
Matt Mountain
Dir. Space Telescope Science Institute, JWST Scientist

1
00:00:06,710 --> 00:00:04,470
hello and welcome to nasa headquarters

2
00:00:08,070 --> 00:00:06,720
i'm ellen stofan nasa's chief scientist

3
00:00:10,470 --> 00:00:08,080
and i'll be your moderator and

4
00:00:13,030 --> 00:00:10,480
facilitator for today's event where

5
00:00:14,950 --> 00:00:13,040
you'll hear about a truly extraordinary

6
00:00:18,470 --> 00:00:14,960
topic the search for life in the

7
00:00:20,230 --> 00:00:18,480
universe are we alone the fundamental

8
00:00:22,950 --> 00:00:20,240
question that drives so much of what we

9
00:00:25,269 --> 00:00:22,960
do at nasa from exploring mars to our

10
00:00:26,870 --> 00:00:25,279
research and astrobiology to the work

11
00:00:28,790 --> 00:00:26,880
that we do in astrophysics that you're

12
00:00:31,189 --> 00:00:28,800
going to be hearing about today

13
00:00:32,870 --> 00:00:31,199

pushing beyond our solar system and out

14
00:00:34,950 --> 00:00:32,880
into the universe

15
00:00:37,510 --> 00:00:34,960
to really address life beyond our solar

16
00:00:39,030 --> 00:00:37,520
system requires complex telescopes and

17
00:00:40,389 --> 00:00:39,040
instruments with truly unique

18
00:00:42,150 --> 00:00:40,399
capabilities

19
00:00:44,150 --> 00:00:42,160
the technological breakthroughs made

20
00:00:46,549 --> 00:00:44,160
possible by missions like the hubble

21
00:00:48,709 --> 00:00:46,559
space telescope kepler and the james

22
00:00:50,549 --> 00:00:48,719
webb space telescope are not only

23
00:00:52,549 --> 00:00:50,559
profoundly important for advancing

24
00:00:54,950 --> 00:00:52,559
discovery they show us what kind of

25
00:00:57,110 --> 00:00:54,960
innovation means for our leadership as a

26
00:00:59,110 --> 00:00:57,120
nation and as an international partner

27
00:01:01,349 --> 00:00:59,120
in exploration

28
00:01:03,510 --> 00:01:01,359
to officially kick off our program with

29
00:01:05,350 --> 00:01:03,520
opening remarks i'm very pleased to

30
00:01:07,510 --> 00:01:05,360
welcome the nasa administrator charlie

31
00:01:09,590 --> 00:01:07,520
bolden who has a strong commitment to

32
00:01:20,630 --> 00:01:09,600
science and to leading this agency

33
00:01:23,590 --> 00:01:21,749
helen thank you very much for the

34
00:01:25,749 --> 00:01:23,600
introduction and uh and thanks for the

35
00:01:27,350 --> 00:01:25,759
welcome to all of you uh thanks for

36
00:01:29,749 --> 00:01:27,360
coming out for those of you who don't

37
00:01:31,990 --> 00:01:29,759
live here normally uh

38
00:01:34,950 --> 00:01:32,000

hopefully you will have a good day it be

39
00:01:36,469 --> 00:01:34,960
a very uh inquisitive day for you i hope

40
00:01:38,310 --> 00:01:36,479
and you'll learn quite a bit i'm i'm

41
00:01:40,630 --> 00:01:38,320
looking forward to it i also want to

42
00:01:44,310 --> 00:01:40,640
thank you ellen and associate

43
00:01:46,149 --> 00:01:44,320
administrator for science john grunsfeld

44
00:01:48,310 --> 00:01:46,159
for really being the catalyst for

45
00:01:49,830 --> 00:01:48,320
organizing this event and for putting it

46
00:01:51,670 --> 00:01:49,840
together and putting together such a

47
00:01:53,670 --> 00:01:51,680
distinguished panel

48
00:01:56,550 --> 00:01:53,680
as former astronauts john and i are

49
00:01:59,109 --> 00:01:56,560
often asked have we seen

50
00:02:01,429 --> 00:01:59,119
or do we believe that there is life

51
00:02:03,429 --> 00:02:01,439
beyond earth

52
00:02:04,950 --> 00:02:03,439
and i can't speak for john i'll let john

53
00:02:07,030 --> 00:02:04,960
speak for himself

54
00:02:08,309 --> 00:02:07,040
later on but while i may not have

55
00:02:10,469 --> 00:02:08,319
actually encountered uh

56
00:02:11,670 --> 00:02:10,479
extraterrestrials and i did not as a

57
00:02:14,390 --> 00:02:11,680
matter of fact

58
00:02:17,190 --> 00:02:14,400
uh although i looked all the time i i

59
00:02:20,470 --> 00:02:17,200
was uh i have always been inquisitive

60
00:02:22,790 --> 00:02:20,480
and so i was looking really hard

61
00:02:25,670 --> 00:02:22,800
i would venture to say however that that

62
00:02:27,430 --> 00:02:25,680
most of my colleagues here uh today as

63
00:02:29,990 --> 00:02:27,440

well as probably most of you in the

64
00:02:31,990 --> 00:02:30,000
audience are probably convinced that

65
00:02:34,070 --> 00:02:32,000
it's highly improbable

66
00:02:35,910 --> 00:02:34,080
in the limitless vastness of the

67
00:02:38,150 --> 00:02:35,920
universe that

68
00:02:40,949 --> 00:02:38,160
that we humans stand alone

69
00:02:42,470 --> 00:02:40,959
um i have always believed that as a

70
00:02:46,949 --> 00:02:42,480
matter of

71
00:02:48,790 --> 00:02:46,959
and other things so so i find it hard to

72
00:02:51,830 --> 00:02:48,800
believe that that we're in this world

73
00:02:53,990 --> 00:02:51,840
alone but the question remains is posed

74
00:02:55,509 --> 00:02:54,000
by nobel prize-winning physicist enrico

75
00:02:58,949 --> 00:02:55,519
fermi

76
00:03:01,430 --> 00:02:58,959
if we're so sure that life exists

77
00:03:03,509 --> 00:03:01,440
elsewhere in the galaxy

78
00:03:05,670 --> 00:03:03,519
where is everybody

79
00:03:07,589 --> 00:03:05,680
and so uh that's a question that

80
00:03:09,670 --> 00:03:07,599
scientists and people the world over

81
00:03:11,750 --> 00:03:09,680
have been asking for centuries

82
00:03:13,830 --> 00:03:11,760
and it's a question that motivates much

83
00:03:15,589 --> 00:03:13,840
of the work that we do at nasa as dr

84
00:03:16,790 --> 00:03:15,599
stouffen mentioned in her introductory

85
00:03:19,350 --> 00:03:16,800
remarks

86
00:03:21,110 --> 00:03:19,360
in fact a big part of what's driving our

87
00:03:22,390 --> 00:03:21,120
next giant leap into deep space

88
00:03:24,309 --> 00:03:22,400

exploration

89
00:03:27,030 --> 00:03:24,319
with human missions planned to an

90
00:03:29,509 --> 00:03:27,040
asteroid in mars is a relentless search

91
00:03:31,190 --> 00:03:29,519
for life in the universe

92
00:03:33,589 --> 00:03:31,200
the path has been illuminated by

93
00:03:35,270 --> 00:03:33,599
missions like the kepler space telescope

94
00:03:37,670 --> 00:03:35,280
which over the course of its life has

95
00:03:39,589 --> 00:03:37,680
shown that our galaxy is host to

96
00:03:40,630 --> 00:03:39,599
billions of planets and planetary

97
00:03:42,789 --> 00:03:40,640
systems

98
00:03:44,550 --> 00:03:42,799
that small planets the size of earth are

99
00:03:46,710 --> 00:03:44,560
common and that planets come in

100
00:03:48,550 --> 00:03:46,720
astonishing diversity

101
00:03:51,190 --> 00:03:48,560
this past april kepler discovered the

102
00:03:53,270 --> 00:03:51,200
first first earth-sized planet in the

103
00:03:55,350 --> 00:03:53,280
so-called habitable zone

104
00:03:57,990 --> 00:03:55,360
the james webb space telescope set to be

105
00:03:59,830 --> 00:03:58,000
deployed in the next few years will also

106
00:04:02,070 --> 00:03:59,840
join this effort as it becomes the

107
00:04:04,309 --> 00:04:02,080
premier space observatory for

108
00:04:06,149 --> 00:04:04,319
astronomers worldwide

109
00:04:08,309 --> 00:04:06,159
extending discoveries of the hubble

110
00:04:11,190 --> 00:04:08,319
space telescope helping us unravel the

111
00:04:13,509 --> 00:04:11,200
mystery of how the universe grew from a

112
00:04:15,830 --> 00:04:13,519
big bang into galaxies

113
00:04:17,590 --> 00:04:15,840

stars and planets and searching for

114
00:04:19,430 --> 00:04:17,600
signs of life

115
00:04:21,590 --> 00:04:19,440
our robotic mars missions including

116
00:04:24,230 --> 00:04:21,600
curiosity opportunity in our planned

117
00:04:26,469 --> 00:04:24,240
mars 2020 mission i'm glad that dr

118
00:04:27,909 --> 00:04:26,479
grunsfeld could take a break

119
00:04:30,070 --> 00:04:27,919
from meeting this morning you may have

120
00:04:32,870 --> 00:04:30,080
finished as a matter of fact but

121
00:04:34,870 --> 00:04:32,880
defining the next mars rover and the

122
00:04:37,670 --> 00:04:34,880
mars 2020 mission

123
00:04:40,150 --> 00:04:37,680
they're all also adding to our knowledge

124
00:04:42,790 --> 00:04:40,160
about the possibility of life on mars as

125
00:04:44,310 --> 00:04:42,800
they pave the way for human explorations

126
00:04:47,670 --> 00:04:44,320
and pioneering

127
00:04:49,830 --> 00:04:47,680
kepler our mars missions jwst and the

128
00:04:52,469 --> 00:04:49,840
work of scientists and astrobiologists

129
00:04:54,390 --> 00:04:52,479
at nasa jpl and throughout the nation

130
00:04:57,590 --> 00:04:54,400
are rewriting textbooks

131
00:04:58,710 --> 00:04:57,600
and talking taking us one step closer to

132
00:05:00,629 --> 00:04:58,720
our search

133
00:05:02,710 --> 00:05:00,639
for life in the universe

134
00:05:04,390 --> 00:05:02,720
today we're privileged to have some of

135
00:05:06,390 --> 00:05:04,400
the leading experts in the field who

136
00:05:08,390 --> 00:05:06,400
will share what they are learning as

137
00:05:10,629 --> 00:05:08,400
they come closer and closer to answering

138
00:05:11,749 --> 00:05:10,639

that elusive question

139
00:05:13,270 --> 00:05:11,759
so

140
00:05:15,909 --> 00:05:13,280
matt mountain

141
00:05:17,749 --> 00:05:15,919
where is everybody

142
00:05:19,909 --> 00:05:17,759
to kick off the discussion i'm pleased

143
00:05:21,670 --> 00:05:19,919
to bring back to the podium nasa chief

144
00:05:31,270 --> 00:05:21,680
scientist ellen stoffen who will

145
00:05:34,870 --> 00:05:33,270
thank you charlie your presence here

146
00:05:37,590 --> 00:05:34,880
really demonstrates how integral this

147
00:05:39,830 --> 00:05:37,600
topic is to the mission of the agency

148
00:05:41,430 --> 00:05:39,840
we have a truly exceptional group of

149
00:05:43,350 --> 00:05:41,440
speakers here today

150
00:05:45,110 --> 00:05:43,360
to help us understand where we are and

151
00:05:47,350 --> 00:05:45,120
where we're going in our search for life

152
00:05:49,590 --> 00:05:47,360
in the odd in the universe

153
00:05:51,110 --> 00:05:49,600
dr john grunsfeld is nasa's associate

154
00:05:53,749 --> 00:05:51,120
administrator for the science mission

155
00:05:56,469 --> 00:05:53,759
directorate he's an astrophysicist and a

156
00:05:58,230 --> 00:05:56,479
five-time shuttle astronaut who

157
00:06:00,309 --> 00:05:58,240
personally repaired the great hubble

158
00:06:09,350 --> 00:06:00,319
observatory in orbit

159
00:06:13,909 --> 00:06:12,070
dr john mather is nasa goddard space

160
00:06:16,469 --> 00:06:13,919
flight center senior project scientist

161
00:06:18,150 --> 00:06:16,479
for the james webb space telescope dr

162
00:06:20,469 --> 00:06:18,160
mather leads the international team of

163
00:06:22,550 --> 00:06:20,479

scientists on the on the web telescope

164
00:06:24,710 --> 00:06:22,560
program as principal investigator for an

165
00:06:25,830 --> 00:06:24,720
instrument on nasa's cosmic background

166
00:06:27,430 --> 00:06:25,840
explorer

167
00:06:29,350 --> 00:06:27,440
dr mather and the team measured the

168
00:06:31,990 --> 00:06:29,360
ancient radiation from the big bang

169
00:06:33,990 --> 00:06:32,000
confirming the cosmological model of the

170
00:06:35,189 --> 00:06:34,000
universe's origins to extraordinary

171
00:06:36,950 --> 00:06:35,199
accuracy

172
00:06:38,710 --> 00:06:36,960
for this stunning achievement he and his

173
00:06:42,309 --> 00:06:38,720
colleague george smoot of the university

174
00:06:50,629 --> 00:06:42,319
of california won the 2006 nobel prize

175
00:06:54,550 --> 00:06:52,790
dr sarah seeger is professor of

176
00:06:57,270 --> 00:06:54,560
planetary science and physics at the

177
00:06:59,589 --> 00:06:57,280
massachusetts institute of technology

178
00:07:01,589 --> 00:06:59,599
dr professor seeger is an astrophysicist

179
00:07:03,670 --> 00:07:01,599
and a planetary scientist at mit whose

180
00:07:05,510 --> 00:07:03,680
work led to the first detection of an

181
00:07:07,350 --> 00:07:05,520
exoplanet atmosphere

182
00:07:09,189 --> 00:07:07,360
she is a co-investigator on the nasa

183
00:07:11,270 --> 00:07:09,199
explorer mission called tess to be

184
00:07:13,510 --> 00:07:11,280
launched in 2017

185
00:07:15,830 --> 00:07:13,520
an all-sky survey focused on finding

186
00:07:16,950 --> 00:07:15,840
rocky rocky planets transiting small

187
00:07:19,830 --> 00:07:16,960
stars

188
00:07:22,710 --> 00:07:19,840

professor seeger is a 2013 macarthur

189
00:07:24,150 --> 00:07:22,720
fellow an award sometimes referred to as

190
00:07:31,749 --> 00:07:24,160
a genius grant

191
00:07:35,909 --> 00:07:33,909
dave gallagher is director for astronomy

192
00:07:37,909 --> 00:07:35,919
and physics at nasa's jet propulsion

193
00:07:39,909 --> 00:07:37,919
laboratory he works at the cutting edge

194
00:07:41,670 --> 00:07:39,919
of technology for nasa and for missions

195
00:07:43,749 --> 00:07:41,680
of national priority

196
00:07:46,469 --> 00:07:43,759
he's an electrical engineer and has run

197
00:07:47,510 --> 00:07:46,479
jpl's advanced optical systems programs

198
00:07:49,430 --> 00:07:47,520
office

199
00:07:51,110 --> 00:07:49,440
with tremendous experience in both

200
00:07:53,029 --> 00:07:51,120
government and private industry he

201
00:07:55,029 --> 00:07:53,039
brings a sophisticated perspective to

202
00:08:04,150 --> 00:07:55,039
the unique challenges facing the us

203
00:08:08,790 --> 00:08:07,189
and our last speaker today will be uh dr

204
00:08:10,869 --> 00:08:08,800
matt mountain who's the director of the

205
00:08:12,550 --> 00:08:10,879
space telescope science institute and

206
00:08:14,869 --> 00:08:12,560
organization responsible for the

207
00:08:16,950 --> 00:08:14,879
groundbreaking research program of the

208
00:08:18,469 --> 00:08:16,960
hubble space telescope and its successor

209
00:08:20,869 --> 00:08:18,479
the webb telescope

210
00:08:22,710 --> 00:08:20,879
dr mountain is also an astrophysicist

211
00:08:25,350 --> 00:08:22,720
the telescope scientist for webb a

212
00:08:27,029 --> 00:08:25,360
professor at johns hopkins department of

213
00:08:30,390 --> 00:08:27,039

physics and astronomy and a visiting

214
00:08:32,389 --> 00:08:30,400
professor at the university of oxford

215
00:08:34,310 --> 00:08:32,399
before leading uh the space telescope

216
00:08:36,949 --> 00:08:34,320
institute dr mountain led the team that

217
00:08:39,269 --> 00:08:36,959
designed built and commissioned the two

218
00:08:41,350 --> 00:08:39,279
eight meter diameter gemini telescopes

219
00:08:43,589 --> 00:08:41,360
and he developed an adaptive optics

220
00:08:45,829 --> 00:08:43,599
group to help gemini remain at the

221
00:08:47,590 --> 00:08:45,839
forefront of observational infrared

222
00:08:55,670 --> 00:08:47,600
astronomy

223
00:09:00,150 --> 00:08:57,590
for our audience today who's watching on

224
00:09:02,150 --> 00:09:00,160
nasa tv and the web uh you can go to

225
00:09:04,230 --> 00:09:02,160
twitter or facebook during the

226
00:09:05,430 --> 00:09:04,240
presentations and use the

227
00:09:07,110 --> 00:09:05,440
hashtag

228
00:09:08,870 --> 00:09:07,120
ask nasa

229
00:09:10,550 --> 00:09:08,880
we will be collecting your questions

230
00:09:12,150 --> 00:09:10,560
throughout our session and we'll address

231
00:09:13,509 --> 00:09:12,160
as many as we can following the

232
00:09:15,430 --> 00:09:13,519
presentations

233
00:09:16,790 --> 00:09:15,440
we'll also be taking a few questions

234
00:09:18,070 --> 00:09:16,800
from our audience here at nasa

235
00:09:25,670 --> 00:09:18,080
headquarters

236
00:09:29,750 --> 00:09:27,509
thank you very much ellen and welcome

237
00:09:32,389 --> 00:09:29,760
everyone to our session on the search

238
00:09:33,829 --> 00:09:32,399

for life in the universe

239
00:09:35,910 --> 00:09:33,839
we are entering a new realm in our

240
00:09:37,350 --> 00:09:35,920
search to answer the question are we

241
00:09:38,949 --> 00:09:37,360
alone

242
00:09:41,190 --> 00:09:38,959
and today we're here to tell you a bit

243
00:09:43,670 --> 00:09:41,200
of a grand story

244
00:09:45,110 --> 00:09:43,680
thanks to investments in technology we

245
00:09:47,509 --> 00:09:45,120
have pushed the limits of our most

246
00:09:49,269 --> 00:09:47,519
creative scientists and engineers and

247
00:09:51,910 --> 00:09:49,279
are about to take a big leap in our

248
00:10:03,430 --> 00:09:51,920
quest to unravel the mysteries of the

249
00:10:12,389 --> 00:10:05,509
that next big step

250
00:10:12,399 --> 00:10:19,110
and we love drama at nasa

251
00:10:28,870 --> 00:10:23,350
coming in 2018 october 2018 in fact the

252
00:10:28,880 --> 00:10:33,590
will transform our view of the universe

253
00:10:40,710 --> 00:10:36,710
in space 2018.

