AbSciCon 2022

Jovian Safari

Dr. Tracy Drain

May 19 · 6:30PM EDT

1
00:00:06,389 --> 00:00:03,270
hello everybody i'm melissa kervin from

2
00:00:09,110 --> 00:00:06,399
the nasa astrobiology program and i am

3
00:00:11,350 --> 00:00:09,120
joined by kristin caitlin clayton the

4
00:00:12,629 --> 00:00:11,360
public events coordinator of science

5
00:00:15,030 --> 00:00:12,639
atlanta

6
00:00:17,349 --> 00:00:15,040
so please feel free to ask any questions

7
00:00:19,109 --> 00:00:17,359
in the chat and after our plenary

8
00:00:21,029 --> 00:00:19,119
session we will ask our speaker to

9
00:00:23,349 --> 00:00:21,039
answer questions from the audience here

10
00:00:24,950 --> 00:00:23,359
at the hilton atlanta as well as those

11
00:00:27,670 --> 00:00:24,960
online

12
00:00:29,669 --> 00:00:27,680
i have the great privilege to introduce

13
00:00:32,709 --> 00:00:29,679

our speaker tonight

14
00:00:34,470 --> 00:00:32,719
tracy drain received a bachelor's of

15
00:00:37,590 --> 00:00:34,480
science in mechanical engineering in

16
00:00:39,750 --> 00:00:37,600
1998 from the university of kentucky

17
00:00:43,670 --> 00:00:39,760
and her master's in mechanical

18
00:00:46,549 --> 00:00:43,680
engineering in 2000 from georgia tech

19
00:00:51,670 --> 00:00:49,029
after leaving georgia tech tracy headed

20
00:00:54,150 --> 00:00:51,680
to jpl and has worked on the mars

21
00:00:56,630 --> 00:00:54,160
reconnaissance orbiter the kepler

22
00:00:58,549 --> 00:00:56,640
mission to discover exoplanets the juno

23
00:01:00,869 --> 00:00:58,559
mission to jupiter and the psyche

24
00:01:02,310 --> 00:01:00,879
mission that will launch in that let me

25
00:01:04,710 --> 00:01:02,320
have psyche launch dead or is it

26
00:01:05,750 --> 00:01:04,720
launching soon i should know that sorry

27
00:01:08,789 --> 00:01:05,760
um

28
00:01:11,109 --> 00:01:08,799
she is now the lead flight systems uh

29
00:01:15,190 --> 00:01:11,119
engineer for the nasa's europa clipper

30
00:01:16,630 --> 00:01:15,200
mission which is set to launch in 2024

31
00:01:18,469 --> 00:01:16,640
or maybe she'll tell us something

32
00:01:21,670 --> 00:01:18,479
different um

33
00:01:27,910 --> 00:01:21,680
so without any further ado please join

34
00:01:31,190 --> 00:01:29,590
thank you everybody and hopefully you

35
00:01:33,350 --> 00:01:31,200
can hear me i know it's going to sound a

36
00:01:36,149 --> 00:01:33,360
little bit weird because i've got

37
00:01:38,469 --> 00:01:36,159
one computer plugged in for audio and

38
00:01:40,469 --> 00:01:38,479

one computer plugged in for video so if

39
00:01:42,230 --> 00:01:40,479
anyone's having trouble hearing me

40
00:01:43,910 --> 00:01:42,240
drop something in chat and i'll see if i

41
00:01:44,950 --> 00:01:43,920
can get that figured out

42
00:01:47,830 --> 00:01:44,960
i'm going to go ahead and share my

43
00:01:53,990 --> 00:01:47,840
screen now and dive into the

44
00:01:56,630 --> 00:01:55,030
great

45
00:01:58,630 --> 00:01:56,640
so uh yes thank you for that

46
00:02:00,389 --> 00:01:58,640
introduction melissa and i really wish

47
00:02:02,870 --> 00:02:00,399
that i could be with all of you there in

48
00:02:04,469 --> 00:02:02,880
atlanta a city that holds a soft spot in

49
00:02:06,550 --> 00:02:04,479
my heart since i was able to go there

50
00:02:08,790 --> 00:02:06,560
for grad school and also just to take

51
00:02:10,510 --> 00:02:08,800
part in the conference i love the fact

52
00:02:13,110 --> 00:02:10,520
that apps icon is such an

53
00:02:15,110 --> 00:02:13,120
interdisciplinary conference you'll hear

54
00:02:16,710 --> 00:02:15,120
about my job as a systems engineer and

55
00:02:18,229 --> 00:02:16,720
why interdisciplinary things are

56
00:02:21,270 --> 00:02:18,239
particularly

57
00:02:23,350 --> 00:02:21,280
attractive for me and also the whole

58
00:02:25,030 --> 00:02:23,360
concept of talking about origins and

59
00:02:26,869 --> 00:02:25,040
exploration which is something near and

60
00:02:28,390 --> 00:02:26,879
dear to my heart as well

61
00:02:30,150 --> 00:02:28,400
i'm going to talk to you guys just one

62
00:02:31,030 --> 00:02:30,160
second can you go full screen on your

63
00:02:33,430 --> 00:02:31,040

slides

64
00:02:35,190 --> 00:02:33,440
oh i sure did

65
00:02:37,509 --> 00:02:35,200
how about that you might need to swap

66
00:02:39,509 --> 00:02:37,519
place if um

67
00:02:41,270 --> 00:02:39,519
it's showing up

68
00:02:43,589 --> 00:02:41,280
it's just a little bit better

69
00:02:44,790 --> 00:02:43,599
yes perfect thank you okay great and

70
00:02:46,710 --> 00:02:44,800
hopefully there won't be too much of a

71
00:02:48,710 --> 00:02:46,720
time delay thank you i appreciate that

72
00:02:50,869 --> 00:02:48,720
so without further ado i'm gonna dive

73
00:02:53,030 --> 00:02:50,879
into this presentation

74
00:02:55,350 --> 00:02:53,040
and i'll start by going over my own

75
00:02:56,790 --> 00:02:55,360
particular origin story

76
00:02:58,470 --> 00:02:56,800
of course started with a big bang like

77
00:03:00,710 --> 00:02:58,480
everybody else but fast forward many

78
00:03:04,390 --> 00:03:00,720
billions of years and i was born as a

79
00:03:05,910 --> 00:03:04,400
tiny baby in louisville kentucky with an

80
00:03:08,070 --> 00:03:05,920
older brother a couple of years older

81
00:03:10,070 --> 00:03:08,080
than i am and that was important for me

82
00:03:12,149 --> 00:03:10,080
especially being a fan geek or having

83
00:03:13,910 --> 00:03:12,159
someone who is a little more popular

84
00:03:17,030 --> 00:03:13,920
into sports and keeping all the kids

85
00:03:18,790 --> 00:03:17,040
from picking on me for being a kind of a

86
00:03:21,670 --> 00:03:18,800
science math

87
00:03:23,589 --> 00:03:21,680
and music nerd and i know that lots of

88
00:03:25,990 --> 00:03:23,599

my colleagues who wound up in the

89
00:03:28,070 --> 00:03:26,000
sciences or in engineering for stem

90
00:03:29,589 --> 00:03:28,080
fields had similar origin stories for

91
00:03:31,190 --> 00:03:29,599
how they got to where they're where they

92
00:03:34,070 --> 00:03:31,200
are and what it is that was important in

93
00:03:36,550 --> 00:03:34,080
their lives for me my mom even though

94
00:03:39,190 --> 00:03:36,560
she was not a very technical person was

95
00:03:41,350 --> 00:03:39,200
always very interested in the sciences

96
00:03:43,750 --> 00:03:41,360
and just discovery and exploration in

97
00:03:45,190 --> 00:03:43,760
general she got me this book which those

98
00:03:47,990 --> 00:03:45,200
of you who are my age and older will

99
00:03:50,309 --> 00:03:48,000
remember are child craft books that kind

100
00:03:52,309 --> 00:03:50,319
of were partnered with the encyclopedias

101
00:03:54,470 --> 00:03:52,319
that we had back in the day and this

102
00:03:57,030 --> 00:03:54,480
particular one on world in space had a

103
00:04:00,309 --> 00:03:57,040
description of how scientists thought

104
00:04:03,190 --> 00:04:00,319
the solar system came to being a big

105
00:04:05,270 --> 00:04:03,200
cloud of dust and gas that was generated

106
00:04:07,110 --> 00:04:05,280
from exploded stars a couple of

107
00:04:08,630 --> 00:04:07,120
generations of stars ago that came

108
00:04:10,470 --> 00:04:08,640
together under gravity and other forces

109
00:04:12,390 --> 00:04:10,480
to form our solar system and i just

110
00:04:15,270 --> 00:04:12,400
remember as a kid being amazed that

111
00:04:17,110 --> 00:04:15,280
people could look up at the sky find

112
00:04:19,349 --> 00:04:17,120
clues that would help them put together

113
00:04:22,150 --> 00:04:19,359

a story of why things are the way they

114
00:04:24,550 --> 00:04:22,160
are now also had a particularly soft

115
00:04:26,150 --> 00:04:24,560
spot in my heart for science fiction i

116
00:04:27,830 --> 00:04:26,160
did a lot of reading my mom in

117
00:04:29,990 --> 00:04:27,840
particular liked watching a lot of

118
00:04:31,030 --> 00:04:30,000
science fiction shows when she was

119
00:04:33,350 --> 00:04:31,040
growing up

120
00:04:35,670 --> 00:04:33,360
and the star trek show came on for the

121
00:04:37,110 --> 00:04:35,680
first time in the 60s lieutenant uhura

122
00:04:39,830 --> 00:04:37,120
looked very much like one of her older

123
00:04:41,990 --> 00:04:39,840
sisters and so that's why she and her

124
00:04:44,070 --> 00:04:42,000
and her three sisters got hooked on that

125
00:04:47,270 --> 00:04:44,080
show and then caught the science fiction

126
00:04:49,270 --> 00:04:47,280
bug in general and i grew up at her knee

127
00:04:51,590 --> 00:04:49,280
watching those shows and also star trek

128
00:04:53,350 --> 00:04:51,600
next generation star wars battlestar

129
00:04:55,189 --> 00:04:53,360
galactica you named it we watched it the

130
00:04:57,990 --> 00:04:55,199
shows that came out in the theater on

131
00:04:59,830 --> 00:04:58,000
the tv etc and that was kind of what

132
00:05:03,510 --> 00:04:59,840
caused me to be interested in doing

133
00:05:06,469 --> 00:05:03,520
something with space as i got older

134
00:05:08,950 --> 00:05:06,479
and also there's a real part that got

135
00:05:11,270 --> 00:05:08,960
played in my life in terms of just

136
00:05:13,670 --> 00:05:11,280
having an opportunity to experience the

137
00:05:15,510 --> 00:05:13,680
wonders of the night sky with the naked

138
00:05:17,590 --> 00:05:15,520

eye i grew up in louisville kentucky

139
00:05:19,590 --> 00:05:17,600
which is not a city that has a patch on

140
00:05:20,469 --> 00:05:19,600
atlanta or even los angeles where i live

141
00:05:22,150 --> 00:05:20,479
now

142
00:05:24,310 --> 00:05:22,160
but there was enough light pollution

143
00:05:26,710 --> 00:05:24,320
that it was only when i was about 14 or

144
00:05:29,670 --> 00:05:26,720
so and had an opportunity to spend a few

145
00:05:32,629 --> 00:05:29,680
weeks at a college farther away from a

146
00:05:35,510 --> 00:05:32,639
big city with a group of kids and

147
00:05:38,070 --> 00:05:35,520
teachers who were introducing us to the

148
00:05:39,830 --> 00:05:38,080
joys of astronomy and they took us out

149
00:05:42,390 --> 00:05:39,840
in a field at night

150
00:05:45,510 --> 00:05:42,400
let our eyes get dark adapted we had the

151
00:05:47,270 --> 00:05:45,520
little flashlights that just had the red

152
00:05:49,749 --> 00:05:47,280
filter over them to not ruin your night

153
00:05:51,990 --> 00:05:49,759
vision and i remembering once my vision

154
00:05:53,909 --> 00:05:52,000
adapted having an opportunity to see the

155
00:05:56,070 --> 00:05:53,919
night sky and having to stop and ask

156
00:05:58,710 --> 00:05:56,080
somebody i'm like what what is that like

157
00:06:01,270 --> 00:05:58,720
i had no idea you could actually see the

158
00:06:02,870 --> 00:06:01,280
milky way with your own naked eye and

159
00:06:05,110 --> 00:06:02,880
once they explain that that's what it is

160
00:06:06,790 --> 00:06:05,120
you can see it without telescopes or

161
00:06:08,629 --> 00:06:06,800
without the hubble or without special

162
00:06:10,550 --> 00:06:08,639
observatories when you can get away from

163
00:06:12,350 --> 00:06:10,560

cities and the night sky is dark enough

164
00:06:15,350 --> 00:06:12,360
it was kind of a jaw-dropping

165
00:06:17,590 --> 00:06:15,360
awe-inspiring experience for me

166
00:06:19,350 --> 00:06:17,600
and similarly in that same few week

167
00:06:21,749 --> 00:06:19,360
summer between my

168
00:06:23,350 --> 00:06:21,759
my junior and senior year in high school

169
00:06:25,350 --> 00:06:23,360
they also had a bunch of telescopes that

170
00:06:27,029 --> 00:06:25,360
they had brought with them and set up

171
00:06:28,950 --> 00:06:27,039
for us to look through this is not an

172
00:06:30,070 --> 00:06:28,960
image we took with that telescope

173
00:06:32,150 --> 00:06:30,080
this one from the internet you can see

174
00:06:34,629 --> 00:06:32,160
the image credit at the bottom but this

175
00:06:37,590 --> 00:06:34,639
is what jupiter and its four moons look

176
00:06:40,230 --> 00:06:37,600
like through a telescope and i remember

177
00:06:42,870 --> 00:06:40,240
being surprised at just how

178
00:06:45,270 --> 00:06:42,880
amazing it felt to see that because

179
00:06:47,430 --> 00:06:45,280
being a child of the 80s 70s and 80s i

180
00:06:49,510 --> 00:06:47,440
got to grow up with the beautiful images

181
00:06:51,830 --> 00:06:49,520
that the voyager sent back of the outer

182
00:06:54,710 --> 00:06:51,840
planet so we knew what they looked like

183
00:06:56,390 --> 00:06:54,720
and all their glory from voyager images

184
00:06:58,390 --> 00:06:56,400
and being able to see it

185
00:07:00,870 --> 00:06:58,400
this way yes it's smaller but you can

186
00:07:03,189 --> 00:07:00,880
actually see the rings you can actually

187
00:07:04,950 --> 00:07:03,199
see the four galilean satellites and

188
00:07:07,270 --> 00:07:04,960

there was something about knowing that

189
00:07:09,270 --> 00:07:07,280
the photons entering my eye that came

190
00:07:10,710 --> 00:07:09,280
through the telescope were actually

191
00:07:12,150 --> 00:07:10,720
originally from the sun that went all

192
00:07:14,309 --> 00:07:12,160
the way out to jupiter bounced off of

193
00:07:16,950 --> 00:07:14,319
that planet all the way back and i was

194
00:07:19,029 --> 00:07:16,960
seeing it in real time with a time delay

195
00:07:21,670 --> 00:07:19,039
from the light time but i also remember

196
00:07:24,710 --> 00:07:21,680
just being astonished that these these

197
00:07:26,230 --> 00:07:24,720
things felt so close in our backyard

198
00:07:28,629 --> 00:07:26,240
that you could see them with your

199
00:07:31,510 --> 00:07:28,639
slightly aided eye and increased my

