Episode 2: Some Like it Hot

July 2018

@NASAKennedy
#NASARocketRanch

New episodes every month!

1
00:00:00,033 --> 00:00:01,301
>> Everything is driven by

2
00:00:01,301 --> 00:00:02,202
the Sun.

3
00:00:02,202 --> 00:00:03,002
It's like the missing piece

4
00:00:03,002 --> 00:00:03,937
of the puzzle.

5
00:00:03,937 --> 00:00:05,438
We don't know, truly,

6
00:00:05,438 --> 00:00:06,740
what physics is going on

7
00:00:06,740 --> 00:00:08,141
in that region because

8
00:00:08,141 --> 00:00:09,376
we've never been there.

9
00:00:12,045 --> 00:00:13,880
>> EGS Program Chief Engineer,

10
00:00:13,880 --> 00:00:15,315
verify no constraints

11
00:00:15,315 --> 00:00:16,282
to launch.

12
00:00:16,282 --> 00:00:17,317
>> EGS Chief Engineer team

13
00:00:17,317 --> 00:00:18,718

has no constraints.

14
00:00:18,718 --> 00:00:19,652
>> I copy that.

15
00:00:19,652 --> 00:00:21,421
You are clear to launch.

16
00:00:21,421 --> 00:00:24,858
>> Five, four, three,

17
00:00:24,858 --> 00:00:28,962
two, one, and lift-off.

18
00:00:28,962 --> 00:00:31,097
>> All clear.

19
00:00:31,097 --> 00:00:32,198
Now passing through max Q,

20
00:00:32,198 --> 00:00:34,000
maximum dynamic pressure.

21
00:00:34,000 --> 00:00:36,202
>> Welcome to space.

22
00:00:36,202 --> 00:00:37,704
>> Welcome to the Rocket Ranch.

23
00:00:37,704 --> 00:00:39,372
I'm Joshua Santora.

24
00:00:39,372 --> 00:00:40,240
Even though our sun shines

25
00:00:40,240 --> 00:00:41,608
bright in the sky, it is

26
00:00:41,608 --> 00:00:43,276
shrouded in mystery.

27
00:00:43,276 --> 00:00:44,310
In this episode, we'll sit down

28
00:00:44,310 --> 00:00:45,512
with scientists working

29
00:00:45,512 --> 00:00:46,846
to get us closer to the Sun

30
00:00:46,846 --> 00:00:48,081
than ever before.

31
00:00:48,081 --> 00:00:49,015
First up, we talk with

32
00:00:49,015 --> 00:00:49,983
a project scientist

33
00:00:49,983 --> 00:00:51,251
on the Parker Solar Probe

34
00:00:51,251 --> 00:00:52,318
mission that will be launching

35
00:00:52,318 --> 00:00:53,720
soon, attempting to fly

36
00:00:53,720 --> 00:00:55,321
inside the Sun's atmosphere

37
00:00:55,321 --> 00:00:55,989
in order to unlock

38
00:00:55,989 --> 00:00:57,223

its many secrets.

39
00:00:57,223 --> 00:00:58,391
>> Um, the big mystery

40
00:00:58,391 --> 00:00:59,426
we're trying to solve is

41
00:00:59,426 --> 00:01:01,294
why is that corona so hot?

42
00:01:01,294 --> 00:01:02,162
>> Next, we talk with

43
00:01:02,162 --> 00:01:03,329
a researcher working on

44
00:01:03,329 --> 00:01:04,464
a cryogenic coating that

45
00:01:04,464 --> 00:01:06,533
could get us even closer.

46
00:01:06,533 --> 00:01:07,333
But his goal is not

47
00:01:07,333 --> 00:01:08,301
to go to the Sun--

48
00:01:08,301 --> 00:01:09,436
it's to store up rocket fuel

49
00:01:09,436 --> 00:01:10,503
in space while keeping it

50
00:01:10,503 --> 00:01:11,604
from boiling off--

51
00:01:11,604 --> 00:01:12,739
a critical breakthrough needed

52
00:01:12,739 --> 00:01:13,673
to help us explore

53
00:01:13,673 --> 00:01:15,108
farther into space.

54
00:01:15,108 --> 00:01:16,576
>> Liquid hydrogen-- hydrogen

55
00:01:16,576 --> 00:01:18,211
has to be down to 20 Kelvin.

56
00:01:18,211 --> 00:01:19,245
I mean, you're talking getting--

57
00:01:19,245 --> 00:01:19,979
you're getting close to

58
00:01:19,979 --> 00:01:20,947
absolute zero when you talk

59
00:01:20,947 --> 00:01:22,682
liquid hydrogen.

60
00:01:25,819 --> 00:01:26,986
>> NASA's Parker Solar Probe

61
00:01:26,986 --> 00:01:27,887
will be the first ever mission

62
00:01:27,887 --> 00:01:29,155
to travel directly into

63
00:01:29,155 --> 00:01:30,523

the Sun's atmosphere,

64
00:01:30,523 --> 00:01:31,491
about 4 million miles

65
00:01:31,491 --> 00:01:33,393
from our star's surface.

66
00:01:33,393 --> 00:01:34,260
With me in the booth today

67
00:01:34,260 --> 00:01:35,728
is Dr. Nicky Fox.

68
00:01:35,728 --> 00:01:36,863
She's from the Johns Hopkins

69
00:01:36,863 --> 00:01:37,997
University Applied Physics

70
00:01:37,997 --> 00:01:39,566
Laboratory, and is also

71
00:01:39,566 --> 00:01:40,900
the project scientist for

72
00:01:40,900 --> 00:01:43,303
the Parker Solar Probe mission.

73
00:01:43,303 --> 00:01:45,071
Dr. Fox, we are celebrating

74
00:01:45,071 --> 00:01:48,308
60 years of NASA this month.

75
00:01:48,308 --> 00:01:50,043
And I understand that

76
00:01:50,043 --> 00:01:52,412
this mission is older than NASA?

77
00:01:52,412 --> 00:01:54,113
>> Yes, that's right.

78
00:01:54,113 --> 00:01:56,349
So Parker Solar Probe was

79
00:01:56,349 --> 00:01:57,684
first thought of and

80
00:01:57,684 --> 00:01:59,986
first proposed in 1958,

81
00:01:59,986 --> 00:02:01,154
so it's also going to turn

82
00:02:01,154 --> 00:02:02,722
60 years as well as NASA

83
00:02:02,722 --> 00:02:03,890
this year.

84
00:02:03,890 --> 00:02:05,525
Um, but when the agencies

85
00:02:05,525 --> 00:02:06,759
were forming-- so NASA,

86
00:02:06,759 --> 00:02:08,127
the National Science Foundation,

87
00:02:08,127 --> 00:02:09,395
and really, the Department

88
00:02:09,395 --> 00:02:10,964

of Defense-- and you know,

89
00:02:10,964 --> 00:02:11,998
what do we wanna do with

90
00:02:11,998 --> 00:02:12,966
this newfound thing

91
00:02:12,966 --> 00:02:14,200
called space?

92
00:02:14,200 --> 00:02:15,635
Um, what do we need a big

93
00:02:15,635 --> 00:02:17,504
agency for that, you know,

94
00:02:17,504 --> 00:02:19,272
these big, grand missions

95
00:02:19,272 --> 00:02:20,840
that-that we really, just

96
00:02:20,840 --> 00:02:22,408
really want to do?

97
00:02:22,408 --> 00:02:23,643
And so, uh, they pulled together

98
00:02:23,643 --> 00:02:24,978
a committee.

99
00:02:24,978 --> 00:02:25,612
It was chaired by

100
00:02:25,612 --> 00:02:26,713
John Simpson, co-chaired by

101
00:02:26,713 --> 00:02:28,214
James Van Allen.

102
00:02:28,214 --> 00:02:29,849
Um, and they had a panel

103
00:02:29,849 --> 00:02:31,251
of experts, and they came up

104
00:02:31,251 --> 00:02:32,785
with these missions that

105
00:02:32,785 --> 00:02:34,821
were just big and shiny,

106
00:02:34,821 --> 00:02:35,922
and that's what everybody

107
00:02:35,922 --> 00:02:36,956
wanted to do.

108
00:02:36,956 --> 00:02:38,324
One of those missions was

109
00:02:38,324 --> 00:02:40,460
a spacecraft to go into

110
00:02:40,460 --> 00:02:42,529
the Sun's corona.

111
00:02:42,529 --> 00:02:44,163
So that's where-- solar probe.

112
00:02:44,163 --> 00:02:46,132
They wanted one to probe

113
00:02:46,132 --> 00:02:47,300

the Sun's corona.

114
00:02:47,300 --> 00:02:48,234
And it was, you know,

115
00:02:48,234 --> 00:02:50,036
high priority for all this time,

116
00:02:50,036 --> 00:02:52,572
um, in the decadal surveys,

117
00:02:52,572 --> 00:02:54,007
in the NASA roadmaps.