254
00:10:42,150 --> 00:10:40,720
now 400 years ago sorry our mission

255
00:10:45,430 --> 00:10:42,160
is to innovate

256
00:10:48,550 --> 00:10:45,440
explore discover and inspire and i hope

257
00:10:51,750 --> 00:10:48,560
today that's our really our main purpose

258
00:10:52,949 --> 00:10:51,760
is to inspire all of you to be along our

259
00:10:54,870 --> 00:10:52,959
our path

260
00:10:55,990 --> 00:10:54,880
to try and unravel these mysteries and

261
00:10:57,829 --> 00:10:56,000
perhaps

262
00:10:59,750 --> 00:10:57,839
to find out the answer to the question

263
00:11:01,509 --> 00:10:59,760

are we alone

264
00:11:03,269 --> 00:11:01,519
and that's really the key we've made

265
00:11:05,190 --> 00:11:03,279
enormous technical advances and you're

266
00:11:07,030 --> 00:11:05,200
going to hear from our speakers that we

267
00:11:09,350 --> 00:11:07,040
are on the cusp perhaps the next

268
00:11:11,990 --> 00:11:09,360
generation to be able to

269
00:11:15,670 --> 00:11:12,000
answer that question are we alone

270
00:11:18,389 --> 00:11:15,680
from a scientific progression

271
00:11:20,710 --> 00:11:18,399
galileo started it all 400 years ago

272
00:11:21,990 --> 00:11:20,720
when he turned the telescope not

273
00:11:25,269 --> 00:11:22,000
from the

274
00:11:27,990 --> 00:11:25,279
italian reconnaissance organization

275
00:11:31,110 --> 00:11:28,000
but to look at the skies and in fact

276
00:11:33,430 --> 00:11:31,120
invented telescopic astronomy and from

277
00:11:35,670 --> 00:11:33,440
there emerged a great scientific

278
00:11:36,949 --> 00:11:35,680
renaissance

279
00:11:39,110 --> 00:11:36,959
in our time

280
00:11:40,790 --> 00:11:39,120
the hubble space telescope deployed by

281
00:11:44,470 --> 00:11:40,800
charlie bolden

282
00:11:45,590 --> 00:11:44,480
in 1990 and repaired by me a few times

283
00:11:47,750 --> 00:11:45,600
the hubble

284
00:11:50,150 --> 00:11:47,760
you know has really transformed our view

285
00:11:52,389 --> 00:11:50,160
of the universe and

286
00:11:54,470 --> 00:11:52,399
not just for scientists but i think for

287
00:11:57,110 --> 00:11:54,480
everybody on planet earth

288
00:11:59,350 --> 00:11:57,120

it's open frontiers in virtually all

289
00:12:03,110 --> 00:11:59,360
areas of not only astronomy but many

290
00:12:06,150 --> 00:12:04,870
today we're going to present to you a

291
00:12:07,350 --> 00:12:06,160
little bit of the history of the

292
00:12:09,990 --> 00:12:07,360
universe

293
00:12:12,550 --> 00:12:10,000
but it won't take 13.72 billion years to

294
00:12:14,629 --> 00:12:12,560
describe but i find it amazing that with

295
00:12:17,350 --> 00:12:14,639
relatively small telescopes the hubble

296
00:12:19,509 --> 00:12:17,360
is a 2.4 meter telescope in earth orbit

297
00:12:21,829 --> 00:12:19,519
we've been able to piece together almost

298
00:12:24,870 --> 00:12:21,839
this entire history of the universe

299
00:12:26,949 --> 00:12:24,880
from uh just a few hundred million years

300
00:12:31,110 --> 00:12:26,959
after the big bang to the evolution of

301
00:12:33,110 --> 00:12:31,120
stars galaxies planets uh our own planet

302
00:12:35,350 --> 00:12:33,120
and the solar system that we live in

303
00:12:43,190 --> 00:12:35,360
john mather will describe this in in

304
00:12:46,550 --> 00:12:44,870
finding earth's twin

305
00:12:47,670 --> 00:12:46,560
that's kind of the holy grail that

306
00:12:49,269 --> 00:12:47,680
doesn't mean

307
00:12:51,030 --> 00:12:49,279
the only place that we might find out

308
00:12:53,509 --> 00:12:51,040
whether there's life elsewhere besides

309
00:12:55,509 --> 00:12:53,519
planet earth but the kepler telescope

310
00:12:58,389 --> 00:12:55,519
has discovered thousands of new planets

311
00:13:00,230 --> 00:12:58,399
and has found out uh as you heard that

312
00:13:03,190 --> 00:13:00,240
there are probably billions of planets

313
00:13:04,949 --> 00:13:03,200

like earth in our own solar system

314
00:13:07,910 --> 00:13:04,959
this is a picture of a system that

315
00:13:09,590 --> 00:13:07,920
kepler discovered kepler-62 and in that

316
00:13:11,350 --> 00:13:09,600
system are several planets that could

317
00:13:13,750 --> 00:13:11,360
live in a so-called habitable zone where

318
00:13:15,509 --> 00:13:13,760
liquid water would exist trying to look

319
00:13:17,269 --> 00:13:15,519
for life that's familiar to us and sarah

320
00:13:19,590 --> 00:13:17,279
seeger will describe that

321
00:13:21,670 --> 00:13:19,600
in some more detail

322
00:13:23,430 --> 00:13:21,680
what are we looking for this is science

323
00:13:24,710 --> 00:13:23,440
we're not looking for

324
00:13:26,310 --> 00:13:24,720
you know what charlie and i might have

325
00:13:28,310 --> 00:13:26,320
been looking for on orbit which were

326
00:13:30,790 --> 00:13:28,320
aliens coming to visit us we're looking

327
00:13:33,190 --> 00:13:30,800
for signs of life on a planet around a

328
00:13:34,550 --> 00:13:33,200
nearby star and what those signs might

329
00:13:36,949 --> 00:13:34,560
look like well if we were looking at

330
00:13:40,150 --> 00:13:36,959
earth we would see signs of our sky our

331
00:13:42,790 --> 00:13:40,160
blue sky we would see signs of oxygen of

332
00:13:44,550 --> 00:13:42,800
carbon dioxide of sulfur dioxide from

333
00:13:46,310 --> 00:13:44,560
volcanoes and we might even see

334
00:13:48,470 --> 00:13:46,320
signatures that there was plant life and

335
00:13:50,310 --> 00:13:48,480
we see that by dissecting the light into

336
00:13:52,150 --> 00:13:50,320
its component colors and sarah will

337
00:13:54,949 --> 00:13:52,160
describe that in some more detail

338
00:13:57,350 --> 00:13:54,959

spectroscopy

339
00:13:58,790 --> 00:13:57,360
occasionally we have a chance alignment

340
00:14:01,189 --> 00:13:58,800
of a planet

341
00:14:03,110 --> 00:14:01,199
with its star and light passes through

342
00:14:04,949 --> 00:14:03,120
the atmosphere and it's some of that

343
00:14:06,949 --> 00:14:04,959
light that we can look at that will tell

344
00:14:08,870 --> 00:14:06,959
us about the characteristics of the

345
00:14:10,790 --> 00:14:08,880
planet it's called a transit or transit

346
00:14:13,269 --> 00:14:10,800
spectroscopy

347
00:14:15,350 --> 00:14:13,279
the james webb space telescope

348
00:14:18,790 --> 00:14:15,360
may allow us to detect the presence of

349
00:14:22,949 --> 00:14:21,189
around a very large planet a rocky

350
00:14:24,790 --> 00:14:22,959
planet a water world

351
00:14:26,389 --> 00:14:24,800
to go the next steps

352
00:14:28,389 --> 00:14:26,399
we want to look for

353
00:14:30,389 --> 00:14:28,399
bio signatures

354
00:14:32,550 --> 00:14:30,399
not just of liquid water but of the

355
00:14:36,310 --> 00:14:32,560
gases in the atmosphere and perhaps

356
00:14:40,470 --> 00:14:38,710
our investments may transform the way we

357
00:14:41,990 --> 00:14:40,480
approach this the space launch system

358
00:14:43,750 --> 00:14:42,000
for example

359
00:14:46,470 --> 00:14:43,760
could provide us the capability to

360
00:14:49,030 --> 00:14:46,480
launch a much larger complex telescope

361
00:14:50,870 --> 00:14:49,040
or perhaps to go investigate europa and

362
00:14:52,870 --> 00:14:50,880
instead of taking seven years to get

363
00:14:56,829 --> 00:14:52,880

there we could get there in an express

364
00:15:02,069 --> 00:14:59,509
years we've seen some amazing things in

365
00:15:04,150 --> 00:15:02,079
our solar system this is a view of part

366
00:15:06,550 --> 00:15:04,160
of saturn and saturn's rings from the

367
00:15:07,829 --> 00:15:06,560
cassini spacecraft and if you look

368
00:15:09,990 --> 00:15:07,839
closely

369
00:15:14,629 --> 00:15:10,000
you see this pale blue dot that's the

370
00:15:18,310 --> 00:15:16,230
pretty amazing it doesn't look like much

371
00:15:20,389 --> 00:15:18,320
but by analyzing the light

372
00:15:21,910 --> 00:15:20,399
of the earth from this distance we can

373
00:15:24,470 --> 00:15:21,920
learn something about the planet and

374
00:15:26,230 --> 00:15:24,480
sarah will talk more about that

375
00:15:28,470 --> 00:15:26,240
so we have a progression we have a road

376
00:15:29,910 --> 00:15:28,480
map or a path that we're trying to take

377
00:15:33,030 --> 00:15:29,920
and it started with ground-based

378
00:15:34,629 --> 00:15:33,040
observatories and the 1995 discovery

379
00:15:36,230 --> 00:15:34,639
that we live in a universe that has

380
00:15:37,829 --> 00:15:36,240
other planets in it

381
00:15:39,430 --> 00:15:37,839
uh originally we thought there were only

382
00:15:42,230 --> 00:15:39,440
nine planets of course then we were

383
00:15:44,389 --> 00:15:42,240
demoted to eight planets

384
00:15:46,629 --> 00:15:44,399
but with hubble the spitzer and the

385
00:15:47,990 --> 00:15:46,639
kepler telescopes we've really

386
00:15:49,990 --> 00:15:48,000
transformed our whole view of the

387
00:15:52,389 --> 00:15:50,000
universe and sarah will talk about that

388
00:15:53,990 --> 00:15:52,399

but such that we now know that we live

389
00:15:56,230 --> 00:15:54,000
in a galaxy and a universe filled with

390
00:15:58,230 --> 00:15:56,240
planets we're working on the transiting

391
00:16:00,389 --> 00:15:58,240
exoplanet survey satellite which will

392
00:16:02,150 --> 00:16:00,399
survey our nearest neighbors the james

393
00:16:04,710 --> 00:16:02,160
webb space telescope which will allow us

394
00:16:06,470 --> 00:16:04,720
to study those neighbors in great detail

395
00:16:07,670 --> 00:16:06,480
we're also working on concept studies

396
00:16:10,470 --> 00:16:07,680
and you'll hear from dave gallagher

397
00:16:11,670 --> 00:16:10,480
about that of the wfirst slash afta

398
00:16:14,150 --> 00:16:11,680
telescope

399
00:16:16,310 --> 00:16:14,160
and in the decadal survey was outlined a

400
00:16:18,310 --> 00:16:16,320
new world's telescope a telescope of a

401
00:16:20,389 --> 00:16:18,320
new generation that might be able to

402
00:16:23,110 --> 00:16:20,399
actually answer that question are we

403
00:16:25,030 --> 00:16:23,120
alone in the universe

404
00:16:27,670 --> 00:16:25,040
these are not just dreams this is what

405
00:16:29,509 --> 00:16:27,680
we do at nasa we cue up things that some

406
00:16:31,990 --> 00:16:29,519
people say are impossible or that our

407
00:16:42,230 --> 00:16:32,000
dreams and we make them reality and with

408
00:16:45,350 --> 00:16:43,910
wes thank you

409
00:16:47,110 --> 00:16:45,360
it's working

410
00:16:49,269 --> 00:16:47,120
i want to tell you about how we're doing

411
00:16:51,189 --> 00:16:49,279
on the james webb telescope itself and

412
00:16:53,030 --> 00:16:51,199
to show you how it fits into the grand

413
00:16:54,629 --> 00:16:53,040

scheme of uh getting ready to discover

414
00:16:56,230 --> 00:16:54,639
life around other planets if it's

415
00:16:57,829 --> 00:16:56,240
actually out there

416
00:16:59,990 --> 00:16:57,839
so i've been a telescope builder all my

417
00:17:01,829 --> 00:17:00,000
life because when i asked my dad when i

418
00:17:04,710 --> 00:17:01,839
was about six years old how did we get

419
00:17:06,309 --> 00:17:04,720
here nobody knew so how do you find out

420
00:17:07,110 --> 00:17:06,319
you build telescopes

421
00:17:09,669 --> 00:17:07,120
so

422
00:17:10,630 --> 00:17:09,679
i want to show you how we're doing it

423
00:17:12,789 --> 00:17:10,640
so

424
00:17:14,470 --> 00:17:12,799
with our first chart here i have an

425
00:17:15,990 --> 00:17:14,480
illustration from edwin hubble that's

426
00:17:18,870 --> 00:17:16,000
him sitting with the big telescope the

427
00:17:20,870 --> 00:17:18,880
mount wilson out in california it's a

428
00:17:23,110 --> 00:17:20,880
100 inch telescope basically the same

429
00:17:24,309 --> 00:17:23,120
size as the hubble telescope that we now

430
00:17:25,990 --> 00:17:24,319
have in space

431
00:17:28,069 --> 00:17:26,000
it took us more or less a century to

432
00:17:30,470 --> 00:17:28,079
catch up with being able to put stuff in

433
00:17:32,150 --> 00:17:30,480
space he was able with that telescope to

434
00:17:34,789 --> 00:17:32,160
make that little picture that we saw on

435
00:17:36,789 --> 00:17:34,799
the lower right which is a picture of

436
00:17:38,870 --> 00:17:36,799
the galaxies how far away they are and

437
00:17:40,310 --> 00:17:38,880
how fast they're going so he was the

438
00:17:42,390 --> 00:17:40,320

first one to really know that this

439
00:17:44,150 --> 00:17:42,400
picture was correct though other a few

440
00:17:45,750 --> 00:17:44,160
other people had predicted it but this

441
00:17:47,190 --> 00:17:45,760
was the discovery of the expanding

442
00:17:48,950 --> 00:17:47,200
universe

443
00:17:51,110 --> 00:17:48,960
if somebody talks about the big bang

444
00:17:53,270 --> 00:17:51,120
theory and they think it's kind of silly

445
00:17:56,549 --> 00:17:53,280
well we were forced into this we saw it

446
00:17:58,070 --> 00:17:56,559
happen in 1929 and people were stunned

447
00:17:59,029 --> 00:17:58,080
this was front page news around the

448
00:18:00,390 --> 00:17:59,039
world

449
00:18:02,710 --> 00:18:00,400
and we've been living with it and trying

450
00:18:04,710 --> 00:18:02,720
to understand it ever since it's a very

451
00:18:05,830 --> 00:18:04,720
strange and amazing story but it seems

452
00:18:07,909 --> 00:18:05,840
to be true

453
00:18:09,270 --> 00:18:07,919
so we haven't got a better story

454
00:18:11,029 --> 00:18:09,280
so

455
00:18:13,590 --> 00:18:11,039
now we are continuing the trend about

456
00:18:15,750 --> 00:18:13,600
building better and bigger telescopes

457
00:18:18,310 --> 00:18:15,760
and trying to figure out what else is

458
00:18:20,390 --> 00:18:18,320
out there so here we have a

459
00:18:22,710 --> 00:18:20,400
see if this is going to come out

460
00:18:24,549 --> 00:18:22,720
a picture taken with the hubble space

461
00:18:27,270 --> 00:18:24,559
telescope as the background and here is

462
00:18:29,430 --> 00:18:27,280
the capsule history in the graphic

463
00:18:32,150 --> 00:18:29,440

so by the way on this chart are two

464
00:18:34,390 --> 00:18:32,160
discoveries that earned nobel prizes uh

465
00:18:35,909 --> 00:18:34,400
one is the little map that's on the left

466
00:18:37,510 --> 00:18:35,919
hand side you see that little green and

467
00:18:38,950 --> 00:18:37,520
blue

468
00:18:40,470 --> 00:18:38,960
speculate pattern that was what was

469
00:18:43,110 --> 00:18:40,480
discovered by the cosmic background

470
00:18:46,070 --> 00:18:43,120
explorer satellite and led to

471
00:18:48,070 --> 00:18:46,080
that prize of 2006 for our team

472
00:18:50,150 --> 00:18:48,080
there's another one on here which is uh

473
00:18:51,830 --> 00:18:50,160
nine billion years later uh where it

474
00:18:53,669 --> 00:18:51,840
says dark energy and accelerated

475
00:18:56,470 --> 00:18:53,679
expansion that was discovered based on

476
00:18:57,909 --> 00:18:56,480
the hubble space telescope as well we

477
00:18:59,590 --> 00:18:57,919
now know there's something called dark

478
00:19:00,710 --> 00:18:59,600
energy which means we don't know what it

479
00:19:05,270 --> 00:19:00,720
is

480
00:19:07,029 --> 00:19:05,280
expand at an accelerating rate

481
00:19:09,270 --> 00:19:07,039
so there's still plenty of mysteries on

482
00:19:10,870 --> 00:19:09,280
this chart we have an idea about how

483
00:19:13,190 --> 00:19:10,880
this whole thing works

484
00:19:14,549 --> 00:19:13,200
we have recognized evidence for dark

485
00:19:16,710 --> 00:19:14,559
matter in the universe much more

486
00:19:19,350 --> 00:19:16,720
abundant than ordinary matter

487
00:19:22,390 --> 00:19:19,360
and this story is pretty spectacular

488
00:19:24,070 --> 00:19:22,400

not to say proven completely but it

489
00:19:26,470 --> 00:19:24,080
matches astonishingly well with the

490
00:19:28,630 --> 00:19:26,480
observations that we have so we claim

491
00:19:30,310 --> 00:19:28,640
from the story that we're telling here

492
00:19:32,390 --> 00:19:30,320
and the formula that go with it that we

493
00:19:34,710 --> 00:19:32,400
know the details of the universe within

494
00:19:37,190 --> 00:19:34,720
a few percent accuracy which is really a

495
00:19:39,029 --> 00:19:37,200
truly stunning accomplishment for modern

496
00:19:40,549 --> 00:19:39,039
science and it is entirely based on

497
00:19:43,669 --> 00:19:40,559
space astronomy

498
00:19:44,470 --> 00:19:43,679
that we have initiated here at nasa

499
00:19:45,430 --> 00:19:44,480
so

500
00:19:47,110 --> 00:19:45,440
um

501
00:19:49,029 --> 00:19:47,120
among the things to point out here are

502
00:19:52,150 --> 00:19:49,039
that the first stars probably formed

503
00:19:55,190 --> 00:19:52,160
about 400 000 years sorry 400 million

504
00:19:57,110 --> 00:19:55,200
years after the expansion began

505
00:19:59,750 --> 00:19:57,120
uh i would also like to point out that

506
00:20:01,590 --> 00:19:59,760
uh the the big bang that we describe as

507
00:20:03,350 --> 00:20:01,600
a big bang is not like a firecracker

508
00:20:05,110 --> 00:20:03,360
going off in the corner but is actually

509
00:20:07,270 --> 00:20:05,120
an infinite universe expanding into

510
00:20:09,110 --> 00:20:07,280
itself probably without a beginning

511
00:20:10,789 --> 00:20:09,120
although we talk about the beginning and

512
00:20:12,870 --> 00:20:10,799
probably without an end

513
00:20:14,710 --> 00:20:12,880

so this is something we don't know but

514
00:20:15,510 --> 00:20:14,720
sure would like to know

515
00:20:17,510 --> 00:20:15,520
so

516
00:20:18,950 --> 00:20:17,520
i'm going on to tell you more about it

517
00:20:21,510 --> 00:20:18,960
there's little earth over there on the

518
00:20:23,110 --> 00:20:21,520
right we're newcomers we have been here

519
00:20:25,029 --> 00:20:23,120
for about one third of the age of the

520
00:20:26,149 --> 00:20:25,039
universe four and a half billion years

521
00:20:27,110 --> 00:20:26,159
for the age of

522
00:20:28,789 --> 00:20:27,120
the earth

523
00:20:30,310 --> 00:20:28,799
13 and a half for the age of the

524
00:20:31,350 --> 00:20:30,320
universe

525
00:20:34,630 --> 00:20:31,360
so

526
00:20:36,710 --> 00:20:34,640
now i want to show you um

527
00:20:38,310 --> 00:20:36,720
a nebula which is somewhat like the

528
00:20:40,789 --> 00:20:38,320
nebula that we live in the milky way

529
00:20:42,630 --> 00:20:40,799
galaxy as you know a galaxy is made of

530
00:20:45,430 --> 00:20:42,640
hundreds of billions of stars orbiting a

531
00:20:47,110 --> 00:20:45,440
common center held together by gravity

532
00:20:48,549 --> 00:20:47,120
some of that gravity comes from dark

533
00:20:50,710 --> 00:20:48,559
matter by the way

534
00:20:52,230 --> 00:20:50,720
and we wouldn't be here without it so if

535
00:20:53,909 --> 00:20:52,240
anybody thinks well dark matter that's

536
00:20:55,669 --> 00:20:53,919
just an amusing thing those astronomers

537
00:20:58,310 --> 00:20:55,679
thought up we wouldn't be here without

538
00:21:00,710 --> 00:20:58,320

it so lots of wonderful things for us to

539
00:21:02,070 --> 00:21:00,720
find if the sun were in that galaxy we

540
00:21:03,510 --> 00:21:02,080
would be somewhere out on the on the

541
00:21:05,430 --> 00:21:03,520
outer edge

542
00:21:07,270 --> 00:21:05,440
and we would be able to look in towards

543
00:21:09,909 --> 00:21:07,280
the center and we would wonder what it

544
00:21:11,510 --> 00:21:09,919
was like because we live in the plane of

545
00:21:13,909 --> 00:21:11,520
our milky way galaxy which is about as

546
00:21:15,750 --> 00:21:13,919
flat as a cd and so you can barely see

547
00:21:16,549 --> 00:21:15,760
the structure of it when you live inside

548
00:21:17,990 --> 00:21:16,559
it

549
00:21:19,669 --> 00:21:18,000
so we have to look at other people's

550
00:21:21,190 --> 00:21:19,679
galaxies if there are indeed people out

551
00:21:23,110 --> 00:21:21,200
there to

552
00:21:25,350 --> 00:21:23,120
think about what does it look like to be

553
00:21:27,350 --> 00:21:25,360
who we are anyway so one of the great

554
00:21:29,750 --> 00:21:27,360
mysteries is how does this happen how do

555
00:21:30,470 --> 00:21:29,760
galaxies like that come to be

556
00:21:32,870 --> 00:21:30,480
so

557
00:21:34,630 --> 00:21:32,880
we have a simulation of course nowadays

558
00:21:36,950 --> 00:21:34,640