200
00:07:34,390 --> 00:07:31,520
desire to have something to do with

201
00:07:37,189 --> 00:07:34,400
space exploration when i grew up and

202
00:07:38,790 --> 00:07:37,199
went to college and got a job

203
00:07:40,469 --> 00:07:38,800
i wound up going to school for my

204
00:07:42,390 --> 00:07:40,479
bachelor's degree at the university of

205
00:07:44,710 --> 00:07:42,400
kentucky not too far from home about 70

206
00:07:46,550 --> 00:07:44,720
miles down the road from louisville

207
00:07:48,390 --> 00:07:46,560
and when i was there i was very very

208
00:07:50,629 --> 00:07:48,400
fortunate to land an internship

209
00:07:53,270 --> 00:07:50,639
opportunity at the nasa langley research

210
00:07:55,670 --> 00:07:53,280
center this was in the 90s and so well

211
00:07:57,510 --> 00:07:55,680
before i or many other people knew

212
00:07:59,510 --> 00:07:57,520
anything about the hidden figures story

213
00:08:01,189 --> 00:07:59,520

is very special to me now to know that i

214
00:08:03,029 --> 00:08:01,199
had an opportunity to be walking those

215
00:08:04,950 --> 00:08:03,039
hallways and working with people in the

216
00:08:07,110 --> 00:08:04,960
same place where all of those beautiful

217
00:08:08,790 --> 00:08:07,120
stories took place when i was there i

218
00:08:10,309 --> 00:08:08,800
got to work with a bunch of engineers

219
00:08:13,110 --> 00:08:10,319
who were doing work more on the

220
00:08:15,909 --> 00:08:13,120
aerospace airplane side of the house and

221
00:08:18,710 --> 00:08:15,919
testing scramjet engine inlets and wind

222
00:08:20,550 --> 00:08:18,720
tunnels and working on flight simulators

223
00:08:23,350 --> 00:08:20,560
very cool things that was my first

224
00:08:25,270 --> 00:08:23,360
experience working with the nasa family

225
00:08:27,270 --> 00:08:25,280
and then i went to school at georgia

226
00:08:29,110 --> 00:08:27,280
tech for my master's degree also in

227
00:08:32,230 --> 00:08:29,120
mechanical engineering i was there from

228
00:08:34,389 --> 00:08:32,240
about um 98 to 2000 working in the

229
00:08:36,310 --> 00:08:34,399
mechanical engineering department on a

230
00:08:38,870 --> 00:08:36,320
on an experiment that had very little to

231
00:08:41,430 --> 00:08:38,880
do with aerospace but was great in terms

232
00:08:44,389 --> 00:08:41,440
of continuing to build my chops as an

233
00:08:46,389 --> 00:08:44,399
engineer for working complex problems

234
00:08:48,790 --> 00:08:46,399
and interacting with different people to

235
00:08:51,110 --> 00:08:48,800
get things resolved and

236
00:08:52,470 --> 00:08:51,120
uh jpl showed up at a career fair at

237
00:08:53,990 --> 00:08:52,480
georgia tech and that's where i met the

238
00:08:56,230 --> 00:08:54,000

first jpl recruiter and got an

239
00:08:59,190 --> 00:08:56,240
opportunity to learn a bit more about

240
00:09:00,870 --> 00:08:59,200
jpl and the work that is done there

241
00:09:03,269 --> 00:09:00,880
this is pre-internet i am that old and

242
00:09:06,230 --> 00:09:03,279
so i actually was not very aware of them

243
00:09:08,070 --> 00:09:06,240
until having that chance so i was very

244
00:09:09,509 --> 00:09:08,080
fortunate to be brought out to interview

245
00:09:10,470 --> 00:09:09,519
with the systems engineering division

246
00:09:12,710 --> 00:09:10,480
i'll talk a little bit about what

247
00:09:15,350 --> 00:09:12,720
systems engineering is and i have been

248
00:09:17,910 --> 00:09:15,360
here a happy member of jcl

249
00:09:19,829 --> 00:09:17,920
for that whole time

250
00:09:21,430 --> 00:09:19,839
so for people who are used to coming to

251
00:09:23,190 --> 00:09:21,440
this conference i know this is all old

252
00:09:24,389 --> 00:09:23,200
hat but since this is a public plenary

253
00:09:26,470 --> 00:09:24,399
for those of you who are not very

254
00:09:29,509 --> 00:09:26,480
familiar with the lab it is a gorgeous

255
00:09:32,070 --> 00:09:29,519
place about 150 buildings roughly 6 000

256
00:09:34,389 --> 00:09:32,080
employees nestled in this valley in

257
00:09:36,070 --> 00:09:34,399
pasadena california where it rarely

258
00:09:38,949 --> 00:09:36,080
snows but they captured that in this

259
00:09:41,910 --> 00:09:38,959
image that i happen to take and jpl is

260
00:09:43,750 --> 00:09:41,920
known for deep space exploration of our

261
00:09:46,550 --> 00:09:43,760
solar system autonomous exploration of

262
00:09:49,030 --> 00:09:46,560
the solar system and there's a lot of

263
00:09:52,230 --> 00:09:49,040

really amazing historical firsts that

264
00:09:53,990 --> 00:09:52,240
happened here the united states first

265
00:09:57,030 --> 00:09:54,000
satellite that was put in orbit around

266
00:09:59,829 --> 00:09:57,040
the whole planet in 1958 was explorer

267
00:10:01,430 --> 00:09:59,839
one that was built and launched by jpl

268
00:10:03,910 --> 00:10:01,440
the voyager spacecraft that i already

269
00:10:06,069 --> 00:10:03,920
mentioned one and two are with our first

270
00:10:07,670 --> 00:10:06,079
experience with exploring the outer

271
00:10:10,150 --> 00:10:07,680
planets and sending back really cool

272
00:10:12,470 --> 00:10:10,160
images and data from those cassini that

273
00:10:13,910 --> 00:10:12,480
orbited saturn for many years and so on

274
00:10:16,230 --> 00:10:13,920
and so on there are

275
00:10:17,910 --> 00:10:16,240
many missions in the past and more than

276
00:10:20,310 --> 00:10:17,920
a couple dozen missions in operation at

277
00:10:23,190 --> 00:10:20,320
any given time and instruments that jpl

278
00:10:25,190 --> 00:10:23,200
has built and put on other spacecraft

279
00:10:27,829 --> 00:10:25,200
partnered with other

280
00:10:31,590 --> 00:10:27,839
centers so it's a very exciting place to

281
00:10:34,310 --> 00:10:31,600
be lots of really cool things going on

282
00:10:36,870 --> 00:10:34,320
and for me personally and my adventures

283
00:10:39,030 --> 00:10:36,880
at the lab i've been here for about 22

284
00:10:40,710 --> 00:10:39,040
years and as an engineer i tend to hop

285
00:10:42,630 --> 00:10:40,720
from mission to mission and have the

286
00:10:44,470 --> 00:10:42,640
great fortune to work on a variety of

287
00:10:47,269 --> 00:10:44,480
things as you heard from melissa in the

288
00:10:49,750 --> 00:10:47,279

intro i spent my i think of my formative

289
00:10:51,910 --> 00:10:49,760
years as a baby systems engineer on the

290
00:10:53,269 --> 00:10:51,920
mars reconnaissance orbiter which is a

291
00:10:55,590 --> 00:10:53,279
partnership with lockheed martin as

292
00:10:57,430 --> 00:10:55,600
assistant contractor i started on that

293
00:10:59,430 --> 00:10:57,440
mission in 2001 which is about four

294
00:11:02,069 --> 00:10:59,440
years before launch and got to go

295
00:11:04,710 --> 00:11:02,079
through a lot of the process of refining

296
00:11:06,790 --> 00:11:04,720
the design doing tests and analyses and

297
00:11:09,430 --> 00:11:06,800
then into operations for a couple of

298
00:11:11,190 --> 00:11:09,440
years which got us all the way to the

299
00:11:13,110 --> 00:11:11,200
planet the six months of aerobraking

300
00:11:15,670 --> 00:11:13,120
that we did and then about a year of

301
00:11:18,150 --> 00:11:15,680
good science good solid science and

302
00:11:20,470 --> 00:11:18,160
relay operations there before i moved on

303
00:11:22,630 --> 00:11:20,480
to a different mission

304
00:11:26,470 --> 00:11:22,640
i joined kepler just about a year and a

305
00:11:27,670 --> 00:11:26,480
half before launch it launched in 2009

306
00:11:29,590 --> 00:11:27,680
and while i'm not going to talk very

307
00:11:31,030 --> 00:11:29,600
much about kepler today if you don't

308
00:11:32,069 --> 00:11:31,040
know much about kepler and maybe those

309
00:11:33,269 --> 00:11:32,079
of you who are familiar with this

310
00:11:34,870 --> 00:11:33,279
conference i've heard lots of

311
00:11:37,829 --> 00:11:34,880
presentations from the scientists over

312
00:11:39,269 --> 00:11:37,839
the years do yourself a favor and go do

313
00:11:40,949 --> 00:11:39,279

a little bit of research into the

314
00:11:44,069 --> 00:11:40,959
amazing discoveries that kepler has

315
00:11:45,670 --> 00:11:44,079
found it really as an exoplanet hunter

316
00:11:47,910 --> 00:11:45,680
and an exoplanet hunter that's looking

317
00:11:49,990 --> 00:11:47,920
for planets that are in the habitable

318
00:11:52,069 --> 00:11:50,000
zone of its planet and elsewhere but all

319
00:11:54,550 --> 00:11:52,079
of its star also there it's kind of

320
00:11:57,509 --> 00:11:54,560
revolutionized our understanding of how

321
00:11:59,350 --> 00:11:57,519
common planets are in our galaxy i think

322
00:12:01,030 --> 00:11:59,360
that's going to be a highlight of my

323
00:12:02,790 --> 00:12:01,040
career for a very long time no matter

324
00:12:04,069 --> 00:12:02,800
how long i keep working

325
00:12:05,509 --> 00:12:04,079
juno is one of the missions that i'm

326
00:12:07,350 --> 00:12:05,519
going to spend some time talking about

327
00:12:09,190 --> 00:12:07,360
today so i won't say much about it right

328
00:12:11,269 --> 00:12:09,200
now except that i joined the mission

329
00:12:13,269 --> 00:12:11,279
about two years prior to launch and

330
00:12:15,750 --> 00:12:13,279
worked on it for another seven years

331
00:12:17,829 --> 00:12:15,760
after that did a whole five year journey

332
00:12:19,670 --> 00:12:17,839
to jupiter in a couple of years once we

333
00:12:22,150 --> 00:12:19,680
got there we had lots of super fun

334
00:12:24,790 --> 00:12:22,160
adventures along the way

335
00:12:28,230 --> 00:12:24,800
then i put a sent in on psyche for a

336
00:12:29,710 --> 00:12:28,240
couple of years from 2000 from 2018 um

337
00:12:32,790 --> 00:12:29,720
all the way to about

338
00:12:34,470 --> 00:12:32,800

2020. that mission has not yet launched

339
00:12:36,550 --> 00:12:34,480
um they're gearing up to be launching

340
00:12:39,190 --> 00:12:36,560
later this year heading out to visit one

341
00:12:41,190 --> 00:12:39,200
of the largest asteroids in the main

342
00:12:43,110 --> 00:12:41,200
belt in order to understand a little

343
00:12:45,350 --> 00:12:43,120
more about its formation it's one that

344
00:12:46,629 --> 00:12:45,360
has a very high metal content and

345
00:12:49,829 --> 00:12:46,639
there's an interesting theories out

346
00:12:51,509 --> 00:12:49,839
there about how it could form

347
00:12:53,269 --> 00:12:51,519
europa clipper is the mission that i am

348
00:12:54,710 --> 00:12:53,279
on now as the lead flight systems

349
00:12:56,629 --> 00:12:54,720
engineer i have been on this mission

350
00:12:58,710 --> 00:12:56,639
since 2020 i joined right at the

351
00:13:01,350 --> 00:12:58,720
beginning of the pandemic about may of

352
00:13:03,350 --> 00:13:01,360
2020 leading a team of about 40 systems

353
00:13:05,190 --> 00:13:03,360
engineers doing various things to help

354
00:13:07,670 --> 00:13:05,200
mature the design of that spacecraft and

355
00:13:09,590 --> 00:13:07,680
get us ready for launching in october

356
00:13:14,069 --> 00:13:09,600
2024 and i'll be talking quite a bit

357
00:13:18,790 --> 00:13:17,190
so what is a system and what do systems

358
00:13:20,870 --> 00:13:18,800
engineers do

359
00:13:22,310 --> 00:13:20,880
this is kind of a cartoon taken from the

360
00:13:24,230 --> 00:13:22,320
mars reconnaissance orbiter which is

361
00:13:26,470 --> 00:13:24,240
where i first learned how we do systems

362
00:13:27,990 --> 00:13:26,480
engineering here at the lab systems

363
00:13:30,150 --> 00:13:28,000

engineers work at a whole bunch of

364
00:13:31,910 --> 00:13:30,160
different levels on missions but i'll

365
00:13:33,509 --> 00:13:31,920
talk a bit about the spacecraft one

366
00:13:35,670 --> 00:13:33,519
because that's the one that's the most

367
00:13:37,110 --> 00:13:35,680
easy to visualize and describe so a

368
00:13:39,750 --> 00:13:37,120
system basically

369
00:13:41,829 --> 00:13:39,760
is a complex set of things that all have

370
00:13:44,790 --> 00:13:41,839
to work together in order to accomplish

371
00:13:46,470 --> 00:13:44,800
some kind of goal and a system engineer

372
00:13:48,389 --> 00:13:46,480
needs to know a bit about all the

373
00:13:50,710 --> 00:13:48,399
different functional areas that have to

374
00:13:53,910 --> 00:13:50,720
work together and make sure that across

375
00:13:57,030 --> 00:13:53,920
the whole cycle of the design we are

376
00:13:59,189 --> 00:13:57,040
making choices that ensure they will all

377
00:14:00,629 --> 00:13:59,199
work well in order to accomplish the

378
00:14:01,990 --> 00:14:00,639
mission goals

379
00:14:03,189 --> 00:14:02,000
and i'll give you an example when you

380
00:14:05,350 --> 00:14:03,199
have a spacecraft like mars

381
00:14:06,870 --> 00:14:05,360
reconnaissance orbiter it needs to

382
00:14:08,870 --> 00:14:06,880
communicate with the earth through some

383
00:14:11,269 --> 00:14:08,880
kind of telecom system it needs to be

384
00:14:13,110 --> 00:14:11,279
able to orient itself relative to the

385
00:14:15,590 --> 00:14:13,120
things it's trying to measure and also

386
00:14:17,829 --> 00:14:15,600
the sun and also the earth that has

387
00:14:19,829 --> 00:14:17,839
mechanisms that help maybe gimbal the

388
00:14:22,310 --> 00:14:19,839

solar array and the high gain antenna

389
00:14:23,990 --> 00:14:22,320
separately from the body power system to

390
00:14:25,750 --> 00:14:24,000
get power to all of the components

391
00:14:27,189 --> 00:14:25,760
propulsion to make sure that you're on

392
00:14:28,069 --> 00:14:27,199
the right trajectory that you need to go

393
00:14:29,990 --> 00:14:28,079
to

394
00:14:31,910 --> 00:14:30,000
