linda and thank you to todd for

740
00:26:38,149 --> 00:26:35,919
joining us today to take your questions

741
00:26:39,909 --> 00:26:38,159
on voyager and so for all of you at home

742
00:26:42,789 --> 00:26:39,919
if you want to follow voyager's journey

743
00:26:45,909 --> 00:26:42,799
on social media you can follow at nasa

744
00:26:48,470 --> 00:26:45,919
jpl and at nasa voyager

745
00:26:50,310 --> 00:26:48,480
and so to kind of take us out because

746
00:26:52,470 --> 00:26:50,320
you know voyager took so many beautiful

747
00:26:54,870 --> 00:26:52,480
images of our solar system we have a

748
00:26:57,430 --> 00:26:54,880
montage of images for you from the