we have computer simulations of the

559
00:21:39,190 --> 00:21:36,960
weather and sometimes they're correct

560
00:21:40,950 --> 00:21:39,200
sometimes not but at any rate

561
00:21:43,110 --> 00:21:40,960
we now are able to start with the

562
00:21:45,190 --> 00:21:43,120
statistical calculations of what the

563
00:21:47,669 --> 00:21:45,200

early universe was like put it into a

564
00:21:49,430 --> 00:21:47,679
computer simulate the action of gravity

565
00:21:50,950 --> 00:21:49,440
operating on the dark matter and the

566
00:21:52,390 --> 00:21:50,960
ordinary matter

567
00:21:54,149 --> 00:21:52,400
and accounting for the

568
00:21:56,549 --> 00:21:54,159
the cosmic dark energy that causes

569
00:21:58,149 --> 00:21:56,559
acceleration so this is a simulation of

570
00:22:00,950 --> 00:21:58,159
early universe you see gravity is

571
00:22:02,710 --> 00:22:00,960
pulling the material back together

572
00:22:04,230 --> 00:22:02,720
by the way the simulation has subtracted

573
00:22:07,909 --> 00:22:04,240
out the fact that again the whole

574
00:22:09,669 --> 00:22:07,919
universe is expanding so it's taken that

575
00:22:11,990 --> 00:22:09,679
viewpoint now you can see galaxies

576
00:22:14,070 --> 00:22:12,000
beginning to light up with explosions

577
00:22:15,270 --> 00:22:14,080
this is a totally spectacular process we

578
00:22:16,950 --> 00:22:15,280
have

579
00:22:18,070 --> 00:22:16,960
black holes forming and drawing in

580
00:22:20,870 --> 00:22:18,080
material

581
00:22:22,549 --> 00:22:20,880
sending out jets of immense intensity

582
00:22:24,149 --> 00:22:22,559
all of these things

583
00:22:26,549 --> 00:22:24,159
happen in the early universe much more

584
00:22:28,390 --> 00:22:26,559
frequently than they do today

585
00:22:30,149 --> 00:22:28,400
if there were people or the intelligent

586
00:22:31,270 --> 00:22:30,159
beings back there to witness this event

587
00:22:32,950 --> 00:22:31,280
it would have been a very very

588
00:22:34,710 --> 00:22:32,960

spectacular event for them to think

589
00:22:36,710 --> 00:22:34,720
about

590
00:22:37,909 --> 00:22:36,720
by the way there were chemical elements

591
00:22:40,070 --> 00:22:37,919
of life being produced in these

592
00:22:41,990 --> 00:22:40,080
explosions so we could imagine that life

593
00:22:45,029 --> 00:22:42,000
was possible within a few hundred

594
00:22:45,909 --> 00:22:45,039
million years of the original expansion

595
00:22:47,510 --> 00:22:45,919
so

596
00:22:49,190 --> 00:22:47,520
we're running along to the universe is

597
00:22:51,669 --> 00:22:49,200
almost nine billion years old in this

598
00:22:53,110 --> 00:22:51,679
simulation and it begins to settle down

599
00:22:54,950 --> 00:22:53,120
and that's an interesting time because

600
00:22:56,950 --> 00:22:54,960
that's about when the solar system was

601
00:22:58,390 --> 00:22:56,960
formed also here it's beginning to

602
00:22:59,830 --> 00:22:58,400
settle down the universe becomes

603
00:23:01,990 --> 00:22:59,840
quiescent

604
00:23:03,430 --> 00:23:02,000
and the solar system forms

605
00:23:05,750 --> 00:23:03,440
so

606
00:23:07,750 --> 00:23:05,760
imagine if you could that we tell

607
00:23:09,830 --> 00:23:07,760
whether this picture is true how would

608
00:23:11,590 --> 00:23:09,840
you know if it's true we take snapshots

609
00:23:13,350 --> 00:23:11,600
of the picture of the movie and you take

610
00:23:14,470 --> 00:23:13,360
compare the snapshots with the snapshots

611
00:23:15,590 --> 00:23:14,480
of the sky

612
00:23:17,510 --> 00:23:15,600
that we can make with the hubble

613
00:23:19,350 --> 00:23:17,520

telescope and the successory telescopes

614
00:23:21,430 --> 00:23:19,360
that we are now building so that's a

615
00:23:25,350 --> 00:23:21,440
great mystery for us we are on the trail

616
00:23:29,350 --> 00:23:27,350
so

617
00:23:30,789 --> 00:23:29,360
by the way this simulation was called

618
00:23:32,149 --> 00:23:30,799
the illustrious and it's just current

619
00:23:34,950 --> 00:23:32,159
this very year

620
00:23:37,029 --> 00:23:34,960
so now i show you a picture of the thing

621
00:23:38,950 --> 00:23:37,039
that you would think of as a star if you

622
00:23:40,390 --> 00:23:38,960
look at the middle star of the sword of

623
00:23:42,070 --> 00:23:40,400
orion this is it

624
00:23:44,630 --> 00:23:42,080
this is not a single star this is a

625
00:23:46,230 --> 00:23:44,640
cloud of glowing gas and dust with

626
00:23:48,870 --> 00:23:46,240
hundreds and hundreds of bright new

627
00:23:50,230 --> 00:23:48,880
stars born in there very recently

628
00:23:51,830 --> 00:23:50,240
shining

629
00:23:53,510 --> 00:23:51,840
beautifully this is where astronomers

630
00:23:55,269 --> 00:23:53,520
always turn their new telescopes to see

631
00:23:57,029 --> 00:23:55,279
what's most beautiful and most

632
00:23:58,710 --> 00:23:57,039
scientifically interesting because it's

633
00:24:01,029 --> 00:23:58,720
one of the places where stars are being

634
00:24:03,510 --> 00:24:01,039
born in great abundance today by the way

635
00:24:06,470 --> 00:24:03,520
there's about five or ten new stars per

636
00:24:07,990 --> 00:24:06,480
year being born in our milky way and so

637
00:24:09,190 --> 00:24:08,000
it's something we have plenty of to

638
00:24:11,269 --> 00:24:09,200

study

639
00:24:13,430 --> 00:24:11,279
presumably some of those have planetary

640
00:24:14,870 --> 00:24:13,440
systems with them one of the great

641
00:24:17,510 --> 00:24:14,880
opportunities for us with the webb

642
00:24:22,230 --> 00:24:20,549
so now i want to talk about uh how did

643
00:24:25,269 --> 00:24:22,240
we get started with the james webb

644
00:24:27,190 --> 00:24:25,279
telescope in particular so back in 1995

645
00:24:29,510 --> 00:24:27,200
alan dressler chaired a committee uh

646
00:24:30,870 --> 00:24:29,520
that recommended two things one was to

647
00:24:33,110 --> 00:24:30,880
build a telescope like the one that

648
00:24:36,549 --> 00:24:33,120
we're building uh it wasn't called james

649
00:24:38,070 --> 00:24:36,559
webb telescope back then um of course

650
00:24:40,149 --> 00:24:38,080
and they said the other the other thing

651
00:24:41,669 --> 00:24:40,159
they said was develop the technology to

652
00:24:42,950 --> 00:24:41,679
find earth-like planets around other

653
00:24:44,470 --> 00:24:42,960
stars

654
00:24:46,630 --> 00:24:44,480
so we've been doing that

655
00:24:48,390 --> 00:24:46,640
now in that day we had no idea how many

656
00:24:50,310 --> 00:24:48,400
of them there would be so we didn't know

657
00:24:51,990 --> 00:24:50,320
how hard the project would be we have

658
00:24:54,149 --> 00:24:52,000
made immense progress both on the

659
00:24:55,830 --> 00:24:54,159
technology which and dave will tell you

660
00:24:58,310 --> 00:24:55,840
more about and on knowing how hard the

661
00:24:59,750 --> 00:24:58,320
job is we know there are billions of

662
00:25:00,870 --> 00:24:59,760
planets out there and they're not all

663
00:25:01,750 --> 00:25:00,880

far away

664
00:25:03,830 --> 00:25:01,760
so

665
00:25:06,789 --> 00:25:03,840
this is definitely a good step forward

666
00:25:08,470 --> 00:25:06,799
so our project was endorsed twice by the

667
00:25:10,789 --> 00:25:08,480
national academy of sciences they do a

668
00:25:13,029 --> 00:25:10,799
survey every 10 years it was their top

669
00:25:15,909 --> 00:25:13,039
priority in 2000 and they built their

670
00:25:17,669 --> 00:25:15,919
entire survey in 2010 around it so we're

671
00:25:19,990 --> 00:25:17,679
doing well with carrying out what they

672
00:25:22,230 --> 00:25:20,000
want us to do and

673
00:25:23,830 --> 00:25:22,240
by the way we got our first peer review

674
00:25:26,789 --> 00:25:23,840
when this project was announced to the

675
00:25:28,950 --> 00:25:26,799
astronomical society in 1996 by the head

676
00:25:31,430 --> 00:25:28,960
of nasa dan golden he got a standing

677
00:25:33,190 --> 00:25:31,440
ovation for the presentation and i think

678
00:25:35,430 --> 00:25:33,200
that was a definitely an encouraging

679
00:25:36,470 --> 00:25:35,440
sign that we this was the project our

680
00:25:38,230 --> 00:25:36,480
entire

681
00:25:41,510 --> 00:25:38,240
user community scientific world would

682
00:25:43,190 --> 00:25:41,520
like us to do so we're doing it

683
00:25:44,710 --> 00:25:43,200
this is what it looks like

684
00:25:46,630 --> 00:25:44,720
and i have the

685
00:25:48,070 --> 00:25:46,640
the logos for the three space agencies

686
00:25:49,110 --> 00:25:48,080
that are partners in this immense

687
00:25:50,789 --> 00:25:49,120
project

688
00:25:53,269 --> 00:25:50,799

the telescope by the way is being built

689
00:25:55,029 --> 00:25:53,279
by our prime contractor northrop grumman

690
00:25:57,669 --> 00:25:55,039
near la but under supervision and

691
00:25:59,590 --> 00:25:57,679
direction from nasa goddard where i work

692
00:26:02,149 --> 00:25:59,600
so i'm speaking here about this one

693
00:26:04,310 --> 00:26:02,159
which is now a project of well over a

694
00:26:06,310 --> 00:26:04,320
thousand people currently working

695
00:26:09,190 --> 00:26:06,320
on behalf of ten thousand roughly future

696
00:26:12,230 --> 00:26:09,200
users uh and all human beings who will

697
00:26:16,310 --> 00:26:14,230
this is a comparison of how large the

698
00:26:18,070 --> 00:26:16,320
telescope is compared with the hubble

699
00:26:19,990 --> 00:26:18,080
these are scale pictures so you see on

700
00:26:22,310 --> 00:26:20,000
the left the mirror of the hubble 2.4

701
00:26:24,310 --> 00:26:22,320
meters in diameter about 8 feet same as

702
00:26:27,510 --> 00:26:24,320
hubble the man's telescope on mount

703
00:26:28,390 --> 00:26:27,520
wilson in 1920

704
00:26:29,909 --> 00:26:28,400
so

705
00:26:31,990 --> 00:26:29,919
on the right hand side you see the james

706
00:26:33,510 --> 00:26:32,000
webb telescope the mirror is about 21

707
00:26:35,510 --> 00:26:33,520
and a half feet roughly the distance

708
00:26:36,470 --> 00:26:35,520
from floor to ceiling in here

709
00:26:38,470 --> 00:26:36,480
so

710
00:26:40,310 --> 00:26:38,480
much much larger clearly much larger

711
00:26:42,149 --> 00:26:40,320
than the rocket is so we have an immense

712
00:26:43,430 --> 00:26:42,159
challenge of folding it up to get it

713
00:26:44,870 --> 00:26:43,440

into space

714
00:26:46,630 --> 00:26:44,880
the wavelength range is illustrated

715
00:26:48,549 --> 00:26:46,640
there on the bottom also

716
00:26:50,789 --> 00:26:48,559
the telescope the new one

717
00:26:51,750 --> 00:26:50,799
overlaps the wavelength coverage of the

718
00:26:53,669 --> 00:26:51,760
hubble

719
00:26:55,430 --> 00:26:53,679
at the near infrared we begin at 0.6

720
00:26:57,990 --> 00:26:55,440
microns which is about the wavelength of

721
00:26:59,990 --> 00:26:58,000
an infrared sorry of a red laser pointer

722
00:27:01,750 --> 00:27:00,000
and we go out to 28 microns which is a

723
00:27:04,789 --> 00:27:01,760
wavelength which your body emits very

724
00:27:06,789 --> 00:27:04,799
intensely and you don't feel it

725
00:27:10,070 --> 00:27:06,799
but you would be cold if you were out in

726
00:27:13,430 --> 00:27:10,080
outer space because of that radiation

727
00:27:16,230 --> 00:27:13,440
so there it is uh this is a

728
00:27:18,870 --> 00:27:16,240
sign of technical progress on the uh

729
00:27:20,630 --> 00:27:18,880
design we require 18 hexagonal mirrors

730
00:27:21,669 --> 00:27:20,640
each is made of beryllium coated with

731
00:27:23,190 --> 00:27:21,679
gold

732
00:27:25,990 --> 00:27:23,200
each of them is light enough that you

733
00:27:28,310 --> 00:27:26,000
could lift it yourself individually

734
00:27:29,750 --> 00:27:28,320
but they are so precise that they're

735
00:27:31,750 --> 00:27:29,760
basically perfect

736
00:27:33,830 --> 00:27:31,760
so the sketch on the right hand side

737
00:27:35,430 --> 00:27:33,840
shows you that if we were to expand the

738
00:27:37,269 --> 00:27:35,440

mirror to the size of the continental

739
00:27:39,430 --> 00:27:37,279
united states the mirror would be

740
00:27:41,830 --> 00:27:39,440
accurate within three inches

741
00:27:43,590 --> 00:27:41,840
so this is completely amazing technology

742
00:27:46,389 --> 00:27:43,600
we have now mastered

743
00:27:47,750 --> 00:27:46,399
and uh and we're using the mirrors are

744
00:27:49,430 --> 00:27:47,760
finished by the way they're all in their

745
00:27:50,710 --> 00:27:49,440
storage cans up at goddard space flight

746
00:27:52,389 --> 00:27:50,720
center

747
00:27:54,149 --> 00:27:52,399
so we've got a little graphic

748
00:27:56,070 --> 00:27:54,159
illustrating how many how many there are

749
00:27:57,750 --> 00:27:56,080
all 18 are done we've measured their

750
00:27:59,590 --> 00:27:57,760
shapes when they're cold

751
00:28:00,950 --> 00:27:59,600
in the giant vacuum tank at marshall

752
00:28:02,470 --> 00:28:00,960
space flight center so we're really

753
00:28:04,310 --> 00:28:02,480
thrilled with the mirror technology

754
00:28:05,669 --> 00:28:04,320
progress this is something where my

755
00:28:07,750 --> 00:28:05,679
friends and colleagues laughed at me and

756
00:28:12,070 --> 00:28:07,760
said you'll never be able to do that

757
00:28:17,430 --> 00:28:14,470
so uh you have here a movie showing what

758
00:28:19,350 --> 00:28:17,440
the sun shield is like the sun shield is

759
00:28:20,950 --> 00:28:19,360
as big as a tennis court imagine roger

760
00:28:22,389 --> 00:28:20,960
federer running back and forth over half

761
00:28:24,149 --> 00:28:22,399
of it

762
00:28:26,230 --> 00:28:24,159
we have to unfold this thing from a

763
00:28:27,990 --> 00:28:26,240

folded condition in outer space and so

764
00:28:29,830 --> 00:28:28,000
of course we've been rehearsing so what

765
00:28:31,909 --> 00:28:29,840
you just saw was rehearsals with a

766
00:28:36,870 --> 00:28:31,919
full-scale

767
00:28:40,470 --> 00:28:39,029
so it works of course

768
00:28:44,549 --> 00:28:40,480
so

769
00:28:46,070 --> 00:28:44,559
okay machine next please there we go

770
00:28:48,549 --> 00:28:46,080
so what we have

771
00:28:50,230 --> 00:28:48,559
here is the instrument module has been

772
00:28:52,470 --> 00:28:50,240
just installed in the cryogenic vacuum

773
00:28:54,789 --> 00:28:52,480
tank at goddard space flight center uh

774
00:28:57,909 --> 00:28:54,799
lowered down from a crane on it being

775
00:29:00,470 --> 00:28:57,919
attached to with the cables into the to

776
00:29:01,990 --> 00:29:00,480
the fixtures in the instrument chamber

777
00:29:03,830 --> 00:29:02,000
this is a place where we simulate the

778
00:29:05,269 --> 00:29:03,840
outer space environment the

779
00:29:07,750 --> 00:29:05,279
the light coming from the telescope is

780
00:29:09,750 --> 00:29:07,760
simulated so we will be able to tell

781
00:29:11,750 --> 00:29:09,760
whether this instrument package will be

782
00:29:13,110 --> 00:29:11,760
focused and working properly when we get

783
00:29:15,029 --> 00:29:13,120
to outer space

784
00:29:16,870 --> 00:29:15,039
here's another view of the same process

785
00:29:19,029 --> 00:29:16,880
the dome has been lifted off the test

786
00:29:21,110 --> 00:29:19,039
chamber you can see the crane lifting

787
00:29:22,710 --> 00:29:21,120
the instrument package down in

788
00:29:24,149 --> 00:29:22,720

so we're very thrilled with this the

789
00:29:26,630 --> 00:29:24,159
instruments are doing very well in their

790
00:29:28,470 --> 00:29:26,640
test as of this week

791
00:29:29,990 --> 00:29:28,480
no surprise there

792
00:29:32,230 --> 00:29:30,000
this is the next place we take the

793
00:29:34,070 --> 00:29:32,240
telescope to this is the chamber a

794
00:29:35,669 --> 00:29:34,080
johnson space flight center

795
00:29:37,190 --> 00:29:35,679
if you were an apollo astronaut you went

796
00:29:39,110 --> 00:29:37,200
here to practice

797
00:29:41,510 --> 00:29:39,120
because this was big enough

798
00:29:43,590 --> 00:29:41,520
for this on the left hand side you see

799
00:29:45,190 --> 00:29:43,600
the apollo capsule in there

800
00:29:47,830 --> 00:29:45,200
astronauts had to practice getting out

801
00:29:49,269 --> 00:29:47,840
of the spacecraf spacecraft and land and

802
00:29:51,830 --> 00:29:49,279
getting off onto the surface of the moon

803
00:29:53,669 --> 00:29:51,840
in a vacuum so they practiced and it

804
00:29:55,510 --> 00:29:53,679
worked of course

805
00:29:57,190 --> 00:29:55,520
now 50 years later we need the same

806
00:30:00,230 --> 00:29:57,200
chamber for another purpose we have

807
00:30:01,990 --> 00:30:00,240
fitted it with cold uh

808
00:30:03,669 --> 00:30:02,000
shroud inside so it can get down to the

809
00:30:05,190 --> 00:30:03,679
temperature that we need for the testing

810
00:30:07,590 --> 00:30:05,200
of the telescope and it turns out to be

811
00:30:08,710 --> 00:30:07,600
just the right size for what we needed

812
00:30:10,310 --> 00:30:08,720
for the web

813
00:30:11,669 --> 00:30:10,320

so we're really thrilled that we have

814
00:30:14,070 --> 00:30:11,679
the equipment and we're doing the right

815
00:30:17,990 --> 00:30:15,510
so in a little while in name of the

816
00:30:19,110 --> 00:30:18,000
october 2018 four and a quarter years

817
00:30:20,710 --> 00:30:19,120
from today

818
00:30:22,870 --> 00:30:20,720
we will push the button and the

819
00:30:24,230 --> 00:30:22,880
telescope will go up on its rocket which

820
00:30:26,070 --> 00:30:24,240
is by a way a contribution of the

821
00:30:27,350 --> 00:30:26,080
european space agency

822
00:30:28,470 --> 00:30:27,360
so we'll go up

823
00:30:30,470 --> 00:30:28,480
and be

824
00:30:32,470 --> 00:30:30,480
unfolded in outer space and this is the

825
00:30:34,230 --> 00:30:32,480
deployment video

826
00:30:36,310 --> 00:30:34,240
it has been all carefully figured out

827
00:30:37,830 --> 00:30:36,320
exactly when and where we do everything

828
00:30:39,909 --> 00:30:37,840
so of course the first thing to happen

829
00:30:41,750 --> 00:30:39,919
is you unfold the solar panel needs

830
00:30:44,389 --> 00:30:41,760
solar juice to keep the batteries from

831
00:30:46,470 --> 00:30:44,399
running down then we will unfold the uh

832
00:30:48,630 --> 00:30:46,480
the telemetry dish stay in touch with

833
00:30:50,149 --> 00:30:48,640
the earth this is happens about by the

834
00:30:52,230 --> 00:30:50,159
time we get to the moon or past the

835
00:30:54,389 --> 00:30:52,240
distance of the moon then the last

836
00:30:58,950 --> 00:30:54,399
things that come out are the solar

837
00:31:01,830 --> 00:31:00,070
and if you look at this and you say

838
00:31:03,269 --> 00:31:01,840

isn't that pretty complicated

839
00:31:05,430 --> 00:31:03,279
yeah

840
00:31:07,029 --> 00:31:05,440
you should be intimidated now you should

841
00:31:08,470 --> 00:31:07,039
know that we have two of everything

842
00:31:10,310 --> 00:31:08,480
where you could possibly have two of

843
00:31:11,509 --> 00:31:10,320
everything and we are rehearsing this

844
00:31:13,990 --> 00:31:11,519
out of town

845
00:31:16,789 --> 00:31:14,000
uh we have done many many practice trips

846
00:31:18,630 --> 00:31:16,799
with the unpl unfolding uh process

847
00:31:19,909 --> 00:31:18,640
at the various labs we have around the

848
00:31:21,990 --> 00:31:19,919
country

849
00:31:24,149 --> 00:31:22,000
both cold and warm for the parts that

850
00:31:25,750 --> 00:31:24,159
can be tested cold the sun shield is

851
00:31:27,669 --> 00:31:25,760
just too darn big there's no way to test

852
00:31:29,430 --> 00:31:27,679
that in a cold tank

853
00:31:31,590 --> 00:31:29,440
and certainly we cannot test it in zero

854
00:31:33,190 --> 00:31:31,600
gravity so we have to think a lot at any

855
00:31:35,509 --> 00:31:33,200
rate this is complex

856
00:31:37,909 --> 00:31:35,519
but it's been very thoroughly rehearsed

857
00:31:40,230 --> 00:31:37,919
and we're pretty sure it will work

858
00:31:41,909 --> 00:31:40,240
that's our job to make sure

859
00:31:43,509 --> 00:31:41,919
so the final steps are to pull on

860
00:31:44,789 --> 00:31:43,519
various cables that stretch out the

861
00:31:47,029 --> 00:31:44,799
sunshield

862
00:31:52,710 --> 00:31:47,039
and separate the five layers

863
00:31:57,110 --> 00:31:54,950

and finally the the mirrors themselves

864
00:31:58,950 --> 00:31:57,120