thermal it's cold out there in face and

395
00:14:33,590 --> 00:14:31,920
also hot when the sun is shining on you

396
00:14:35,430 --> 00:14:33,600
so we have to keep things from getting

397
00:14:36,629 --> 00:14:35,440
too hot or too cold and then the whole

398
00:14:38,230 --> 00:14:36,639
reason we're sending the spacecraft

399
00:14:40,470 --> 00:14:38,240
where they're going which is the

400
00:14:41,829 --> 00:14:40,480
instruments in order to take data to

401
00:14:43,750 --> 00:14:41,839
send back to the ground to the

402
00:14:46,230 --> 00:14:43,760
scientists to make all of their great

403
00:14:48,389 --> 00:14:46,240
discoveries and as a systems engineer i

404
00:14:50,550 --> 00:14:48,399
am never going to be 100

405
00:14:52,150 --> 00:14:50,560
up to speed on every single aspect of

406
00:14:54,150 --> 00:14:52,160
the spacecraft i have to rely very

407
00:14:56,949 --> 00:14:54,160
heavily on the subject matter experts

408
00:14:58,470 --> 00:14:56,959
who work in those areas but there are

409
00:15:00,870 --> 00:14:58,480
decisions that we have to make early on

410
00:15:03,430 --> 00:15:00,880
in a design for instance should we have

411
00:15:05,269 --> 00:15:03,440
solar array should we have nuclear power

412
00:15:07,189 --> 00:15:05,279
and the choices that you make the pros

413
00:15:09,269 --> 00:15:07,199

and cons associated with both of those

414
00:15:10,710 --> 00:15:09,279
end up driving a lot of other aspects of

415
00:15:13,269 --> 00:15:10,720
the design

416
00:15:15,590 --> 00:15:13,279
telecom versus attitude control is

417
00:15:17,509 --> 00:15:15,600
another good one we want to have a very

418
00:15:19,189 --> 00:15:17,519
strong telecom signal so that we can

419
00:15:20,870 --> 00:15:19,199
send high data rate back to earth

420
00:15:22,230 --> 00:15:20,880
especially for some of these science

421
00:15:25,430 --> 00:15:22,240
missions that are sending back lots of

422
00:15:27,590 --> 00:15:25,440
data you can do that by having a very

423
00:15:28,550 --> 00:15:27,600
strong amplifier that uses a lot of

424
00:15:32,470 --> 00:15:28,560
power

425
00:15:35,030 --> 00:15:32,480
that are going out in deep space you can

426
00:15:37,590 --> 00:15:35,040
have less power for telecom and have a

427
00:15:39,350 --> 00:15:37,600
much tighter attitude control system so

428
00:15:41,430 --> 00:15:39,360
that you can put the strongest point of

429
00:15:43,670 --> 00:15:41,440
your signal directly on a deep space

430
00:15:45,749 --> 00:15:43,680
antenna and be able to get the link that

431
00:15:48,389 --> 00:15:45,759
you need and preserve a lot of power for

432
00:15:50,389 --> 00:15:48,399
other things like meters and running the

433
00:15:52,069 --> 00:15:50,399
other components on a spacecraft and

434
00:15:54,550 --> 00:15:52,079
i'll talk in a minute perhaps the next

435
00:15:57,829 --> 00:15:54,560
slide about uh yeah the different

436
00:16:00,069 --> 00:15:57,839
aspects of a whole flight system design

437
00:16:02,230 --> 00:16:00,079
cycle and what it is that systems

438
00:16:04,389 --> 00:16:02,240

engineers are doing a little bit

439
00:16:07,590 --> 00:16:04,399
across that whole thing so this is based

440
00:16:10,069 --> 00:16:07,600
on a juno example missions start off

441
00:16:12,389 --> 00:16:10,079
with science questions um what are what

442
00:16:14,870 --> 00:16:12,399
are we trying to learn about the

443
00:16:17,269 --> 00:16:14,880
bodies that we are studying for juno

444
00:16:19,670 --> 00:16:17,279
what what is the core like how deep do

445
00:16:23,350 --> 00:16:19,680
those storms on the surface go how much

446
00:16:24,949 --> 00:16:23,360
water is in the atmosphere etc and then

447
00:16:27,189 --> 00:16:24,959
we come up with some kind of a mission

448
00:16:28,870 --> 00:16:27,199
design in order to learn those things to

449
00:16:29,749 --> 00:16:28,880
get the data necessary to learn those

450
00:16:32,230 --> 00:16:29,759
things

451
00:16:34,949 --> 00:16:32,240
can you point a giant telescope from the

452
00:16:36,389 --> 00:16:34,959
earth at that body can you have a flyby

453
00:16:38,389 --> 00:16:36,399
mission for that body do you need to go

454
00:16:40,069 --> 00:16:38,399
into orbit around that body should you

455
00:16:41,990 --> 00:16:40,079
go in orbit at the equator should you go

456
00:16:43,990 --> 00:16:42,000
into orbit around the poles all sorts of

457
00:16:46,870 --> 00:16:44,000
things and that's where engineers get

458
00:16:48,710 --> 00:16:46,880
involved in order to help determine how

459
00:16:50,550 --> 00:16:48,720
we get that information

460
00:16:52,310 --> 00:16:50,560
and working with the scientists still we

461
00:16:54,069 --> 00:16:52,320
come up with a detailed design of the

462
00:16:55,430 --> 00:16:54,079
spacecraft and they're engineers who

463
00:16:58,790 --> 00:16:55,440

work with scientists to come up with

464
00:17:00,629 --> 00:16:58,800
detailed design instruments and you are

465
00:17:03,030 --> 00:17:00,639
working out ways to put them together as

466
00:17:05,590 --> 00:17:03,040
an overall system which will be able to

467
00:17:07,909 --> 00:17:05,600
accomplish those goals

468
00:17:09,990 --> 00:17:07,919
we go through the assembly and test

469
00:17:11,189 --> 00:17:10,000
process at every level even down at the

470
00:17:13,110 --> 00:17:11,199
component levels we're doing lots of

471
00:17:14,789 --> 00:17:13,120
testing and analyses and you get to a

472
00:17:16,789 --> 00:17:14,799
point at the system level where you're

473
00:17:18,390 --> 00:17:16,799
integrating everything together and

474
00:17:20,069 --> 00:17:18,400
you're testing it in all sorts of ways

475
00:17:21,590 --> 00:17:20,079
in order to make sure it's functioning

476
00:17:23,189 --> 00:17:21,600
the way you should i'll talk a little

477
00:17:24,390 --> 00:17:23,199
bit about how we

478
00:17:27,110 --> 00:17:24,400
try to think of all the things that can

479
00:17:29,590 --> 00:17:27,120
go wrong and deal with those as well

480
00:17:32,070 --> 00:17:29,600
then we button it all up on the top of a

481
00:17:33,830 --> 00:17:32,080
rocket and send it on its way and we're

482
00:17:36,310 --> 00:17:33,840
in the operations phase where we're

483
00:17:38,549 --> 00:17:36,320
making our way to our destination in

484
00:17:40,390 --> 00:17:38,559
order to gather the data that the

485
00:17:42,630 --> 00:17:40,400
scientists need to answer the questions

486
00:17:47,270 --> 00:17:42,640
and close the circle all the way back to

487
00:17:49,190 --> 00:17:47,280
why we're going there in the first one

488
00:17:51,669 --> 00:17:49,200

so as an engineer working on these

489
00:17:53,510 --> 00:17:51,679
missions it is really valuable for me to

490
00:17:55,669 --> 00:17:53,520
know enough about the science that the

491
00:17:57,590 --> 00:17:55,679
scientists are trying to do so that if

492
00:17:59,510 --> 00:17:57,600
we have to make choices that could

493
00:18:00,950 --> 00:17:59,520
impact the science we are

494
00:18:03,110 --> 00:18:00,960
well-versed enough to communicate with

495
00:18:04,870 --> 00:18:03,120
the scientists and do the right thing by

496
00:18:06,470 --> 00:18:04,880
the mission as well as making sure that

497
00:18:08,230 --> 00:18:06,480
we're going to be able to

498
00:18:10,070 --> 00:18:08,240
execute the mission

499
00:18:11,750 --> 00:18:10,080
on time and on budget within all the

500
00:18:13,590 --> 00:18:11,760
resources that we have

501
00:18:15,669 --> 00:18:13,600
and the science is just cool that's the

502
00:18:17,750 --> 00:18:15,679
reason why i got into doing this kind of

503
00:18:19,750 --> 00:18:17,760
work in the first place and so i think

504
00:18:22,630 --> 00:18:19,760
about the kinds of things that we knew

505
00:18:23,909 --> 00:18:22,640
about jupiter before we sent juno to go

506
00:18:26,390 --> 00:18:23,919
study it and the kinds of things i like

507
00:18:27,270 --> 00:18:26,400
to talk to kids about it's really big

508
00:18:28,950 --> 00:18:27,280
got

509
00:18:30,870 --> 00:18:28,960
lots of hydrogen and helium it has this

510
00:18:33,110 --> 00:18:30,880
cool red spot you can fit 11 earths

511
00:18:35,830 --> 00:18:33,120
across the middle lots and lots of moons

512
00:18:38,230 --> 00:18:35,840
including the 4 that galileo discovered

513
00:18:40,549 --> 00:18:38,240

with this telescope and rings like all

514
00:18:42,230 --> 00:18:40,559
of the gas giants have

515
00:18:44,230 --> 00:18:42,240
and then

516
00:18:46,549 --> 00:18:44,240
for juno in the beginning of that circle

517
00:18:48,230 --> 00:18:46,559
that i showed about the mission design

518
00:18:50,390 --> 00:18:48,240
there are several questions that the

519
00:18:52,070 --> 00:18:50,400
scientists wanted to answer and i won't

520
00:18:54,070 --> 00:18:52,080
go into these in detail juno's been

521
00:18:56,870 --> 00:18:54,080
around for long enough that you've heard

522
00:18:59,510 --> 00:18:56,880
this talk from many scientists at this

523
00:19:01,430 --> 00:18:59,520
con at this conference in other places

524
00:19:02,950 --> 00:19:01,440
describing all the details of the juicy

525
00:19:04,310 --> 00:19:02,960
things that they're trying to squeeze

526
00:19:05,990 --> 00:19:04,320
out of this spacecraft and the

527
00:19:07,430 --> 00:19:06,000
instruments to learn about the planet

528
00:19:09,510 --> 00:19:07,440
but it's basically something that'll

529
00:19:12,070 --> 00:19:09,520
help the scientists zero in on specific

530
00:19:13,430 --> 00:19:12,080
theories of how jupiter was formed its

531
00:19:15,430 --> 00:19:13,440
origin story

532
00:19:17,510 --> 00:19:15,440
understand more about the interior and

533
00:19:20,230 --> 00:19:17,520
how it's structured in there the

534
00:19:21,909 --> 00:19:20,240
atmosphere to map variations in the

535
00:19:24,789 --> 00:19:21,919
composition understand how these those

536
00:19:26,630 --> 00:19:24,799
storms go and the magnetic sphere to to

537
00:19:29,110 --> 00:19:26,640
kind of characterize that whole

538
00:19:31,270 --> 00:19:29,120

structure of its magnetic field and as

539
00:19:32,630 --> 00:19:31,280
an engineer the thing that is most

540
00:19:35,029 --> 00:19:32,640
relevant to what we're doing in

541
00:19:37,270 --> 00:19:35,039
designing the spacecraft in my mind is

542
00:19:39,190 --> 00:19:37,280
really this last one the magnetic field

543
00:19:41,750 --> 00:19:39,200
jupiter's magnetic field is really

544
00:19:43,909 --> 00:19:41,760
really powerful and it traps charged

545
00:19:46,950 --> 00:19:43,919
particles from the solar wind and also

546
00:19:48,950 --> 00:19:46,960
from volcanic io and accelerates those

547
00:19:51,110 --> 00:19:48,960
particles to near relativistic speeds

548
00:19:54,390 --> 00:19:51,120
and creates this i think of it as a

549
00:19:56,470 --> 00:19:54,400
donut of radiation around the planet um

550
00:19:58,150 --> 00:19:56,480
jupiter is like a it's like a little

551
00:19:59,909 --> 00:19:58,160
bead sitting in the middle of this donut

552
00:20:01,990 --> 00:19:59,919
hole and if we're going to go there and

553
00:20:04,070 --> 00:20:02,000
study it we have to deal with this

554
00:20:05,750 --> 00:20:04,080
radiation environment and figure out how

555
00:20:08,470 --> 00:20:05,760
to have a spacecraft that is going to

556
00:20:11,190 --> 00:20:08,480
survive it and be able to get all the

557
00:20:12,630 --> 00:20:11,200
data and send it back to the scientists

558
00:20:14,789 --> 00:20:12,640
and there are a couple of ways that juno

559
00:20:16,870 --> 00:20:14,799
was able to do this by combining both

560
00:20:19,029 --> 00:20:16,880
the way the spacecraft was designed and

561
00:20:21,110 --> 00:20:19,039
also the way the mission was designed to

562
00:20:24,710 --> 00:20:21,120
not spend a whole lot of time down

563
00:20:30,230 --> 00:20:27,430

the spacecraft was launched in august

564
00:20:32,390 --> 00:20:30,240
2011 from the cape and you can see how

565
00:20:33,990 --> 00:20:32,400
it was folded up with the solar rays fit

566
00:20:35,510 --> 00:20:34,000
in the top of the rocket and then once

567
00:20:37,990 --> 00:20:35,520
the fairing

568
00:20:40,149 --> 00:20:38,000
ejected the solar arrays were deployed

569
00:20:41,590 --> 00:20:40,159
out and pointed at the sun

570
00:20:43,029 --> 00:20:41,600
we didn't have a launch vehicle big

571
00:20:44,549 --> 00:20:43,039
enough to send us all the way out to

572
00:20:46,149 --> 00:20:44,559
jupiter and one fell swoop with this

573
00:20:47,669 --> 00:20:46,159
giant spacecraft you'll see how big it

574
00:20:50,230 --> 00:20:47,679
is in a couple of slides

575
00:20:52,710 --> 00:20:50,240
so we sent it out on a path that took it

576
00:20:54,070 --> 00:20:52,720
out past the orbit of mars that's this

577
00:20:56,070 --> 00:20:54,080
red circle

578
00:20:58,149 --> 00:20:56,080
all the way out and about a year after

579
00:21:00,149 --> 00:20:58,159
launch we did two deep space maneuvers

580
00:21:02,070 --> 00:21:00,159
where we fired our main engines for

581
00:21:04,390 --> 00:21:02,080
about half an hour each spread apart by

582
00:21:06,390 --> 00:21:04,400
a couple of weeks and that put us on a

583
00:21:08,390 --> 00:21:06,400
trajectory coming back by the earth a

584
00:21:11,430 --> 00:21:08,400
couple of years after launch to do an

585
00:21:13,510 --> 00:21:11,440
earth flyby gravity assist to give us a

586
00:21:16,470 --> 00:21:13,520
boost in our velocity to get all the way

587
00:21:17,990 --> 00:21:16,480
out to jupiter about three years later

588
00:21:21,990 --> 00:21:18,000

arriving there i think technically it

589
00:21:24,789 --> 00:21:22,000
was july 4th the local time in 2016.