118
00:02:54,007 --> 00:02:57,176
A solar probe has been there

119
00:02:57,176 --> 00:02:58,077
since then.

120
00:02:58,077 --> 00:02:59,479
Um, other countries, other

121
00:02:59,479 --> 00:03:01,247
agencies have tried to do it.

122
00:03:01,247 --> 00:03:03,316
But it's really taken 60 years

123
00:03:03,316 --> 00:03:04,851
for technology to catch up

124
00:03:04,851 --> 00:03:05,952
with our dreams.

125
00:03:05,952 --> 00:03:07,153
And we're now sitting

126
00:03:07,153 --> 00:03:08,321
on the verge of

127
00:03:08,321 --> 00:03:09,722
making this come true.

128
00:03:09,722 --> 00:03:11,758
And so it does predate NASA.

129
00:03:11,758 --> 00:03:12,926
And I wouldn't say that

130
00:03:12,926 --> 00:03:14,127
we are competitive, but

131
00:03:14,127 --> 00:03:15,328
we are faster, hotter,

132
00:03:15,328 --> 00:03:16,496
and closer than anything has

133
00:03:16,496 --> 00:03:18,031
ever been before.

134
00:03:18,031 --> 00:03:19,599
In fact, I always like to

135
00:03:19,599 --> 00:03:21,067
call this-- call the mission,

136
00:03:21,067 --> 00:03:22,602
"the coolest, hottest mission

137
00:03:22,602 --> 00:03:24,203
"under the sun."

138
00:03:24,203 --> 00:03:24,904

>> And so you talk about

139
00:03:24,904 --> 00:03:26,105
technology catching up,

140
00:03:26,105 --> 00:03:27,307
and I'm assuming

141
00:03:27,307 --> 00:03:28,641
that has to do with the heat

142
00:03:28,641 --> 00:03:30,076
involved, because we've been

143
00:03:30,076 --> 00:03:31,311
sending things out into space

144
00:03:31,311 --> 00:03:32,812
for decades now.

145
00:03:32,812 --> 00:03:34,514
So i-is that the challenge,

146
00:03:34,514 --> 00:03:35,348
the technology of getting

147
00:03:35,348 --> 00:03:36,115
close to the Sun?

148
00:03:36,115 --> 00:03:37,383
And how hot are we talking?

149
00:03:37,383 --> 00:03:38,217
>> There are many different

150
00:03:38,217 --> 00:03:39,285
challenges with

151
00:03:39,285 --> 00:03:40,186
Parker Solar Probe.

152
00:03:40,186 --> 00:03:41,754
It isn't just the heat.

153
00:03:41,754 --> 00:03:42,455
And we can talk about

154
00:03:42,455 --> 00:03:43,790
the heat, obviously.

155
00:03:43,790 --> 00:03:44,591
We're going to

156
00:03:44,591 --> 00:03:46,593
3 million-degree plasma.

157
00:03:46,593 --> 00:03:48,127
Um, the big mystery

158
00:03:48,127 --> 00:03:49,195
we're trying to solve is

159
00:03:49,195 --> 00:03:51,197
why is that corona so hot?

160
00:03:51,197 --> 00:03:52,198
The surface of the Sun is

161
00:03:52,198 --> 00:03:53,967
about 6,000 degrees Centigrade,

162
00:03:53,967 --> 00:03:55,568
10,000 degrees Fahrenheit.

163
00:03:55,568 --> 00:03:57,036

And now we're talking about

164
00:03:57,036 --> 00:03:58,972
plasma that's 3 million degrees?

165
00:03:58,972 --> 00:04:00,873
You walk away from a campfire,

166
00:04:00,873 --> 00:04:02,208
you don't suddenly get hotter.

167
00:04:02,208 --> 00:04:03,843
You get colder.

168
00:04:03,843 --> 00:04:05,712
And so why is this bizarre

169
00:04:05,712 --> 00:04:06,613
thing happening?

170
00:04:06,613 --> 00:04:07,480
And the only way we can

171
00:04:07,480 --> 00:04:08,381
answer that question is

172
00:04:08,381 --> 00:04:09,782
to travel into this region

173
00:04:09,782 --> 00:04:10,850
where this plasma,

174
00:04:10,850 --> 00:04:12,452
this coronal material is

175
00:04:12,452 --> 00:04:13,720
3 million degrees.

176
00:04:13,720 --> 00:04:15,288
And so obviously, we have to

177
00:04:15,288 --> 00:04:16,789
have materials that are

178
00:04:16,789 --> 00:04:17,790
specially developed.

179
00:04:17,790 --> 00:04:19,459
Um, they can't melt.

180
00:04:19,459 --> 00:04:20,526
Uh, also, they can't

181
00:04:20,526 --> 00:04:21,861
change their properties.

182
00:04:21,861 --> 00:04:23,630
And so we have this very highly

183
00:04:23,630 --> 00:04:25,231
elliptical orbit.

184
00:04:25,231 --> 00:04:25,965
It looks like a petal

185
00:04:25,965 --> 00:04:26,866
of a flower.

186
00:04:26,866 --> 00:04:28,201
We go very close to the Sun

187
00:04:28,201 --> 00:04:29,302
on one side, and then

188
00:04:29,302 --> 00:04:30,837

we come out around the orbit

189
00:04:30,837 --> 00:04:32,872
of Venus on the other side.

190
00:04:32,872 --> 00:04:34,474
And so we're going super hot

191
00:04:34,474 --> 00:04:36,042
and then very cold.

192
00:04:36,042 --> 00:04:37,010
And if you think of taking

193
00:04:37,010 --> 00:04:38,845
any material that you know,

194
00:04:38,845 --> 00:04:39,812
and you heat it, and cool it,

195
00:04:39,812 --> 00:04:41,247
and heat it, and cool it--

196
00:04:41,247 --> 00:04:42,081
>> This is-- usually

197
00:04:42,081 --> 00:04:42,949
doesn't end well.

198
00:04:42,949 --> 00:04:43,616
>> It's either gonna become

199
00:04:43,616 --> 00:04:44,884
elastic, it's gonna become

200
00:04:44,884 --> 00:04:45,852
brittle-- whatever.

201
00:04:45,852 --> 00:04:46,486
It's going to change

202
00:04:46,486 --> 00:04:47,253
its properties.

203
00:04:47,253 --> 00:04:48,988
And so these materials have to

204
00:04:48,988 --> 00:04:50,089
withstand these incredible

205
00:04:50,089 --> 00:04:52,058
changes in heat.

206
00:04:52,058 --> 00:04:54,727
But also, it's miniaturization.

207
00:04:54,727 --> 00:04:55,428
It's getting technology

208
00:04:55,428 --> 00:04:56,562
into small packages.

209
00:04:56,562 --> 00:04:57,930
Um, we are traveling at

210
00:04:57,930 --> 00:05:00,233
430,000 miles an hour,

211
00:05:00,233 --> 00:05:02,735
or 118 miles a second, um,

212
00:05:02,735 --> 00:05:04,103
and we have to keep our heat

213
00:05:04,103 --> 00:05:06,239

shield between us and the Sun.

214
00:05:06,239 --> 00:05:07,340
And so the spacecraft

215
00:05:07,340 --> 00:05:08,274
is incredibly,

216
00:05:08,274 --> 00:05:09,742
incredibly independent.

217
00:05:09,742 --> 00:05:10,677
She's a plucky little

218
00:05:10,677 --> 00:05:12,011
spacecraft, going out there

219
00:05:12,011 --> 00:05:13,479
and looking after herself.

220
00:05:13,479 --> 00:05:15,381
Because if we have any kind of

221
00:05:15,381 --> 00:05:17,684
fault, the spacecraft has to

222
00:05:17,684 --> 00:05:19,585
know how to correct that fault.

223
00:05:19,585 --> 00:05:20,820
It takes light 8 minutes

224
00:05:20,820 --> 00:05:21,854
to go from the Sun

225
00:05:21,854 --> 00:05:23,156
to the Earth.

226
00:05:23,156 --> 00:05:24,023
We don't have time

227
00:05:24,023 --> 00:05:25,892
to joystick this spacecraft.

228
00:05:25,892 --> 00:05:27,460
She has to correct herself.

229
00:05:27,460 --> 00:05:28,695
And so if you think of

230
00:05:28,695 --> 00:05:30,763
the sheer technology that

231
00:05:30,763 --> 00:05:32,732
would have taken to do that

232
00:05:32,732 --> 00:05:33,800
in 1958--

233
00:05:33,800 --> 00:05:34,434
>> Sure.

234
00:05:34,434 --> 00:05:35,401
>> You're talking city blocks'

235
00:05:35,401 --> 00:05:36,502
worth of buildings with

236
00:05:36,502 --> 00:05:38,104
computer power in them.

237
00:05:38,104 --> 00:05:38,805
>> Not easy to get

238
00:05:38,805 --> 00:05:39,505

off the ground.