finally unfold so this is what it takes

865
00:32:00,630 --> 00:31:58,960
to get a big telescope into a not big

866
00:32:02,389 --> 00:32:00,640
enough rocket

867
00:32:04,149 --> 00:32:02,399
so when we have a bigger rocket we can

868
00:32:10,789 --> 00:32:04,159
put up bigger stuff

869
00:32:15,269 --> 00:32:12,630
and of course you can also imagine when

870
00:32:17,110 --> 00:32:15,279
we have astronaut capabilities in deep

871
00:32:19,990 --> 00:32:17,120
space we'll be able to make sure the

872
00:32:21,430 --> 00:32:20,000
telescope keeps on working longer

873
00:32:23,269 --> 00:32:21,440
anyway there it is it's finally in the

874
00:32:24,789 --> 00:32:23,279
right shape it's not focused at that

875
00:32:26,950 --> 00:32:24,799
point it takes another couple of months

876
00:32:29,110 --> 00:32:26,960
to cool down and be focused

877
00:32:31,909 --> 00:32:29,120
anyway this is our

878
00:32:33,669 --> 00:32:31,919
two months of terror perhaps

879
00:32:35,990 --> 00:32:33,679
but we have to make sure it works so we

880
00:32:37,990 --> 00:32:36,000
do that

881
00:32:39,350 --> 00:32:38,000
so just to wrap up to show you an

882
00:32:41,430 --> 00:32:39,360
illustration of some of the things we're

883
00:32:43,430 --> 00:32:41,440
expecting to see and to tantalize you

884
00:32:45,590 --> 00:32:43,440
with what we'll be able to ask questions

885
00:32:47,750 --> 00:32:45,600
about this is looking back towards the

886
00:32:49,269 --> 00:32:47,760
earliest moments in the universe this is

887
00:32:50,389 --> 00:32:49,279
an expansion of the hubble telescope

888
00:32:52,630 --> 00:32:50,399

picture

889
00:32:53,990 --> 00:32:52,640
imagine that the the real one is much

890
00:32:55,590 --> 00:32:54,000
sharper like this with many more

891
00:32:56,549 --> 00:32:55,600
galaxies in it

892
00:32:58,070 --> 00:32:56,559
so this

893
00:33:01,110 --> 00:32:58,080
tells you that there's an awful lot more

894
00:33:02,389 --> 00:33:01,120
to know than what we can see today

895
00:33:04,230 --> 00:33:02,399
looking back towards the earliest

896
00:33:05,430 --> 00:33:04,240
moments of the universe

897
00:33:07,269 --> 00:33:05,440
also

898
00:33:08,470 --> 00:33:07,279
going on to

899
00:33:10,630 --> 00:33:08,480
things that are close to home where

900
00:33:12,710 --> 00:33:10,640
stars are being born today

901
00:33:15,190 --> 00:33:12,720
this is a dust cloud that with a star

902
00:33:16,950 --> 00:33:15,200
being born inside as seen by the hubble

903
00:33:18,950 --> 00:33:16,960
uh using the first the visible camera

904
00:33:20,710 --> 00:33:18,960
and then the infrared camera on hubble

905
00:33:22,149 --> 00:33:20,720
so there's a little star in there making

906
00:33:24,230 --> 00:33:22,159
planets probably

907
00:33:25,830 --> 00:33:24,240
we'd like to know so we will definitely

908
00:33:27,430 --> 00:33:25,840
be pointing the web telescope over there

909
00:33:29,750 --> 00:33:27,440
to see about planets

910
00:33:31,750 --> 00:33:29,760
and learn how uh so systems like the

911
00:33:33,590 --> 00:33:31,760
solar system may be formed it's not the

912
00:33:35,269 --> 00:33:33,600
only thing we'll be doing but i think

913
00:33:37,830 --> 00:33:35,279

this is time for me to hand over to our

914
00:33:40,149 --> 00:33:37,840
next speaker so she can tell you how we

915
00:33:51,350 --> 00:33:40,159
will be using these telescopes to search

916
00:33:54,710 --> 00:33:53,269
good afternoon before we get started i'd

917
00:33:56,070 --> 00:33:54,720
like you all to take a look in that

918
00:33:58,549 --> 00:33:56,080
corner of the room it's kind of the

919
00:34:00,230 --> 00:33:58,559
front one quarter at that aesthetic

920
00:34:01,830 --> 00:34:00,240
piece of

921
00:34:04,870 --> 00:34:01,840
equipment which i'll be talking about a

922
00:34:09,270 --> 00:34:06,870
back to the image of

923
00:34:11,270 --> 00:34:09,280
it's a real photo of a dark sky

924
00:34:13,990 --> 00:34:11,280
and every star just to remind everybody

925
00:34:15,750 --> 00:34:14,000
here that every star in the sky is a sun

926
00:34:17,589 --> 00:34:15,760
and if our sun has planets we naturally

927
00:34:20,230 --> 00:34:17,599
expect those other stars to have planets

928
00:34:22,389 --> 00:34:20,240
also and they do in fact if you're so

929
00:34:24,550 --> 00:34:22,399
lucky to go out to a dark sky

930
00:34:26,550 --> 00:34:24,560
and ask and wonder how many of those

931
00:34:28,869 --> 00:34:26,560
stars that you see have planets

932
00:34:30,230 --> 00:34:28,879
it turns out that it's basically every

933
00:34:31,829 --> 00:34:30,240
single one

934
00:34:34,629 --> 00:34:31,839
astronomers have found statistically

935
00:34:36,069 --> 00:34:34,639
speaking that every star in our milky

936
00:34:36,950 --> 00:34:36,079
way galaxy should have at least one

937
00:34:38,310 --> 00:34:36,960
planet

938
00:34:40,149 --> 00:34:38,320

that might not be surprising if you

939
00:34:41,750 --> 00:34:40,159
think logically but what is surprising

940
00:34:44,149 --> 00:34:41,760
is that all of these planets they're so

941
00:34:45,990 --> 00:34:44,159
very different from our solar system our

942
00:34:48,069 --> 00:34:46,000
own earth is actually extremely hard to

943
00:34:49,829 --> 00:34:48,079
find and so in the short term we have

944
00:34:52,950 --> 00:34:49,839
mostly found

945
00:34:55,270 --> 00:34:52,960
planets that are that are uh unusually

946
00:34:57,270 --> 00:34:55,280
not like our solar system for example

947
00:34:59,589 --> 00:34:57,280
planets jupiter size or jupiter mass

948
00:35:01,430 --> 00:34:59,599
where mercury should be hot super earths

949
00:35:03,349 --> 00:35:01,440
that are so close to their star that

950
00:35:05,750 --> 00:35:03,359
their surfaces are likely hot enough to

951
00:35:07,589 --> 00:35:05,760
melt rock planets orbiting two stars and

952
00:35:09,190 --> 00:35:07,599
we have this list of incredible

953
00:35:10,630 --> 00:35:09,200
discoveries made by astronomers and

954
00:35:12,710 --> 00:35:10,640
various ground and space-based

955
00:35:15,430 --> 00:35:12,720
telescopes everywhere

956
00:35:17,030 --> 00:35:15,440
so our own earth twin remains elusive

957
00:35:19,190 --> 00:35:17,040
but that's what i'm going to be talking

958
00:35:20,790 --> 00:35:19,200
about today now what's most relevant for

959
00:35:22,630 --> 00:35:20,800
us actually is one of my favorite

960
00:35:25,190 --> 00:35:22,640
discoveries ever in astronomy and

961
00:35:27,270 --> 00:35:25,200
planetary science and that is that small

962
00:35:29,030 --> 00:35:27,280
planets are extremely common and this

963
00:35:31,510 --> 00:35:29,040

bar chart shows some of the results from

964
00:35:33,910 --> 00:35:31,520
the pioneering kepler space telescope it

965
00:35:36,390 --> 00:35:33,920
shows you on the left axis fraction of

966
00:35:38,150 --> 00:35:36,400
stars with planets and it says periods

967
00:35:40,630 --> 00:35:38,160
less than 50 days but that number is now

968
00:35:42,870 --> 00:35:40,640
increased to a couple of hundred days on

969
00:35:44,550 --> 00:35:42,880
the bottom it shows planet size relative

970
00:35:46,390 --> 00:35:44,560
to earth and the cartoon picture just

971
00:35:48,150 --> 00:35:46,400
reminds you

972
00:35:50,230 --> 00:35:48,160
the images actually remind you of the

973
00:35:51,990 --> 00:35:50,240
relative sizes of earth and jupiter now

974
00:35:54,550 --> 00:35:52,000
i want you to just focus on the relative

975
00:35:55,990 --> 00:35:54,560
heights of those bars and if you look at

976
00:35:57,910 --> 00:35:56,000
the far right

977
00:36:00,950 --> 00:35:57,920
you'll see that jupiter-sized planet at

978
00:36:03,109 --> 00:36:00,960
11 times earth radii they're hardly any

979
00:36:05,109 --> 00:36:03,119
actually very few

980
00:36:06,550 --> 00:36:05,119
compared to the bins that have these

981
00:36:07,589 --> 00:36:06,560
planets that are one to three earth

982
00:36:09,750 --> 00:36:07,599
radii

983
00:36:11,589 --> 00:36:09,760
and essentially what this is telling us

984
00:36:12,390 --> 00:36:11,599
is that small planets are extremely

985
00:36:14,150 --> 00:36:12,400
common

986
00:36:15,990 --> 00:36:14,160
and we don't have super hard exact

987
00:36:17,990 --> 00:36:16,000
numbers for you but it may be as high as

988
00:36:20,470 --> 00:36:18,000

one in five sun-like stars may have a

989
00:36:22,710 --> 00:36:20,480
planet that is a favorable not too hot

990
00:36:24,230 --> 00:36:22,720
not too cold but just right for life and

991
00:36:26,550 --> 00:36:24,240
in fact when we talk about the search

992
00:36:28,390 --> 00:36:26,560
for life beyond our solar system

993
00:36:30,550 --> 00:36:28,400
we first fixate on the so-called

994
00:36:32,950 --> 00:36:30,560
goldilocks zone or habitable zone

995
00:36:35,270 --> 00:36:32,960
illustrated here very roughly in green

996
00:36:37,430 --> 00:36:35,280
this schematic shows you our solar

997
00:36:39,829 --> 00:36:37,440
reminds you of part of our solar system

998
00:36:41,750 --> 00:36:39,839
mercury venus earth mars and jupiter and

999
00:36:43,030 --> 00:36:41,760
the other planets aren't shown

1000
00:36:44,790 --> 00:36:43,040
and i just want you to know that in the

1001
00:36:47,270 --> 00:36:44,800
so-called goldilocks zone it's not too

1002
00:36:49,349 --> 00:36:47,280
hot not too right not not too hot not

1003
00:36:51,270 --> 00:36:49,359
too cold but just right for life and

1004
00:36:53,030 --> 00:36:51,280
small rocky planets are heated by their

1005
00:36:54,470 --> 00:36:53,040
star from the outside and so it's this

1006
00:36:56,550 --> 00:36:54,480
distance from the star

1007
00:36:58,230 --> 00:36:56,560
that really sets the temperature and i

1008
00:37:00,390 --> 00:36:58,240
just want you to know for those um

1009
00:37:01,750 --> 00:37:00,400
astronomy buffs here that astronomers

1010
00:37:03,030 --> 00:37:01,760
are hotly debating the boundaries of

1011
00:37:04,950 --> 00:37:03,040
this curve right now what makes the

1012
00:37:06,390 --> 00:37:04,960
planet habitable and what the main

1013
00:37:07,750 --> 00:37:06,400

problem actually is it's uh the

1014
00:37:09,670 --> 00:37:07,760
greenhouse gases in the planet

1015
00:37:11,910 --> 00:37:09,680
atmosphere just like here on earth the

1016
00:37:14,150 --> 00:37:11,920
distant planets the exact composition

1017
00:37:19,190 --> 00:37:14,160
and the amounts of gases will actually

1018
00:37:23,430 --> 00:37:21,349
so what we're going to do to search for

1019
00:37:24,790 --> 00:37:23,440
planets is we want to be light that may

1020
00:37:26,550 --> 00:37:24,800
have life on them we want to be able to

1021
00:37:28,390 --> 00:37:26,560
look at the atmosphere to assess the

1022
00:37:30,069 --> 00:37:28,400
greenhouse gases and assess the surface

1023
00:37:32,550 --> 00:37:30,079
temperature and even to look for

1024
00:37:34,390 --> 00:37:32,560
biosignature gases which are gases

1025
00:37:37,030 --> 00:37:34,400
created by life that fill the atmosphere

1026
00:37:38,870 --> 00:37:37,040
that we could detect remotely by space

1027
00:37:40,870 --> 00:37:38,880
telescopes and we have two pronged

1028
00:37:43,349 --> 00:37:40,880
approach this decade we'll be searching

1029
00:37:46,790 --> 00:37:43,359
for super earths transiting small stars

1030
00:37:48,790 --> 00:37:46,800
and to start with in 2017 nasa will

1031
00:37:51,750 --> 00:37:48,800
launch the transiting exoplanet survey

1032
00:37:53,670 --> 00:37:51,760
satellite tests this is an mit-lead

1033
00:37:56,230 --> 00:37:53,680
mission that consists of you can see in

1034
00:37:58,630 --> 00:37:56,240
the image for the illustration for very

1035
00:38:00,230 --> 00:37:58,640
specialized telephoto lenses that are

1036
00:38:03,349 --> 00:38:00,240
really not all that huge they have big

1037
00:38:05,349 --> 00:38:03,359
baffles and they will have about um 24

1038
00:38:08,150 --> 00:38:05,359

by 24 square degree field of view for

1039
00:38:09,910 --> 00:38:08,160
each lens and tess will do an all sky

1040
00:38:12,069 --> 00:38:09,920
survey and look at hundreds of thousands

1041
00:38:15,190 --> 00:38:12,079
of stars for thousands of planets the

1042
00:38:17,750 --> 00:38:15,200
prime return will be small rocky planets

1043
00:38:20,069 --> 00:38:17,760
transiting small stars those are what

1044
00:38:21,910 --> 00:38:20,079
are our easiest ones to find so far and

1045
00:38:23,910 --> 00:38:21,920
among these will be the closest 1000

1046
00:38:25,510 --> 00:38:23,920
small stars that will be a source list

1047
00:38:27,349 --> 00:38:25,520
for the james webb telescope to look at

1048
00:38:29,349 --> 00:38:27,359
in more detail and what the james webb

1049
00:38:31,349 --> 00:38:29,359
telescope will do it will find what a

1050
00:38:33,349 --> 00:38:31,359
now is actually a standard approach to

1051
00:38:36,550 --> 00:38:33,359
studying exoplanet atmospheres and you

1052
00:38:38,550 --> 00:38:36,560
can see in the cartoon image on the left

1053
00:38:40,470 --> 00:38:38,560
a planet transiting the star if a planet

1054
00:38:42,390 --> 00:38:40,480
is very specially aligned it will go in

1055
00:38:44,630 --> 00:38:42,400
front of its star as seen from the

1056
00:38:46,950 --> 00:38:44,640
telescope and you see a small drop in

1057
00:38:48,870 --> 00:38:46,960
brightness of the star we don't see any

1058
00:38:50,870 --> 00:38:48,880
stars other than our sun spatial

1059
00:38:52,950 --> 00:38:50,880
spatially resolved in that detail and

1060
00:38:54,550 --> 00:38:52,960
the cartoon on the right is illustrating

1061
00:38:56,310 --> 00:38:54,560
what happens when the planet is in front

1062
00:38:58,069 --> 00:38:56,320
of the star some of the starlight shines

1063
00:38:59,829 --> 00:38:58,079

through the atmosphere

1064
00:39:01,589 --> 00:38:59,839
and if we do it right we can actually

1065
00:39:03,750 --> 00:39:01,599
pick up the gases from the planet that

1066
00:39:05,589 --> 00:39:03,760
are imprinted on the atmosphere

1067
00:39:07,670 --> 00:39:05,599
and we hope to do all that we plan to

1068
00:39:09,589 --> 00:39:07,680
with the james webb space telescope

1069
00:39:11,190 --> 00:39:09,599
and what we hope to see is a spectrum

1070
00:39:13,270 --> 00:39:11,200
that looks something like this

1071
00:39:15,430 --> 00:39:13,280
what this is its wavelength

1072
00:39:17,030 --> 00:39:15,440
absorption as a function of wavelength

1073
00:39:19,510 --> 00:39:17,040
and just so you know for the people who

1074
00:39:21,030 --> 00:39:19,520
aren't experts in spectroscopy if we

1075
00:39:22,470 --> 00:39:21,040
can't see it gases in the atmosphere if

1076
00:39:23,910 --> 00:39:22,480
there's a cloud blocking the planet or

1077
00:39:25,510 --> 00:39:23,920
if there happens to be no atmosphere for

1078
00:39:27,270 --> 00:39:25,520
some bizarre reason this would be a

1079
00:39:29,349 --> 00:39:27,280
straight line so we're looking for

1080
00:39:31,349 --> 00:39:29,359
deviations from a straight line with a

1081
00:39:33,510 --> 00:39:31,359
special imprint that will indicate

1082
00:39:35,109 --> 00:39:33,520
liquid water or other things

1083
00:39:37,430 --> 00:39:35,119
now about the tess and james webb

1084
00:39:39,190 --> 00:39:37,440
combination james webb space telescope

1085
00:39:41,270 --> 00:39:39,200
was not designed to actually find signs

1086
00:39:43,349 --> 00:39:41,280
of life on another planet and i do get

1087
00:39:45,109 --> 00:39:43,359
asked all the time what are the chances

1088
00:39:47,510 --> 00:39:45,119

that the james webb will find signs of

1089
00:39:48,790 --> 00:39:47,520
life and so i will answer it in two ways

1090
00:39:50,950 --> 00:39:48,800
in one ways you know we have to get

1091
00:39:52,870 --> 00:39:50,960
really lucky every small star has to

1092
00:39:54,870 --> 00:39:52,880
have a planet in its habitable zone and

1093
00:39:56,870 --> 00:39:54,880
each of those planets most of them would

1094
00:39:58,310 --> 00:39:56,880
have to have life and most of that life

1095
00:39:59,750 --> 00:39:58,320
would have to actually generate a

1096
00:40:01,589 --> 00:39:59,760
byproduct gas that could fill the

1097
00:40:03,030 --> 00:40:01,599
atmosphere and the second way that i'd

1098
00:40:04,790 --> 00:40:03,040
like to answer it which i'd like you to

1099
00:40:06,630 --> 00:40:04,800
walk away with is that with the james

1100
00:40:09,030 --> 00:40:06,640
webb we have our first chance our first

1101
00:40:10,950 --> 00:40:09,040
capability of finding signs of life on

1102
00:40:12,710 --> 00:40:10,960
another planet now nature just has to

1103
00:40:14,630 --> 00:40:12,720
provide for us

1104
00:40:16,870 --> 00:40:14,640
so to make sure we beat the odds we want

1105
00:40:19,349 --> 00:40:16,880
to follow the next approach in parallel

1106
00:40:20,550 --> 00:40:19,359
investing in a more futuristic way and

1107
00:40:22,309 --> 00:40:20,560
that way we want to search for

1108
00:40:24,470 --> 00:40:22,319
earth-like planets orbiting sun-like

1109
00:40:26,870 --> 00:40:24,480
stars we all are kind of self-centered

1110
00:40:28,790 --> 00:40:26,880
here we call it terra centric we want to

1111
00:40:30,710 --> 00:40:28,800
find planets like earth because in many

1112
00:40:32,630 --> 00:40:30,720
ways well earth is our only planet that

1113
00:40:35,030 --> 00:40:32,640

we know of with life on it and we'd like

1114
00:40:36,870 --> 00:40:35,040
to find a replica and in this way we

1115
00:40:39,910 --> 00:40:36,880
have a major challenge here because

1116
00:40:41,190 --> 00:40:39,920
unlike the big plan big earth transiting

1117
00:40:43,109 --> 00:40:41,200
small stars

1118
00:40:46,069 --> 00:40:43,119
the problem is extremely challenging in

1119
00:40:47,910 --> 00:40:46,079
that earth itself is 10 billion times

1120
00:40:49,349 --> 00:40:47,920
fainter than the sun

1121
00:40:53,910 --> 00:40:49,359
and here you can see

1122
00:40:57,030 --> 00:40:55,510
that is the size of earth but it's not

1123
00:40:58,870 --> 00:40:57,040
just the size that's relevant here it's

1124
00:41:00,630 --> 00:40:58,880
the fact that light has to go from the

1125
00:41:02,630 --> 00:41:00,640
star to the earth and reflect off of

1126
00:41:04,470 --> 00:41:02,640
earth and for us to be able to detect

1127
00:41:05,990 --> 00:41:04,480
that and just to pause for a moment i'd

1128
00:41:08,230 --> 00:41:06,000
ask each of you if you've ever made a

1129
00:41:09,510 --> 00:41:08,240
measurement that goes to 10 decimal

1130
00:41:11,190 --> 00:41:09,520
places

1131
00:41:13,349 --> 00:41:11,200
that's like me asking you to measure the

1132
00:41:14,950 --> 00:41:13,359
width of you know this piece of paper to

1133
00:41:16,309 --> 00:41:14,960
10 decimal places is extremely

1134
00:41:18,710 --> 00:41:16,319
challenging and that's what we're

1135
00:41:20,470 --> 00:41:18,720
setting out to do um at nasa north

1136
00:41:22,150 --> 00:41:20,480
grumman corp northrop grumman

1137
00:41:24,309 --> 00:41:22,160
corporation and other places around the

1138
00:41:26,150 --> 00:41:24,319

country so this is showing you the glare

1139
00:41:28,069 --> 00:41:26,160
of how bright a star would be and

1140
00:41:29,750 --> 00:41:28,079
ideally we'd like a way to go to space

1141
00:41:31,589 --> 00:41:29,760
and it's what we call direct imaging we

1142
00:41:33,270 --> 00:41:31,599
want to a get above the blurring effects

1143
00:41:35,430 --> 00:41:33,280
of earth's atmosphere and b block out

1144
00:41:37,109 --> 00:41:35,440
that starlight so we could see a planet

1145
00:41:38,870 --> 00:41:37,119
directly i'm just actually going to

1146
00:41:40,309 --> 00:41:38,880
black back up and show you that one more

1147
00:41:42,550 --> 00:41:40,319
time our goal is somehow we need to

1148
00:41:44,230 --> 00:41:42,560
block out that starlight now this shows

1149
00:41:46,630 --> 00:41:44,240
you um we can block out the light and

1150
00:41:47,430 --> 00:41:46,640
then hopefully we'll be able to see

1151
00:41:48,950 --> 00:41:47,440
other

1152
00:41:51,349 --> 00:41:48,960
planets

1153
00:41:53,670 --> 00:41:51,359
and i just want you to see that

1154
00:41:55,030 --> 00:41:53,680
we have this um starshade and the goal

1155
00:41:56,150 --> 00:41:55,040
would be actually to block out the

1156
00:41:58,630 --> 00:41:56,160
starlight

1157
00:42:00,069 --> 00:41:58,640