590
00:21:27,430 --> 00:21:24,799
and once we arrived we went into orbit

591
00:21:29,350 --> 00:21:27,440
around jupiter and the way that the

592
00:21:32,310 --> 00:21:29,360
mission was designed in order to help us

593
00:21:34,149 --> 00:21:32,320
with the radiation story was instead of

594
00:21:36,310 --> 00:21:34,159
orbiting jupiter and spending a bunch of

595
00:21:38,710 --> 00:21:36,320
time going in and out of these high

596
00:21:40,870 --> 00:21:38,720
radiation zones we kind of thread the

597
00:21:43,190 --> 00:21:40,880
needle a little bit and dip between

598
00:21:45,350 --> 00:21:43,200
jupiter and the inside edge of this

599
00:21:47,510 --> 00:21:45,360
donut for each of the different orbits

600
00:21:49,510 --> 00:21:47,520
and over time the orbit kind of walks

601
00:21:52,470 --> 00:21:49,520
its way down and so we end up spending

602
00:21:54,789 --> 00:21:52,480
more time going through the radiation

603
00:21:56,789 --> 00:21:54,799
belts but doing it this way meant that

604
00:21:59,830 --> 00:21:56,799
the primary mission design was going to

605
00:22:02,070 --> 00:21:59,840
collect about 30 kilorads of radiation

606
00:22:03,430 --> 00:22:02,080
over the life of the mission um and i

607
00:22:04,789 --> 00:22:03,440
you know that is a number that i'm used

608
00:22:06,950 --> 00:22:04,799
to thinking about in terms of what the

609
00:22:08,549 --> 00:22:06,960
hardware can handle but for those of you

610
00:22:11,270 --> 00:22:08,559
who don't think about radiation doses

611
00:22:13,110 --> 00:22:11,280
all the time i've recently gone out and

612
00:22:15,110 --> 00:22:13,120
learned that when you think about how

613
00:22:16,710 --> 00:22:15,120

much dose a human body can withstand

614
00:22:18,070 --> 00:22:16,720
there's a range of radiation doses you

615
00:22:20,310 --> 00:22:18,080
could get before it will totally kill

616
00:22:23,270 --> 00:22:20,320
you but something around 1000 rads or

617
00:22:25,190 --> 00:22:23,280
one kilorad is pretty unsurvivable and

618
00:22:26,549 --> 00:22:25,200
so 30 kilorads is a pretty pretty

619
00:22:29,029 --> 00:22:26,559
healthy dose for us to design the

620
00:22:30,710 --> 00:22:29,039
spacecraft to be able to withstand

621
00:22:33,430 --> 00:22:30,720
this mission was originally designed to

622
00:22:35,350 --> 00:22:33,440
do about 32 science orbits plus a couple

623
00:22:37,270 --> 00:22:35,360
of uh precursor orbits

624
00:22:40,390 --> 00:22:37,280
and uh the rece the mission was recently

625
00:22:43,990 --> 00:22:40,400
extended out to september 2025 adding

626
00:22:45,909 --> 00:22:44,000
about 42 more orbits which will shrink

627
00:22:47,669 --> 00:22:45,919
the period and also fly by several of

628
00:22:49,590 --> 00:22:47,679
the moons for those of you who have been

629
00:22:50,870 --> 00:22:49,600
following along with juno and the

630
00:22:52,390 --> 00:22:50,880
discoveries that they've made it's been

631
00:22:54,789 --> 00:22:52,400
some pretty exciting science that they

632
00:22:56,470 --> 00:22:54,799
found so far

633
00:22:57,830 --> 00:22:56,480
a little more about the spacecraft there

634
00:22:59,590 --> 00:22:57,840
were several engineering challenges we

635
00:23:01,750 --> 00:22:59,600
had to meet i just talked a bit about

636
00:23:03,510 --> 00:23:01,760
high radiation and what we did with the

637
00:23:06,230 --> 00:23:03,520
mission design in order to try to keep

638
00:23:08,549 --> 00:23:06,240

that to a minimum we also had this

639
00:23:10,310 --> 00:23:08,559
titanium vault tucked up under the high

640
00:23:12,950 --> 00:23:10,320
gain antenna where the sensitive

641
00:23:14,950 --> 00:23:12,960
electronics live in order to knock the

642
00:23:16,310 --> 00:23:14,960
amount of radiation they would see in

643
00:23:17,750 --> 00:23:16,320
their environment down to something more

644
00:23:19,750 --> 00:23:17,760
like the environment that is typical

645
00:23:21,750 --> 00:23:19,760
around mars

646
00:23:23,669 --> 00:23:21,760
we are very very far from the sun i'll

647
00:23:25,990 --> 00:23:23,679
say a little bit about that and how big

648
00:23:28,070 --> 00:23:26,000
the spacecraft is but about five times

649
00:23:29,990 --> 00:23:28,080
farther away from the sun out of jupiter

650
00:23:32,470 --> 00:23:30,000
than the earth is and so we have these

651
00:23:34,470 --> 00:23:32,480
giant solar arrays to collect enough of

652
00:23:35,750 --> 00:23:34,480
that lights to turn into power from the

653
00:23:37,590 --> 00:23:35,760
spacecraft you can get a sense of their

654
00:23:39,590 --> 00:23:37,600
scale by looking at the folks here in

655
00:23:41,269 --> 00:23:39,600
these bunny suits it's also very cold

656
00:23:43,269 --> 00:23:41,279
out there so like most spacecraft here

657
00:23:45,430 --> 00:23:43,279
used to sing we have thermal blankets

658
00:23:47,190 --> 00:23:45,440
and also heaters to keep the spacecraft

659
00:23:50,310 --> 00:23:47,200
warm about half the power generated by

660
00:23:52,310 --> 00:23:50,320
the arrays goes to heater power very

661
00:23:54,310 --> 00:23:52,320
very far away from the earth so we have

662
00:23:55,990 --> 00:23:54,320
this large three meter

663
00:23:57,590 --> 00:23:56,000

high gain antenna that we use to

664
00:23:58,390 --> 00:23:57,600
communicate back at the highest data

665
00:24:00,070 --> 00:23:58,400
rates

666
00:24:01,830 --> 00:24:00,080
for the people who have really good eyes

667
00:24:03,430 --> 00:24:01,840
you can also see a medium gain antenna

668
00:24:05,350 --> 00:24:03,440
and a low gain antenna there are several

669
00:24:06,870 --> 00:24:05,360
other low gains around the spacecraft

670
00:24:08,950 --> 00:24:06,880
that we use to communicate at lower

671
00:24:11,269 --> 00:24:08,960
rates when the spacecraft isn't pointed

672
00:24:13,510 --> 00:24:11,279
directly at the earth

673
00:24:15,190 --> 00:24:13,520
and then getting into orbit we had to

674
00:24:17,029 --> 00:24:15,200
get that earth flyby to boost the

675
00:24:18,390 --> 00:24:17,039
spacecraft velocity to get all the way

676
00:24:19,750 --> 00:24:18,400
out to jupiter and then once we got

677
00:24:21,830 --> 00:24:19,760
there we had to kill off some of that

678
00:24:24,070 --> 00:24:21,840
velocity and slow down enough to get

679
00:24:26,149 --> 00:24:24,080
captured so there's a main engine

680
00:24:28,310 --> 00:24:26,159
on the business end of juno that we

681
00:24:30,710 --> 00:24:28,320
fired for half an hour in order to slow

682
00:24:35,430 --> 00:24:30,720
down enough to get captured and on july

683
00:24:38,950 --> 00:24:37,750
so the payload payload for real because

684
00:24:40,950 --> 00:24:38,960
that's the thing that is to pay off for

685
00:24:42,390 --> 00:24:40,960
going there in the first place many many

686
00:24:44,630 --> 00:24:42,400
instruments that you saw on the one

687
00:24:46,789 --> 00:24:44,640
slide are trying to gather enough data

688
00:24:48,470 --> 00:24:46,799

to allow the scientists to answer the

689
00:24:51,269 --> 00:24:48,480
questions that they had about this

690
00:24:52,630 --> 00:24:51,279
mission juno spins as it's going around

691
00:24:54,549 --> 00:24:52,640
the planet you can almost think about it

692
00:24:57,029 --> 00:24:54,559
as pinwheeling around the planet

693
00:24:59,350 --> 00:24:57,039
multiple times during each science past

694
00:25:01,350 --> 00:24:59,360
when we're closest to jupiter to gather

695
00:25:03,750 --> 00:25:01,360
information from this whole suite of

696
00:25:06,149 --> 00:25:03,760
instruments in order to answer those

697
00:25:08,149 --> 00:25:06,159
questions we also use like many missions

698
00:25:10,630 --> 00:25:08,159
do the telecom system the high gain

699
00:25:13,190 --> 00:25:10,640
antenna to do gravity science and that

700
00:25:15,269 --> 00:25:13,200
takes advantage of the doppler effect as

701
00:25:16,470 --> 00:25:15,279
the deep space network on the ground is

702
00:25:19,110 --> 00:25:16,480
listening to the signal from the

703
00:25:20,310 --> 00:25:19,120
spacecraft that gravity variations in

704
00:25:22,950 --> 00:25:20,320
jupiter

705
00:25:24,549 --> 00:25:22,960
changes the motion of the spacecraft in

706
00:25:26,549 --> 00:25:24,559
a way that we can detect in the doppler

707
00:25:33,190 --> 00:25:26,559
shift and let us learn some things about

708
00:25:37,190 --> 00:25:35,269
about the size of those solar arrays so

709
00:25:38,950 --> 00:25:37,200
out of jupiter way less light than there

710
00:25:41,190 --> 00:25:38,960
is here and when i give this talk for

711
00:25:42,789 --> 00:25:41,200
much younger people i tend to tell them

712
00:25:44,789 --> 00:25:42,799
that they can imagine the sunlight

713
00:25:46,950 --> 00:25:44,799

spreading out the way they can imagine

714
00:25:48,950 --> 00:25:46,960
plastic spreading out on a balloon you

715
00:25:50,789 --> 00:25:48,960
start with a balloon you blow it up part

716
00:25:53,430 --> 00:25:50,799
way and draw a square on it and then

717
00:25:54,630 --> 00:25:53,440
blow it up to twice that that

718
00:25:56,950 --> 00:25:54,640
width

719
00:25:58,710 --> 00:25:56,960
you end up stretching the square that

720
00:26:00,470 --> 00:25:58,720
you originally drew on there so you end

721
00:26:01,830 --> 00:26:00,480
up with a square that's twice the length

722
00:26:03,190 --> 00:26:01,840
and twice the width and you're

723
00:26:06,149 --> 00:26:03,200
stretching that same amount of plastic

724
00:26:07,990 --> 00:26:06,159
over four times the area so an area that

725
00:26:09,590 --> 00:26:08,000
is the same size only has one quarter of

726
00:26:12,470 --> 00:26:09,600
the plastic or if you're thinking about

727
00:26:14,470 --> 00:26:12,480
it as a surface of light from the sun

728
00:26:16,149 --> 00:26:14,480
going out you have one quarter of the

729
00:26:18,070 --> 00:26:16,159
amount of flight same thing you go three

730
00:26:19,830 --> 00:26:18,080
times the distance you have one ninth

731
00:26:21,029 --> 00:26:19,840
five times the distance which is where

732
00:26:22,870 --> 00:26:21,039
jupiter is

733
00:26:24,950 --> 00:26:22,880
you end up with just one twenty-fifth of

734
00:26:26,710 --> 00:26:24,960
the light out there and in order to

735
00:26:27,990 --> 00:26:26,720
power the spacecraft even though we do

736
00:26:29,909 --> 00:26:28,000
our best to make sure all of our

737
00:26:32,390 --> 00:26:29,919
components are efficient and don't need

738
00:26:34,870 --> 00:26:32,400

a lot of power you end up needing a very

739
00:26:36,870 --> 00:26:34,880
large solar array these solar arrays all

740
00:26:39,269 --> 00:26:36,880
the way out at jupiter is about a

741
00:26:42,549 --> 00:26:39,279
total what is it 66 feet across 20

742
00:26:44,070 --> 00:26:42,559
meters in diameter generate about 530

743
00:26:45,510 --> 00:26:44,080
watts of power all the way out there at

744
00:26:47,669 --> 00:26:45,520
jupiter about half of that is used for

745
00:26:49,590 --> 00:26:47,679
heat and the rest of it is used to power

746
00:26:51,110 --> 00:26:49,600
all of the instruments and do all the

747
00:26:53,269 --> 00:26:51,120
telecom and all of the engineering

748
00:26:55,750 --> 00:26:53,279
equipment onboard the spacecraft so you

749
00:26:58,149 --> 00:26:55,760
wind up with a spacecraft that is about

750
00:26:59,750 --> 00:26:58,159
the size of an nba basketball court in

751
00:27:01,510 --> 00:26:59,760
order to generate that amount of power

752
00:27:02,789 --> 00:27:01,520
which is about a third of a microwave

753
00:27:04,070 --> 00:27:02,799
which is kind of crazy when you think

754
00:27:06,630 --> 00:27:04,080
about it next time you're at home

755
00:27:08,549 --> 00:27:06,640
warming up your leftovers

756
00:27:11,590 --> 00:27:08,559
and with very complex spacecraft like

757
00:27:13,669 --> 00:27:11,600
this we have to figure out a way to find

758
00:27:14,549 --> 00:27:13,679
all the problems that can go wrong with

759
00:27:15,269 --> 00:27:14,559
it

760
00:27:16,789 --> 00:27:15,279
and

761
00:27:18,870 --> 00:27:16,799
design them out or figure out how the

762
00:27:20,230 --> 00:27:18,880
spacecraft can deal with them and this

763
00:27:22,950 --> 00:27:20,240

is one of my favorite systems

764
00:27:25,350 --> 00:27:22,960
engineering kind of processes and

765
00:27:26,389 --> 00:27:25,360
practices to go and apply because it

766
00:27:28,070 --> 00:27:26,399
gets to

767
00:27:30,310 --> 00:27:28,080
it allows you an opportunity to just do

768
00:27:32,230 --> 00:27:30,320
that creative thinking and

769
00:27:33,669 --> 00:27:32,240
in order to build out a fault tree for

770
00:27:35,430 --> 00:27:33,679
example we would start with something

771
00:27:37,190 --> 00:27:35,440
like launch we need launch to be

772
00:27:39,269 --> 00:27:37,200
successful and for lives to be

773
00:27:41,669 --> 00:27:39,279
considered successful when you get to

774
00:27:43,190 --> 00:27:41,679
the end you need to be power positive

775
00:27:45,350 --> 00:27:43,200
you're making power and not running out

776
00:27:47,190 --> 00:27:45,360
of power you need to be thermally stable

777
00:27:49,190 --> 00:27:47,200
nothing's getting too hot or too cold

778
00:27:50,789 --> 00:27:49,200
you need to be in communication with the

779
00:27:52,310 --> 00:27:50,799
spacecraft you need to be on the right

780
00:27:54,630 --> 00:27:52,320
trajectory to where you're going and so

781
00:27:56,389 --> 00:27:54,640
on and so forth and so we take those

782
00:27:58,950 --> 00:27:56,399
things and we turn them around what

783
00:28:01,669 --> 00:27:58,960
could keep us from being power positive

784
00:28:03,830 --> 00:28:01,679
well maybe my solar array did not deploy

785
00:28:05,750 --> 00:28:03,840
maybe my battery is not charging and so

786
00:28:07,510 --> 00:28:05,760
on and so forth and for each of those

787
00:28:09,750 --> 00:28:07,520
things you break it down into smaller

788
00:28:11,909 --> 00:28:09,760

parts why might my solar array not have

789
00:28:13,909 --> 00:28:11,919
deployed maybe the command didn't go out

790
00:28:15,750 --> 00:28:13,919
maybe a hinge got stuck maybe a release

791
00:28:18,230 --> 00:28:15,760
mechanism didn't fire and so on and so

792
00:28:19,669 --> 00:28:18,240
forth and you keep doing that across all

793
00:28:22,149 --> 00:28:19,679
of these different areas and you end up

794
00:28:24,870 --> 00:28:22,159
with hundreds of these little leaves for

795
00:28:27,269 --> 00:28:24,880
launch for orbit insertion for all of

796
00:28:29,110 --> 00:28:27,279
the major activities that you need to do

797
00:28:30,710 --> 00:28:29,120
and for each one of these things you go

798
00:28:31,510 --> 00:28:30,720
through this thought process of figuring

799
00:28:33,269 --> 00:28:31,520
out

800
00:28:36,070 --> 00:28:33,279
what is it that we can do to literally

801
00:28:37,590 --> 00:28:36,080
design it out so it cannot happen or

802
00:28:39,430 --> 00:28:37,600
what do we do such that if it does

803
00:28:40,789 --> 00:28:39,440
happen the spacecraft can deal with it

804
00:28:42,950 --> 00:28:40,799
and a lot of the things falling into

805
00:28:44,950 --> 00:28:42,960
that second category is that we have

806
00:28:46,310 --> 00:28:44,960
backup parts for everything that's

807
00:28:48,389 --> 00:28:46,320
really important we have two star

808
00:28:49,750 --> 00:28:48,399
trackers and four reaction wheels and we

809
00:28:51,750 --> 00:28:49,760
only need three and two inertial

810
00:28:54,070 --> 00:28:51,760
measurement units and so on and so forth

811
00:28:56,950 --> 00:28:54,080
and then for each of those things you

812
00:28:58,789 --> 00:28:56,960
have to then prove to yourself that what

813
00:29:01,269 --> 00:28:58,799

you said was going to mitigate that

814
00:29:02,870 --> 00:29:01,279
fault is actually going to work so that

815
00:29:04,630 --> 00:29:02,880
usually involves some kind of analysis

816
00:29:06,789 --> 00:29:04,640
or some kind of test or some kind of

817
00:29:08,950 --> 00:29:06,799
inspection and it's a tremendous amount

818
00:29:10,710 --> 00:29:08,960
of work at the systems engineering level

819
00:29:12,470 --> 00:29:10,720
to go through this process find all

820
00:29:14,630 --> 00:29:12,480