239
00:05:39,505 --> 00:05:40,173
>> Not easy to get

240
00:05:40,173 --> 00:05:41,140
off the ground.

241
00:05:41,140 --> 00:05:41,941
Um, I mean, if you think,

242
00:05:41,941 --> 00:05:43,743
in 1958, you wanted to talk

243
00:05:43,743 --> 00:05:44,510
to somebody, you went

244
00:05:44,510 --> 00:05:45,645
to the wall where

245
00:05:45,645 --> 00:05:47,480
your rotary dial phone was

246
00:05:47,480 --> 00:05:49,182
attached, and you made

247
00:05:49,182 --> 00:05:50,049
your phone call.

248
00:05:51,384 --> 00:05:52,952
Now we all have iPhones,

249
00:05:52,952 --> 00:05:54,754
and we probably do everything

250
00:05:54,754 --> 00:05:55,955
except make a phone call

251
00:05:55,955 --> 00:05:56,923
with them.

252
00:05:56,923 --> 00:05:57,824
Uh, you know, the whole way

253
00:05:57,824 --> 00:05:59,525
we communicate-- I mean,

254
00:05:59,525 --> 00:06:00,827
it's a last ditch attempt

255
00:06:00,827 --> 00:06:01,694
if you have to make

256
00:06:01,694 --> 00:06:02,829
a phone call now.

257
00:06:02,829 --> 00:06:03,496
By the time you've tried

258
00:06:03,496 --> 00:06:04,831
texting, and instant messenger,

259
00:06:04,831 --> 00:06:06,299
and-and Instagram,

260
00:06:06,299 --> 00:06:07,366
and Snapchat, and you've done

261
00:06:07,366 --> 00:06:08,801
all those things.

262
00:06:08,801 --> 00:06:09,268
>> Sure.

263
00:06:09,268 --> 00:06:10,903

>> And so just the sheer way

264
00:06:10,903 --> 00:06:12,739
that w-- that society has

265
00:06:12,739 --> 00:06:14,607
changed is dramatic.

266
00:06:14,607 --> 00:06:16,609
And that's very-- um,

267
00:06:16,609 --> 00:06:17,810
a good demonstration of

268
00:06:17,810 --> 00:06:18,878
what we needed to do

269
00:06:18,878 --> 00:06:20,279
to be able to get Parker

270
00:06:20,279 --> 00:06:22,281
Solar Probe into orbit.

271
00:06:22,281 --> 00:06:23,816
>> So we were talking about

272
00:06:23,816 --> 00:06:25,952
this for decades as a priority

273
00:06:25,952 --> 00:06:26,686
and just really didn't

274
00:06:26,686 --> 00:06:28,020
touch it, or has it really

275
00:06:28,020 --> 00:06:30,022
been worked on for 60 years now?

276
00:06:30,022 --> 00:06:30,923
>> There have been many,

277
00:06:30,923 --> 00:06:32,291
many incarnations of

278
00:06:32,291 --> 00:06:33,526
a solar probe.

279
00:06:33,526 --> 00:06:34,727
Um, I think there was

280
00:06:34,727 --> 00:06:36,596
a Russian one called Firebird.

281
00:06:36,596 --> 00:06:37,730
Um, you know, JPL had

282
00:06:37,730 --> 00:06:39,432
a-a design.

283
00:06:39,432 --> 00:06:40,566
Um, the Johns Hopkins

284
00:06:40,566 --> 00:06:41,567
Applied Physics Lab had

285
00:06:41,567 --> 00:06:42,769
a different design.

286
00:06:42,769 --> 00:06:43,803
Um, it looked kind of like

287
00:06:43,803 --> 00:06:44,871
a bullet.

288
00:06:44,871 --> 00:06:46,005

And it was gonna go super close,

289
00:06:46,005 --> 00:06:46,906
but it was going to go out

290
00:06:46,906 --> 00:06:49,175
to Jupiter, kick out of

291
00:06:49,175 --> 00:06:51,043
the, um, the kind of-- the plane

292
00:06:51,043 --> 00:06:52,745
of the Sun and the Earth,

293
00:06:52,745 --> 00:06:54,080
and then come up and go

294
00:06:54,080 --> 00:06:55,681
over the pole and go down,

295
00:06:55,681 --> 00:06:56,949
sort of north-south,

296
00:06:56,949 --> 00:06:58,417
if you like, past the Sun.

297
00:06:58,417 --> 00:06:59,485
Um, but they were

298
00:06:59,485 --> 00:07:00,686
very expensive missions.

299
00:07:00,686 --> 00:07:02,355
They required some kind of

300
00:07:02,355 --> 00:07:04,423
nuclear RTG, some kind of,

301
00:07:04,423 --> 00:07:06,125
you know, power source.

302
00:07:06,125 --> 00:07:07,360
Um, and they were very,

303
00:07:07,360 --> 00:07:08,561
very expensive.

304
00:07:08,561 --> 00:07:10,096
Um, they took a long time

305
00:07:10,096 --> 00:07:11,898
to get into the orbit,

306
00:07:11,898 --> 00:07:12,932
and then they got, you know,

307
00:07:12,932 --> 00:07:14,100
a few hours' worth of data,

308
00:07:14,100 --> 00:07:15,234
if you like.

309
00:07:15,234 --> 00:07:16,402
And so it really was just

310
00:07:16,402 --> 00:07:18,204
the ability to afford

311
00:07:18,204 --> 00:07:19,405
all of the technology,

312
00:07:19,405 --> 00:07:20,807
to come up with a mission

313
00:07:20,807 --> 00:07:22,375

design that would allow us

314
00:07:22,375 --> 00:07:24,043
to-to go where we need to go

315
00:07:24,043 --> 00:07:24,911
and do it for

316
00:07:24,911 --> 00:07:26,879
a reasonable price.

317
00:07:26,879 --> 00:07:28,581
So that was where the mission

318
00:07:28,581 --> 00:07:29,282
used to be called

319
00:07:29,282 --> 00:07:30,650
Solar Probe Plus, and that's

320
00:07:30,650 --> 00:07:32,185
where the plus came from.

321
00:07:32,185 --> 00:07:34,220
Uh, we changed, and we stay

322
00:07:34,220 --> 00:07:35,688
in the ecliptic plane.

323
00:07:35,688 --> 00:07:36,856
So you put the Sun and the Earth

324
00:07:36,856 --> 00:07:38,858
and you stay in that sort of

325
00:07:38,858 --> 00:07:39,926
plane there.

326
00:07:39,926 --> 00:07:41,994
Um, and we don't use any kind of

327
00:07:41,994 --> 00:07:45,431
RTGs-- we use solar cells.

328
00:07:45,431 --> 00:07:46,632
And you may look at me and say,

329
00:07:46,632 --> 00:07:47,967
"hey, Nicky, well, duh.

330
00:07:47,967 --> 00:07:48,768
"You're going to the sun.

331
00:07:48,768 --> 00:07:49,502
"Why wouldn't you use

332
00:07:49,502 --> 00:07:50,603
"solar power?

333
00:07:50,603 --> 00:07:52,004
"That's a no-brainer."

334
00:07:52,004 --> 00:07:52,905
Except what happens

335
00:07:52,905 --> 00:07:54,340
if you leave your iPhone

336
00:07:54,340 --> 00:07:56,108
in the car on a beautiful

337
00:07:56,108 --> 00:07:57,510
Florida day?

338
00:07:57,510 --> 00:07:58,477

It overheats.

339
00:07:58,477 --> 00:07:59,011
>> Yeah.

340
00:07:59,011 --> 00:08:00,046
>> And solar panels are

341
00:08:00,046 --> 00:08:02,114
extremely sensitive to heat.

342
00:08:02,114 --> 00:08:03,049
And so we have to find a way

343
00:08:03,049 --> 00:08:04,183
to keep them cool.

344
00:08:04,183 --> 00:08:05,484
Um, and so they-- you know,

345
00:08:05,484 --> 00:08:06,252
we have them--

346
00:08:06,252 --> 00:08:07,220
they're articulated, kind of

347
00:08:07,220 --> 00:08:08,654
on a shoulder joint,

348
00:08:08,654 --> 00:08:09,655
and so they can move out

349
00:08:09,655 --> 00:08:10,556
and they can also kind of

350
00:08:10,556 --> 00:08:12,325
twist around, um, so that

351
00:08:12,325 --> 00:08:13,426
we can maximize the amount

352
00:08:13,426 --> 00:08:14,861
of power and minimize it

353
00:08:14,861 --> 00:08:16,429
by tucking them all the way in

354
00:08:16,429 --> 00:08:18,364
as we get close to the Sun.

355
00:08:18,364 --> 00:08:19,899
Um, we also cool them

356
00:08:19,899 --> 00:08:21,868
with water, and again,

357
00:08:21,868 --> 00:08:23,236
not a very exotic material,

358
00:08:23,236 --> 00:08:25,137
but the best coolant, um,

359
00:08:25,137 --> 00:08:26,672
that-that we have.