so we can see the planet directly

1158
00:42:02,870 --> 00:42:00,079
and i hope you'll all admire this for a

1159
00:42:05,030 --> 00:42:02,880
moment it's actually was really used in

1160
00:42:07,589 --> 00:42:05,040
the desert for testing of a concept we

1161
00:42:09,510 --> 00:42:07,599
call the starshade

1162
00:42:11,910 --> 00:42:09,520
so what the starshade is its goal is to

1163
00:42:13,829 --> 00:42:11,920

block out the starlight so that only the

1164
00:42:15,270 --> 00:42:13,839
planet light will enter the telescope

1165
00:42:17,349 --> 00:42:15,280
but i hope you're all wondering why this

1166
00:42:18,950 --> 00:42:17,359
is such a very special shape

1167
00:42:21,030 --> 00:42:18,960
and actually the reason has to do with

1168
00:42:23,190 --> 00:42:21,040
diffracted light and this is my only

1169
00:42:25,109 --> 00:42:23,200
professorial slide here but i want you

1170
00:42:26,550 --> 00:42:25,119
to be able to walk away with a uh

1171
00:42:28,390 --> 00:42:26,560
something that i think you'll find

1172
00:42:30,150 --> 00:42:28,400
interesting

1173
00:42:31,829 --> 00:42:30,160
and that is if we were to put imagine

1174
00:42:34,150 --> 00:42:31,839
putting up a big circular screen in

1175
00:42:35,990 --> 00:42:34,160
space or big square and to block out a

1176
00:42:38,069 --> 00:42:36,000
point source a star right behind that

1177
00:42:39,349 --> 00:42:38,079
screen we would get what you see on the

1178
00:42:41,510 --> 00:42:39,359
top right

1179
00:42:43,349 --> 00:42:41,520
i think you can see rings we wouldn't

1180
00:42:44,710 --> 00:42:43,359
see a point source the star in the image

1181
00:42:46,630 --> 00:42:44,720
we would actually see these rings

1182
00:42:48,390 --> 00:42:46,640
they're called airy rings and what it is

1183
00:42:50,390 --> 00:42:48,400
is the starlight is

1184
00:42:52,390 --> 00:42:50,400
diffracting around would be diffracting

1185
00:42:53,829 --> 00:42:52,400
around the edge of the screen it's the

1186
00:42:56,069 --> 00:42:53,839
same as if we used a

1187
00:42:57,829 --> 00:42:56,079
circular telescope it's actually just

1188
00:42:59,270 --> 00:42:57,839

because the waves are bending around the

1189
00:43:00,950 --> 00:42:59,280
edge and interfering

1190
00:43:03,030 --> 00:43:00,960
we give an analogy it would be like

1191
00:43:06,230 --> 00:43:03,040
dropping a pebble in a pond

1192
00:43:08,950 --> 00:43:06,240
and you see ripples those water waves

1193
00:43:10,390 --> 00:43:08,960
so how can we handle this when the first

1194
00:43:11,750 --> 00:43:10,400
of those light waves is a hundred

1195
00:43:14,230 --> 00:43:11,760
thousand times brighter than the planet

1196
00:43:15,990 --> 00:43:14,240
we're looking for well the answer

1197
00:43:17,589 --> 00:43:16,000
is to have a very specially shaped

1198
00:43:20,150 --> 00:43:17,599
screen and you can see in the bottom

1199
00:43:21,990 --> 00:43:20,160
left there a kind of a star-shaped

1200
00:43:23,589 --> 00:43:22,000
and the equivalent image you would get

1201
00:43:25,589 --> 00:43:23,599
with that screen and a point source star

1202
00:43:27,910 --> 00:43:25,599
is the one on the bottom right

1203
00:43:30,309 --> 00:43:27,920
and in this case the analogy is like

1204
00:43:31,750 --> 00:43:30,319
dropping a pebble in a pond

1205
00:43:33,990 --> 00:43:31,760
when all of a sudden all around the

1206
00:43:36,390 --> 00:43:34,000
pebble it would be so perfectly smooth

1207
00:43:37,990 --> 00:43:36,400
to one part and 10 billion

1208
00:43:41,190 --> 00:43:38,000
and all the waves would be pushed away

1209
00:43:42,950 --> 00:43:41,200
at the very outer edges going crazy

1210
00:43:45,349 --> 00:43:42,960
and that's the basic concept a special

1211
00:43:48,150 --> 00:43:45,359
shape to handle diffracted light

1212
00:43:49,829 --> 00:43:48,160
so that it works to your advantage

1213
00:43:51,589 --> 00:43:49,839

so here's the concept of the star shade

1214
00:43:52,470 --> 00:43:51,599
a telescope and star shade could launch

1215
00:43:54,470 --> 00:43:52,480
together

1216
00:43:57,670 --> 00:43:54,480
with the petals unfurling from a stowed

1217
00:43:59,670 --> 00:43:57,680
position and a central truss

1218
00:44:01,510 --> 00:43:59,680
expanding and snapping the pedals into

1219
00:44:03,670 --> 00:44:01,520
place in fact that truss has heritage

1220
00:44:05,349 --> 00:44:03,680
from large radio deployables these

1221
00:44:06,870 --> 00:44:05,359
pedals have to be manufactured to

1222
00:44:09,030 --> 00:44:06,880
hundreds of microns

1223
00:44:10,550 --> 00:44:09,040
and the star shade itself is tens of

1224
00:44:12,390 --> 00:44:10,560
meters in diameter

1225
00:44:15,109 --> 00:44:12,400
and would have to fly tens of thousands

1226
00:44:17,109 --> 00:44:15,119
of kilometers from the space telescope

1227
00:44:19,109 --> 00:44:17,119
right now nasa is sponsoring a detailed

1228
00:44:20,390 --> 00:44:19,119
study and the team members of a team

1229
00:44:22,630 --> 00:44:20,400
that i chair they're all out working

1230
00:44:25,030 --> 00:44:22,640
very hard now to put the exact

1231
00:44:27,030 --> 00:44:25,040
details together mechanically thermally

1232
00:44:29,030 --> 00:44:27,040
and the heritage story of the star shade

1233
00:44:30,470 --> 00:44:29,040
so we're making a lot of progress here

1234
00:44:32,150 --> 00:44:30,480
and there are other ways to block out

1235
00:44:34,870 --> 00:44:32,160
the starlight from space and we'll hear

1236
00:44:36,390 --> 00:44:34,880
more about those uh in a moment from

1237
00:44:38,630 --> 00:44:36,400
we'll hear about more about those in a

1238
00:44:39,910 --> 00:44:38,640

moment from dan gallagher oh this was

1239
00:44:41,589 --> 00:44:39,920
just to remind you that we want to

1240
00:44:43,430 --> 00:44:41,599
actually see the planet directly and

1241
00:44:45,910 --> 00:44:43,440
break up the light and to see the

1242
00:44:47,430 --> 00:44:45,920
spectrum to look for biosignature gases

1243
00:44:48,950 --> 00:44:47,440
and water vapor and other things that

1244
00:44:50,550 --> 00:44:48,960
indicate that the planet would be a

1245
00:44:52,630 --> 00:44:50,560
terrestrial planet

1246
00:44:54,870 --> 00:44:52,640
so to finish i just want to show you

1247
00:44:57,270 --> 00:44:54,880
this image of earth it's earth as seen

1248
00:45:00,069 --> 00:44:57,280
from the voyager 1 spacecraft at 4

1249
00:45:01,829 --> 00:45:00,079
billion miles away because when all is

1250
00:45:04,069 --> 00:45:01,839
said and done at the end of the day to

1251
00:45:06,230 --> 00:45:04,079
the rest of the galaxy and universe our

1252
00:45:08,150 --> 00:45:06,240
earth is just an exoplanet

1253
00:45:09,589 --> 00:45:08,160
and so we want to find another planet to

1254
00:45:12,230 --> 00:45:09,599
understand what our place is in the

1255
00:45:14,230 --> 00:45:12,240
cosmos and i want you to know that we're

1256
00:45:16,710 --> 00:45:14,240
all here today because we believe we're

1257
00:45:18,309 --> 00:45:16,720
very very close in terms of technology

1258
00:45:20,470 --> 00:45:18,319
and science in actually finding the

1259
00:45:27,670 --> 00:45:20,480
other earth and our chance to find signs

1260
00:45:31,910 --> 00:45:30,069
i'm now i'm

1261
00:45:33,190 --> 00:45:31,920
i'm now going to turn to dave gallagher

1262
00:45:35,190 --> 00:45:33,200
who's going to tell us about some of the

1263
00:45:40,309 --> 00:45:35,200

technology being developed to do the

1264
00:45:45,349 --> 00:45:42,790
thank you sarah uh it's truly an honor

1265
00:45:47,670 --> 00:45:45,359
to be included on a panel

1266
00:45:49,430 --> 00:45:47,680
of esteemed scientists like this

1267
00:45:51,109 --> 00:45:49,440
i'm very excited to be here it's a

1268
00:45:52,790 --> 00:45:51,119
little bit intimidating

1269
00:45:55,510 --> 00:45:52,800
i thought of a few jokes to make about

1270
00:45:57,030 --> 00:45:55,520
that but i'll limit myself for you stu i

1271
00:45:59,750 --> 00:45:57,040
see there are a lot of students in the

1272
00:46:01,750 --> 00:45:59,760
audience i will uh i will remind you and

1273
00:46:03,990 --> 00:46:01,760
others that it does take a few engineers

1274
00:46:07,109 --> 00:46:04,000
to make this stuff happen so

1275
00:46:09,510 --> 00:46:07,119
i i have not been to space i've not got

1276
00:46:10,790 --> 00:46:09,520
my nobel prize in my rental car but i'm

1277
00:46:11,910 --> 00:46:10,800
working on it

1278
00:46:12,630 --> 00:46:11,920
so

1279
00:46:14,790 --> 00:46:12,640
uh

1280
00:46:17,750 --> 00:46:14,800
what you heard about here was

1281
00:46:19,750 --> 00:46:17,760
a lot of of the the why

1282
00:46:21,589 --> 00:46:19,760
and some of the what and it's i mean

1283
00:46:23,349 --> 00:46:21,599
what could be better than searching for

1284
00:46:25,510 --> 00:46:23,359
life in the universe i'm gonna talk a

1285
00:46:27,109 --> 00:46:25,520
little bit about the how

1286
00:46:29,670 --> 00:46:27,119
uh

1287
00:46:36,069 --> 00:46:29,680
the

1288
00:46:39,030 --> 00:46:36,079

technology side are that number one this

1289
00:46:41,750 --> 00:46:39,040
is really challenging and number two

1290
00:46:44,390 --> 00:46:41,760
we have made a big investment between

1291
00:46:46,150 --> 00:46:44,400
nasa and the dod and others and and have

1292
00:46:49,510 --> 00:46:46,160
actually made a huge amount of technical

1293
00:46:50,870 --> 00:46:49,520
progress it's very exciting and so while

1294
00:46:53,109 --> 00:46:50,880
a lot of these things will look very

1295
00:46:54,790 --> 00:46:53,119
hard we've done a lot of work to to get

1296
00:46:55,750 --> 00:46:54,800
ourselves down the road to making that

1297
00:46:57,349 --> 00:46:55,760
happen

1298
00:47:00,630 --> 00:46:57,359
so the first challenge

1299
00:47:03,670 --> 00:47:00,640
earth is 10 billion times fainter

1300
00:47:04,950 --> 00:47:03,680
than its parent star our sun as you just

1301
00:47:06,950 --> 00:47:04,960
heard

1302
00:47:09,510 --> 00:47:06,960
there's a whole bunch of

1303
00:47:11,829 --> 00:47:09,520
analogies for that a firefly by a

1304
00:47:12,790 --> 00:47:11,839
searchlight but it's a really hard thing

1305
00:47:14,790 --> 00:47:12,800
to do

1306
00:47:16,710 --> 00:47:14,800
and i'm going to talk first about that

1307
00:47:20,150 --> 00:47:16,720
challenge there's there's really two

1308
00:47:21,750 --> 00:47:20,160
ways to approach it one is external

1309
00:47:23,190 --> 00:47:21,760
that's what sarah's been talking about

1310
00:47:25,349 --> 00:47:23,200
the sun shade

1311
00:47:27,910 --> 00:47:25,359
let me say a little bit about the team

1312
00:47:29,750 --> 00:47:27,920
uh this has been going on for a while

1313
00:47:32,630 --> 00:47:29,760

some of the previous and current team

1314
00:47:34,630 --> 00:47:32,640
members are uh jeremy kasdan from

1315
00:47:38,230 --> 00:47:34,640
princeton webcash from the university of

1316
00:47:40,950 --> 00:47:38,240
colorado northrop grumman and jpl uh in

1317
00:47:44,150 --> 00:47:40,960
the top right image there you can see

1318
00:47:46,630 --> 00:47:44,160
a video of a pedal deployment uh this

1319
00:47:49,270 --> 00:47:46,640
this was done uh last year very

1320
00:47:51,430 --> 00:47:49,280
successfully the tolerances on this are

1321
00:47:53,910 --> 00:47:51,440
extremely tight we're doing it

1322
00:47:56,390 --> 00:47:53,920
at the bottom image you can see the

1323
00:47:58,790 --> 00:47:56,400
inner hub with four of the pedals

1324
00:48:01,030 --> 00:47:58,800
extended there we have nine summer

1325
00:48:02,870 --> 00:48:01,040
students this summer at jpl who are

1326
00:48:04,870 --> 00:48:02,880
working on actually building the

1327
00:48:07,430 --> 00:48:04,880
deployable inner hub

1328
00:48:09,589 --> 00:48:07,440
that work is going extremely well and

1329
00:48:11,589 --> 00:48:09,599
all indications are we can meet the

1330
00:48:13,109 --> 00:48:11,599
tolerances required we've measured them

1331
00:48:16,230 --> 00:48:13,119
they're repeatable

1332
00:48:18,069 --> 00:48:16,240
so this is well within our capability

1333
00:48:20,470 --> 00:48:18,079
on this chart

1334
00:48:21,990 --> 00:48:20,480
rather than in the lab this is some

1335
00:48:24,710 --> 00:48:22,000
testing that was done out in the desert

1336
00:48:26,870 --> 00:48:24,720
by northrop grumman uh what's really

1337
00:48:29,589 --> 00:48:26,880
impressive about this is

1338
00:48:31,510 --> 00:48:29,599

this was a relatively crude test done in

1339
00:48:33,670 --> 00:48:31,520
the desert at night with

1340
00:48:35,270 --> 00:48:33,680
temperature variations and wind and

1341
00:48:37,270 --> 00:48:35,280
stuff floating around in the air and

1342
00:48:39,190 --> 00:48:37,280
rattlesnakes and whatever

1343
00:48:41,670 --> 00:48:39,200
and we've actually been able to

1344
00:48:43,910 --> 00:48:41,680
demonstrate contrast ratios extremely

1345
00:48:47,190 --> 00:48:43,920
close to what we need with the star

1346
00:48:50,470 --> 00:48:47,200
shades this is a small scale star shade

1347
00:48:52,470 --> 00:48:50,480
separated by about two kilometers uh and

1348
00:48:54,069 --> 00:48:52,480
and it really works so

1349
00:48:55,670 --> 00:48:54,079
what you know the first slide was

1350
00:48:57,190 --> 00:48:55,680
showing you how this works in the lab

1351
00:48:59,589 --> 00:48:57,200
that we're measuring and demonstrating

1352
00:49:01,670 --> 00:48:59,599
that and this is you know proof that

1353
00:49:04,870 --> 00:49:01,680
again exceeded our expectations given

1354
00:49:07,349 --> 00:49:04,880
the the test conditions

1355
00:49:09,750 --> 00:49:07,359
so that's the external way so now from

1356
00:49:11,990 --> 00:49:09,760
the large to the very small there is

1357
00:49:13,910 --> 00:49:12,000
another way to block out the parent

1358
00:49:17,349 --> 00:49:13,920
light and that's using an internal

1359
00:49:21,190 --> 00:49:17,359
occulter also known as a coronagraph

1360
00:49:22,549 --> 00:49:21,200
the cartoon at the top left is a

1361
00:49:24,790 --> 00:49:22,559
simplified

1362
00:49:27,190 --> 00:49:24,800
illustration of our high contrast

1363
00:49:29,109 --> 00:49:27,200

imaging testbed at jpl

1364
00:49:32,309 --> 00:49:29,119
where we allow scientists to come from

1365
00:49:35,109 --> 00:49:32,319
around the world with various types of

1366
00:49:37,030 --> 00:49:35,119
coronagraphs or essentially masks

1367
00:49:39,510 --> 00:49:37,040
so when you think about that star shade

1368
00:49:41,670 --> 00:49:39,520
on a large scale blocking the light the

1369
00:49:44,870 --> 00:49:41,680
coronagraph is doing it on a very small

1370
00:49:45,910 --> 00:49:44,880
scale and in the cartoon on the left you

1371
00:49:46,630 --> 00:49:45,920
can see

1372
00:49:47,510 --> 00:49:46,640
a

1373
00:49:48,230 --> 00:49:47,520
uh

1374
00:50:29,829 --> 00:49:48,240
a

1375
00:50:31,510 --> 00:50:29,839
extremely well

1376
00:50:33,030 --> 00:50:31,520
and and proving that these things are

1377
00:50:35,990 --> 00:50:33,040
possible

1378
00:50:38,549 --> 00:50:36,000
so we're studying a 2.4 meter mission

1379
00:50:40,230 --> 00:50:38,559
called wfirst after if i had more time i

1380
00:50:42,950 --> 00:50:40,240
would expand the acronym that would take

1381
00:50:43,829 --> 00:50:42,960
about five minutes uh the

1382
00:50:45,829 --> 00:50:43,839
this

1383
00:50:48,470 --> 00:50:45,839
program was made possible by the

1384
00:50:50,790 --> 00:50:48,480
generous donation of a 2.4 meter tele

1385
00:50:53,109 --> 00:50:50,800
that sounds like a pbs spot by the

1386
00:50:55,430 --> 00:50:53,119
donation by the nro national

1387
00:50:57,829 --> 00:50:55,440
reconnaissance office of a 2.4 meter

1388
00:50:58,790 --> 00:50:57,839

telescope it's really enabled this

1389
00:51:00,870 --> 00:50:58,800
mission

1390
00:51:03,510 --> 00:51:00,880
and it's under study now in in

1391
00:51:05,349 --> 00:51:03,520
astrophysics it's going extremely well

1392
00:51:07,990 --> 00:51:05,359
uh and if you look at the the three

1393
00:51:10,470 --> 00:51:08,000
images the first one is is a no mask

1394
00:51:12,309 --> 00:51:10,480
image the second one is with a mask and

1395
00:51:13,670 --> 00:51:12,319
then the bottom right is

1396
00:51:15,990 --> 00:51:13,680
shows you

1397
00:51:17,910 --> 00:51:16,000
a simulation with a planet of the mask

1398
00:51:20,710 --> 00:51:17,920
and deformable mirror so this will be

1399
00:51:23,910 --> 00:51:20,720
our first chance to fly a coronagraph in

1400
00:51:25,829 --> 00:51:23,920
space and demonstrate this

1401
00:51:27,589 --> 00:51:25,839
okay i talked about two challenges the

1402
00:51:30,069 --> 00:51:27,599
second challenge is that earth is

1403
00:51:32,150 --> 00:51:30,079
intrinsically very faint

1404
00:51:34,150 --> 00:51:32,160
i won't dwell on this i think my uh

1405
00:51:37,270 --> 00:51:34,160
co-panelists got this point across

1406
00:51:39,190 --> 00:51:37,280
that's a hubble image uh with a planet

1407
00:51:42,309 --> 00:51:39,200
uh that you can see

1408
00:51:44,069 --> 00:51:42,319
extracted by a very crude uh early

1409
00:51:45,430 --> 00:51:44,079
instantiation of a

1410
00:51:47,990 --> 00:51:45,440
coronagraph

1411
00:51:49,910 --> 00:51:48,000
and then the what we would need to to

1412
00:51:51,510 --> 00:51:49,920
find these earth twins or to find an

1413
00:51:53,510 --> 00:51:51,520

earth-like planet as we've been talking

1414
00:51:55,750 --> 00:51:53,520
about is something that's a million

1415
00:51:57,990 --> 00:51:55,760
times fainter than that and when it

1416
00:51:59,349 --> 00:51:58,000
comes to finding fake things it's a very

1417
00:52:01,349 --> 00:51:59,359
simple

1418
00:52:03,589 --> 00:52:01,359
algorithm you need bigger telescopes you

1419
00:52:06,309 --> 00:52:03,599
need more collecting area

1420
00:52:08,150 --> 00:52:06,319
james webb is leading the way uh in

1421
00:52:10,950 --> 00:52:08,160
increasing the collecting area as you've

1422
00:52:12,230 --> 00:52:10,960
seen it's our biggest telescope yet

1423
00:52:14,230 --> 00:52:12,240
and uh

1424
00:52:16,069 --> 00:52:14,240
mirrors are built everything appears to

1425
00:52:19,270 --> 00:52:16,079
be working perfectly and we're well on

1426
00:52:21,270 --> 00:52:19,280
our way to to success in 2018

1427
00:52:24,309 --> 00:52:21,280
the search for life is going to require

1428
00:52:26,870 --> 00:52:24,319
even larger lighter space telescopes so

1429
00:52:29,670 --> 00:52:26,880
you can see the evolution from hubble to

1430
00:52:32,549 --> 00:52:29,680
james webb to an artist's conception

1431
00:52:35,030 --> 00:52:32,559
there of a 16 meter space telescope

1432
00:52:37,510 --> 00:52:35,040
in green is the ratio of the launch mass

1433
00:52:39,670 --> 00:52:37,520
to the collecting area of the telescopes

1434
00:52:42,790 --> 00:52:39,680
so the message is you got to get bigger

1435
00:52:45,270 --> 00:52:42,800
and to do that you got to get lighter

1436
00:52:47,670 --> 00:52:45,280
one of the ways we do that is with very

1437
00:52:50,069 --> 00:52:47,680
lightweight replicated optics sitting

1438
00:52:52,710 --> 00:52:50,079

over there in the in the case is a

1439
00:52:54,630 --> 00:52:52,720
what's called a advanced hybrid mirror

1440
00:52:58,470 --> 00:52:54,640
uh northrop grumman

1441
00:53:00,790 --> 00:52:58,480
has built that's about a 1.2 meter

1442
00:53:02,790 --> 00:53:00,800
hex segment these are lightweight

1443
00:53:04,630 --> 00:53:02,800
silicon carbide mirrors that are

1444
00:53:07,829 --> 00:53:04,640
actuated and have a

1445
00:53:09,670 --> 00:53:07,839
very very fine uh nanolaminate foil

1446
00:53:12,309 --> 00:53:09,680
across the top kind of the the

1447
00:53:14,150 --> 00:53:12,319
composition of heavy aluminum foil

1448
00:53:16,470 --> 00:53:14,160
these have been built proved out the

1449
00:53:19,430 --> 00:53:16,480
technology matured up to a very high

1450
00:53:22,870 --> 00:53:19,440
level and uh essentially ready to go

1451
00:53:25,750 --> 00:53:22,880
uh at last uh expanded there for you is

1452
00:53:27,990 --> 00:53:25,760
just to show you a couple of uh concepts

1453
00:53:30,270 --> 00:53:28,000
for larger space telescopes there's a

1454
00:53:33,349 --> 00:53:30,280
9.2 meter and a

1455
00:53:35,190 --> 00:53:33,359
16.8 meter version those are being

1456
00:53:36,069 --> 00:53:35,200
studied um

1457
00:53:39,349 --> 00:53:36,079
there's