these leads and then prove to yourself

821
00:29:15,909 --> 00:29:14,640
that it's all going to be fine and you

822
00:29:17,830 --> 00:29:15,919
would like to think that having gone

823
00:29:19,350 --> 00:29:17,840
through all of that effort and also

824
00:29:21,190 --> 00:29:19,360
something called a failure mode effects

825
00:29:23,269 --> 00:29:21,200
criticality analysis from the bottoms up

826
00:29:25,269 --> 00:29:23,279
you take every single component and say

827
00:29:26,789 --> 00:29:25,279
if every single tiny piece failed what

828
00:29:27,830 --> 00:29:26,799
are the symptoms and would you notice

829
00:29:29,110 --> 00:29:27,840
those symptoms and what would you do

830
00:29:31,029 --> 00:29:29,120
about it it's kind of a top-down

831
00:29:33,269 --> 00:29:31,039
bottoms-up approach you would like to

832
00:29:34,470 --> 00:29:33,279
think that in flight we would have like

833
00:29:36,470 --> 00:29:34,480
found all the things and there's never

834
00:29:38,149 --> 00:29:36,480
any issues but that is absolutely not

835
00:29:39,830 --> 00:29:38,159
true because the spacecraft are so

836
00:29:41,909 --> 00:29:39,840
complex sometimes

837
00:29:44,389 --> 00:29:41,919
small things will slip past us and we

838
00:29:46,389 --> 00:29:44,399

get a little bit surprised in flight

839
00:29:48,549 --> 00:29:46,399
and so that's another interesting task

840
00:29:51,110 --> 00:29:48,559
for systems engineers is that we have an

841
00:29:52,950 --> 00:29:51,120
opportunity to play this mystery hunt

842
00:29:55,110 --> 00:29:52,960
game when something goes a little bit

843
00:29:58,149 --> 00:29:55,120
sideways of what you expected in flight

844
00:29:59,990 --> 00:29:58,159
you get to go on this discovery path to

845
00:30:01,750 --> 00:30:00,000
determine what happened why did that

846
00:30:03,750 --> 00:30:01,760
happen what can we do about it my

847
00:30:05,430 --> 00:30:03,760
spacecraft is 300 million miles from

848
00:30:07,269 --> 00:30:05,440
here i can't send an astronaut to go

849
00:30:09,750 --> 00:30:07,279
whack it for the wrench we have to do

850
00:30:11,909 --> 00:30:09,760
the investigative work figure out from

851
00:30:13,909 --> 00:30:11,919
the symptoms what the constellation of

852
00:30:16,149 --> 00:30:13,919
options could be that happen and then

853
00:30:18,789 --> 00:30:16,159
what we can do about it oftentimes in

854
00:30:21,029 --> 00:30:18,799
terms of software changes or adjusting

855
00:30:22,870 --> 00:30:21,039
the way in which we do activities or

856
00:30:24,389 --> 00:30:22,880
changing the order of commands in order

857
00:30:27,029 --> 00:30:24,399
to make sure our mission is still going

858
00:30:28,950 --> 00:30:27,039
to be on track and we had some fun times

859
00:30:30,950 --> 00:30:28,960
with juno in the five years

860
00:30:31,750 --> 00:30:30,960
along to the planet and also when we got

861
00:30:34,549 --> 00:30:31,760
there

862
00:30:36,470 --> 00:30:34,559
couple of components that were much

863
00:30:38,789 --> 00:30:36,480

warmer than we expected them to be at

864
00:30:40,630 --> 00:30:38,799
1au and so we wound up doing some

865
00:30:42,870 --> 00:30:40,640
investigations into that one of the

866
00:30:45,029 --> 00:30:42,880
components we put into this thermal

867
00:30:47,110 --> 00:30:45,039
vacuum chamber shut the door there's a

868
00:30:49,830 --> 00:30:47,120
window in here that you can't see and we

869
00:30:51,990 --> 00:30:49,840
shine some artificial sunlight on it in

870
00:30:53,750 --> 00:30:52,000
order to to simulate the conditions in

871
00:30:55,990 --> 00:30:53,760
space as much as we could and that

872
00:30:57,909 --> 00:30:56,000
allowed us to adjust our thermal model

873
00:31:00,310 --> 00:30:57,919
to be more like what we saw on the

874
00:31:01,590 --> 00:31:00,320
ground and then make predictions of what

875
00:31:03,430 --> 00:31:01,600
the temperature of those components

876
00:31:05,190 --> 00:31:03,440
would be farther downstream and

877
00:31:06,710 --> 00:31:05,200
fortunately it turned out for both of

878
00:31:08,230 --> 00:31:06,720
those cases they were not going to get

879
00:31:09,590 --> 00:31:08,240
above a temperature that was going to be

880
00:31:11,990 --> 00:31:09,600
problematic

881
00:31:13,590 --> 00:31:12,000
earth flyby was another fun time for us

882
00:31:16,149 --> 00:31:13,600
the way the original mission was

883
00:31:18,470 --> 00:31:16,159
designed we were going around jupiter at

884
00:31:20,950 --> 00:31:18,480
the poles and if you imagine you guys

885
00:31:23,590 --> 00:31:20,960
are the sun watching me and jupiter is

886
00:31:25,990 --> 00:31:23,600
orbiting kind of in a circle around my

887
00:31:27,990 --> 00:31:26,000
head around my face we never were going

888
00:31:29,990 --> 00:31:28,000

to be in a cliff we're never going to be

889
00:31:31,590 --> 00:31:30,000
behind jupiter with respect to the sun

890
00:31:33,590 --> 00:31:31,600
but we knew we were going to be behind

891
00:31:35,430 --> 00:31:33,600
the earth with effect to the sun during

892
00:31:37,190 --> 00:31:35,440
earth flyby and that was a situation

893
00:31:39,430 --> 00:31:37,200
where we were going to be relying on our

894
00:31:41,350 --> 00:31:39,440
batteries for about 19 minutes until we

895
00:31:43,990 --> 00:31:41,360
came out the other side these batteries

896
00:31:46,710 --> 00:31:44,000
were sized for like two hour eclipses at

897
00:31:48,310 --> 00:31:46,720
jupiter didn't expect any issues but we

898
00:31:49,590 --> 00:31:48,320
did have a fun surprise where the

899
00:31:51,669 --> 00:31:49,600
spacecraft did something a little bit

900
00:31:53,350 --> 00:31:51,679
different from what we had expected and

901
00:31:54,950 --> 00:31:53,360
uh turned off all the instruments and

902
00:31:57,110 --> 00:31:54,960
entered a mode we called safe mode and

903
00:31:59,350 --> 00:31:57,120
called home to tell us it had a problem

904
00:32:00,950 --> 00:31:59,360
and that is us in the jkl side of the

905
00:32:03,029 --> 00:32:00,960
mission support area standing around

906
00:32:05,029 --> 00:32:03,039
looking a little bit perplexed on that

907
00:32:06,870 --> 00:32:05,039
day fortunately we were able to figure

908
00:32:08,470 --> 00:32:06,880
out fairly quickly what that issue was

909
00:32:09,750 --> 00:32:08,480
and get things back on track

910
00:32:11,750 --> 00:32:09,760
and it turned out to be a little bit of

911
00:32:13,430 --> 00:32:11,760
a blessing in disguise because we

912
00:32:15,750 --> 00:32:13,440
updated the way that we were doing some

913
00:32:17,269 --> 00:32:15,760

of our power analyses in a way that was

914
00:32:19,269 --> 00:32:17,279
going to hold us in good stead once we

915
00:32:20,389 --> 00:32:19,279
got all the way out to jupiter

916
00:32:21,909 --> 00:32:20,399
not everything goes sideways in

917
00:32:23,909 --> 00:32:21,919
operations though jupiter orbit

918
00:32:26,230 --> 00:32:23,919
insertion day is an example of one that

919
00:32:27,909 --> 00:32:26,240
went off without a hitch for this one i

920
00:32:29,909 --> 00:32:27,919
was out in the mission support area with

921
00:32:31,750 --> 00:32:29,919
our colleague and lockheed martin um you

922
00:32:33,990 --> 00:32:31,760
can see here wow one of my colleagues

923
00:32:36,389 --> 00:32:34,000
had on his his fourth of july hat

924
00:32:38,789 --> 00:32:36,399
because it was that holiday for us and

925
00:32:40,070 --> 00:32:38,799
the spacecraft fired his engine for 35

926
00:32:41,509 --> 00:32:40,080
minutes the way that it was supposed to

927
00:32:43,909 --> 00:32:41,519
and all the things leading up to and

928
00:32:46,470 --> 00:32:43,919
after that it was a very exciting day to

929
00:32:49,590 --> 00:32:46,480
put the spacecraft in orbit after years

930
00:32:51,509 --> 00:32:49,600
of time and effort by hundreds of people

931
00:32:53,509 --> 00:32:51,519
at jpl and lockheed martin and all the

932
00:32:55,509 --> 00:32:53,519
institutions for the instruments

933
00:32:58,149 --> 00:32:55,519
and and vendors who provided if we

934
00:32:59,190 --> 00:32:58,159
provided a hardware for us it was just a

935
00:33:03,590 --> 00:32:59,200
great

936
00:33:05,830 --> 00:33:03,600
once juno has gotten there it's been in

937
00:33:07,909 --> 00:33:05,840
orbit now since summer of 2016. there

938
00:33:10,470 --> 00:33:07,919

have been any number of fantastic

939
00:33:11,669 --> 00:33:10,480
discoveries that have been made papers

940
00:33:14,149 --> 00:33:11,679
that the scientists have been able to

941
00:33:15,509 --> 00:33:14,159
write to describe the the lessons that

942
00:33:17,110 --> 00:33:15,519
they're learning from the data that they

943
00:33:19,190 --> 00:33:17,120
have gotten back i'm not going to go

944
00:33:20,549 --> 00:33:19,200
into detail of these just inviting you

945
00:33:22,549 --> 00:33:20,559
to go off and take a look for those of

946
00:33:24,870 --> 00:33:22,559
you who aren't familiar with the details

947
00:33:27,110 --> 00:33:24,880
and then as a kind of a lay person not

948
00:33:29,590 --> 00:33:27,120
scientist engineer but i'll tell you

949
00:33:31,750 --> 00:33:29,600
some of the things that i was the most

950
00:33:34,230 --> 00:33:31,760
excited about in hearing back from the

951
00:33:37,350 --> 00:33:34,240
scientists and the spacecraft number one

952
00:33:39,350 --> 00:33:37,360
was that the the way that the north and

953
00:33:41,269 --> 00:33:39,360
the south poles looked was so different

954
00:33:43,909 --> 00:33:41,279
from what i had expected based on just

955
00:33:46,070 --> 00:33:43,919
the normal view we tend to have of

956
00:33:49,430 --> 00:33:46,080
jupiter from the spacecraft that go by

957
00:33:51,830 --> 00:33:49,440
its midsection i remember being in the

958
00:33:54,310 --> 00:33:51,840
audience in the science team meeting

959
00:33:55,750 --> 00:33:54,320
where the folks from the gerum team the

960
00:33:58,549 --> 00:33:55,760
jovi and

961
00:34:00,470 --> 00:33:58,559
infrared auroral mepper from the italian

962
00:34:01,909 --> 00:34:00,480
space agency put up one of their first

963
00:34:03,350 --> 00:34:01,919

images not exactly this one but their

964
00:34:05,590 --> 00:34:03,360
first image of what the poles look like

965
00:34:07,990 --> 00:34:05,600
in infrared and the whole room burst

966
00:34:10,230 --> 00:34:08,000
into applause it was so exciting to get

967
00:34:12,230 --> 00:34:10,240
to be among the first humans saying for

968
00:34:14,869 --> 00:34:12,240
the first time what the polls looked

969
00:34:17,030 --> 00:34:14,879
like and that there were these crazy

970
00:34:19,349 --> 00:34:17,040
storms like over a thousand kilometers

971
00:34:21,829 --> 00:34:19,359
wide especially this at the north pole

972
00:34:24,310 --> 00:34:21,839
where there's these eight storms in this

973
00:34:26,710 --> 00:34:24,320
oddly symmetric pattern up there like

974
00:34:27,829 --> 00:34:26,720
that was just really cool first

975
00:34:30,629 --> 00:34:27,839
one of the things the scientists were

976
00:34:32,230 --> 00:34:30,639
interested in is how deep the storms go

977
00:34:33,589 --> 00:34:32,240
this is one of my favorite compilations

978
00:34:37,030 --> 00:34:33,599
that was put together quite some time

979
00:34:39,589 --> 00:34:37,040
ago with a visible image from junocam

980
00:34:42,230 --> 00:34:39,599
layered on top of microwave radiometer

981
00:34:44,550 --> 00:34:42,240
data which gives you a sense of areas

982
00:34:46,310 --> 00:34:44,560
that are warmer areas that are cooler

983
00:34:48,149 --> 00:34:46,320
and you can see all the way down as far

984
00:34:49,750 --> 00:34:48,159
as this instrument could measure there

985
00:34:51,829 --> 00:34:49,760
were differences across the great red

986
00:34:53,270 --> 00:34:51,839
spot so that storm had some pretty deep

987
00:34:55,750 --> 00:34:53,280
roots and i think there was a paper

988
00:34:57,589 --> 00:34:55,760

written later that was talking about an

989
00:34:59,829 --> 00:34:57,599
estimate for a lower bound of that too

990
00:35:01,430 --> 00:34:59,839
so scientists have a decent idea of

991
00:35:03,030 --> 00:35:01,440
what's going on there

992
00:35:04,790 --> 00:35:03,040
and these images i just include because

993
00:35:06,630 --> 00:35:04,800
they're cool i always think about

994
00:35:09,750 --> 00:35:06,640
jupiter as this place this place that

995
00:35:11,510 --> 00:35:09,760
has these tan and rust-colored bands but

996
00:35:13,349 --> 00:35:11,520
with all of the really cool images

997
00:35:15,910 --> 00:35:13,359
junocam has been sending back it's just

998
00:35:17,430 --> 00:35:15,920
a place that has a lot of complexity a

999
00:35:19,430 --> 00:35:17,440
lot of color

1000
00:35:22,790 --> 00:35:19,440
and i love the fact that the junocam

1001
00:35:25,430 --> 00:35:22,800
data the raw data is posted and regular

1002
00:35:28,470 --> 00:35:25,440
citizens from anywhere in the world can

1003
00:35:31,109 --> 00:35:28,480
log on grab that data image process it

1004
00:35:32,790 --> 00:35:31,119
and repost it and that's why you see the

1005
00:35:34,310 --> 00:35:32,800
image credits include the names of

1006
00:35:36,150 --> 00:35:34,320
people who have been doing that on their

1007
00:35:38,069 --> 00:35:36,160
own time and for those of you who want

1008
00:35:40,310 --> 00:35:38,079
to see more information about juno feel

1009
00:35:42,470 --> 00:35:40,320
free to visit at the mission website and

1010
00:35:44,390 --> 00:35:42,480
go to the juno gallery to see all of the

1011
00:35:45,910 --> 00:35:44,400
gorgeous images that are coming back and

1012
00:35:47,270 --> 00:35:45,920
links to all the papers and

1013
00:35:50,950 --> 00:35:47,280

presentations that the scientists have

1014
00:35:52,310 --> 00:35:50,960
made about the exciting discovery

1015
00:35:53,829 --> 00:35:52,320
now i'm just going to spend a little bit

1016
00:35:55,990 --> 00:35:53,839
of time talking about another cool

1017
00:35:59,270 --> 00:35:56,000
destination pun intended in the joking

1018
00:36:01,750 --> 00:35:59,280
neighborhood which is the moon of europa

1019
00:36:04,790 --> 00:36:01,760
the galilean satellites of jupiter

1020
00:36:07,030 --> 00:36:04,800
galileo way back in 1601 i think it was

1021
00:36:09,589 --> 00:36:07,040
was observing jupiter in his telescope

1022
00:36:11,589 --> 00:36:09,599
and saw these bright points that i think

1023
00:36:15,349 --> 00:36:11,599
he originally believed were stars but

1024
00:36:17,190 --> 00:36:15,359
they were moving relative to jupiter and

1025
00:36:19,270 --> 00:36:17,200
eventually he realized that they were

1026
00:36:21,910 --> 00:36:19,280
bodies that were in orbit around that

1027
00:36:24,310 --> 00:36:21,920
planet and those ultimately were io

1028
00:36:26,710 --> 00:36:24,320
europa ganymede and callisto

1029
00:36:29,829 --> 00:36:26,720
and the galileo spacecraft was able to

1030
00:36:32,710 --> 00:36:29,839
visit jupiter back in the late 90s early

1031
00:36:34,950 --> 00:36:32,720
august and sent us back uh this full

1032
00:36:36,790 --> 00:36:34,960
image and a couple of others of the moon

1033
00:36:38,390 --> 00:36:36,800
europa

1034
00:36:40,710 --> 00:36:38,400
why are we sending another spacecraft

1035
00:36:42,310 --> 00:36:40,720
back to europa again i'm an engineer but

1036
00:36:43,829 --> 00:36:42,320
i'm really interested in why the

1037
00:36:45,670 --> 00:36:43,839
scientists are going to do things and so

1038
00:36:47,829 --> 00:36:45,680

what i've learned in my time on the

1039
00:36:49,990 --> 00:36:47,839
mission is and i stole these lives from

1040
00:36:52,150 --> 00:36:50,000
the science of course is that the

1041
00:36:54,470 --> 00:36:52,160
scientists believe that underneath this

1042
00:36:57,109 --> 00:36:54,480
ice shell there is lots and lots of

1043
00:36:59,670 --> 00:36:57,119
liquid water above a rocky mantle and

1044
00:37:02,870 --> 00:36:59,680
then down to a solid core and compared

1045
00:37:05,910 --> 00:37:02,880
to earth europa has way more water than

1046
00:37:07,750 --> 00:37:05,920
earth about twice all of the water on

1047
00:37:11,030 --> 00:37:07,760
the earth combined

1048
00:37:12,390 --> 00:37:11,040
in this layer of a moon wide ocean on