360
00:08:26,672 --> 00:08:28,407
And we run, uh, water

361
00:08:28,407 --> 00:08:29,609
through the veins.

362
00:08:29,609 --> 00:08:30,977
Like the veins in your, uh,

363
00:08:30,977 --> 00:08:32,778

your hand, they run between

364
00:08:32,778 --> 00:08:34,046
each of the solar cells

365
00:08:34,046 --> 00:08:36,048
all the time, continually

366
00:08:36,048 --> 00:08:37,717
keeping those cells cool.

367
00:08:37,717 --> 00:08:38,885
And so, you know, it's taken

368
00:08:38,885 --> 00:08:40,386
a lot to get the technology,

369
00:08:40,386 --> 00:08:41,721
but also to bring it in

370
00:08:41,721 --> 00:08:43,623
in a really good mission design

371
00:08:43,623 --> 00:08:44,323
that does the science

372
00:08:44,323 --> 00:08:45,691
we want to do.

373
00:08:45,691 --> 00:08:46,325
>> I have the benefit of

374
00:08:46,325 --> 00:08:47,126
sitting across the table

375
00:08:47,126 --> 00:08:48,794
from you, so I know the answer

376
00:08:48,794 --> 00:08:49,762
to this question, but

377
00:08:49,762 --> 00:08:51,130
did you start working on this

378
00:08:51,130 --> 00:08:52,198
60 years ago?

379
00:08:52,198 --> 00:08:53,199
And if not, when did you

380
00:08:53,199 --> 00:08:54,100
do that?

381
00:08:54,100 --> 00:08:55,434
>> I have a very good

382
00:08:55,434 --> 00:08:56,636
plastic surgeon.

383
00:08:56,636 --> 00:08:59,171
Um, uh, no, I started working

384
00:08:59,171 --> 00:09:01,407
on this mission in 2010.

385
00:09:01,407 --> 00:09:02,475
So I'm a relative newbie

386
00:09:02,475 --> 00:09:03,943
to the mission.

387
00:09:03,943 --> 00:09:04,911
Uh, there are people who've

388
00:09:04,911 --> 00:09:05,611

been working on it

389
00:09:05,611 --> 00:09:06,646
for a lot longer than that.

390
00:09:06,646 --> 00:09:07,580
Even this particular

391
00:09:07,580 --> 00:09:08,915
incarnation, there have been

392
00:09:08,915 --> 00:09:09,548
people working on it

393
00:09:09,548 --> 00:09:10,917
for well over a decade.

394
00:09:10,917 --> 00:09:12,685
So I'm-I'm a little new.

395
00:09:12,685 --> 00:09:13,486
>> And-and how has this been

396
00:09:13,486 --> 00:09:15,488
from a-an-a personal

397
00:09:15,488 --> 00:09:16,188
perspective?

398
00:09:16,188 --> 00:09:17,290
Because I know that we talk to

399
00:09:17,290 --> 00:09:18,157
people all the time, and

400
00:09:18,157 --> 00:09:20,092
we hear similar stories--

401
00:09:20,092 --> 00:09:21,460
"we've spent a decade or more

402
00:09:21,460 --> 00:09:22,194
"working on this and giving

403
00:09:22,194 --> 00:09:23,696
"our lives to this project."

404
00:09:23,696 --> 00:09:25,398
So how has that been for you

405
00:09:25,398 --> 00:09:26,699
kind of through this process

406
00:09:26,699 --> 00:09:28,467
and getting ready for launch?

407
00:09:28,467 --> 00:09:29,602
>> So I think for me, um,

408
00:09:29,602 --> 00:09:30,937
it's-it's been a very

409
00:09:30,937 --> 00:09:32,071
personal journey.

410
00:09:32,071 --> 00:09:32,872
Uh, you know, I started

411
00:09:32,872 --> 00:09:33,806
working on the mission

412
00:09:33,806 --> 00:09:37,109
late in 2010, and about

413
00:09:37,109 --> 00:09:38,678

six weeks after I accepted

414
00:09:38,678 --> 00:09:40,947
my position, my husband died,

415
00:09:40,947 --> 00:09:43,316
um, very suddenly, leaving me

416
00:09:43,316 --> 00:09:44,083
with a 1-year-old

417
00:09:44,083 --> 00:09:45,418
and a 3-year-old.

418
00:09:45,418 --> 00:09:46,252
>> I'm sorry to hear that.

419
00:09:46,252 --> 00:09:46,986
>> And my life kind of

420
00:09:46,986 --> 00:09:48,187
fell apart.

421
00:09:48,187 --> 00:09:48,988
You know, I felt like

422
00:09:48,988 --> 00:09:50,356
I can't take on anything.

423
00:09:50,356 --> 00:09:51,390
Um, you know, I'm never gonna

424
00:09:51,390 --> 00:09:52,692
be able to do anything.

425
00:10:00,900 --> 00:10:02,868
And the way this team kind of

426
00:10:02,868 --> 00:10:04,370
gathered around and

427
00:10:04,370 --> 00:10:06,439
supported me through

428
00:10:06,439 --> 00:10:08,507
this period, it was almost like

429
00:10:08,507 --> 00:10:10,042
I used Solar Probe as

430
00:10:10,042 --> 00:10:12,979
a grief kind of solving mission.

431
00:10:12,979 --> 00:10:13,679
You know, there were things

432
00:10:13,679 --> 00:10:14,580
I could come in, I could

433
00:10:14,580 --> 00:10:15,247
actually do things.

434
00:10:15,247 --> 00:10:16,115
I could-could make

435
00:10:16,115 --> 00:10:16,916
this thing work.

436
00:10:16,916 --> 00:10:18,150
And just the tremendous

437
00:10:18,150 --> 00:10:20,186
support of, you know, people

438
00:10:20,186 --> 00:10:21,220

that just said, "ah,

439
00:10:21,220 --> 00:10:21,887
"do you need me to pick up

440
00:10:21,887 --> 00:10:22,488
"your kids tonight?"

441
00:10:22,488 --> 00:10:23,723
Um, "do you need groceries?"

442
00:10:23,723 --> 00:10:25,124
Um, "what can we do

443
00:10:25,124 --> 00:10:25,925
"to help you?"

444
00:10:25,925 --> 00:10:27,994
And the science team also.

445
00:10:27,994 --> 00:10:29,261
You know, my first science team

446
00:10:29,261 --> 00:10:30,162
meeting where I had to

447
00:10:30,162 --> 00:10:31,163
stand up and lead them,

448
00:10:31,163 --> 00:10:32,531
and you know, I was nervous,

449
00:10:32,531 --> 00:10:34,567
and one of the principal

450
00:10:34,567 --> 00:10:35,768
investigators just said,

451
00:10:35,768 --> 00:10:36,635
"hey, you know, I thought

452
00:10:36,635 --> 00:10:37,470
"it might be nice just

453
00:10:37,470 --> 00:10:38,337
"to come and have dinner with

454
00:10:38,337 --> 00:10:39,271
"my wife and I.

455
00:10:39,271 --> 00:10:40,406
"And you know, you don't have to

456
00:10:40,406 --> 00:10:41,640
"do anything big in the evening.

457
00:10:41,640 --> 00:10:42,975
"It'll be low stress for you,

458
00:10:42,975 --> 00:10:44,010
"and we'll just give you

459
00:10:44,010 --> 00:10:44,744
"some food."

460
00:10:44,744 --> 00:10:45,978
And just the-the sort of--

461
00:10:45,978 --> 00:10:48,114
the people realizing,

462
00:10:48,114 --> 00:10:49,382
"this person is really falling

463
00:10:49,382 --> 00:10:50,983

"apart, and they're really

464
00:10:50,983 --> 00:10:52,685
"hurting, and we are going to

465
00:10:52,685 --> 00:10:53,786
"support you through it."

466
00:10:53,786 --> 00:10:55,755
So they're like a family.

467
00:10:55,755 --> 00:10:57,189
I come down to Astrotech here

468
00:10:57,189 --> 00:10:58,157
and I walk in the door,

469
00:10:58,157 --> 00:10:58,691
and everyone's like,

470
00:10:58,691 --> 00:11:00,059
"hey, Nicky, how's it going?"

471
00:11:00,059 --> 00:11:01,494
You know, and-and it's just

472
00:11:01,494 --> 00:11:03,863
such a friendly, lovely,

473
00:11:03,863 --> 00:11:05,231
highly professional, highly

474
00:11:05,231 --> 00:11:06,866
skilled, best at the--

475
00:11:06,866 --> 00:11:07,633
you know, in the world at

476
00:11:07,633 --> 00:11:09,468
what they do, but real people.

477
00:11:09,468 --> 00:11:10,002
>> Yeah.