1458
00:53:40,950 --> 00:53:39,359
them you can see a lot of large

1459
00:53:43,030 --> 00:53:40,960
deployments required but we'll have a

1460
00:53:44,710 --> 00:53:43,040
lot of confidence because of the work

1461
00:53:47,270 --> 00:53:44,720
done on james webb as well as the

1462
00:53:49,990 --> 00:53:47,280
technology work being done now

1463
00:53:52,390 --> 00:53:50,000

and then finally uh

1464
00:53:54,630 --> 00:53:52,400
there are some really far out concepts

1465
00:53:57,030 --> 00:53:54,640
ball and darpa are working on

1466
00:53:58,470 --> 00:53:57,040
essentially a 20 meter membrane

1467
00:54:00,710 --> 00:53:58,480
telescope

1468
00:54:02,870 --> 00:54:00,720
that that looks very promising and it's

1469
00:54:05,510 --> 00:54:02,880
essentially got an etched diffraction

1470
00:54:07,589 --> 00:54:05,520
pattern on the membrane and that's been

1471
00:54:08,710 --> 00:54:07,599
demonstrated at subscale versions in the

1472
00:54:10,069 --> 00:54:08,720
lab

1473
00:54:22,309 --> 00:54:10,079
thank you very much i'd like to turn it

1474
00:54:27,190 --> 00:54:25,589
so let's bring this to conclusion

1475
00:54:29,589 --> 00:54:27,200
so here is

1476
00:54:30,870 --> 00:54:29,599
the challenge before us how do we find

1477
00:54:32,069 --> 00:54:30,880
earth point

1478
00:54:35,270 --> 00:54:32,079
two

1479
00:54:41,349 --> 00:54:38,069
as sarah's told us we already know that

1480
00:54:43,030 --> 00:54:41,359
our galaxy has hun at least a hundred

1481
00:54:44,630 --> 00:54:43,040
billion

1482
00:54:46,390 --> 00:54:44,640
planets in it and we didn't know that

1483
00:54:48,470 --> 00:54:46,400
five years ago just think about that

1484
00:54:50,630 --> 00:54:48,480
five years ago we couldn't have actually

1485
00:54:52,710 --> 00:54:50,640
put those words on this chart

1486
00:54:53,990 --> 00:54:52,720
that's what kepler and nasa has done for

1487
00:54:55,910 --> 00:54:54,000
us

1488
00:54:57,750 --> 00:54:55,920

we actually know now

1489
00:55:00,150 --> 00:54:57,760
what life might look like we know life

1490
00:55:02,470 --> 00:55:00,160
can actually imprint itself

1491
00:55:04,870 --> 00:55:02,480
on the atmosphere of planets going

1492
00:55:07,510 --> 00:55:04,880
around other stars this is what a living

1493
00:55:10,470 --> 00:55:07,520
planet looks like

1494
00:55:12,950 --> 00:55:10,480
we actually know where all the stars are

1495
00:55:14,549 --> 00:55:12,960
here are all the stars nearby to us

1496
00:55:16,870 --> 00:55:14,559
within 200 light years this is every

1497
00:55:18,150 --> 00:55:16,880
single star within 200 light years of

1498
00:55:20,630 --> 00:55:18,160
the sun

1499
00:55:22,870 --> 00:55:20,640
we actually know how many stars live a

1500
00:55:24,549 --> 00:55:22,880
long time between five and 10 billion

1501
00:55:25,430 --> 00:55:24,559
years that's where we have to look it

1502
00:55:27,270 --> 00:55:25,440
took

1503
00:55:31,430 --> 00:55:27,280
four and a half billion years for us to

1504
00:55:37,030 --> 00:55:34,710
we actually have done the census kepler

1505
00:55:39,030 --> 00:55:37,040
has actually done the census

1506
00:55:41,030 --> 00:55:39,040
of how many planets there might be in

1507
00:55:43,670 --> 00:55:41,040
our galaxy

1508
00:55:47,510 --> 00:55:43,680
and what we've learned is remarkable

1509
00:55:49,829 --> 00:55:47,520
between 10 and 20 percent

1510
00:55:51,829 --> 00:55:49,839
of stars have earth-like planets or at

1511
00:55:53,190 --> 00:55:51,839
least earth-sized planets

1512
00:55:54,870 --> 00:55:53,200
in that amazing zone called the

1513
00:55:59,030 --> 00:55:54,880

habitable zone the goldilocks zone not

1514
00:56:02,069 --> 00:55:59,040
too hot not too cold just right

1515
00:56:04,390 --> 00:56:02,079
so let's take those statistics

1516
00:56:06,230 --> 00:56:04,400
take that census data and let's do the

1517
00:56:08,309 --> 00:56:06,240
discovery

1518
00:56:10,230 --> 00:56:08,319
here all those stars

1519
00:56:12,710 --> 00:56:10,240
we can now apply those statistics and

1520
00:56:14,710 --> 00:56:12,720
ask how many stars can we see

1521
00:56:16,789 --> 00:56:14,720
with a five meter telescope roughly the

1522
00:56:19,270 --> 00:56:16,799
james webb apply those statistics what

1523
00:56:21,829 --> 00:56:19,280
you see on the right is how many stars

1524
00:56:22,710 --> 00:56:21,839
the james webb or telescope like it very

1525
00:56:25,510 --> 00:56:22,720
few

1526
00:56:27,430 --> 00:56:25,520
how lucky as sarah said do we feel

1527
00:56:29,190 --> 00:56:27,440
with 10 meters we can peer even deeper

1528
00:56:31,510 --> 00:56:29,200
into that cloud of stars we can go

1529
00:56:33,109 --> 00:56:31,520
deeper and we can separate out and see

1530
00:56:35,430 --> 00:56:33,119
even more planets

1531
00:56:37,990 --> 00:56:35,440
and with a 20-meter telescope we can see

1532
00:56:39,510 --> 00:56:38,000
hundreds of earth-like planets around

1533
00:56:43,349 --> 00:56:39,520
other stars

1534
00:56:43,359 --> 00:56:46,150
of course

1535
00:56:49,510 --> 00:56:47,829
this is a hard problem

1536
00:56:51,829 --> 00:56:49,520
but nasa has been very good at doing

1537
00:56:53,349 --> 00:56:51,839
these hard problems

1538
00:56:55,270 --> 00:56:53,359

nasa's ability to launch great

1539
00:56:56,829 --> 00:56:55,280
telescopes like the hubble

1540
00:56:59,589 --> 00:56:56,839
and soon the james

1541
00:57:04,710 --> 00:56:59,599
webb it's going to do anything here we

1542
00:57:08,870 --> 00:57:05,589
oh

1543
00:57:12,549 --> 00:57:11,349
there we go

1544
00:57:14,309 --> 00:57:12,559
that's what

1545
00:57:16,950 --> 00:57:14,319
but to actually and we may find liquid

1546
00:57:19,349 --> 00:57:16,960
water we may be really lucky

1547
00:57:20,950 --> 00:57:19,359
but to find evidence of actual life is

1548
00:57:23,510 --> 00:57:20,960
going to take another generation of

1549
00:57:25,109 --> 00:57:23,520
telescopes

1550
00:57:27,349 --> 00:57:25,119
and to do that

1551
00:57:29,589 --> 00:57:27,359
we're going to need new rockets

1552
00:57:32,069 --> 00:57:29,599
new approaches to getting into space new

1553
00:57:34,710 --> 00:57:32,079
approaches to large telescopes

1554
00:57:37,030 --> 00:57:34,720
highly advanced optical systems as david

1555
00:57:39,030 --> 00:57:37,040
and sarah showed us

1556
00:57:40,549 --> 00:57:39,040
but between us

1557
00:57:42,549 --> 00:57:40,559
between science

1558
00:57:45,430 --> 00:57:42,559
nasa's technology

1559
00:57:47,750 --> 00:57:45,440
and today's space enterprise

1560
00:57:50,710 --> 00:57:47,760
it's within our grasp for the first time

1561
00:57:52,829 --> 00:57:50,720
in human history

1562
00:57:56,230 --> 00:57:52,839
to make a discovery that will change the

1563
00:57:58,470 --> 00:57:56,240

world well to plagiarize steve jobs a

1564
00:58:01,990 --> 00:57:58,480
discovery that will put a serious dent

1565
00:58:04,390 --> 00:58:02,789
now

1566
00:58:08,150 --> 00:58:04,400
if we can get

1567
00:58:10,710 --> 00:58:08,160
a telescope into space of the sufficient

1568
00:58:16,870 --> 00:58:14,470
and get it launched imagine the moment

1569
00:58:19,510 --> 00:58:16,880
that the news breaks we've discovered

1570
00:58:21,270 --> 00:58:19,520
earth 2.0

1571
00:58:23,109 --> 00:58:21,280
imagine the moment

1572
00:58:25,349 --> 00:58:23,119
the middle school kid

1573
00:58:29,430 --> 00:58:25,359
who looks up from procrastinating about

1574
00:58:34,470 --> 00:58:31,270
or her math homework

1575
00:58:37,829 --> 00:58:34,480
but realizes that he or she could be the

1576
00:58:39,910 --> 00:58:37,839
person who could design

1577
00:58:43,910 --> 00:58:39,920
the rocket engine that could take a

1578
00:58:46,710 --> 00:58:43,920
starship to earth 2.0

1579
00:58:49,510 --> 00:58:46,720
imagine the moment a biology teacher

1580
00:58:53,030 --> 00:58:49,520
struggling to engage a high school class

1581
00:58:58,470 --> 00:58:55,589
she could tell an amazing story

1582
00:58:59,990 --> 00:58:58,480
for the first time in human history we

1583
00:59:01,510 --> 00:59:00,000
have reached the point where we can look

1584
00:59:03,190 --> 00:59:01,520
out to the stars

1585
00:59:04,870 --> 00:59:03,200
and realize

1586
00:59:07,190 --> 00:59:04,880
the miracle of life has occurred

1587
00:59:09,030 --> 00:59:07,200
elsewhere on a planet going around

1588
00:59:10,870 --> 00:59:09,040

another star

1589
00:59:13,670 --> 00:59:10,880
imagine the moment

1590
00:59:16,710 --> 00:59:13,680
the whole world wakes up to the news

1591
00:59:19,510 --> 00:59:16,720
a long loneliness in time and space may

1592
00:59:21,510 --> 00:59:19,520
have ended we may no longer be alone in

1593
00:59:24,710 --> 00:59:21,520
the universe

1594
00:59:25,910 --> 00:59:24,720
now each of us

1595
00:59:28,950 --> 00:59:25,920
every day

1596
00:59:31,349 --> 00:59:28,960
have much more immediate concerns

1597
00:59:33,270 --> 00:59:31,359
there's so many problems here on earth

1598
00:59:35,190 --> 00:59:33,280
we need to deal with today

1599
00:59:37,270 --> 00:59:35,200
how will i get my project finished how

1600
00:59:40,549 --> 00:59:37,280
will i get that next contract how will i

1601
00:59:42,230 --> 00:59:40,559
play college for my kids in this economy

1602
00:59:44,390 --> 00:59:42,240
do we even have the space infrastructure

1603
00:59:46,789 --> 00:59:44,400
for our national security or

1604
00:59:48,309 --> 00:59:46,799
economic security let alone looking for

1605
00:59:51,109 --> 00:59:48,319
life elsewhere

1606
00:59:52,870 --> 00:59:51,119
i have deadlines to meet

1607
00:59:55,349 --> 00:59:52,880
do i really have time to think out of

1608
00:59:57,750 --> 00:59:55,359
the box

1609
00:59:59,829 --> 00:59:57,760
but imagine

1610
01:00:01,829 --> 00:59:59,839
if each one of us sets aside just a

1611
01:00:03,430 --> 01:00:01,839
little bit of time

1612
01:00:07,270 --> 01:00:03,440
just to think

1613
01:00:10,789 --> 01:00:08,950

could we use those technologies those

1614
01:00:13,270 --> 01:00:10,799
crazy scientists want

1615
01:00:15,270 --> 01:00:13,280
for other things

1616
01:00:16,870 --> 01:00:15,280
how do we do audacious things in space

1617
01:00:19,910 --> 01:00:16,880
again that inspired the generation of

1618
01:00:20,870 --> 01:00:19,920
people sitting before you

1619
01:00:22,470 --> 01:00:20,880
and

1620
01:00:24,950 --> 01:00:22,480
what is our legacy

1621
01:00:26,789 --> 01:00:24,960
actually going to be

1622
01:00:29,510 --> 01:00:26,799
and while you reflect on what we've all

1623
01:00:35,589 --> 01:00:29,520
said here today we wanted to finish on

1624
01:00:41,030 --> 01:00:39,270
what new wonders undreamt of in our time

1625
01:00:44,390 --> 01:00:41,040
will we have wrought in another

1626
01:00:47,030 --> 01:00:44,400
generation and another

1627
01:00:48,230 --> 01:00:47,040
how far will our nomadic species have

1628
01:00:50,870 --> 01:00:48,240
wandered

1629
01:00:55,750 --> 01:00:50,880
by the end of the next century

1630
01:01:00,069 --> 01:00:57,990
our remote descendants

1631
01:01:03,030 --> 01:01:00,079
safely arrayed on many worlds through

1632
01:01:05,349 --> 01:01:03,040
the solar system and beyond

1633
01:01:07,829 --> 01:01:05,359
will be unified

1634
01:01:11,030 --> 01:01:07,839
by their common heritage

1635
01:01:12,710 --> 01:01:11,040
by their regard for their home planet

1636
01:01:15,589 --> 01:01:12,720
and by the knowledge

1637
01:01:17,910 --> 01:01:15,599
that whatever other life may be the only

1638
01:01:20,390 --> 01:01:17,920

humans in all the universe

1639
01:01:23,990 --> 01:01:20,400
come from earth

1640
01:01:25,030 --> 01:01:24,000
they will gaze up and stream to find the

1641
01:01:26,789 --> 01:01:25,040
blue dot

1642
01:01:28,470 --> 01:01:26,799
in their skies

1643
01:01:30,950 --> 01:01:28,480
they will marvel

1644
01:01:33,589 --> 01:01:30,960
at how vulnerable the repository of all

1645
01:01:34,950 --> 01:01:33,599
our potential once was

1646
01:01:36,309 --> 01:01:34,960
how perilous

1647
01:01:37,829 --> 01:01:36,319
our infancy

1648
01:01:41,589 --> 01:01:37,839
how humble

1649
01:01:46,390 --> 01:01:44,870
how many rivers we had to cross

1650
01:01:50,069 --> 01:01:46,400
before we found

1651
01:01:53,670 --> 01:01:51,670
so imagine the world

1652
01:01:56,710 --> 01:01:53,680
we've gone from galileo

1653
01:01:59,270 --> 01:01:56,720
hubble spitzer kepler enabled by nasa

1654
01:02:00,789 --> 01:01:59,280
and their partners

1655
01:02:02,870 --> 01:02:00,799
what's it going to take to cross that

1656
01:02:04,230 --> 01:02:02,880
next river it's going to take a

1657
01:02:07,589 --> 01:02:04,240
partnership

1658
01:02:09,270 --> 01:02:07,599
webb space telescope

1659
01:02:11,750 --> 01:02:09,280
partnership that may be able to lead to

1660
01:02:12,950 --> 01:02:11,760
other telescopes putting together the

1661
01:02:15,910 --> 01:02:12,960
partnership

1662
01:02:18,309 --> 01:02:15,920
the confined earth 2.0

1663
01:02:19,670 --> 01:02:18,319

is a challenge worthy of a great

1664
01:02:21,270 --> 01:02:19,680
generation

1665
01:02:34,870 --> 01:02:21,280
thank you for listening to us

1666
01:02:39,750 --> 01:02:38,069
that was truly amazing and we do have a

1667
01:02:42,069 --> 01:02:39,760
fair amount of time for questions and i

1668
01:02:44,710 --> 01:02:42,079
want to remind our audience who's out

1669
01:02:47,670 --> 01:02:44,720
there to send us questions at hashtag

1670
01:02:50,470 --> 01:02:47,680
ask nasa um but i'm going gonna take the

1671
01:02:51,829 --> 01:02:50,480
moderator's prerogative here and uh ask

1672
01:02:53,510 --> 01:02:51,839
the first question

1673
01:02:55,349 --> 01:02:53,520
um you know we're often the most

1674
01:02:57,029 --> 01:02:55,359
surprised in science by things that we

1675
01:02:59,349 --> 01:02:57,039
don't expect for example the arrangement

1676
01:03:01,190 --> 01:02:59,359
of planets around stars kepler all the

1677
01:03:03,430 --> 01:03:01,200
work we've done it's totally turned our

1678
01:03:05,109 --> 01:03:03,440
views of how solar systems form uh sort

1679
01:03:06,710 --> 01:03:05,119
of upside down

1680
01:03:08,710 --> 01:03:06,720
where do you and of course i'm asking

1681
01:03:10,470 --> 01:03:08,720
about an unknown unknown here but where

1682
01:03:12,390 --> 01:03:10,480
do you think the next the really big

1683
01:03:14,630 --> 01:03:12,400
surprise is going to come in tess or

1684
01:03:15,829 --> 01:03:14,640
jwst what are you sort of saying

1685
01:03:17,910 --> 01:03:15,839
you know i bet something cool is going

1686
01:03:19,990 --> 01:03:17,920
to come out come from there what are you

1687
01:03:21,670 --> 01:03:20,000
thinking

1688
01:03:23,029 --> 01:03:21,680

i'll start by just saying right now you

1689
01:03:25,109 --> 01:03:23,039
know we've just like a lot of other

1690
01:03:27,750 --> 01:03:25,119
sciences astronomy and exoplanets in

1691
01:03:29,990 --> 01:03:27,760
particular is moving into a big data

1692
01:03:31,750 --> 01:03:30,000
regime and so essentially we don't

1693
01:03:33,190 --> 01:03:31,760
totally know what the next thing is

1694
01:03:36,150 --> 01:03:33,200
it'll be the new discoveries and it'll

1695
01:03:37,910 --> 01:03:36,160
be the statistics the having lots of the

1696
01:03:39,750 --> 01:03:37,920
same object knowing how many numbers

1697
01:03:41,190 --> 01:03:39,760
there are and what their distribution is

1698
01:03:43,349 --> 01:03:41,200
i think our hope is actually just

1699
01:03:45,029 --> 01:03:43,359
speaking scientifically in addition to

1700
01:03:46,549 --> 01:03:45,039
looking for other planets that might be

1701
01:03:48,470 --> 01:03:46,559
like earth because we're so fixated on

1702
01:03:50,470 --> 01:03:48,480
that it's just really understanding

1703
01:03:52,150 --> 01:03:50,480
planet formation you have to understand

1704
01:03:54,549 --> 01:03:52,160
that for generations we thought we would

1705
01:03:56,069 --> 01:03:54,559
have a jupiter far out where our jupiter

1706
01:03:57,270 --> 01:03:56,079
is the big giant planets would be far

1707
01:03:59,190 --> 01:03:57,280
from the star and that smaller

1708
01:04:00,710 --> 01:03:59,200
terrestrial planets will be close in and

1709
01:04:02,150 --> 01:04:00,720
so i would say that planet formation

1710
01:04:04,390 --> 01:04:02,160
theory has been turned on its head and

1711
01:04:06,309 --> 01:04:04,400
only with more and more data covering

1712
01:04:08,150 --> 01:04:06,319
all the regimes of planets possible can

1713
01:04:10,829 --> 01:04:08,160

we start to understand planet formation

1714
01:04:16,950 --> 01:04:13,270
great okay we do have a fair amount of

1715
01:04:19,270 --> 01:04:16,960
time for questions from the audience so

1716
01:04:21,910 --> 01:04:19,280
questions please uh right down here in

1717
01:04:24,950 --> 01:04:21,920
front may well grab you

1718
01:04:28,230 --> 01:04:24,960
lindley for space policyonline.com

1719
01:04:30,950 --> 01:04:28,240
uh in the search for uh looking or earth

1720
01:04:33,510 --> 01:04:30,960
2.0 is there a specific uh

1721
01:04:35,190 --> 01:04:33,520
number that you're looking for and if

1722
01:04:36,710 --> 01:04:35,200
you find more than one what would be the

1723
01:04:41,670 --> 01:04:36,720
scientific criteria that would weigh

1724
01:04:43,829 --> 01:04:41,680
most in determining which to focus on

1725
01:04:45,910 --> 01:04:43,839
well the reason why we showed the many

1726
01:04:46,710 --> 01:04:45,920
different sizes of telescopes is we

1727
01:04:48,710 --> 01:04:46,720
believe that this will be a

1728
01:04:50,549 --> 01:04:48,720
multi-generational search

1729
01:04:52,069 --> 01:04:50,559
as i mentioned with the tests and james

1730
01:04:54,950 --> 01:04:52,079
webb space telescope combination we have

1731
01:04:56,710 --> 01:04:54,960
a shot at finding something interesting

1732
01:04:57,510 --> 01:04:56,720
and then our next generation would be

1733
01:04:59,029 --> 01:04:57,520
our

1734
01:05:01,029 --> 01:04:59,039
say two meter class telescope for

1735
01:05:03,349 --> 01:05:01,039
example or a little bigger where we will

1736
01:05:04,870 --> 01:05:03,359
look at the nearest say 20 to 100

1737
01:05:06,549 --> 01:05:04,880
sun-like stars

1738
01:05:07,430 --> 01:05:06,559

and we hope that we would find a few to

1739
01:05:09,190 --> 01:05:07,440
study

1740
01:05:11,109 --> 01:05:09,200
in the more distant future when we want

1741
01:05:13,029 --> 01:05:11,119
to have handfuls of them so we really

1742
01:05:15,029 --> 01:05:13,039
have the chance to find a sign of life

1743
01:05:17,109 --> 01:05:15,039
and we can be sure because in any one

1744
01:05:20,390 --> 01:05:17,119
case we might not be 100 sure we may say

1745
01:05:22,390 --> 01:05:20,400
oh that planet has maybe 80 chance of

1746
01:05:24,549 --> 01:05:22,400
that that signature we see is from life

1747
01:05:26,230 --> 01:05:24,559
that one may have 99 but to have enough

1748
01:05:28,230 --> 01:05:26,240
to really really truly believe and have

1749
01:05:30,150 --> 01:05:28,240
enough to actually study in detail will

1750
01:05:32,150 --> 01:05:30,160
require the futuristic space telescope

1751
01:05:33,910 --> 01:05:32,160
that we don't have plans for yet that we

1752
01:05:35,910 --> 01:05:33,920
all showed you maybe in the 10 to 20

1753
01:05:37,910 --> 01:05:35,920
meter class so it's actually graduated

1754
01:05:41,029 --> 01:05:37,920
approach i mean another way another way

1755
01:05:42,789 --> 01:05:41,039
of saying this is we have no idea

1756
01:05:45,109 --> 01:05:42,799
we know how many earth-like planets are

1757
01:05:47,349 --> 01:05:45,119
we know we think we know how to

1758
01:05:49,510 --> 01:05:47,359
characterize the atmospheres

1759
01:05:52,390 --> 01:05:49,520
but there are 10 to the 22 stars in the

1760
01:05:54,710 --> 01:05:52,400
known universe that's one with 22 zeros

1761
01:05:56,870 --> 01:05:54,720
after it and some people believe life is

1762
01:05:58,390 --> 01:05:56,880
everywhere there's one some people

1763
01:06:00,309 --> 01:05:58,400

believe we're completely unique that's

1764
01:06:02,390 --> 01:06:00,319
one part and 10 to the 22. that's a

1765
01:06:03,750 --> 01:06:02,400
really big error bar even by cosmology

1766
01:06:05,029 --> 01:06:03,760
standards

1767
01:06:06,950 --> 01:06:05,039
and the only way we're actually going to

1768
01:06:08,789 --> 01:06:06,960