1049
00:37:14,550 --> 00:37:12,400
europa

1050
00:37:16,069 --> 00:37:14,560
and for me i always thought it was like

1051
00:37:18,470 --> 00:37:16,079
how do we know that there's water down

1052
00:37:21,109 --> 00:37:18,480
there and my understanding is that when

1053
00:37:24,069 --> 00:37:21,119
galileo visited jupiter and had its

1054
00:37:25,910 --> 00:37:24,079
magnetometer taking data around jupiter

1055
00:37:27,910 --> 00:37:25,920
and also near europa

1056
00:37:30,230 --> 00:37:27,920
it measured a

1057
00:37:32,870 --> 00:37:30,240
bend the perturbation in the magnetic

1058
00:37:34,790 --> 00:37:32,880
field around europa and the best

1059
00:37:36,790 --> 00:37:34,800
explanation that the scientists can come

1060
00:37:39,109 --> 00:37:36,800
up with is that there was some kind of

1061
00:37:41,190 --> 00:37:39,119
conductive liquid under there we know

1062
00:37:43,990 --> 00:37:41,200
that the earth's tides perturbs the

1063
00:37:47,349 --> 00:37:44,000

earth's magnetic field and so briny

1064
00:37:49,990 --> 00:37:47,359
water of some sort is the most likely

1065
00:37:51,750 --> 00:37:50,000
culprit for causing this signature in

1066
00:37:53,270 --> 00:37:51,760
the magnetic field

1067
00:37:54,710 --> 00:37:53,280
and then the next question i ask myself

1068
00:37:56,950 --> 00:37:54,720
and that all the kids ask me when i talk

1069
00:37:58,390 --> 00:37:56,960
to them is okay you just said that

1070
00:37:59,670 --> 00:37:58,400
jupiter is five times farther away from

1071
00:38:01,750 --> 00:37:59,680
the sun than the earth is how can there

1072
00:38:05,030 --> 00:38:01,760
possibly be liquid water out there and

1073
00:38:07,270 --> 00:38:05,040
the answer is tidal flexing the orbit of

1074
00:38:09,430 --> 00:38:07,280
europa around jupiter is not perfectly

1075
00:38:11,190 --> 00:38:09,440
circular when it's closer to jupiter the

1076
00:38:13,030 --> 00:38:11,200
gravity pulls on it harder when it's

1077
00:38:15,190 --> 00:38:13,040
farther away the gravity is a little bit

1078
00:38:16,550 --> 00:38:15,200
weaker and so that's essentially

1079
00:38:18,470 --> 00:38:16,560
stretching and releasing and stretching

1080
00:38:21,030 --> 00:38:18,480
and releasing the moon causing lots of

1081
00:38:26,150 --> 00:38:21,040
friction in there which is enough energy

1082
00:38:30,470 --> 00:38:28,390
why do we care about that um and that's

1083
00:38:31,670 --> 00:38:30,480
because here on earth whenever there's

1084
00:38:33,990 --> 00:38:31,680
water

1085
00:38:35,910 --> 00:38:34,000
there is life we know that for the

1086
00:38:37,030 --> 00:38:35,920
scientists strongly suspect maybe many

1087
00:38:38,630 --> 00:38:37,040
of them would say we know that there is

1088
00:38:40,630 --> 00:38:38,640

more water than all of the earth oceans

1089
00:38:42,790 --> 00:38:40,640
combined there are essential elements

1090
00:38:44,710 --> 00:38:42,800
there from formation and impact that we

1091
00:38:46,630 --> 00:38:44,720
can tell by the observations that have

1092
00:38:47,510 --> 00:38:46,640
been made of it today one of the things

1093
00:38:49,510 --> 00:38:47,520
that

1094
00:38:51,270 --> 00:38:49,520
europa is going to do is get more

1095
00:38:53,430 --> 00:38:51,280
information about the surface

1096
00:38:55,109 --> 00:38:53,440
composition and also any particles that

1097
00:38:56,950 --> 00:38:55,119
we can fly by with the spacecraft

1098
00:38:58,870 --> 00:38:56,960
there's lots of chemical energy pretty

1099
00:39:00,550 --> 00:38:58,880
warm down there we talked about why

1100
00:39:02,150 --> 00:39:00,560
there's so much water there in the first

1101
00:39:03,670 --> 00:39:02,160
place and also even though there's

1102
00:39:06,069 --> 00:39:03,680
weaker sunlight out there there's still

1103
00:39:09,030 --> 00:39:06,079
sunlight and the radiation from

1104
00:39:11,349 --> 00:39:09,040
jupiter makes changes in the chemical

1105
00:39:13,270 --> 00:39:11,359
composition of the surface and it's been

1106
00:39:16,230 --> 00:39:13,280
stable it's been simmering down there

1107
00:39:17,750 --> 00:39:16,240
like that for about four billion years

1108
00:39:20,390 --> 00:39:17,760
and on earth when we think about

1109
00:39:23,430 --> 00:39:20,400
extremophiles way down at the bottom of

1110
00:39:25,349 --> 00:39:23,440
the oceans where it's far too much water

1111
00:39:28,550 --> 00:39:25,359
for light to be able to penetrate there

1112
00:39:30,630 --> 00:39:28,560
are hydrothermal vents with energy from

1113
00:39:32,470 --> 00:39:30,640

the heat inside of the earth creating

1114
00:39:33,349 --> 00:39:32,480
these water jets providing energy to

1115
00:39:35,510 --> 00:39:33,359
drive

1116
00:39:37,589 --> 00:39:35,520
life forms in that environment and so

1117
00:39:39,270 --> 00:39:37,599
there's the wonder and something like

1118
00:39:41,750 --> 00:39:39,280
that um at least enough to support

1119
00:39:43,589 --> 00:39:41,760
microbial life be going on down under

1120
00:39:45,990 --> 00:39:43,599
the ice and the water

1121
00:39:47,910 --> 00:39:46,000
of europa

1122
00:39:49,750 --> 00:39:47,920
so i'm very happy to be part of a

1123
00:39:51,670 --> 00:39:49,760
mission that is planning to go out there

1124
00:39:52,870 --> 00:39:51,680
and grab a lot of data in order to help

1125
00:39:54,069 --> 00:39:52,880
the scientists answer some of those

1126
00:39:55,510 --> 00:39:54,079
questions

1127
00:39:58,550 --> 00:39:55,520
europa clipper is going to launch in

1128
00:40:00,550 --> 00:39:58,560
october of 2024. the dates here are day

1129
00:40:01,829 --> 00:40:00,560
month year by the way and a little out

1130
00:40:03,510 --> 00:40:01,839
of date i think the opening of our

1131
00:40:04,390 --> 00:40:03,520
launch winner right now is october that

1132
00:40:05,670 --> 00:40:04,400
10th

1133
00:40:08,870 --> 00:40:05,680
so we'll launch it from the cape in

1134
00:40:11,270 --> 00:40:08,880
2024. um similarly we're going to do

1135
00:40:13,430 --> 00:40:11,280
like juno did a fly-by but we're doing

1136
00:40:15,990 --> 00:40:13,440
two we're gonna go off on a trajectory

1137
00:40:18,309 --> 00:40:16,000
to mars do a mars gravity assist which

1138
00:40:20,150 --> 00:40:18,319

will kick us back by the earth a couple

1139
00:40:22,550 --> 00:40:20,160
of years after launch for our final

1140
00:40:25,190 --> 00:40:22,560
boost to get all the way out to jupiter

1141
00:40:26,710 --> 00:40:25,200
a few years after that it's about a

1142
00:40:28,870 --> 00:40:26,720
five and a half year journey which we

1143
00:40:33,030 --> 00:40:28,880
call the mega trajectory mars first

1144
00:40:35,990 --> 00:40:33,040
gravity assist and will arrive in 2030

1145
00:40:38,230 --> 00:40:36,000
in order to start our science tour

1146
00:40:40,790 --> 00:40:38,240
similarly to juno rather than orbiting

1147
00:40:42,950 --> 00:40:40,800
directly around europa which is nestled

1148
00:40:44,390 --> 00:40:42,960
in that nice little radiation donut

1149
00:40:46,870 --> 00:40:44,400
around jupiter we're going to be

1150
00:40:49,910 --> 00:40:46,880
orbiting around jupiter technically but

1151
00:40:53,030 --> 00:40:49,920
doing multiple flybys of europa at

1152
00:40:55,109 --> 00:40:53,040
fairly low altitude i think the majority

1153
00:40:58,790 --> 00:40:55,119
of the 50 or so flybys we're going to do

1154
00:41:00,870 --> 00:40:58,800
are below 100 kilometers in order to let

1155
00:41:03,750 --> 00:41:00,880
a suite of instruments gather lots and

1156
00:41:05,990 --> 00:41:03,760
lots of information about that moon

1157
00:41:08,870 --> 00:41:06,000
for the spacecraft we had a lot of very

1158
00:41:11,910 --> 00:41:08,880
similar challenges radiation at jupiter

1159
00:41:13,910 --> 00:41:11,920
flash europa and so similarly to jupiter

1160
00:41:15,109 --> 00:41:13,920
to juno we have an avionics vault that

1161
00:41:17,910 --> 00:41:15,119
we're using for some of the sensitive

1162
00:41:20,470 --> 00:41:17,920
components this spacecraft because

1163
00:41:22,069 --> 00:41:20,480

because europa is in the radiation belt

1164
00:41:23,829 --> 00:41:22,079
and we have to go deeper in than juno

1165
00:41:26,390 --> 00:41:23,839
did in order to get our science data is

1166
00:41:29,030 --> 00:41:26,400
going to take a lot more of a radiation

1167
00:41:30,550 --> 00:41:29,040
dose than juno did juno's design

1168
00:41:32,710 --> 00:41:30,560
radiation dose is something like 30

1169
00:41:34,950 --> 00:41:32,720
kilowatts i had mentioned for europa

1170
00:41:36,950 --> 00:41:34,960
clipper inside the vault um the design

1171
00:41:39,030 --> 00:41:36,960
intent is to get it down to about 150

1172
00:41:41,109 --> 00:41:39,040
kilohertz so five times that outside the

1173
00:41:43,349 --> 00:41:41,119
vault will be even higher

1174
00:41:45,030 --> 00:41:43,359
we are very far away from the sun just

1175
00:41:47,349 --> 00:41:45,040
as we were since we're going back to the

1176
00:41:49,270 --> 00:41:47,359
same neighborhood so we have large solar

1177
00:41:50,950 --> 00:41:49,280
arrays about 100 square meters in area

1178
00:41:52,309 --> 00:41:50,960
you'll see i might have included an

1179
00:41:54,230 --> 00:41:52,319
image of what this one looks like the it

1180
00:41:56,309 --> 00:41:54,240
the edges of this hang off a little bit

1181
00:41:59,190 --> 00:41:56,319
over the edges of a basketball court

1182
00:42:01,670 --> 00:41:59,200
it's about 30 and a half meters and and

1183
00:42:03,670 --> 00:42:01,680
across the whole stage graph and instead

1184
00:42:06,069 --> 00:42:03,680
of just relying on electric heaters we

1185
00:42:09,190 --> 00:42:06,079
have a heat redistribution system with

1186
00:42:10,870 --> 00:42:09,200
fluid filled pipes that run around the

1187
00:42:12,710 --> 00:42:10,880
avionics fault to capture some of the

1188
00:42:14,470 --> 00:42:12,720

waste heat from the components in there

1189
00:42:18,150 --> 00:42:14,480
and then use that heat to warm up the

1190
00:42:19,510 --> 00:42:18,160
rest of the propulsion module

1191
00:42:21,270 --> 00:42:19,520
a long way away from the earth so

1192
00:42:23,109 --> 00:42:21,280
similar to juno we have another three

1193
00:42:24,390 --> 00:42:23,119
meter high gain antenna and lots of

1194
00:42:26,790 --> 00:42:24,400
other antenna that we use when the

1195
00:42:28,390 --> 00:42:26,800
spacecraft is in different orientations

1196
00:42:30,150 --> 00:42:28,400
and getting into jupiter orbit a little

1197
00:42:32,230 --> 00:42:30,160
bit different from juno we don't have a

1198
00:42:33,910 --> 00:42:32,240
single main engine but we're going to

1199
00:42:36,230 --> 00:42:33,920
use several of the thrusters that we

1200
00:42:38,230 --> 00:42:36,240
also use for just attitude control and

1201
00:42:40,069 --> 00:42:38,240
burn them for about six and a half hours

1202
00:42:42,710 --> 00:42:40,079
in order to slow down enough to get

1203
00:42:45,750 --> 00:42:42,720
captured by the jupiter gravity once we

1204
00:42:47,349 --> 00:42:45,760
get there

1205
00:42:48,950 --> 00:42:47,359
for the instruments and science

1206
00:42:50,710 --> 00:42:48,960
objectives lots of stuff that the

1207
00:42:52,390 --> 00:42:50,720
scientists want to learn about the

1208
00:42:54,950 --> 00:42:52,400
planet there's kind of three main

1209
00:42:56,870 --> 00:42:54,960
thrusts ice shell and ocean how deep is

1210
00:42:59,030 --> 00:42:56,880
the ocean how thick is the ice shell are

1211
00:43:00,470 --> 00:42:59,040
there hot spots where there are there

1212
00:43:01,349 --> 00:43:00,480
are pockets where you have a little bit

1213
00:43:02,710 --> 00:43:01,359

of

1214
00:43:03,829 --> 00:43:02,720
liquid water that's closer to the

1215
00:43:05,510 --> 00:43:03,839
surface

1216
00:43:07,109 --> 00:43:05,520
we want to learn that and many more

1217
00:43:09,030 --> 00:43:07,119
things about it and we have several

1218
00:43:11,030 --> 00:43:09,040
instruments that are geared to do that

1219
00:43:12,950 --> 00:43:11,040
one of my personal faves is the ice

1220
00:43:15,270 --> 00:43:12,960
penetrating radar which will help us

1221
00:43:17,430 --> 00:43:15,280
plumb the ice shell i want to learn more

1222
00:43:19,030 --> 00:43:17,440
about the composition and we have

1223
00:43:21,990 --> 00:43:19,040
spectrometers that are going to be able

1224
00:43:24,069 --> 00:43:22,000
to tell us more about what kinds of

1225
00:43:26,470 --> 00:43:24,079
materials there are on the surface and

1226
00:43:27,829 --> 00:43:26,480
then a bit about the geology there's all

1227
00:43:30,870 --> 00:43:27,839
of these huge

1228
00:43:32,390 --> 00:43:30,880
um features that to me look like cracks

1229
00:43:34,150 --> 00:43:32,400
in the ice lots of things that the

1230
00:43:35,030 --> 00:43:34,160
scientists want to understand about that

1231
00:43:37,109 --> 00:43:35,040
and

1232
00:43:39,190 --> 00:43:37,119
the one of the interesting things is how

1233
00:43:41,589 --> 00:43:39,200
things are changing over time which kind

1234
00:43:44,470 --> 00:43:41,599
of cuts across all of these different

1235
00:43:46,069 --> 00:43:44,480
elements and so similar to galileo we'll

1236
00:43:47,750 --> 00:43:46,079
have a magnetometer on board which is

1237
00:43:49,510 --> 00:43:47,760
going to help us sense the ocean

1238
00:43:52,069 --> 00:43:49,520

properties there'll be a couple of

1239
00:43:53,990 --> 00:43:52,079
cameras a narrow and wide angle ice

1240
00:43:55,510 --> 00:43:54,000
camera that'll let us map the landscape

1241
00:43:57,349 --> 00:43:55,520
and 3d and color

1242
00:43:59,750 --> 00:43:57,359
i talked about the spectrometers we'll

1243
00:44:02,390 --> 00:43:59,760
be using the telecom system for gravity

1244
00:44:03,990 --> 00:44:02,400
and radio science to kind of understand

1245
00:44:06,309 --> 00:44:04,000
more about the ice shell and ocean depth

1246
00:44:07,589 --> 00:44:06,319
and also measuring tidal flexing i don't

1247
00:44:09,430 --> 00:44:07,599
want to leave out any that might be

1248
00:44:11,349 --> 00:44:09,440
people favorites but a whole suite of

1249
00:44:13,510 --> 00:44:11,359
instruments um festooned around the

1250
00:44:15,109 --> 00:44:13,520
spacecraft so they're gonna gather lots

1251
00:44:17,829 --> 00:44:15,119
of data to help us understand this

1252
00:44:19,990 --> 00:44:17,839
exciting moon better

1253
00:44:21,510 --> 00:44:20,000
where are we now with europa clipper we

1254
00:44:23,270 --> 00:44:21,520
are in the process of integrating

1255
00:44:24,710 --> 00:44:23,280
hardware our first instrument the

1256
00:44:26,470 --> 00:44:24,720
ultraviolet spectrograph has been

1257
00:44:27,910 --> 00:44:26,480
delivered to jbl

1258
00:44:29,510 --> 00:44:27,920
and many of the components that are

1259
00:44:31,910 --> 00:44:29,520
being built by our partners at applied

1260
00:44:33,829 --> 00:44:31,920
physics laboratory in baltimore the

1261
00:44:36,630 --> 00:44:33,839
propulsion module the radio frequency

1262
00:44:39,030 --> 00:44:36,640
module are ready to be shipped soon and

1263
00:44:42,309 --> 00:44:39,040

we will be assembling them at jpl while

1264
00:44:44,550 --> 00:44:42,319
running through final suites of testing

1265
00:44:46,550 --> 00:44:44,560
all of our vmp finding and fixing little

1266
00:44:49,109 --> 00:44:46,560
issues as you do on spacecraft is

1267
00:44:52,069 --> 00:44:49,119
complicated on our way towards a launch

1268
00:44:53,510 --> 00:44:52,079
in october 2024. and if you'd like more

1269
00:44:55,109 --> 00:44:53,520
information about the mission you can

1270
00:44:56,710 --> 00:44:55,119
visit the mission website here which

1271
00:44:57,510 --> 00:44:56,720
will eventually walk to the places that

1272
00:44:59,589 --> 00:44:57,520
have

1273
00:45:01,109 --> 00:44:59,599
mission news releases and also a really

1274
00:45:03,430 --> 00:45:01,119
nice 3d model you can find in the

1275
00:45:04,470 --> 00:45:03,440
spacecraft and spin around to learn more

1276
00:45:07,910 --> 00:45:04,480
about the different parts of the

1277
00:45:11,190 --> 00:45:09,510
and that's the end of the talk hopefully

1278
00:45:16,480 --> 00:45:11,200
i still left this a little bit of time

1279
00:45:25,990 --> 00:45:23,270
[Applause]