478
00:11:10,002 --> 00:11:11,037
>> That see someone that's

479
00:11:11,037 --> 00:11:13,005
really struggling and

480
00:11:13,005 --> 00:11:14,440
they'll all band together

481
00:11:14,440 --> 00:11:15,541
and help that person

482
00:11:15,541 --> 00:11:16,909
be successful.

483
00:11:16,909 --> 00:11:18,144
And so this mission is

484
00:11:18,144 --> 00:11:19,378
deeply personal for me.

485
00:11:19,378 --> 00:11:21,047
I put my husband's name

486
00:11:21,047 --> 00:11:21,947
on the spacecraft.

487
00:11:21,947 --> 00:11:23,015
My children are all excited

488
00:11:23,015 --> 00:11:24,050

about "Daddy's gonna orbit

489
00:11:24,050 --> 00:11:24,884
"the Sun forever."

490
00:11:24,884 --> 00:11:25,751
And you know, it's a very

491
00:11:25,751 --> 00:11:27,153
personal thing.

492
00:11:27,153 --> 00:11:27,920
>> I'm sure that that extends

493
00:11:27,920 --> 00:11:29,655
now beyond just the trust

494
00:11:29,655 --> 00:11:31,023
of this personal relationship

495
00:11:31,023 --> 00:11:32,124
with people into a professional

496
00:11:32,124 --> 00:11:34,226
engineering and problem solving

497
00:11:34,226 --> 00:11:36,429
reality of your team.

498
00:11:36,429 --> 00:11:37,430
>> Absolutely.

499
00:11:37,430 --> 00:11:38,531
I mean, when-- you know,

500
00:11:38,531 --> 00:11:39,432
when we have an issue,

501
00:11:39,432 --> 00:11:40,499
a technical issue,

502
00:11:40,499 --> 00:11:42,268
people just deal with it.

503
00:11:42,268 --> 00:11:43,069
Nobody panics.

504
00:11:43,069 --> 00:11:43,769
They say, "okay, we've got

505
00:11:43,769 --> 00:11:44,570
"a technical issue.

506
00:11:44,570 --> 00:11:45,137
"We're gonna do it--

507
00:11:45,137 --> 00:11:45,838
"we're gonna come up with

508
00:11:45,838 --> 00:11:47,239
"a plan, we're gonna do this,

509
00:11:47,239 --> 00:11:48,040
"we're gonna do the action

510
00:11:48,040 --> 00:11:49,275
"items, we're gonna status it,

511
00:11:49,275 --> 00:11:49,942
"and we're going to

512
00:11:49,942 --> 00:11:50,776
"get through it."

513
00:11:50,776 --> 00:11:52,078

Um, you know, my-my project

514
00:11:52,078 --> 00:11:54,046
manager, Andy Driesman, um,

515
00:11:54,046 --> 00:11:55,181
from the Applied Physics Lab,

516
00:11:55,181 --> 00:11:56,849
he, um, he always says,

517
00:11:56,849 --> 00:11:57,983
"you know, you work on

518
00:11:57,983 --> 00:11:58,784
"the missions.

519
00:11:58,784 --> 00:11:59,785
"The missions are fantastic.

520
00:11:59,785 --> 00:12:00,619
"The technology is great.

521
00:12:00,619 --> 00:12:01,854
"The science is awesome.

522
00:12:01,854 --> 00:12:03,222
"But it's the relationships

523
00:12:03,222 --> 00:12:04,190
"you make with the people

524
00:12:04,190 --> 00:12:05,124
"that stay with you for life."

525
00:12:05,124 --> 00:12:06,192
And it's really true.

526
00:12:06,192 --> 00:12:07,593
>> That's awesome.

527
00:12:07,593 --> 00:12:08,360
So kind of getting back to

528
00:12:08,360 --> 00:12:10,096
Parker Solar Probe, how close

529
00:12:10,096 --> 00:12:11,464
are we getting to the Sun?

530
00:12:11,464 --> 00:12:12,231
Obviously, coming out

531
00:12:12,231 --> 00:12:13,632
past Venus is pretty far

532
00:12:13,632 --> 00:12:14,767
from the Sun, so what are

533
00:12:14,767 --> 00:12:15,634
our distances like here

534
00:12:15,634 --> 00:12:17,269
in-- compared to Earth?

535
00:12:17,269 --> 00:12:19,038
>> So, you know, I often say--

536
00:12:19,038 --> 00:12:19,605
people ask me,

537
00:12:19,605 --> 00:12:20,406
"well, how close?"

538
00:12:20,406 --> 00:12:21,040

"'Cause you're getting

539
00:12:21,040 --> 00:12:21,907
"so excited, it must be

540
00:12:21,907 --> 00:12:22,775
"really close."

541
00:12:22,775 --> 00:12:23,275
And I say, "oh, yeah,

542
00:12:23,275 --> 00:12:24,110
"we're just gonna get, um,

543
00:12:24,110 --> 00:12:25,277
"just below 4 million miles

544
00:12:25,277 --> 00:12:26,445
"from the Sun's surface."

545
00:12:26,445 --> 00:12:27,313
And I always get people

546
00:12:27,313 --> 00:12:28,347
that look at me like, "oh,

547
00:12:28,347 --> 00:12:29,648
"I thought you said

548
00:12:29,648 --> 00:12:30,683
"you were gonna get really,

549
00:12:30,683 --> 00:12:31,383
"really close."

550
00:12:31,383 --> 00:12:32,084
>> 'Cause what I'd like you

551
00:12:32,084 --> 00:12:32,751
to say is be like,

552
00:12:32,751 --> 00:12:33,419
"we're gonna just like drive

553
00:12:33,419 --> 00:12:34,320
"right into the Sun."

554
00:12:34,320 --> 00:12:35,054
>> Exactly.

555
00:12:35,054 --> 00:12:37,056
>> And just like--

556
00:12:37,056 --> 00:12:37,957
>> Exactly, exactly, and--

557
00:12:37,957 --> 00:12:38,691
>> Go out in a blaze of glory.

558
00:12:38,691 --> 00:12:40,126
>> If I put the Sun and

559
00:12:40,126 --> 00:12:41,026
the Earth in, um, the-- uh,

560
00:12:41,026 --> 00:12:42,228
either side of the football

561
00:12:42,228 --> 00:12:43,262
field, at the touchdown

562
00:12:43,262 --> 00:12:44,263
in the goal area...

563
00:12:44,263 --> 00:12:44,897

>> Okay.

564
00:12:44,897 --> 00:12:45,564
So American football.

565
00:12:45,564 --> 00:12:46,532
>> And-- American football.

566
00:12:46,532 --> 00:12:48,234
Uh, I can-- I can translate.

567
00:12:48,234 --> 00:12:50,302
Um, um, and, uh, you know,

568
00:12:50,302 --> 00:12:52,671
we'd have, um, Venus about

569
00:12:52,671 --> 00:12:54,173
the 27 yard line of

570
00:12:54,173 --> 00:12:55,508
the Earth's 27.

571
00:12:55,508 --> 00:12:56,642
You'd have Mercury at about

572
00:12:56,642 --> 00:12:58,477
the Sun's 35.

573
00:12:58,477 --> 00:12:59,311
Um, some of those big

574
00:12:59,311 --> 00:13:00,446
coronal loops that you see

575
00:13:00,446 --> 00:13:01,714
come out, um, they can

576
00:13:01,714 --> 00:13:02,448
come out to maybe

577
00:13:02,448 --> 00:13:03,716
the 15 yard line.

578
00:13:03,716 --> 00:13:04,617
But you know, welcome to

579
00:13:04,617 --> 00:13:05,451
the main event-- Parker

580
00:13:05,451 --> 00:13:06,385
Solar Probe, who's gonna

581
00:13:06,385 --> 00:13:07,887
tuck and run all the way

582
00:13:07,887 --> 00:13:09,755
to the 4 yard line.

583
00:13:09,755 --> 00:13:10,389
>> Okay.

584
00:13:10,389 --> 00:13:11,423
>> So in the red zone,

585
00:13:11,423 --> 00:13:12,224
knockin' on the door

586
00:13:12,224 --> 00:13:13,025
for the touchdown.

587
00:13:13,025 --> 00:13:14,126
Let's go Ravens.

588
00:13:14,126 --> 00:13:18,297

Um, so-- um, it's very close.

589
00:13:18,297 --> 00:13:19,632
Uh, you know, on a meter scale

590
00:13:19,632 --> 00:13:21,033
it's 4 centimeters away.

591
00:13:21,033 --> 00:13:21,734
On a football field,

592
00:13:21,734 --> 00:13:23,102
it's 4 yards away.

593
00:13:23,102 --> 00:13:24,670
It's really close.

594
00:13:24,670 --> 00:13:25,504
We-- you know, we tend to

595
00:13:25,504 --> 00:13:26,639
not think about just

596
00:13:26,639 --> 00:13:27,373
the sheer scales, but

597
00:13:27,373 --> 00:13:28,674
the Sun is 93 million

598
00:13:28,674 --> 00:13:29,575
miles away.