find that out is to make a measurement

1769
01:06:10,230 --> 01:06:08,799
the way astronomy has always proceeded

1770
01:06:11,670 --> 01:06:10,240
is we make measurements and we're then

1771
01:06:13,670 --> 01:06:11,680
surprised

1772
01:06:15,270 --> 01:06:13,680
and so by making that measurement you

1773
01:06:18,789 --> 01:06:15,280
know we don't know if we're finding one

1774
01:06:20,390 --> 01:06:18,799
two or three or zero

1775
01:06:21,829 --> 01:06:20,400
and the real question just to follow up

1776
01:06:23,270 --> 01:06:21,839
because this is you've asked a really

1777
01:06:25,349 --> 01:06:23,280
central question

1778
01:06:28,630 --> 01:06:25,359
and to quote another great philosopher

1779
01:06:30,230 --> 01:06:28,640
you know do you feel lucky

1780
01:06:33,270 --> 01:06:30,240
the

1781
01:06:35,109 --> 01:06:33,280
amazing thing from where we sit today

1782
01:06:37,430 --> 01:06:35,119
and it's from the kepler telescope is

1783
01:06:38,950 --> 01:06:37,440
and sarah described it very eloquently

1784
01:06:41,190 --> 01:06:38,960
when you look up at the night sky at

1785
01:06:43,190 --> 01:06:41,200
night we now know that virtually every

1786
01:06:45,670 --> 01:06:43,200
star has a planet around it in fact most

1787
01:06:47,990 --> 01:06:45,680
stars have solar systems around them and

1788
01:06:50,630 --> 01:06:48,000

so the the idea that we're going to find

1789
01:06:53,190 --> 01:06:50,640
planets that are very much like earth

1790
01:06:55,109 --> 01:06:53,200
i think is a very high probability the

1791
01:06:56,789 --> 01:06:55,119
question is

1792
01:06:58,789 --> 01:06:56,799
how hard is it for life to get a

1793
01:06:59,670 --> 01:06:58,799
foothold how hard is it for life to

1794
01:07:02,069 --> 01:06:59,680
start

1795
01:07:03,589 --> 01:07:02,079
and that's where we really have no idea

1796
01:07:05,829 --> 01:07:03,599
and where i think the discovery of a

1797
01:07:07,430 --> 01:07:05,839
planet like earth with signs of life on

1798
01:07:09,829 --> 01:07:07,440
it will be so remarkable that will be

1799
01:07:11,510 --> 01:07:09,839
our first scientific evidence you know

1800
01:07:13,430 --> 01:07:11,520
that life might be elsewhere even

1801
01:07:15,109 --> 01:07:13,440
primitive life

1802
01:07:17,829 --> 01:07:15,119
next question hi eric neal our discovery

1803
01:07:19,270 --> 01:07:17,839
news uh when you turn this thing on when

1804
01:07:20,549 --> 01:07:19,280
you turn the web on

1805
01:07:23,510 --> 01:07:20,559
do you have an idea of where to look

1806
01:07:25,829 --> 01:07:23,520
first are you just going to go fishing

1807
01:07:27,670 --> 01:07:25,839
oh well maybe i should take that um we

1808
01:07:29,270 --> 01:07:27,680
will have a very detailed plan before we

1809
01:07:31,029 --> 01:07:29,280
turn it on right now we haven't argued

1810
01:07:32,309 --> 01:07:31,039
it through

1811
01:07:33,510 --> 01:07:32,319
clearly there's a tension between

1812
01:07:35,510 --> 01:07:33,520
wanting to make sure that all the

1813
01:07:36,789 --> 01:07:35,520

pictures are beautiful and making sure

1814
01:07:37,750 --> 01:07:36,799
that they're very scientifically

1815
01:07:39,430 --> 01:07:37,760
important

1816
01:07:40,470 --> 01:07:39,440
i showed you the andromeda

1817
01:07:42,309 --> 01:07:40,480
sorry the

1818
01:07:44,309 --> 01:07:42,319
orion nebula where we know that stars

1819
01:07:46,230 --> 01:07:44,319
are being born and every telescope is

1820
01:07:47,990 --> 01:07:46,240
always pointed when it's new i'm sure

1821
01:07:48,870 --> 01:07:48,000
we'll look over there we will look at

1822
01:07:53,589 --> 01:07:48,880
the

1823
01:07:57,270 --> 01:07:53,599
as soon as we think we're able

1824
01:08:00,309 --> 01:07:58,789
i just want to add one thing that go

1825
01:08:01,589 --> 01:08:00,319
ahead oh before you start i just want to

1826
01:08:02,950 --> 01:08:01,599
add one thing that in terms of which

1827
01:08:03,829 --> 01:08:02,960
stars and which planets we're going to

1828
01:08:05,510 --> 01:08:03,839
look at

1829
01:08:07,510 --> 01:08:05,520
what's interesting is there's relatively

1830
01:08:08,710 --> 01:08:07,520
a democratic process where members from

1831
01:08:11,270 --> 01:08:08,720
the astronomy community will put in

1832
01:08:13,190 --> 01:08:11,280
proposals and time will be awarded by a

1833
01:08:15,270 --> 01:08:13,200
community a committee of people from the

1834
01:08:17,110 --> 01:08:15,280
community themselves so this sort of

1835
01:08:18,789 --> 01:08:17,120
shuffle the best candidates will

1836
01:08:21,510 --> 01:08:18,799
definitely rise and multiple people will

1837
01:08:25,269 --> 01:08:21,520
propose to study the same objects so

1838
01:08:29,590 --> 01:08:26,229

uh

1839
01:08:32,229 --> 01:08:29,600
work that's been done i'm sure there's

1840
01:08:34,390 --> 01:08:32,239
gonna be even more progress made but

1841
01:08:36,550 --> 01:08:34,400
my takeaway from this is that your end

1842
01:08:39,349 --> 01:08:36,560
point in terms of uh saying is their

1843
01:08:41,510 --> 01:08:39,359
life or not basically are uh signatures

1844
01:08:43,269 --> 01:08:41,520
in the atmosphere uh

1845
01:08:44,229 --> 01:08:43,279
biology occurring

1846
01:08:46,070 --> 01:08:44,239
um

1847
01:08:48,870 --> 01:08:46,080
there's nothing really

1848
01:08:49,990 --> 01:08:48,880
more specific than that i mean

1849
01:08:52,070 --> 01:08:50,000
obviously people want is there

1850
01:08:53,669 --> 01:08:52,080
intelligent life out there if you had a

1851
01:08:55,510 --> 01:08:53,679
system that for instance would be able

1852
01:08:56,550 --> 01:08:55,520
to discover incandescent or be able to

1853
01:08:59,110 --> 01:08:56,560
observe

1854
01:09:02,070 --> 01:08:59,120
electricity or incandescent uh

1855
01:09:04,950 --> 01:09:02,080
life or light to me incandescent

1856
01:09:06,390 --> 01:09:04,960
electrical energy that would uh also be

1857
01:09:08,070 --> 01:09:06,400
very exciting but the way i think you've

1858
01:09:09,749 --> 01:09:08,080
presented it is it's basically you're

1859
01:09:11,590 --> 01:09:09,759
looking for biological signatures

1860
01:09:13,510 --> 01:09:11,600
generically is that correct

1861
01:09:15,669 --> 01:09:13,520
yes i want to add that we are looking

1862
01:09:17,110 --> 01:09:15,679
for biological signatures gases that are

1863
01:09:18,470 --> 01:09:17,120

produced by life

1864
01:09:20,470 --> 01:09:18,480
gases that don't belong in the

1865
01:09:22,070 --> 01:09:20,480
atmosphere that like our own our own

1866
01:09:24,550 --> 01:09:22,080
earth we have oxygen which fills our

1867
01:09:26,390 --> 01:09:24,560
atmosphere to 20 by volume but without

1868
01:09:28,630 --> 01:09:26,400
plants and photosynthetic bacteria we

1869
01:09:30,470 --> 01:09:28,640
basically have no oxygen except in some

1870
01:09:32,229 --> 01:09:30,480
unusual circumstances what you're

1871
01:09:33,910 --> 01:09:32,239
talking we often refer to as techno

1872
01:09:36,149 --> 01:09:33,920
signatures signatures that there's you

1873
01:09:38,229 --> 01:09:36,159
know people or creatures on another

1874
01:09:39,990 --> 01:09:38,239
planet that can generate a signal that's

1875
01:09:41,269 --> 01:09:40,000
not naturally occurring

1876
01:09:42,870 --> 01:09:41,279
people have studied that in a lot of

1877
01:09:44,550 --> 01:09:42,880
detail but it's just too hard for our

1878
01:09:47,349 --> 01:09:44,560
first generation space telescopes those

1879
01:09:48,950 --> 01:09:47,359
signatures are super small and very

1880
01:09:51,430 --> 01:09:48,960
narrow and very very weak so we hope

1881
01:09:52,630 --> 01:09:51,440
that someday a much later generation

1882
01:09:54,470 --> 01:09:52,640
will actually be able to see those

1883
01:09:57,110 --> 01:09:54,480
things and follow up on what we have

1884
01:09:59,910 --> 01:09:58,310
thank you

1885
01:10:02,310 --> 01:09:59,920
okay let's go to some questions from

1886
01:10:04,630 --> 01:10:02,320
social media

1887
01:10:07,270 --> 01:10:04,640
sure this one is a popular question here

1888
01:10:09,110 --> 01:10:07,280

it comes from james on twitter who asks

1889
01:10:10,790 --> 01:10:09,120
if and when life out there is discovered

1890
01:10:15,990 --> 01:10:10,800
will the u.s government actually let the

1891
01:10:16,000 --> 01:10:20,790
like a good chief scientist question

1892
01:10:25,110 --> 01:10:22,709
you know of course we would that that

1893
01:10:26,470 --> 01:10:25,120
would be so amazingly exciting and at

1894
01:10:28,310 --> 01:10:26,480
nasa our

1895
01:10:30,149 --> 01:10:28,320
our policy whether it's data coming back

1896
01:10:31,510 --> 01:10:30,159
from mars data coming back from kepler

1897
01:10:33,030 --> 01:10:31,520
we try to get it out to the public as

1898
01:10:38,550 --> 01:10:33,040
soon as we can because we want everybody

1899
01:10:42,630 --> 01:10:41,189
okay our next question here

1900
01:10:44,070 --> 01:10:42,640
comes from

1901
01:10:47,030 --> 01:10:44,080
excuse me our next question here comes

1902
01:10:48,870 --> 01:10:47,040
from um brian on twitter who's asking

1903
01:10:51,910 --> 01:10:48,880
are you looking for intelligent life or

1904
01:10:53,910 --> 01:10:51,920
living single organism bacteria

1905
01:10:56,070 --> 01:10:53,920
well in fact we won't

1906
01:10:58,229 --> 01:10:56,080
we believe that our we don't know what

1907
01:11:00,790 --> 01:10:58,239
will be generating that byproduct gas it

1908
01:11:03,270 --> 01:11:00,800
might be some kind of sophisticated life

1909
01:11:04,550 --> 01:11:03,280
it may just be single-celled bacteria

1910
01:11:06,149 --> 01:11:04,560
and by the way thanks for asking that

1911
01:11:06,950 --> 01:11:06,159
question because we forgot to specify

1912
01:11:08,870 --> 01:11:06,960
here

1913
01:11:10,310 --> 01:11:08,880

um we're not you know

1914
01:11:11,830 --> 01:11:10,320
we're looking for whatever's out there

1915
01:11:13,430 --> 01:11:11,840
that's generating gases that don't

1916
01:11:14,950 --> 01:11:13,440
belong in the atmosphere there's a

1917
01:11:16,229 --> 01:11:14,960
separate approach that we didn't talk

1918
01:11:17,669 --> 01:11:16,239
about today seti search for

1919
01:11:19,110 --> 01:11:17,679
extraterrestrial intelligence and i

1920
01:11:21,110 --> 01:11:19,120
think you can believe that if we find

1921
01:11:23,430 --> 01:11:21,120
any signs of life by these biological

1922
01:11:26,950 --> 01:11:23,440
gases other people with other techniques

1923
01:11:28,149 --> 01:11:26,960
will be following up in any way

1924
01:11:31,030 --> 01:11:28,159
okay we'll take another from social

1925
01:11:32,470 --> 01:11:31,040
media indeed wonderful here um this

1926
01:11:34,550 --> 01:11:32,480
question is regarding the star shade

1927
01:11:36,550 --> 01:11:34,560
here comes from katrina who asks how

1928
01:11:38,870 --> 01:11:36,560
does the star shade move away from its

1929
01:11:40,390 --> 01:11:38,880
telescope and stay in relative position

1930
01:11:43,830 --> 01:11:40,400
i didn't see any thrusters in the

1931
01:11:47,830 --> 01:11:45,510
it's essentially

1932
01:11:49,910 --> 01:11:47,840
think of it as a separate spacecraft

1933
01:11:52,550 --> 01:11:49,920
while it could be launched together it

1934
01:11:54,390 --> 01:11:52,560
has to formation fly it's not as

1935
01:11:55,910 --> 01:11:54,400
challenging as you might think but it's

1936
01:11:57,750 --> 01:11:55,920
going to be out

1937
01:11:59,669 --> 01:11:57,760
thousands tens of thousands potentially

1938
01:12:02,070 --> 01:11:59,679

a hundred thousand kilometers away but

1939
01:12:03,910 --> 01:12:02,080
it has to maintain a relatively

1940
01:12:05,990 --> 01:12:03,920
straightforward stability that's well

1941
01:12:08,310 --> 01:12:06,000
within the the state of the art right

1942
01:12:09,510 --> 01:12:08,320
now for for its guidance navigation and

1943
01:12:11,270 --> 01:12:09,520
control

1944
01:12:12,870 --> 01:12:11,280
right and i forgot to point i forgot to

1945
01:12:15,110 --> 01:12:12,880
say at the end of my presentation that

1946
01:12:17,510 --> 01:12:15,120
the object back there in the corner it's

1947
01:12:19,350 --> 01:12:17,520
a prototype pedal one that was shown in

1948
01:12:20,870 --> 01:12:19,360
one of the pictures and so i guess we

1949
01:12:22,229 --> 01:12:20,880
need an animation in the future that

1950
01:12:23,669 --> 01:12:22,239
shows the spacecraft bus with the

1951
01:12:26,709 --> 01:12:23,679
thrusters and other things that actually

1952
01:12:28,630 --> 01:12:26,719
the starship is attached to

1953
01:12:32,229 --> 01:12:28,640
let's take a few questions in the room

1954
01:12:32,239 --> 01:12:34,870
go ahead

1955
01:12:39,189 --> 01:12:37,110
i can talk okay

1956
01:12:40,709 --> 01:12:39,199
well thank you very much um

1957
01:12:43,590 --> 01:12:40,719
i have a question have you thought about

1958
01:12:46,310 --> 01:12:43,600
using the sun as a gravitational lens or

1959
01:12:51,350 --> 01:12:46,320
using an array of a small telescope

1960
01:12:55,669 --> 01:12:53,350
i mean one of the problems is pointing

1961
01:12:57,110 --> 01:12:55,679
towards the sun is a really bad idea

1962
01:12:58,709 --> 01:12:57,120
we go to an awful lot of trouble to keep

1963
01:13:00,550 --> 01:12:58,719

the hubble away from pointing at the sun

1964
01:13:02,709 --> 01:13:00,560
because the sun is really bright

1965
01:13:04,070 --> 01:13:02,719
so it's a really dangerous undertaking

1966
01:13:05,430 --> 01:13:04,080
you know i mean you'd have to think it

1967
01:13:07,510 --> 01:13:05,440
through though though people have looked

1968
01:13:09,189 --> 01:13:07,520
at this idea the problem with the array

1969
01:13:11,030 --> 01:13:09,199
of telescopes is it gives you the

1970
01:13:12,229 --> 01:13:11,040
angular resolution but it doesn't give

1971
01:13:14,470 --> 01:13:12,239
you the collecting air we're trying to

1972
01:13:16,070 --> 01:13:14,480
solve two problems one

1973
01:13:17,430 --> 01:13:16,080
how do you separate the star from the

1974
01:13:19,830 --> 01:13:17,440
planet that's where an array of

1975
01:13:21,350 --> 01:13:19,840
telescopes can work the other problem is

1976
01:13:23,590 --> 01:13:21,360
how do you take something which is

1977
01:13:26,310 --> 01:13:23,600
fainter than the faintest galaxy in the

1978
01:13:28,070 --> 01:13:26,320
hubble deep field and their

1979
01:13:30,390 --> 01:13:28,080
a distributed ray is no good you don't

1980
01:13:31,350 --> 01:13:30,400
get enough photons so you actually need

1981
01:13:33,350 --> 01:13:31,360
both

1982
01:13:34,870 --> 01:13:33,360
a big telescope and a big collecting

1983
01:13:36,470 --> 01:13:34,880
area so you can actually detect this

1984
01:13:37,990 --> 01:13:36,480
really faint thing next to this really

1985
01:13:40,550 --> 01:13:38,000
bright object i mean it's a very hard

1986
01:13:49,110 --> 01:13:42,310
i think i saw a hand there was another

1987
01:13:53,270 --> 01:13:50,709
um my question is

1988
01:13:55,510 --> 01:13:53,280

uh what words of inspiration can you

1989
01:13:58,070 --> 01:13:55,520
offer future generations that are going

1990
01:14:03,430 --> 01:13:58,080
to lead the journey to find earth earth

1991
01:14:06,630 --> 01:14:04,790
well i think the first thing is if you

1992
01:14:08,229 --> 01:14:06,640
if you look at us up here on

1993
01:14:10,630 --> 01:14:08,239
on the podium

1994
01:14:11,910 --> 01:14:10,640
this is not going to be our telescope

1995
01:14:15,910 --> 01:14:11,920
we're the

1996
01:14:20,390 --> 01:14:18,070
you you you have you haven't known a

1997
01:14:22,229 --> 01:14:20,400
world without the hubble space telescope

1998
01:14:24,070 --> 01:14:22,239
uh the next generation which is going to

1999
01:14:26,229 --> 01:14:24,080
be very exciting and a telescope you may

2000
01:14:28,229 --> 01:14:26,239
use some day and i know sarah will use

2001
01:14:30,229 --> 01:14:28,239
is the james webb space telescope and

2002
01:14:32,550 --> 01:14:30,239
that gets us very close and you know who

2003
01:14:34,709 --> 01:14:32,560
knows maybe we're very lucky but that

2004
01:14:37,510 --> 01:14:34,719
next generation telescope involves

2005
01:14:39,189 --> 01:14:37,520
technology uh it involves you know a lot

2006
01:14:40,630 --> 01:14:39,199
of hard work and the things that we've

2007
01:14:42,149 --> 01:14:40,640
talked about

2008
01:14:43,750 --> 01:14:42,159
and that's something that you can be a

2009
01:14:46,790 --> 01:14:43,760
part of in fact you know maybe the

2010
01:14:49,110 --> 01:14:46,800
critical inventor uh for for the optics

2011
01:14:51,990 --> 01:14:49,120
or the technology the electronics or the

2012
01:14:54,709 --> 01:14:52,000
waveform wavefront sensing control that

2013
01:14:57,510 --> 01:14:54,719

will enable such a rocket or how are we

2014
01:14:59,189 --> 01:14:57,520
gonna package a 20 meter telescope into

2015
01:15:00,870 --> 01:14:59,199
a smaller rocket

2016
01:15:03,110 --> 01:15:00,880
perhaps even

2017
01:15:04,709 --> 01:15:03,120
the astronaut who will assemble it

2018
01:15:05,990 --> 01:15:04,719
in space

2019
01:15:07,910 --> 01:15:06,000
another way of saying that is if you

2020
01:15:09,990 --> 01:15:07,920
want to work on something really hard

2021
01:15:13,030 --> 01:15:10,000
really complicated that would change the

2022
01:15:14,950 --> 01:15:13,040
world this is the project

2023
01:15:16,229 --> 01:15:14,960
before we go to the next question i just

2024
01:15:17,669 --> 01:15:16,239
we have a question up here but before

2025
01:15:20,550 --> 01:15:17,679
that i just want to remind people to be

2026
01:15:22,630 --> 01:15:20,560
following us at hashtag ask nasa and get

2027
01:15:25,030 --> 01:15:22,640
your questions onto there now go ahead

2028
01:15:27,350 --> 01:15:25,040
yeah all these great telescopes have

2029
01:15:28,390 --> 01:15:27,360
international collaborators uh what's

2030
01:15:31,510 --> 01:15:28,400
going on

2031
01:15:33,510 --> 01:15:31,520
uh elsewhere overseas great telescopes

2032
01:15:36,310 --> 01:15:33,520
that that don't have nasa as the lead

2033
01:15:40,550 --> 01:15:36,320
partner or or do they all involve

2034
01:15:43,189 --> 01:15:41,669
well really

2035
01:15:46,470 --> 01:15:43,199
the

2036
01:15:47,669 --> 01:15:46,480
observatories

2037
01:15:49,910 --> 01:15:47,679
compton

2038
01:15:51,510 --> 01:15:49,920

hubble chandra spitzer have been

2039
01:15:53,189 --> 01:15:51,520
international collaborations and the

2040
01:15:54,950 --> 01:15:53,199
james webb space telescope with our

2041
01:15:57,350 --> 01:15:54,960
partners with the european space agency

2042
01:15:59,030 --> 01:15:57,360
and the canadian space agency are

2043
01:16:01,750 --> 01:15:59,040
wonderful examples where the world has

2044
01:16:04,229 --> 01:16:01,760
come together and the us is the leader

2045
01:16:06,709 --> 01:16:04,239
in large space telescopes in space space

2046
01:16:08,149 --> 01:16:06,719
astronomy something we're very proud of

2047
01:16:09,510 --> 01:16:08,159
but we're even more proud that we've

2048
01:16:12,950 --> 01:16:09,520
always done it in partnership and i

2049
01:16:14,390 --> 01:16:12,960
think that is the wave of the future

2050
01:16:16,149 --> 01:16:14,400
before we go to the next question i'm

2051
01:16:17,830 --> 01:16:16,159
gonna i'm gonna insert kind of maybe a

2052
01:16:19,750 --> 01:16:17,840
sticky question that sarah brought up a

2053
01:16:21,430 --> 01:16:19,760
little bit earlier when we look for life

2054
01:16:23,990 --> 01:16:21,440
in our own solar system we're really

2055
01:16:25,990 --> 01:16:24,000
focusing on mars because mars maybe at

2056
01:16:27,910 --> 01:16:26,000
one point was in that habitable zone we

2057
01:16:30,149 --> 01:16:27,920
think mars is the most likely place

2058
01:16:33,030 --> 01:16:30,159
where where life could have developed

2059
01:16:35,030 --> 01:16:33,040
here on in our own solar system

2060
01:16:37,270 --> 01:16:35,040
but also in our solar system we really

2061
01:16:38,950 --> 01:16:37,280
want to go to europa and find out is

2062
01:16:40,149 --> 01:16:38,960
there life under that icy crust on

2063
01:16:42,550 --> 01:16:40,159

europa

2064
01:16:45,030 --> 01:16:42,560
we look at places like enceladus

2065
01:16:46,790 --> 01:16:45,040
like like titan not really in a

2066
01:16:48,390 --> 01:16:46,800