1280
00:45:29,190 --> 00:45:26,000
thank you tracy that was fabulous

1281
00:45:32,550 --> 00:45:29,200
so we are now ready to take uh questions

1282
00:45:35,910 --> 00:45:32,560
from the audience so those online can

1283
00:45:39,109 --> 00:45:35,920
ask questions and on youtube

1284
00:45:40,150 --> 00:45:39,119
kristen will read out the questions and

1285
00:45:41,829 --> 00:45:40,160
on

1286
00:45:47,109 --> 00:45:41,839
vimeo

1287
00:45:49,109 --> 00:45:47,119
jane glass will ask the questions and if

1288
00:45:55,670 --> 00:45:49,119

we have anybody here in the audience we

1289
00:45:59,109 --> 00:45:56,870
and

1290
00:46:01,910 --> 00:45:59,119
i know that there is one question

1291
00:46:03,430 --> 00:46:01,920
available in vimeo

1292
00:46:05,589 --> 00:46:03,440
but maybe

1293
00:46:07,589 --> 00:46:05,599
in the time that we have maybe i'll ask

1294
00:46:10,710 --> 00:46:07,599
one quick question tracy would you know

1295
00:46:13,349 --> 00:46:10,720
you showed those pictures of juno do you

1296
00:46:15,430 --> 00:46:13,359
mentioned cooler and warmer temperatures

1297
00:46:17,910 --> 00:46:15,440
do you have any clue what those cooler

1298
00:46:19,670 --> 00:46:17,920
and warmer temperatures might be like

1299
00:46:21,349 --> 00:46:19,680
oh you know i used to know the answer to

1300
00:46:24,710 --> 00:46:21,359
that

1301
00:46:26,790 --> 00:46:24,720
plugged into my brain i do i do think

1302
00:46:27,510 --> 00:46:26,800
that if you do a search

1303
00:46:28,550 --> 00:46:27,520
for

1304
00:46:30,630 --> 00:46:28,560
gerum

1305
00:46:33,109 --> 00:46:30,640
j-i-r-a-n

1306
00:46:34,950 --> 00:46:33,119
jupiter temperature you'll probably get

1307
00:46:36,950 --> 00:46:34,960
something that pops right out on that

1308
00:46:40,309 --> 00:46:36,960
okay thank you i could do that so we

1309
00:46:42,390 --> 00:46:40,319
have one question here at the hilton so

1310
00:46:44,950 --> 00:46:42,400
hello garrett roberts kingman here from

1311
00:46:47,670 --> 00:46:44,960
ames research center i was wondering if

1312
00:46:50,390 --> 00:46:47,680
there was anything that you as an

1313
00:46:52,870 --> 00:46:50,400

engineer wish that the scientists kept

1314
00:46:57,109 --> 00:46:52,880
in mind from the earliest stages of

1315
00:47:01,670 --> 00:46:59,430
yeah is there anything that i wish that

1316
00:47:03,990 --> 00:47:01,680
the scientists kept in mind from the

1317
00:47:06,069 --> 00:47:04,000
earlier stages of development

1318
00:47:08,550 --> 00:47:06,079
hmm that's a good question i'll i'll

1319
00:47:10,069 --> 00:47:08,560
answer it in this way because the

1320
00:47:11,270 --> 00:47:10,079
project scientist on juno steve levin

1321
00:47:13,589 --> 00:47:11,280
and i have given a couple of fun

1322
00:47:15,910 --> 00:47:13,599
thoughts on this topic which is the the

1323
00:47:18,309 --> 00:47:15,920
healthy interplay between scientists and

1324
00:47:20,630 --> 00:47:18,319
engineers which is engineers tend to be

1325
00:47:22,710 --> 00:47:20,640
a little conservative right we have this

1326
00:47:24,230 --> 00:47:22,720
this spacecraft that we pour all our

1327
00:47:25,670 --> 00:47:24,240
blood sweat and tears in we're sending

1328
00:47:27,270 --> 00:47:25,680
out into the scary environment and we

1329
00:47:29,910 --> 00:47:27,280
want it to be able to last for a very

1330
00:47:32,950 --> 00:47:29,920
long time and so we tend to be a little

1331
00:47:35,109 --> 00:47:32,960
bit hesitant to push the bounds of the

1332
00:47:37,270 --> 00:47:35,119
spacecraft capability beyond what we

1333
00:47:39,349 --> 00:47:37,280
originally designed it to do

1334
00:47:40,870 --> 00:47:39,359
but scientists oftentimes they spend

1335
00:47:42,230 --> 00:47:40,880
their whole careers trying to get an

1336
00:47:44,069 --> 00:47:42,240
instrument on a spacecraft so that they

1337
00:47:45,829 --> 00:47:44,079
can again get back data and solve these

1338
00:47:48,549 --> 00:47:45,839

questions that they that they want

1339
00:47:49,750 --> 00:47:48,559
answers to and so for them they're like

1340
00:47:51,670 --> 00:47:49,760
we have the spacecraft and these

1341
00:47:53,589 --> 00:47:51,680
instruments all the way out there can we

1342
00:47:55,030 --> 00:47:53,599
please just like do a little more go a

1343
00:47:56,230 --> 00:47:55,040
little farther or turn the spacecraft a

1344
00:47:58,069 --> 00:47:56,240
little farther than we said we would

1345
00:47:59,829 --> 00:47:58,079
because you can get all of this great

1346
00:48:02,470 --> 00:47:59,839
data from it and so

1347
00:48:03,910 --> 00:48:02,480
they are not wrong um but they also have

1348
00:48:05,670 --> 00:48:03,920
a vested interest in making sure that

1349
00:48:08,069 --> 00:48:05,680
the spacecraft stays healthy and safe

1350
00:48:10,710 --> 00:48:08,079
for a long operation and so we end up

1351
00:48:11,829 --> 00:48:10,720
having a really good interaction talking

1352
00:48:13,190 --> 00:48:11,839
about

1353
00:48:14,710 --> 00:48:13,200
how much risk there might be in doing

1354
00:48:16,549 --> 00:48:14,720
some stuff like that how much benefit

1355
00:48:18,710 --> 00:48:16,559
there could be and and finding a good

1356
00:48:20,390 --> 00:48:18,720
line that is acceptable so i tend to

1357
00:48:22,470 --> 00:48:20,400
think about that from a late mission

1358
00:48:24,309 --> 00:48:22,480
phase thing in operations and i think

1359
00:48:26,549 --> 00:48:24,319
that some of that same mindset can and

1360
00:48:29,109 --> 00:48:26,559
should play in the early development and

1361
00:48:29,990 --> 00:48:29,119
design and back then it's more in terms

1362
00:48:32,230 --> 00:48:30,000
of

1363
00:48:34,069 --> 00:48:32,240

how complex do we make the mission in

1364
00:48:35,829 --> 00:48:34,079
order to get the most science possible

1365
00:48:38,950 --> 00:48:35,839
versus trying to make things a little

1366
00:48:41,990 --> 00:48:38,960
simpler so that it's more robust

1367
00:48:43,990 --> 00:48:42,000
tracy can i have you turn on your camera

1368
00:48:47,109 --> 00:48:44,000
uh yeah so here's what's going on i am

1369
00:48:49,510 --> 00:48:47,119
using my camera from one computer and my

1370
00:48:51,349 --> 00:48:49,520
audio from a different computer let me

1371
00:48:55,400 --> 00:48:51,359
let me see if i can turn on this one and

1372
00:48:59,270 --> 00:48:57,349
[Music]