599
00:13:29,575 --> 00:13:32,378
So getting to 3.7 million miles

600
00:13:32,378 --> 00:13:34,046
is super close.

601
00:13:34,046 --> 00:13:36,415
And it's in that region where

602
00:13:36,415 --> 00:13:37,683
all the excitement happens.

603
00:13:37,683 --> 00:13:39,084
And so last year, a lot of us

604
00:13:39,084 --> 00:13:40,419
here were treated to

605
00:13:40,419 --> 00:13:41,987
this amazing celestial sight

606
00:13:41,987 --> 00:13:43,022
when we had the total

607
00:13:43,022 --> 00:13:44,056
solar eclipse.

608
00:13:44,056 --> 00:13:45,224
>> This is the celestial

609
00:13:45,224 --> 00:13:46,258
event that we've all been

610
00:13:46,258 --> 00:13:47,359
waiting and anticipating

611
00:13:47,359 --> 00:13:48,394
for years.

612
00:13:48,394 --> 00:13:50,529
>> And you saw that beautiful

613
00:13:50,529 --> 00:13:52,064

hazy atmosphere.

614
00:13:52,064 --> 00:13:53,232
That's the corona.

615
00:13:53,232 --> 00:13:54,533
Uh, it's basically the outer

616
00:13:54,533 --> 00:13:56,101
atmosphere of the Sun.

617
00:13:56,101 --> 00:13:57,269
Um, the reason it's called

618
00:13:57,269 --> 00:13:58,270
corona is 'cause it's Latin

619
00:13:58,270 --> 00:13:59,138
for crown.

620
00:13:59,138 --> 00:14:00,039
It does look like a crown

621
00:14:00,039 --> 00:14:01,207
around the Sun.

622
00:14:01,207 --> 00:14:01,941
>> So look now.

623
00:14:01,941 --> 00:14:03,809
We see the corona in Madras.

624
00:14:03,809 --> 00:14:04,743
That's gorgeous.

625
00:14:04,743 --> 00:14:05,411
>> That's amazing.

626
00:14:05,411 --> 00:14:06,812
I mean, and that only can be

627
00:14:06,812 --> 00:14:07,780
seen when you have

628
00:14:07,780 --> 00:14:08,981
this kind of totality.

629
00:14:08,981 --> 00:14:09,882
>> So the corona, that's

630
00:14:09,882 --> 00:14:11,150
what solar scientists really

631
00:14:11,150 --> 00:14:12,251
live for, right?

632
00:14:12,251 --> 00:14:12,751
>> Right.

633
00:14:12,751 --> 00:14:13,953
That is where the origin

634
00:14:13,953 --> 00:14:15,554
of space weather comes from.

635
00:14:15,554 --> 00:14:16,689
>> That's where we're going.

636
00:14:16,689 --> 00:14:18,290
And so what you are looking at

637
00:14:18,290 --> 00:14:19,558
is basically where

638
00:14:19,558 --> 00:14:22,194

Solar Probe will be orbiting.

639
00:14:22,194 --> 00:14:22,895
>> How long is it gonna take

640
00:14:22,895 --> 00:14:23,762
to get there?

641
00:14:23,762 --> 00:14:25,264
>> So, uh, we are a very busy

642
00:14:25,264 --> 00:14:27,099
team, uh, at the very beginning.

643
00:14:27,099 --> 00:14:29,068
Uh, we launch on a Delta IV

644
00:14:29,068 --> 00:14:30,536
Heavy with a-an upper stage

645
00:14:30,536 --> 00:14:32,338
from right here at

646
00:14:32,338 --> 00:14:32,972
Kennedy Space Center.

647
00:14:32,972 --> 00:14:34,106
A Delta IV Heavy, the reason

648
00:14:34,106 --> 00:14:35,507
we need such a big launch

649
00:14:35,507 --> 00:14:37,409
vehicle is-- and we're tiny,

650
00:14:37,409 --> 00:14:38,143
by the way.

651
00:14:38,143 --> 00:14:39,044
The spacecraft is tiny.

652
00:14:39,044 --> 00:14:39,645
We look like a little

653
00:14:39,645 --> 00:14:40,846
hood ornament on the top of

654
00:14:40,846 --> 00:14:42,314
the Delta IV Heavy.

655
00:14:42,314 --> 00:14:44,183
Um, and we are so small

656
00:14:44,183 --> 00:14:45,484
and we're so mass-constrained

657
00:14:45,484 --> 00:14:46,885
because we need to be

658
00:14:46,885 --> 00:14:48,053
thrown away from the Earth,

659
00:14:48,053 --> 00:14:50,089
essentially, as fast as possible

660
00:14:50,089 --> 00:14:51,724
with a huge amount of energy.

661
00:14:51,724 --> 00:14:53,192
Because we don't want to be

662
00:14:53,192 --> 00:14:54,526
influenced by the Earth's

663
00:14:54,526 --> 00:14:55,794

orbit around the Sun.

664
00:14:55,794 --> 00:14:56,829
We don't want to be dragged

665
00:14:56,829 --> 00:14:58,797
around with the Earth.

666
00:14:58,797 --> 00:14:59,898
We want to go in

667
00:14:59,898 --> 00:15:01,734
towards the Sun.

668
00:15:01,734 --> 00:15:03,402
Just 6 weeks after launch,

669
00:15:03,402 --> 00:15:04,937
we will fly past the planet

670
00:15:04,937 --> 00:15:06,639
Venus for the first time.

671
00:15:06,639 --> 00:15:07,840
Uh, we use Venus for

672
00:15:07,840 --> 00:15:09,208
gravity assists.

673
00:15:09,208 --> 00:15:10,109
And a lot of people are

674
00:15:10,109 --> 00:15:11,510
familiar with the idea of,

675
00:15:11,510 --> 00:15:12,611
you know, we do sling-shots

676
00:15:12,611 --> 00:15:13,946
around Jupiter.

677
00:15:13,946 --> 00:15:15,714
Uh, New Horizons, for example,

678
00:15:15,714 --> 00:15:16,749
did one and took more than

679
00:15:16,749 --> 00:15:17,683
a year off its journey

680
00:15:17,683 --> 00:15:18,984
to Pluto because it was

681
00:15:18,984 --> 00:15:19,718
able to speed up

682
00:15:19,718 --> 00:15:20,686
using Jupiter.

683
00:15:20,686 --> 00:15:21,587
And really, we use it

684
00:15:21,587 --> 00:15:22,621
more like a little hand brake

685
00:15:22,621 --> 00:15:25,224
turn to kind of just focus,

686
00:15:25,224 --> 00:15:27,026
um, and turn the spacecraft

687
00:15:27,026 --> 00:15:29,061
in towards the Sun

688
00:15:29,061 --> 00:15:30,229

so we're now going directly

689
00:15:30,229 --> 00:15:31,196
to the Sun.

690
00:15:31,196 --> 00:15:32,965
About 6 weeks after we pass

691
00:15:32,965 --> 00:15:35,134
Venus, we are in the corona

692
00:15:35,134 --> 00:15:36,302
for the first time.

693
00:15:36,302 --> 00:15:37,603
So it's a very busy time

694
00:15:37,603 --> 00:15:39,371
as we have to commission

695
00:15:39,371 --> 00:15:40,139
all the instruments, get

696
00:15:40,139 --> 00:15:41,173
all the subsystems on,

697
00:15:41,173 --> 00:15:42,775
get everything working.

698
00:15:42,775 --> 00:15:43,742
We are traveling at

699
00:15:43,742 --> 00:15:46,578
430,000 miles an hour,

700
00:15:46,578 --> 00:15:48,013
118 miles a second, um,

701
00:15:48,013 --> 00:15:49,248
New York to Tokyo in

702
00:15:49,248 --> 00:15:50,649
much less than a minute.

703
00:15:50,649 --> 00:15:52,785
>> Oh-ho-ho-ho, what?

704
00:15:52,785 --> 00:15:54,119
>> It's blistering speeds.

705
00:15:54,119 --> 00:15:56,055
Um, you know, it's-it's sort of

706
00:15:56,055 --> 00:15:58,324
DC to Philadelphia in a second.

707
00:15:58,324 --> 00:15:59,625
You know, it's-it's just

708
00:15:59,625 --> 00:16:01,260
incredible how fast

709
00:16:01,260 --> 00:16:02,094
we're moving.

710
00:16:02,094 --> 00:16:03,562
That's-that's why we're small.

711
00:16:03,562 --> 00:16:04,596
Um, that's why we need to

712
00:16:04,596 --> 00:16:05,931
move so fast-- we need to

713
00:16:05,931 --> 00:16:07,566

not be in any way influenced

714
00:16:07,566 --> 00:16:08,867
by the Earth.