conventional habitable zone and sarah

2067
01:16:49,830 --> 01:16:48,400
you mentioned the fact that habitable

2068
01:16:50,870 --> 01:16:49,840
zones are a little bit hard to get your

2069
01:16:52,790 --> 01:16:50,880
head around

2070
01:16:54,550 --> 01:16:52,800
right well in exoplanets we're only

2071
01:16:56,870 --> 01:16:54,560
focused on what we can see by remote

2072
01:16:58,950 --> 01:16:56,880
sensing and so if there is a europa-like

2073
01:17:01,990 --> 01:16:58,960
world let's say water world where an

2074
01:17:04,470 --> 01:17:02,000
ice-capped planet that has liquid oceans

2075
01:17:05,990 --> 01:17:04,480
underneath we won't see signs of life on

2076
01:17:07,669 --> 01:17:06,000
those but we're not worried about it

2077
01:17:09,590 --> 01:17:07,679
because stars are plentiful and planets

2078
01:17:11,189 --> 01:17:09,600
are plentiful and so we believe that

2079
01:17:12,709 --> 01:17:11,199
they're the right combinations out there

2080
01:17:15,270 --> 01:17:12,719
for us

2081
01:17:17,430 --> 01:17:15,280
and i'll just add that uh we're just on

2082
01:17:19,910 --> 01:17:17,440
the cusp of releasing an announcement of

2083
01:17:22,310 --> 01:17:19,920
opportunity for instruments for a future

2084
01:17:24,470 --> 01:17:22,320
europa mission and so for the listeners

2085
01:17:27,270 --> 01:17:24,480
in the audience and and on the web stay

2086
01:17:28,790 --> 01:17:27,280
tuned uh very soon great

2087
01:17:29,590 --> 01:17:28,800
i think there's a question down here in

2088
01:17:31,750 --> 01:17:29,600

front

2089
01:17:33,830 --> 01:17:31,760
yeah i was just curious um

2090
01:17:35,990 --> 01:17:33,840
all the excitement of people now looking

2091
01:17:38,229 --> 01:17:36,000
for life elsewhere was there a point in

2092
01:17:40,709 --> 01:17:38,239
the scientific community was there a

2093
01:17:42,149 --> 01:17:40,719
discovery that sort of turned people's

2094
01:17:44,709 --> 01:17:42,159
scientists minds to saying you know i

2095
01:17:46,709 --> 01:17:44,719
really do think there's more out there

2096
01:17:48,390 --> 01:17:46,719
we're not alone or did different

2097
01:17:49,830 --> 01:17:48,400
scientists come to it

2098
01:17:52,950 --> 01:17:49,840
through different discoveries or was

2099
01:17:54,390 --> 01:17:52,960
there one you know sort of tipping point

2100
01:17:56,229 --> 01:17:54,400
well i'd like to say there was one

2101
01:17:57,990 --> 01:17:56,239
tipping point if i may we talked a bit

2102
01:17:59,669 --> 01:17:58,000
about transiting planets when planets go

2103
01:18:01,510 --> 01:17:59,679
in front of the stars seen

2104
01:18:03,350 --> 01:18:01,520
from the telescope well a number of

2105
01:18:05,830 --> 01:18:03,360
planets had been discovered maybe 30 or

2106
01:18:08,070 --> 01:18:05,840
40 by a different technique called the

2107
01:18:09,750 --> 01:18:08,080
wobble method it's not so relevant and

2108
01:18:11,430 --> 01:18:09,760
we started to understand as a community

2109
01:18:13,510 --> 01:18:11,440
that planets could be quite plentiful

2110
01:18:14,630 --> 01:18:13,520
and in all sorts of crazy orbits but

2111
01:18:15,830 --> 01:18:14,640
there were many people because in

2112
01:18:17,990 --> 01:18:15,840
science we're supposed to give each

2113
01:18:19,510 --> 01:18:18,000

other a hard time it's our job to when

2114
01:18:21,270 --> 01:18:19,520
there's a discovery push back and make

2115
01:18:22,870 --> 01:18:21,280
sure it's real and there's a large part

2116
01:18:24,470 --> 01:18:22,880
of the community probably most of them

2117
01:18:25,910 --> 01:18:24,480
who believe that the planets weren't

2118
01:18:27,510 --> 01:18:25,920
planets it was some effect of the star

2119
01:18:29,030 --> 01:18:27,520
and so i believe a defining moment was

2120
01:18:31,510 --> 01:18:29,040
when two independent planet binding

2121
01:18:33,350 --> 01:18:31,520
techniques saw the same planet it was

2122
01:18:35,590 --> 01:18:33,360
basically incontrovertible that yes

2123
01:18:37,830 --> 01:18:35,600
planets exist around other stars other

2124
01:18:40,149 --> 01:18:37,840
than the sun yes planets are in unusual

2125
01:18:41,990 --> 01:18:40,159
orbits and wow we could find something

2126
01:18:44,070 --> 01:18:42,000
so challenging the

2127
01:18:45,830 --> 01:18:44,080
universe is now open for us i think

2128
01:18:47,750 --> 01:18:45,840
there are two points

2129
01:18:50,229 --> 01:18:47,760
one and sarah was actually responsible

2130
01:18:51,990 --> 01:18:50,239
for this one was we've realized that

2131
01:18:53,430 --> 01:18:52,000
planets did transit but then we also

2132
01:18:54,950 --> 01:18:53,440
realized from space and this is

2133
01:18:57,030 --> 01:18:54,960
something we never anticipated first

2134
01:18:58,790 --> 01:18:57,040
with the hubble and then with spitzer

2135
01:19:01,750 --> 01:18:58,800
was that we could actually measure the

2136
01:19:02,950 --> 01:19:01,760
gaseous constituents of exoplanets big

2137
01:19:05,350 --> 01:19:02,960
jupiters but we actually could see

2138
01:19:06,950 --> 01:19:05,360

methane and oxygen and sulfur

2139
01:19:08,470 --> 01:19:06,960
couldn't see that before and the second

2140
01:19:10,950 --> 01:19:08,480
breakthrough was the realization with

2141
01:19:13,350 --> 01:19:10,960
kepler that there are

2142
01:19:14,790 --> 01:19:13,360
100 billion planets out there i mean as

2143
01:19:16,870 --> 01:19:14,800
i said five years ago we couldn't have

2144
01:19:18,550 --> 01:19:16,880
said that and so that's these tipping

2145
01:19:20,630 --> 01:19:18,560
points that nasa has enabled with the

2146
01:19:22,550 --> 01:19:20,640
hubble spitzer and then kepler it's

2147
01:19:24,310 --> 01:19:22,560
revolutionized the way we think about

2148
01:19:25,669 --> 01:19:24,320
exoplanets we all came into this

2149
01:19:27,669 --> 01:19:25,679
believing planets but that we had no

2150
01:19:29,350 --> 01:19:27,679
evidence today

2151
01:19:31,350 --> 01:19:29,360
we now know every time you look up in

2152
01:19:32,790 --> 01:19:31,360
the night sky you're looking at a planet

2153
01:19:34,790 --> 01:19:32,800
when you look at a star we didn't know

2154
01:19:36,149 --> 01:19:34,800
that before the world has changed and

2155
01:19:38,390 --> 01:19:36,159
i'd like to add one more point this is

2156
01:19:40,950 --> 01:19:38,400
sort of on the inspiration category and

2157
01:19:42,149 --> 01:19:40,960
that is countless people myself included

2158
01:19:43,910 --> 01:19:42,159
you know we're constantly told this will

2159
01:19:45,510 --> 01:19:43,920
never happen what you know you or the

2160
01:19:46,950 --> 01:19:45,520
community could never do this and this

2161
01:19:48,709 --> 01:19:46,960
has happened over and over again in the

2162
01:19:50,709 --> 01:19:48,719
field and the engineers

2163
01:19:52,630 --> 01:19:50,719

at nasa and other places the scientists

2164
01:19:53,990 --> 01:19:52,640
the instrument workers have pushed all

2165
01:19:56,149 --> 01:19:54,000
the instruments beyond what they thought

2166
01:19:57,750 --> 01:19:56,159
were capable of or built new ones and so

2167
01:19:59,430 --> 01:19:57,760
the story happens over and over again

2168
01:20:00,950 --> 01:19:59,440
that not only are the planets out there

2169
01:20:03,030 --> 01:20:00,960
but you know if we work hard enough we

2170
01:20:05,270 --> 01:20:03,040
can push our technology that exists a

2171
01:20:07,350 --> 01:20:05,280
new technology to do even more precise

2172
01:20:10,149 --> 01:20:07,360
discoveries more precise measurements

2173
01:20:11,510 --> 01:20:10,159
for new discoveries

2174
01:20:14,070 --> 01:20:11,520
jim green

2175
01:20:16,229 --> 01:20:14,080
okay uh you know planetary scientists uh

2176
01:20:18,310 --> 01:20:16,239
have been working on this on trying to

2177
01:20:20,550 --> 01:20:18,320
understand the origin and evolution of

2178
01:20:23,110 --> 01:20:20,560
our own solar system and they recognize

2179
01:20:24,790 --> 01:20:23,120
that jupiter plays a unique role it's

2180
01:20:28,229 --> 01:20:24,800
really run black

2181
01:20:30,550 --> 01:20:28,239
and so looking for exoplanets where life

2182
01:20:32,790 --> 01:20:30,560
may have existed requires time for that

2183
01:20:35,270 --> 01:20:32,800
life to be there and it may require

2184
01:20:37,750 --> 01:20:35,280
large planets like jupiter more complex

2185
01:20:39,990 --> 01:20:37,760
solar systems have to be brought into

2186
01:20:41,750 --> 01:20:40,000
the understanding of

2187
01:20:43,110 --> 01:20:41,760
where we might actually find life and i

2188
01:20:44,790 --> 01:20:43,120

was wondering what your thoughts on that

2189
01:20:46,310 --> 01:20:44,800
were

2190
01:20:47,990 --> 01:20:46,320
i'll start by saying you know so there

2191
01:20:50,070 --> 01:20:48,000
are kind of two camps and exoplanets you

2192
01:20:51,669 --> 01:20:50,080
have one represented here we just want

2193
01:20:54,390 --> 01:20:51,679
to go for the gold find the planet see

2194
01:20:55,990 --> 01:20:54,400
the unusual signs and you know thumbs up

2195
01:20:57,430 --> 01:20:56,000
and then the other camp which your

2196
01:20:59,270 --> 01:20:57,440
question represents is we need to have a

2197
01:21:01,350 --> 01:20:59,280
comprehensive understanding of the

2198
01:21:02,550 --> 01:21:01,360
entire planetary system and see the

2199
01:21:04,470 --> 01:21:02,560
equivalent of you know those

2200
01:21:05,510 --> 01:21:04,480
exoskeletons see the asteroid belts the

2201
01:21:07,189 --> 01:21:05,520
planets

2202
01:21:08,390 --> 01:21:07,199
all the ones there understand if water

2203
01:21:10,070 --> 01:21:08,400
got delivered

2204
01:21:12,790 --> 01:21:10,080
and so in the ideal world we want that

2205
01:21:14,390 --> 01:21:12,800
one that's a much harder problem as as

2206
01:21:15,830 --> 01:21:14,400
crazy as it might sound to get that

2207
01:21:17,750 --> 01:21:15,840
comprehensive approach because one would

2208
01:21:20,229 --> 01:21:17,760
have to see all those planets and the

2209
01:21:22,070 --> 01:21:20,239
asteroid belts etc etc or the effects of

2210
01:21:23,510 --> 01:21:22,080
those so we really hope to do that and

2211
01:21:25,430 --> 01:21:23,520
we hope that in our search for earth

2212
01:21:27,990 --> 01:21:25,440
because earth is so hard to find we'll

2213
01:21:29,270 --> 01:21:28,000

also be able to study planetary systems

2214
01:21:30,870 --> 01:21:29,280
and that will help answer all those

2215
01:21:32,870 --> 01:21:30,880
questions as well we just didn't focus

2216
01:21:34,629 --> 01:21:32,880
it on it here

2217
01:21:36,229 --> 01:21:34,639
we've only got time for a few more

2218
01:21:37,750 --> 01:21:36,239
questions so i want to take at least one

2219
01:21:38,950 --> 01:21:37,760
from social media and at least one from

2220
01:21:40,310 --> 01:21:38,960
here in the room and we've got somebody

2221
01:21:41,830 --> 01:21:40,320
waiting here in the room

2222
01:21:43,990 --> 01:21:41,840
mark kaufman with washington post and

2223
01:21:46,470 --> 01:21:44,000
national geographic um

2224
01:21:47,270 --> 01:21:46,480
be interested in your thoughts about

2225
01:21:48,149 --> 01:21:47,280
uh

2226
01:21:50,950 --> 01:21:48,159
how

2227
01:21:52,470 --> 01:21:50,960
the search for life on mars or in the

2228
01:21:53,510 --> 01:21:52,480
solar system

2229
01:21:55,510 --> 01:21:53,520
uh

2230
01:21:57,990 --> 01:21:55,520
correlates with the search for life

2231
01:22:00,870 --> 01:21:58,000
beyond i mean are there ways in which

2232
01:22:03,750 --> 01:22:00,880
uh they will inform each other and

2233
01:22:06,310 --> 01:22:03,760
similarly or or taking a step further if

2234
01:22:09,669 --> 01:22:06,320
there is something that is found on mars

2235
01:22:12,070 --> 01:22:09,679
or io or wherever uh europa that that

2236
01:22:16,470 --> 01:22:12,080
appears to be life what does that mean

2237
01:22:18,950 --> 01:22:16,480
for the search for life on exoplanets

2238
01:22:20,790 --> 01:22:18,960

well there's you know ellen could answer

2239
01:22:22,310 --> 01:22:20,800
this i could answer it and you know the

2240
01:22:25,030 --> 01:22:22,320
big pictures we don't know i mean we

2241
01:22:27,270 --> 01:22:25,040
only know about like on earth

2242
01:22:29,669 --> 01:22:27,280
this field of astrobiology that

2243
01:22:32,149 --> 01:22:29,679
is part of nasa as well and a worldwide

2244
01:22:34,149 --> 01:22:32,159
endeavor looks at life in extreme

2245
01:22:36,229 --> 01:22:34,159
environments and has seen life in very

2246
01:22:38,470 --> 01:22:36,239
hostile places that

2247
01:22:40,790 --> 01:22:38,480
would indicate that perhaps life could

2248
01:22:42,229 --> 01:22:40,800
have gotten a foothold on mars or could

2249
01:22:44,709 --> 01:22:42,239
be living under

2250
01:22:47,189 --> 01:22:44,719
the icy crust of europa in a warm salty

2251
01:22:49,110 --> 01:22:47,199
ocean you know these are very exciting

2252
01:22:51,030 --> 01:22:49,120
opportunities for us to go investigate

2253
01:22:53,030 --> 01:22:51,040
but at the present time we only know

2254
01:22:55,270 --> 01:22:53,040
about life on earth if we find life in

2255
01:22:57,669 --> 01:22:55,280
our own solar system it depends on what

2256
01:22:59,750 --> 01:22:57,679
we find if we find life that's dna based

2257
01:23:02,229 --> 01:22:59,760
and looks a lot like the extremophiles

2258
01:23:04,229 --> 01:23:02,239
here on earth or life as we know it

2259
01:23:05,750 --> 01:23:04,239
was there a common origin because we do

2260
01:23:07,510 --> 01:23:05,760
exchange materials with the other

2261
01:23:09,110 --> 01:23:07,520
planets on a routine basis it goes back

2262
01:23:11,110 --> 01:23:09,120
to jim green's statement you know we

2263
01:23:13,910 --> 01:23:11,120

have mars meteorites on earth they're

2264
01:23:16,070 --> 01:23:13,920
probably earth meteorites on mars

2265
01:23:18,310 --> 01:23:16,080
so then the question is you know okay

2266
01:23:20,950 --> 01:23:18,320
there's if we find life on any of these

2267
01:23:22,390 --> 01:23:20,960
other planetary bodies what about other

2268
01:23:24,550 --> 01:23:22,400
solar systems and that's really what

2269
01:23:26,229 --> 01:23:24,560
we're addressing here you know

2270
01:23:28,790 --> 01:23:26,239
i think so charlie bolden's statement

2271
01:23:31,110 --> 01:23:28,800
about enrico fermi's paradox

2272
01:23:33,189 --> 01:23:31,120
you know if life is pervasive in in the

2273
01:23:35,270 --> 01:23:33,199
galaxy where is everybody and let's just

2274
01:23:37,110 --> 01:23:35,280
follow up on that because the current

2275
01:23:39,590 --> 01:23:37,120
the answer to the contradiction is this

2276
01:23:41,750 --> 01:23:39,600
the big filter maybe they're not here

2277
01:23:43,189 --> 01:23:41,760
because life is extraordinarily rare or

2278
01:23:45,189 --> 01:23:43,199
they're not here because life didn't

2279
01:23:48,229 --> 01:23:45,199
survive very long

2280
01:23:50,229 --> 01:23:48,239
so if life is very common maybe we don't

2281
01:23:52,229 --> 01:23:50,239
get to survive very long so i personally

2282
01:23:54,229 --> 01:23:52,239
hope we don't find life too prevalent in

2283
01:23:56,470 --> 01:23:54,239
our own solar system

2284
01:23:57,990 --> 01:23:56,480
to answer the fermi brooks i think what

2285
01:24:00,310 --> 01:23:58,000
the excitement that you're seeing today

2286
01:24:02,070 --> 01:24:00,320
is we we know in our own solar system we

2287
01:24:04,149 --> 01:24:02,080
know where to go we know what to measure

2288
01:24:05,350 --> 01:24:04,159

and we're we're in the process of doing

2289
01:24:07,910 --> 01:24:05,360
just that

2290
01:24:09,430 --> 01:24:07,920
looking out beyond our solar system

2291
01:24:10,870 --> 01:24:09,440
we're on the right track we're making

2292
01:24:13,270 --> 01:24:10,880
the right measurements and we're just on

2293
01:24:15,189 --> 01:24:13,280
the cusp of learning so much it's an

2294
01:24:16,870 --> 01:24:15,199
incredibly exciting time

2295
01:24:19,030 --> 01:24:16,880
i just want to add there's also a

2296
01:24:20,390 --> 01:24:19,040
potential merging which we're just

2297
01:24:22,950 --> 01:24:20,400
starting to see

2298
01:24:25,430 --> 01:24:22,960
we're calling it comparative planetology

2299
01:24:28,070 --> 01:24:25,440
or exoplanet planetology to back to

2300
01:24:30,390 --> 01:24:28,080
jim's question where you start to see

2301
01:24:32,229 --> 01:24:30,400
the science the experts in both those

2302
01:24:34,390 --> 01:24:32,239
fields start to realize their their

2303
01:24:36,709 --> 01:24:34,400
worlds are coming together and so we're

2304
01:24:39,590 --> 01:24:36,719
we're already setting up a lot of

2305
01:24:40,950 --> 01:24:39,600
interchanges between those two camps

2306
01:24:42,629 --> 01:24:40,960
we're going to take one quick question

2307
01:24:43,830 --> 01:24:42,639
from social media

2308
01:24:45,830 --> 01:24:43,840
sure this question has been asked in a

2309
01:24:48,629 --> 01:24:45,840
couple of variety of forms here but um

2310
01:24:50,629 --> 01:24:48,639
geosporatech asks how can startups and

2311
01:24:55,830 --> 01:24:50,639
backyard scientists help in the search

2312
01:24:59,590 --> 01:24:57,350
you know citizen science is something

2313
01:25:01,510 --> 01:24:59,600

we're extremely excited about at nasa

2314
01:25:03,590 --> 01:25:01,520
the more people we get involved the more

2315
01:25:05,110 --> 01:25:03,600
we can bring the public with us on this

2316
01:25:07,110 --> 01:25:05,120
amazing adventure that we're on the

2317
01:25:08,229 --> 01:25:07,120
better and we have a lot of efforts um

2318
01:25:09,750 --> 01:25:08,239
throughout

2319
01:25:11,510 --> 01:25:09,760
the science division really trying to

2320
01:25:13,189 --> 01:25:11,520
get the public involved

2321
01:25:14,870 --> 01:25:13,199
i'd like to add that i've started to get

2322
01:25:16,709 --> 01:25:14,880
asked that question pretty much at every

2323
01:25:18,149 --> 01:25:16,719
single event and i want to just speak

2324
01:25:19,510 --> 01:25:18,159
perhaps on behalf of everyone here but

2325
01:25:21,270 --> 01:25:19,520
certainly on behalf of a large part of

2326
01:25:22,790 --> 01:25:21,280
the community that we're community that

2327
01:25:24,870 --> 01:25:22,800
we are working on a better answer for

2328
01:25:26,870 --> 01:25:24,880
you because we're finding untold numbers

2329
01:25:29,030 --> 01:25:26,880
of people who are extremely tech savvy

2330
01:25:31,189 --> 01:25:29,040
who want to do more than just um

2331
01:25:33,750 --> 01:25:31,199
crowdsourcing and some of these people

2332
01:25:35,110 --> 01:25:33,760
even actually worked in engineering and

2333
01:25:36,709 --> 01:25:35,120
you know and got a degree and and

2334
01:25:38,790 --> 01:25:36,719
decided just to go into industry so

2335
01:25:40,950 --> 01:25:38,800
we're we're working on this

2336
01:25:43,110 --> 01:25:40,960
and one example is that anybody can go

2337
01:25:45,910 --> 01:25:43,120
on the web and look for planets in

2338
01:25:48,790 --> 01:25:45,920

kepler data and their citizen science

2339
01:25:50,709 --> 01:25:48,800
tools to do that

2340
01:25:52,070 --> 01:25:50,719
all right thank you all so much for

2341
01:25:53,350 --> 01:25:52,080
coming today this has been really

2342
01:26:04,229 --> 01:25:53,360
exciting let's have another round of

2343
01:26:08,229 --> 01:26:05,830
we didn't have time to answer all the

2344
01:26:09,990 --> 01:26:08,239
questions today but i want you to keep

2345
01:26:12,070 --> 01:26:10,000
checking we're going to try to answer

2346
01:26:14,229 --> 01:26:12,080
them on social media so keep using that

2347
01:26:15,590 --> 01:26:14,239
hashtag ask nasa and get us the

2348
01:26:18,310 --> 01:26:15,600
questions and we'll try to get you the

2349
01:26:21,350 --> 01:26:18,320
answers you'll also be able to view this

2350
01:26:23,590 --> 01:26:21,360
entire program on nasa

2351
01:26:26,229 --> 01:26:23,600
you can go to our website at nasa.gov to

2352
01:26:28,229 --> 01:26:26,239
our youtube channel and watch it again

2353
01:26:30,310 --> 01:26:28,239
and please stay connected with nasa as

2354
01:26:33,510 --> 01:26:30,320
we take this great journey into the

2355
01:26:35,510 --> 01:26:33,520
future uh a journey that we think is

2356
01:26:37,750 --> 01:26:35,520
really on the cusp of being able to