1373
00:49:01,109 --> 00:48:59,280
yep

1374
00:49:03,270 --> 00:49:01,119
slightly different background there we

1375
00:49:04,549 --> 00:49:03,280
go there we go is that better

1376
00:49:05,510 --> 00:49:04,559
wonderful

1377
00:49:06,790 --> 00:49:05,520
yeah

1378
00:49:08,630 --> 00:49:06,800
okay

1379
00:49:12,069 --> 00:49:08,640
kristen do you have the next question we

1380
00:49:13,430 --> 00:49:12,079
have a few questions from online the

1381
00:49:15,670 --> 00:49:13,440
first one

1382
00:49:18,950 --> 00:49:15,680
is will the james webb telescope have a

1383
00:49:20,549 --> 00:49:18,960
role in exploring the jupiter system

1384
00:49:22,150 --> 00:49:20,559
uh yeah and that's what i'll have to say

1385
00:49:23,670 --> 00:49:22,160
sometimes that we engineers can be a

1386
00:49:25,750 --> 00:49:23,680
little head down in our in our own

1387
00:49:27,349 --> 00:49:25,760
little bins of things i do not know much

1388
00:49:29,589 --> 00:49:27,359

about that james webb telescope and what

1389
00:49:32,950 --> 00:49:29,599
we're intending to do with the data so i

1390
00:49:35,349 --> 00:49:32,960
gotta say i got nothing on that one

1391
00:49:36,710 --> 00:49:35,359
no worries we have another question as

1392
00:49:39,829 --> 00:49:36,720
well um

1393
00:49:43,030 --> 00:49:39,839
what is the expected or the expected

1394
00:49:45,270 --> 00:49:43,040
life expectancy of the orbiter or the

1395
00:49:46,790 --> 00:49:45,280
length of the mission

1396
00:49:49,910 --> 00:49:46,800
uh we're talking about the europa

1397
00:49:51,829 --> 00:49:49,920
clipper mission i believe so yeah yeah

1398
00:49:55,030 --> 00:49:51,839
the the planned mission duration we're

1399
00:49:55,750 --> 00:49:55,040
going to arrive in like april of 2030

1400
00:49:58,069 --> 00:49:55,760
and

1401
00:50:00,309 --> 00:49:58,079
the primary mission duration is about

1402
00:50:02,790 --> 00:50:00,319
three and a half years i think that it

1403
00:50:04,870 --> 00:50:02,800
has just like juno we always have to

1404
00:50:06,549 --> 00:50:04,880
build spacecraft to be robust to make

1405
00:50:08,950 --> 00:50:06,559
sure they're going to last their entire

1406
00:50:10,790 --> 00:50:08,960
mission lifetime and so there's some

1407
00:50:12,710 --> 00:50:10,800
possibility usually when you get near

1408
00:50:14,309 --> 00:50:12,720
the end of a mission the the scientists

1409
00:50:16,390 --> 00:50:14,319
and the engineers work with nasa

1410
00:50:18,470 --> 00:50:16,400
headquarters to put together a mission

1411
00:50:19,990 --> 00:50:18,480
extension proposal to see if it can last

1412
00:50:21,589 --> 00:50:20,000
longer so definitely three and a half

1413
00:50:23,750 --> 00:50:21,599

years after the mission starts and tv

1414
00:50:25,270 --> 00:50:23,760
being how much longer after that

1415
00:50:26,870 --> 00:50:25,280
right

1416
00:50:28,390 --> 00:50:26,880
and we have another question here in the

1417
00:50:30,230 --> 00:50:28,400
auditorium

1418
00:50:33,589 --> 00:50:30,240
hello uh first of all i would like to

1419
00:50:35,349 --> 00:50:33,599
say that um fantastic thought uh talk i

1420
00:50:36,950 --> 00:50:35,359
thought it was very exciting

1421
00:50:38,870 --> 00:50:36,960
um i'm irish i'm a high schooler

1422
00:50:41,670 --> 00:50:38,880
developing at georgia tech

1423
00:50:43,670 --> 00:50:41,680
and i wanted to ask

1424
00:50:46,309 --> 00:50:43,680
what kind of challenges do you foresee

1425
00:50:48,710 --> 00:50:46,319
with the europa clipper mission which

1426
00:50:50,069 --> 00:50:48,720
might cause you know big problems down

1427
00:50:52,390 --> 00:50:50,079
in july or what kind of challenges

1428
00:50:54,069 --> 00:50:52,400
they're facing right now

1429
00:50:56,069 --> 00:50:54,079
yeah and i won't go as far as to say

1430
00:50:57,510 --> 00:50:56,079
might cause big problems but

1431
00:50:59,430 --> 00:50:57,520
uh it's the standard challenges that we

1432
00:51:01,750 --> 00:50:59,440
have with all spacecraft at this level

1433
00:51:03,670 --> 00:51:01,760
of complexity um you saw the the whole

1434
00:51:05,430 --> 00:51:03,680
fault tree this description of the

1435
00:51:07,109 --> 00:51:05,440
things we try to envision that can go

1436
00:51:08,790 --> 00:51:07,119
wrong and all the things we do in order

1437
00:51:11,109 --> 00:51:08,800
to design them out

1438
00:51:12,870 --> 00:51:11,119

one of the things that stands high on my

1439
00:51:14,470 --> 00:51:12,880
list of things to think about is just

1440
00:51:17,190 --> 00:51:14,480
the radiation environment in general

1441
00:51:19,270 --> 00:51:17,200
because it is so much stronger than juno

1442
00:51:20,390 --> 00:51:19,280
experience but we know about that uh

1443
00:51:21,670 --> 00:51:20,400
people i've only been on this mission

1444
00:51:22,950 --> 00:51:21,680
for a couple of years people knew about

1445
00:51:25,510 --> 00:51:22,960
that years and years ago when it was

1446
00:51:27,109 --> 00:51:25,520
proposed so i've taken many steps to

1447
00:51:30,069 --> 00:51:27,119
make sure the design is going to be very

1448
00:51:31,750 --> 00:51:30,079
robust to that but in my 20 years at the

1449
00:51:33,270 --> 00:51:31,760
lab the things that i have learned is

1450
00:51:35,190 --> 00:51:33,280
it's the things that are

1451
00:51:37,190 --> 00:51:35,200
newer and different which are the places

1452
00:51:40,069 --> 00:51:37,200
where you have the most opportunity to

1453
00:51:41,349 --> 00:51:40,079
find challenges to go and resolve so so

1454
00:51:42,549 --> 00:51:41,359
that's when that kind of stands out for

1455
00:51:45,750 --> 00:51:42,559
me

1456
00:51:50,870 --> 00:51:48,549
then we've got one more online question

1457
00:51:54,309 --> 00:51:50,880
and that is could you speak more about

1458
00:51:56,549 --> 00:51:54,319
nuclear power on outer space missions

1459
00:51:58,150 --> 00:51:56,559
ah yeah so i'll just say a little bit

1460
00:51:59,829 --> 00:51:58,160
about it because you may have noticed

1461
00:52:01,829 --> 00:51:59,839
all the missions that i have been on are

1462
00:52:04,150 --> 00:52:01,839
all solar power so that's where most of

1463
00:52:06,069 --> 00:52:04,160

my experience lies i know that one of

1464
00:52:08,470 --> 00:52:06,079
the things that is nice about nuclear

1465
00:52:11,109 --> 00:52:08,480
power that as used on the rover missions

1466
00:52:13,270 --> 00:52:11,119
as was used on cassini is that it's a a

1467
00:52:15,990 --> 00:52:13,280
pretty steady source of heat that you

1468
00:52:18,390 --> 00:52:16,000
can use so similar to the way that that

1469
00:52:21,109 --> 00:52:18,400
the europa clipper spacecraft we use the

1470
00:52:23,430 --> 00:52:21,119
the fluid-filled roots to pump waste

1471
00:52:25,349 --> 00:52:23,440
heat around to to warm other parts of

1472
00:52:26,950 --> 00:52:25,359
the spacecraft on nuclear power

1473
00:52:29,109 --> 00:52:26,960
emissions you can totally do that and

1474
00:52:30,630 --> 00:52:29,119
you know that you'll you'll always have

1475
00:52:32,150 --> 00:52:30,640
the energy for that

1476
00:52:33,990 --> 00:52:32,160
one of the things that i know is

1477
00:52:36,309 --> 00:52:34,000
beneficial about nuclear power is you

1478
00:52:37,910 --> 00:52:36,319
don't have to always think about

1479
00:52:39,750 --> 00:52:37,920
where are your solar arrays are they

1480
00:52:41,589 --> 00:52:39,760
pointed at the sun if you're so if your

1481
00:52:43,030 --> 00:52:41,599
spacecraft has a problem with its

1482
00:52:44,069 --> 00:52:43,040
attitude control system and goes off

1483
00:52:45,670 --> 00:52:44,079
point well now you don't have enough

1484
00:52:47,910 --> 00:52:45,680
power you don't have to worry about that

1485
00:52:49,349 --> 00:52:47,920
with nuclear systems which is nice but

1486
00:52:50,630 --> 00:52:49,359
then there are other things that you do

1487
00:52:52,870 --> 00:52:50,640
have to worry about there's just pros

1488
00:52:55,190 --> 00:52:52,880

and cons on both sides and so we always

1489
00:52:57,990 --> 00:52:55,200
look at the specific goals of the

1490
00:52:59,430 --> 00:52:58,000
mission we have the specific

1491
00:53:01,510 --> 00:52:59,440
kind of parameters of mission to

1492
00:53:02,870 --> 00:53:01,520
determine which one is better but it

1493
00:53:08,470 --> 00:53:02,880
just has turned out for me all my

1494
00:53:08,480 --> 00:53:13,990
wonderful

1495
00:53:21,030 --> 00:53:16,630
and jen do we have any more questions

1496
00:53:26,630 --> 00:53:23,589
i don't know if you can hear that

1497
00:53:30,630 --> 00:53:28,549
hi uh this is christina buffa from

1498
00:53:33,510 --> 00:53:30,640
georgia tech i wanted to thank you so

1499
00:53:35,109 --> 00:53:33,520
much for a really fantastic presentation

1500
00:53:37,030 --> 00:53:35,119
i'm a scientist i have very little

1501
00:53:39,990 --> 00:53:37,040
engineering background so

1502
00:53:40,950 --> 00:53:40,000
seeing this perspective was so cool

1503
00:53:44,390 --> 00:53:40,960
um

1504
00:53:46,710 --> 00:53:44,400
i i'm wondering if you have any

1505
00:53:49,670 --> 00:53:46,720
i don't know favorite uh detection

1506
00:53:52,390 --> 00:53:49,680
methods or measuring tools or

1507
00:53:54,150 --> 00:53:52,400
systems or something that you used in

1508
00:53:56,150 --> 00:53:54,160
your mechanical engineering training

1509
00:54:00,309 --> 00:53:56,160
that you wish could be miniaturized and

1510
00:54:01,990 --> 00:54:00,319
sent into space that we have yet to do

1511
00:54:03,829 --> 00:54:02,000
oh wow that's a great question no one

1512
00:54:05,589 --> 00:54:03,839
has ever asked me that before if there's

1513
00:54:07,670 --> 00:54:05,599

something i wish we could miniaturize

1514
00:54:10,470 --> 00:54:07,680
and send into space that we have yet to

1515
00:54:13,270 --> 00:54:10,480
do

1516
00:54:15,030 --> 00:54:13,280
maybe it's because i have been so

1517
00:54:16,790 --> 00:54:15,040
spoiled in terms of talking to

1518
00:54:19,270 --> 00:54:16,800
scientists like you and the kinds of

1519
00:54:20,630 --> 00:54:19,280
things that they want to learn and being

1520
00:54:23,430 --> 00:54:20,640
always so

1521
00:54:25,349 --> 00:54:23,440
amazed by the types of inferences they

1522
00:54:27,270 --> 00:54:25,359
can make by the stuff that we already

1523
00:54:28,549 --> 00:54:27,280
have i might have to say some things

1524
00:54:30,230 --> 00:54:28,559
about

1525
00:54:31,990 --> 00:54:30,240
what i've heard scientists say they wish

1526
00:54:35,190 --> 00:54:32,000
they had one of the things that was cool

1527
00:54:36,950 --> 00:54:35,200
for me way back in my early

1528
00:54:39,670 --> 00:54:36,960
career at the lab they took a bunch of

1529
00:54:41,670 --> 00:54:39,680
us engineers out on a class field trip

1530
00:54:44,150 --> 00:54:41,680
wandering around the dry riverbed

1531
00:54:46,549 --> 00:54:44,160
arroyos at jpl it was a geology for

1532
00:54:48,230 --> 00:54:46,559
engineers class that was taught by a

1533
00:54:50,230 --> 00:54:48,240
couple of the scientists who work on the

1534
00:54:52,230 --> 00:54:50,240
rover mission and they were explaining

1535
00:54:55,030 --> 00:54:52,240
to us the kinds of things they as

1536
00:54:56,470 --> 00:54:55,040
geologists want to understand or can can

1537
00:54:58,150 --> 00:54:56,480
draw conclusions from based on the

1538
00:54:59,670 --> 00:54:58,160

terrain what kinds of things they want

1539
00:55:00,710 --> 00:54:59,680
to see what kinds of things they want to

1540
00:55:01,990 --> 00:55:00,720
measure

1541
00:55:03,430 --> 00:55:02,000
and i was trying i was trying to

1542
00:55:06,390 --> 00:55:03,440
remember if there's anything specific

1543
00:55:07,829 --> 00:55:06,400
that they said that made me go if we had

1544
00:55:09,589 --> 00:55:07,839
this thing or that thing and we could

1545
00:55:11,190 --> 00:55:09,599
put it on a planet then it'd be easier

1546
00:55:11,910 --> 00:55:11,200
for us to learn stuff but

1547
00:55:13,270 --> 00:55:11,920
yeah

1548
00:55:15,270 --> 00:55:13,280
nothing specifically comes to mind but

1549
00:55:16,549 --> 00:55:15,280
that's a fun thought experiment to do

1550
00:55:18,789 --> 00:55:16,559
i'll think about it and be ready for

1551
00:55:23,510 --> 00:55:18,799
that if someone asked me that later

1552
00:55:28,549 --> 00:55:26,230
and we have another vimeo

1553
00:55:30,950 --> 00:55:28,559
question and that is of all the missions

1554
00:55:32,829 --> 00:55:30,960
you've been involved in was there one

1555
00:55:35,270 --> 00:55:32,839
that was more challenging or more

1556
00:55:37,030 --> 00:55:35,280
satisfying or stood out in some other

1557
00:55:38,630 --> 00:55:37,040
way

1558
00:55:40,150 --> 00:55:38,640
yeah and that's like

1559
00:55:42,150 --> 00:55:40,160
for people who have children that's like

1560
00:55:44,230 --> 00:55:42,160
i love all my babies the same and the

1561
00:55:45,670 --> 00:55:44,240
thing for me across all five i'm gonna

1562
00:55:47,589 --> 00:55:45,680
cheat and just give you the long answer

1563
00:55:49,270 --> 00:55:47,599

the thing that is special for me about

1564
00:55:51,190 --> 00:55:49,280
mars reconnaissance orbiter is that with

1565
00:55:53,190 --> 00:55:51,200
the very first mission that i was ever

1566
00:55:54,789 --> 00:55:53,200
on and so always have a little spot in

1567
00:55:57,589 --> 00:55:54,799
my heart my first launch my first orbit

1568
00:55:59,430 --> 00:55:57,599
insertion my first time being an ace on

1569
00:56:00,870 --> 00:55:59,440
console at three in the morning during

1570
00:56:03,510 --> 00:56:00,880
six months of aerobraking like all of

1571
00:56:05,750 --> 00:56:03,520
those things were great um and since i

1572
00:56:07,430 --> 00:56:05,760
was on that mission for six years i made

1573
00:56:09,030 --> 00:56:07,440
a lot of friends with the people that i

1574
00:56:10,630 --> 00:56:09,040
work with and it's very cool to get the

1575
00:56:12,069 --> 00:56:10,640
bump into those people later on in your

1576
00:56:14,870 --> 00:56:12,079
career so that one will always have a

1577
00:56:17,829 --> 00:56:14,880
top spot my next mission kepler just in

1578
00:56:20,230 --> 00:56:17,839
terms of the sheer magnitude of

1579
00:56:22,069 --> 00:56:20,240
paradigm shift of our understanding of

1580
00:56:23,349 --> 00:56:22,079
the universe that one is probably going

1581
00:56:25,750 --> 00:56:23,359
to take the cake

1582
00:56:28,390 --> 00:56:25,760
for a long time because our

1583
00:56:31,270 --> 00:56:28,400
understanding now that that on average

1584
00:56:33,270 --> 00:56:31,280
right most stars have a planet or some

1585
00:56:35,190 --> 00:56:33,280
have none but some have many the idea

1586
00:56:36,710 --> 00:56:35,200
that you look up in the night sky like

1587
00:56:39,510 --> 00:56:36,720
at that milky way picture that i showed

1588
00:56:42,470 --> 00:56:39,520

before and the sky is basically dripping

1589
00:56:43,670 --> 00:56:42,480
with planet is ridiculous to me and it's

1590
00:56:47,910 --> 00:56:43,680
really

1591
00:56:49,430 --> 00:56:47,920
part in helping to get that mission to

1592
00:56:51,589 --> 00:56:49,440
the launch pad so that scientists can

1593
00:56:54,069 --> 00:56:51,599
make those kinds of discoveries and then

1594
00:56:55,589 --> 00:56:54,079
juno is another one that's great um if

1595
00:56:57,349 --> 00:56:55,599
you made me pick a favorite planet it

1596
00:56:59,910 --> 00:56:57,359
would probably be jupiter because come

1597
00:57:02,710 --> 00:56:59,920
on it's really cool and getting a chance

1598
00:57:04,309 --> 00:57:02,720
to be part of a team that

1599
00:57:06,710 --> 00:57:04,319
sent a spacecraft out there to learn so

1600
00:57:09,430 --> 00:57:06,720
many things about it is great i still

1601
00:57:11,270 --> 00:57:09,440
love that that image of the north pole

1602
00:57:13,910 --> 00:57:11,280
and infrared with all of those storms

1603
00:57:15,910 --> 00:57:13,920
it's very i didn't expect that kind of

1604
00:57:17,829 --> 00:57:15,920
science which is cool to see and i was

1605
00:57:19,750 --> 00:57:17,839
on that mission for nine years so again

1606
00:57:21,910 --> 00:57:19,760
made a lot of friends almost family

1607
00:57:23,510 --> 00:57:21,920
members of some of those folks went to

1608
00:57:24,950 --> 00:57:23,520
costa rica with my boss and his wife and

1609
00:57:27,030 --> 00:57:24,960
my husband and a bunch of geology

1610
00:57:28,630 --> 00:57:27,040
students one so that one will have a

1611
00:57:30,950 --> 00:57:28,640
soft spot too

1612
00:57:33,109 --> 00:57:30,960
psyche was special to me because it's

1613
00:57:34,309 --> 00:57:33,119

such a different technology than i was

1614
00:57:36,309 --> 00:57:34,319
used to

1615
00:57:38,710 --> 00:57:36,319
that mission was using low thrust

1616
00:57:40,630 --> 00:57:38,720
instead of the usual chemical propulsion

1617
00:57:43,109 --> 00:57:40,640
that i'm used to and there were so many

1618
00:57:44,870 --> 00:57:43,119
different challenges with respect to how

1619
00:57:47,270 --> 00:57:44,880
we designed a spacecraft and understood

1620
00:57:48,789 --> 00:57:47,280
the error sources and we're planning to

1621
00:57:50,309 --> 00:57:48,799
have those engines on all the time in

1622
00:57:52,630 --> 00:57:50,319
order to hit our maneuver execution

1623
00:57:54,870 --> 00:57:52,640
errors like all those things will remain

1624
00:57:56,470 --> 00:57:54,880
in my mind is just fresh different

1625
00:57:58,069 --> 00:57:56,480
challenges that were also really fun

1626
00:57:59,670 --> 00:57:58,079
there's a great team of people to be

1627
00:58:01,589 --> 00:57:59,680
working with so i will be

1628
00:58:03,109 --> 00:58:01,599
happily watching and keeping my fingers

1629
00:58:05,030 --> 00:58:03,119
crossed for the folks who are still

1630
00:58:06,710 --> 00:58:05,040
working to get that mission off the

1631
00:58:08,710 --> 00:58:06,720
ground and off to its destination and

1632
00:58:11,109 --> 00:58:08,720
then europa just because

1633
00:58:12,630 --> 00:58:11,119
when when i again not as a scientist so

1634
00:58:14,870 --> 00:58:12,640
sorry i have my favorites think about

1635
00:58:17,109 --> 00:58:14,880
the places in the solar system that are

1636
00:58:18,789 --> 00:58:17,119
the most intriguing for life um i can't

1637
00:58:22,069 --> 00:58:18,799
help but absorb the messages from all of

1638
00:58:24,150 --> 00:58:22,079

our science teams that europa is is off

1639
00:58:27,030 --> 00:58:24,160
the charts just a cool place to go and

1640
00:58:28,630 --> 00:58:27,040
study and i'm expecting hoping for a

1641
00:58:30,789 --> 00:58:28,640
similar game-changing shift in our

1642
00:58:33,349 --> 00:58:30,799
understanding of things here about in

1643
00:58:35,589 --> 00:58:33,359
our solar system and ocean moons in

1644
00:58:36,950 --> 00:58:35,599
general once we have the stagecraft out

1645
00:58:39,270 --> 00:58:36,960
there and gathering data that's a long

1646
00:58:41,109 --> 00:58:39,280
time from now but i'm patient and based

1647
00:58:47,190 --> 00:58:41,119
on my juno experience that five-year

1648
00:58:51,990 --> 00:58:49,510
can i squeeze in one more question so

1649
00:58:53,589 --> 00:58:52,000
tracy i read that um you really like

1650
00:58:55,349 --> 00:58:53,599
science fiction and one of the things

1651
00:58:56,870 --> 00:58:55,359
that i've heard a lot here this past

1652
00:58:59,190 --> 00:58:56,880
week is that there are many people who

1653
00:59:01,670 --> 00:58:59,200
were inspired by science fiction i was

1654
00:59:03,270 --> 00:59:01,680
wondering if you could speak to that

1655
00:59:05,109 --> 00:59:03,280
yeah to me

1656
00:59:07,430 --> 00:59:05,119
science fiction is one of those things

1657
00:59:10,230 --> 00:59:07,440
that just everyone's going to watch tv

1658
00:59:12,230 --> 00:59:10,240
right uh and it's something that is a a

1659
00:59:13,750 --> 00:59:12,240
way to

1660
00:59:16,789 --> 00:59:13,760
have a different vision of what the

1661
00:59:19,190 --> 00:59:16,799
future might be like in a way that just

1662
00:59:20,789 --> 00:59:19,200
inspires us to be creative i mean i

1663
00:59:22,309 --> 00:59:20,799

totally wanted to go have a job in space

1664
00:59:23,829 --> 00:59:22,319
so that i can make the world look more

1665
00:59:25,670 --> 00:59:23,839
like star trek then i didn't have any

1666
00:59:27,270 --> 00:59:25,680
illusions we were going to be on on the

1667
00:59:28,710 --> 00:59:27,280
enterprise and finding aliens and all

1668
00:59:31,109 --> 00:59:28,720
that stuff but just a little bit a

1669
00:59:33,190 --> 00:59:31,119
little baby steps in that direction it's

1670
00:59:35,190 --> 00:59:33,200
very very exciting for me and there's

1671
00:59:37,030 --> 00:59:35,200
all sorts of really interesting

1672
00:59:39,190 --> 00:59:37,040
collaborations especially living in los

1673
00:59:41,510 --> 00:59:39,200
angeles that you get to see between

1674
00:59:43,030 --> 00:59:41,520
scientists and and

1675
00:59:44,870 --> 00:59:43,040
people who scientists and engineers

1676
00:59:46,710 --> 00:59:44,880
people who are in stem field and folks

1677
00:59:49,030 --> 00:59:46,720
who work in entertainment industry

1678
00:59:50,230 --> 00:59:49,040
because they know that it's it's even

1679
00:59:52,230 --> 00:59:50,240
more

1680
00:59:54,069 --> 00:59:52,240
fun for people to watch films that have

1681
00:59:56,470 --> 00:59:54,079
more realistic science that have more

1682
00:59:58,390 --> 00:59:56,480
realistic characters in the movie that

1683
01:00:00,549 --> 00:59:58,400
have more realistic plot lines that are

1684
01:00:02,789 --> 01:00:00,559
related to science uh one of my favorite

1685
01:00:03,990 --> 01:00:02,799
recent movies was interstellar i also

1686
01:00:06,309 --> 01:00:04,000
really love the martian because there's

1687
01:00:08,470 --> 01:00:06,319
so much realistic engineering in it that

1688
01:00:10,230 --> 01:00:08,480

um it's just it's a it's a great way to

1689
01:00:11,829 --> 01:00:10,240
have fun with science and also think

1690
01:00:12,870 --> 01:00:11,839
about how we can apply it to the real

1691
01:00:14,549 --> 01:00:12,880
world not that applying it to the real

1692
01:00:17,109 --> 01:00:14,559
robot isn't fun too

1693
01:00:21,430 --> 01:00:18,950
and there was one question that jen

1694
01:00:23,589 --> 01:00:21,440
glass asked if you have any

1695
01:00:25,589 --> 01:00:23,599
words of advice for any young people who

1696
01:00:27,750 --> 01:00:25,599
might be listening

1697
01:00:29,430 --> 01:00:27,760
i do oh so much ah we could have spent a

1698
01:00:30,230 --> 01:00:29,440
whole hour just talking about that i

1699
01:00:31,829 --> 01:00:30,240
think

1700
01:00:33,750 --> 01:00:31,839
the thing that i like for young people

1701
01:00:35,750 --> 01:00:33,760
to know is that

1702
01:00:37,190 --> 01:00:35,760
number one

1703
01:00:38,630 --> 01:00:37,200
people always say you know find your

1704
01:00:40,069 --> 01:00:38,640
passion follow your passion okay great

1705
01:00:42,150 --> 01:00:40,079
but how do you do that and then young

1706
01:00:43,349 --> 01:00:42,160
people have all this stress on them how

1707
01:00:44,630 --> 01:00:43,359
do i find the thing that i'm going to

1708
01:00:46,470 --> 01:00:44,640
love and make sure i'm doing the thing

1709
01:00:48,309 --> 01:00:46,480
that i'm going to love and my own

1710
01:00:50,390 --> 01:00:48,319
personal origin story is a little bit

1711
01:00:52,069 --> 01:00:50,400
annoying to me because it sounds so

1712
01:00:53,510 --> 01:00:52,079
linear i grew up on science fiction i

1713
01:00:54,309 --> 01:00:53,520

wanted to be an engineer i work in nasa

1714
01:00:56,230 --> 01:00:54,319
now

1715
01:00:58,309 --> 01:00:56,240
but it does not work that way for all

1716
01:00:59,829 --> 01:00:58,319
people and i want fox to know i know

1717
01:01:01,589 --> 01:00:59,839
people who work at the lab who started

1718
01:01:03,109 --> 01:01:01,599
off in music and synthesizers and then

1719
01:01:05,109 --> 01:01:03,119
realized they could use that technology

1720
01:01:06,870 --> 01:01:05,119
and science data and people who started

1721
01:01:08,150 --> 01:01:06,880
at the lab doing science stuff and went

1722
01:01:09,990 --> 01:01:08,160
off to go do something completely

1723
01:01:12,390 --> 01:01:10,000
different like i want young people to

1724
01:01:13,190 --> 01:01:12,400
know that your your whole life

1725
01:01:15,349 --> 01:01:13,200
is

1726
01:01:16,710 --> 01:01:15,359
an exploration and you don't have to

1727
01:01:18,230 --> 01:01:16,720
feel like you have to be on this one

1728
01:01:19,910 --> 01:01:18,240
track and go that way forever you can

1729
01:01:21,910 --> 01:01:19,920
take a left turn and a right turn like

1730
01:01:23,030 --> 01:01:21,920
have some fun with it and don't panic

1731
01:01:25,109 --> 01:01:23,040
that you're not going to get it right

1732
01:01:28,069 --> 01:01:25,119
the first time

1733
01:01:28,789 --> 01:01:28,079
excellent advice wonderful

1734
01:01:31,270 --> 01:01:28,799
well

1735
01:01:33,190 --> 01:01:31,280
can you all join me in thanking tracy

1736
01:01:42,309 --> 01:01:33,200
for this excellent discussion this

1737
01:01:45,430 --> 01:01:43,750
thank you so much