715
00:16:08,867 --> 00:16:10,169
We wanna go to the Sun

716
00:16:10,169 --> 00:16:11,637
and study the corona.

717
00:16:11,637 --> 00:16:12,905
>> So you're hurtling towards

718
00:16:12,905 --> 00:16:14,406
the Sun at unbelievable

719
00:16:14,406 --> 00:16:16,041
speeds-- how do you not

720
00:16:16,041 --> 00:16:17,643
burn up in the heat of

721
00:16:17,643 --> 00:16:18,911
the Sun, that feels hot

722
00:16:18,911 --> 00:16:19,912
on a Florida day

723
00:16:19,912 --> 00:16:21,714
from 93 million miles?

724
00:16:21,714 --> 00:16:23,415
>> Solar Probe, when she is

725
00:16:23,415 --> 00:16:26,452
at her closest, um, to the Sun,

726
00:16:26,452 --> 00:16:27,686
will experience just a little

727
00:16:27,686 --> 00:16:29,455
bit less than 500 times

728
00:16:29,455 --> 00:16:31,357
the Sun that we see here.

729
00:16:31,357 --> 00:16:32,758
So essentially, 500 suns

730
00:16:32,758 --> 00:16:34,159
in the sky at the same time

731
00:16:34,159 --> 00:16:35,394
beating down on us

732
00:16:35,394 --> 00:16:36,962
is what Parker Solar Probe

733
00:16:36,962 --> 00:16:38,163
will experience.

734
00:16:38,163 --> 00:16:40,165
We have a wonderful heat shield.

735
00:16:40,165 --> 00:16:41,633
Uh, sits out the front of

736
00:16:41,633 --> 00:16:43,035
our spacecraft.

737
00:16:43,035 --> 00:16:44,203
Um, the spacecraft itself is

738
00:16:44,203 --> 00:16:46,071

very small-- um, about

739
00:16:46,071 --> 00:16:48,173
a meter, um, across,

740
00:16:48,173 --> 00:16:49,742
about a meter and a half tall.

741
00:16:49,742 --> 00:16:50,709
Uh, the whole spacecraft

742
00:16:50,709 --> 00:16:53,345
stands about 3 meters tall.

743
00:16:53,345 --> 00:16:54,213
She's very small.

744
00:16:54,213 --> 00:16:55,681
The heat shield sits at

745
00:16:55,681 --> 00:16:57,449
the-the top.

746
00:16:57,449 --> 00:16:58,984
Um, we lovingly call that

747
00:16:58,984 --> 00:17:01,053
our 8-foot Frisbee because

748
00:17:01,053 --> 00:17:03,689
it is, uh, a big disc,

749
00:17:03,689 --> 00:17:04,623
and it's very thin.

750
00:17:04,623 --> 00:17:06,191
It's only 4 1/2 inches thick.

751
00:17:06,191 --> 00:17:07,793
Obviously, one of our biggest

752
00:17:07,793 --> 00:17:09,128
technology developments was

753
00:17:09,128 --> 00:17:11,063
coming up with that heat shield.

754
00:17:11,063 --> 00:17:11,797
When I tell people

755
00:17:11,797 --> 00:17:12,331
what it's made with,

756
00:17:12,331 --> 00:17:13,465
they always sort of look at me

757
00:17:13,465 --> 00:17:14,299
like, "oh, I thought

758
00:17:14,299 --> 00:17:14,867
"it would've been something

759
00:17:14,867 --> 00:17:15,934
"really exotic."

760
00:17:15,934 --> 00:17:17,069
It's made out of carbon.

761
00:17:17,069 --> 00:17:18,270
There are two phase sheets

762
00:17:18,270 --> 00:17:19,238
that are very thin.

763
00:17:19,238 --> 00:17:21,006

Uh, they're 8 feet in diameter,

764
00:17:21,006 --> 00:17:22,875
uh, very thin, and they're made

765
00:17:22,875 --> 00:17:25,077
from like a graphite epoxy.

766
00:17:25,077 --> 00:17:26,011
So something that you would

767
00:17:26,011 --> 00:17:27,980
have in a nice bicycle,

768
00:17:27,980 --> 00:17:29,048
or your golf clubs,

769
00:17:29,048 --> 00:17:30,182
or a nice tennis racket.

770
00:17:30,182 --> 00:17:32,317
In between the, uh, the two

771
00:17:32,317 --> 00:17:33,185
phase sheets, there is

772
00:17:33,185 --> 00:17:34,853
a carbon-carbon foam.

773
00:17:34,853 --> 00:17:36,221
Um, it has the texture

774
00:17:36,221 --> 00:17:37,990
very similar to that horrible

775
00:17:37,990 --> 00:17:40,259
green florist foam that you get

776
00:17:40,259 --> 00:17:41,527
that always sort of falls apart.

777
00:17:41,527 --> 00:17:42,461
So we have to handle it

778
00:17:42,461 --> 00:17:43,328
very, very carefully.

779
00:17:43,328 --> 00:17:45,597
It's about 97% air.

780
00:17:45,597 --> 00:17:47,433
Um, and that is a tremendous

781
00:17:47,433 --> 00:17:49,568
way to-to keep everything cool.

782
00:17:49,568 --> 00:17:50,969
And on the very front of it,

783
00:17:50,969 --> 00:17:52,771
we have our whiter than white,

784
00:17:52,771 --> 00:17:54,873
uh, plasma-sprayed.

785
00:17:54,873 --> 00:17:55,374
It's a bit like

786
00:17:55,374 --> 00:17:56,809
a ceramic coating.

787
00:17:56,809 --> 00:17:58,777
It's an alumina, um, and

788
00:17:58,777 --> 00:18:00,045

it's plasma-sprayed.

789
00:18:00,045 --> 00:18:01,380
So we say it's plasma-tized

790
00:18:01,380 --> 00:18:02,848
in that you heat it

791
00:18:02,848 --> 00:18:03,949
so much that

792
00:18:03,949 --> 00:18:05,217
it-it basically dissociates.

793
00:18:05,217 --> 00:18:07,920
And you fire it from a gun.

794
00:18:07,920 --> 00:18:08,387
>> Huh.

795
00:18:08,387 --> 00:18:09,822
>> A paint gun, and coat

796
00:18:09,822 --> 00:18:11,056
the front of the spacecraft

797
00:18:11,056 --> 00:18:11,990
with that, and that's actually

798
00:18:11,990 --> 00:18:13,625
going to reflect, um,

799
00:18:13,625 --> 00:18:14,293
a tremendous amount of

800
00:18:14,293 --> 00:18:16,295
the Sun's energy before

801
00:18:16,295 --> 00:18:17,463
the heat shield even has to

802
00:18:17,463 --> 00:18:18,430
deal with it.

803
00:18:18,430 --> 00:18:18,897
>> Interesting.

804
00:18:18,897 --> 00:18:19,965
So I'm assuming that that end

805
00:18:19,965 --> 00:18:21,233
is pointed towards the Sun,

806
00:18:21,233 --> 00:18:22,000
and everything else kind of

807
00:18:22,000 --> 00:18:22,868
hides behind it.

808
00:18:22,868 --> 00:18:23,635
>> Absolutely.

809
00:18:23,635 --> 00:18:24,937
Um, that-that basically

810
00:18:24,937 --> 00:18:26,939
creates a nice shade.

811
00:18:26,939 --> 00:18:28,707
Our heat shield is so good

812
00:18:28,707 --> 00:18:30,476
that the front side of

813
00:18:30,476 --> 00:18:31,910

the heat shield will be

814
00:18:31,910 --> 00:18:33,312
at temperatures of about

815
00:18:33,312 --> 00:18:36,348
2,500 degrees Fahrenheit,

816
00:18:36,348 --> 00:18:37,916
1,400 degrees Centigrade.

817
00:18:37,916 --> 00:18:39,518
But those instruments that are

818
00:18:39,518 --> 00:18:41,420
on the main body of

819
00:18:41,420 --> 00:18:43,055
the spacecraft, they're a little

820
00:18:43,055 --> 00:18:44,590
warmer than room temperature.

821
00:18:44,590 --> 00:18:46,225
It's a sort of-- basically,

822
00:18:46,225 --> 00:18:47,960
not even a hot Florida day.

823
00:18:47,960 --> 00:18:48,861
It's a-- you know,

824
00:18:48,861 --> 00:18:50,896
it's a pleasant Florida day.

825
00:18:50,896 --> 00:18:51,997
>> Awesome.

826
00:18:51,997 --> 00:18:52,631
>> It's about 80 degrees

827
00:18:52,631 --> 00:18:53,999
Fahrenheit that those-those

828
00:18:53,999 --> 00:18:55,501
instruments are working at.

829
00:18:55,501 --> 00:18:56,969
And so that is mind-blowing

830
00:18:56,969 --> 00:18:58,403
as well, uh, that you can

831
00:18:58,403 --> 00:19:01,240
actually manage to cool, um,

832
00:19:01,240 --> 00:19:02,641
the environment that much.

833
00:19:02,641 --> 00:19:03,609
Most of the instruments sit

834
00:19:03,609 --> 00:19:04,710
on that main body of

835
00:19:04,710 --> 00:19:05,677
the spacecraft, and they kind of

836
00:19:05,677 --> 00:19:06,778
look sort of sideways

837
00:19:06,778 --> 00:19:08,280
around the heat shield.

838
00:19:08,280 --> 00:19:09,781

Um, however, we have-- do have

839
00:19:09,781 --> 00:19:11,149
a couple of brave guys

840
00:19:11,149 --> 00:19:13,719
that sit out in the-- in

841
00:19:13,719 --> 00:19:15,087
the full environment.

842
00:19:15,087 --> 00:19:17,022
Uh, we have four sort of

843
00:19:17,022 --> 00:19:18,223
radio antennas.

844
00:19:18,223 --> 00:19:19,491
Uh, they're electric field

845
00:19:19,491 --> 00:19:21,159
antennas that come out, um,

846
00:19:21,159 --> 00:19:22,661
and they-they are on each side

847
00:19:22,661 --> 00:19:24,129
of the, uh, of the heat shield.

848
00:19:24,129 --> 00:19:25,030
So they make a nice cross

849
00:19:25,030 --> 00:19:26,999
shape so we can do, um, full,

850
00:19:26,999 --> 00:19:28,433
uh, sweeps and get

851
00:19:28,433 --> 00:19:30,102
all of the-the data we want.

852
00:19:30,102 --> 00:19:31,503
Um, they're very thin whips.

853
00:19:31,503 --> 00:19:32,871
They're made of niobium.

854
00:19:32,871 --> 00:19:34,573
And, uh, they're sort of like

855
00:19:34,573 --> 00:19:35,908
little tubes of niobium.

856
00:19:35,908 --> 00:19:37,409
Um, and they-they stick out.

857
00:19:37,409 --> 00:19:38,577
And then we have an instrument

858
00:19:38,577 --> 00:19:39,511
that I always think of

859
00:19:39,511 --> 00:19:40,546
as the bravest little instrument

860
00:19:40,546 --> 00:19:41,747
on the spacecraft, because

861
00:19:41,747 --> 00:19:43,782
it is not a thin tube of--

862
00:19:43,782 --> 00:19:45,751
it's a big, honking instrument.

863
00:19:45,751 --> 00:19:47,319

And it's, uh, it's

864
00:19:47,319 --> 00:19:48,353
a Faraday cup.

865
00:19:48,353 --> 00:19:49,087
So we call it

866
00:19:49,087 --> 00:19:50,789
the Solar Probe Cup, SPC.

867
00:19:50,789 --> 00:19:52,324
Faraday cups have been flown

868
00:19:52,324 --> 00:19:53,191
for years and years.

869
00:19:53,191 --> 00:19:54,326
They're very simple instruments.

870
00:19:54,326 --> 00:19:55,027
They measure particle

871
00:19:55,027 --> 00:19:56,128
populations.

872
00:19:56,128 --> 00:19:57,029
But getting one that can

873
00:19:57,029 --> 00:19:58,797
survive this incredible

874
00:19:58,797 --> 00:20:00,499
heat, and cool, and heat,

875
00:20:00,499 --> 00:20:01,266
and cool--

876
00:20:01,266 --> 00:20:01,733
>> Yeah.

877
00:20:01,733 --> 00:20:02,701
>> It's a really important

878
00:20:02,701 --> 00:20:03,769
instrument because it's looking

879
00:20:03,769 --> 00:20:05,003
at exactly what is

880
00:20:05,003 --> 00:20:06,071
coming towards the spacecraft

881
00:20:06,071 --> 00:20:07,205
right now.

882
00:20:07,205 --> 00:20:08,273
>> Oh, interesting.

883
00:20:08,273 --> 00:20:09,308
>> There's no hid-- no hiding

884
00:20:09,308 --> 00:20:10,142
behind the shade,

885
00:20:10,142 --> 00:20:11,276
no peeping around the side.

886
00:20:11,276 --> 00:20:12,477
It's looking at what we're

887
00:20:12,477 --> 00:20:13,612
flying into.

888
00:20:13,612 --> 00:20:14,546

And so it's a very important

889
00:20:14,546 --> 00:20:15,781
instrument for us.

890
00:20:15,781 --> 00:20:17,683
>> One of my questions, concerns

891
00:20:17,683 --> 00:20:18,750
would be that you're gonna have

892
00:20:18,750 --> 00:20:20,552
plasma coming around the edge

893
00:20:20,552 --> 00:20:21,286
of your heat shield.

894
00:20:21,286 --> 00:20:22,020
Are you expecting this thing

895
00:20:22,020 --> 00:20:23,322
to have issues with that?

896
00:20:23,322 --> 00:20:24,556
>> So one of the things--

897
00:20:24,556 --> 00:20:25,490
it's-it's difficult

898
00:20:25,490 --> 00:20:26,458
to visualize.

899
00:20:26,458 --> 00:20:28,660
You know, I-I explain, "well,

900
00:20:28,660 --> 00:20:29,328
"the heat shield gets

901
00:20:29,328 --> 00:20:30,329
"really hot, and everything else

902
00:20:30,329 --> 00:20:31,229
"is in the shade."

903
00:20:31,229 --> 00:20:32,197
And people will say, "but,

904
00:20:32,197 --> 00:20:33,065
"well, I mean, you've still got

905
00:20:33,065 --> 00:20:33,799
"3 million degree plasma

906
00:20:33,799 --> 00:20:34,700
"all around you.

907
00:20:34,700 --> 00:20:36,602
"Why are you not still

908
00:20:36,602 --> 00:20:39,404
"feeling, um, the-the effects

909
00:20:39,404 --> 00:20:41,373
"of it?" but if you think of

910
00:20:41,373 --> 00:20:42,541
being on the beach,

911
00:20:42,541 --> 00:20:44,176
here you're sitting under

912
00:20:44,176 --> 00:20:44,676
an umbrella.

913
00:20:44,676 --> 00:20:45,310

You have, essentially,

914
00:20:45,310 --> 00:20:46,311
a heat shield, but

915
00:20:46,311 --> 00:20:47,879
you're still incredibly hot.

916
00:20:47,879 --> 00:20:48,380
>> Sure.

917
00:20:48,380 --> 00:20:49,648
>> Because the sand has absorbed

918
00:20:49,648 --> 00:20:52,217
all of the-the heat, um,

919
00:20:52,217 --> 00:20:53,552
and you've got a lot of

920
00:20:53,552 --> 00:20:54,386
convection, and you've got

921
00:20:54,386 --> 00:20:55,320
wind, you've got current things

922
00:20:55,320 --> 00:20:56,188
that are blowing.

923
00:20:56,188 --> 00:20:58,557
In space, there are no--

924
00:20:58,557 --> 00:20:59,524
there's no convection.

925
00:20:59,524 --> 00:21:00,826
There's no, um, there's no

926
00:21:00,826 --> 00:21:02,995
real atmosphere in the same way.

927
00:21:02,995 --> 00:21:05,831
So space is cold, um,

928
00:21:05,831 --> 00:21:07,499
around you.

929
00:21:07,499 --> 00:21:08,700
There's no-- there's no sort of

930
00:21:08,700 --> 00:21:09,935
plasma that can come around

931
00:21:09,935 --> 00:21:11,937
because there-there's nothing

932
00:21:11,937 --> 00:21:13,605
to sort of blow it into

933
00:21:13,605 --> 00:21:14,906
the side of the spacecraft.

934
00:21:14,906 --> 00:21:15,707
>> Okay.

935
00:21:15,707 --> 00:21:16,375
>> And so the-the side of

936
00:21:16,375 --> 00:21:17,242
the spacecraft will stay

937
00:21:17,242 --> 00:21:19,811
nice and-and sort of cool

938
00:21:19,811 --> 00:21:21,947

at this about 80-degree, um,

939
00:21:21,947 --> 00:21:23,281
Fahrenheit level.

940
00:21:23,281 --> 00:21:25,984
Um, but the-the-the way the--

941
00:21:25,984 --> 00:21:26,818
that we're traveling,

942
00:21:26,818 --> 00:21:28,053
we will see a great deal of

943
00:21:28,053 --> 00:21:29,554
different temperatures

944
00:21:29,554 --> 00:21:30,722
on the heat shield as we get

945
00:21:30,722 --> 00:21:32,124
close, and then we get cold.

946
00:21:32,124 --> 00:21:33,058
And so we do know that

947
00:21:33,058 --> 00:21:34,026
the heat shield will kind of

948
00:21:34,026 --> 00:21:35,761
deform on orbit.

949
00:21:35,761 --> 00:21:37,162
It will sort of maybe puff out

950
00:21:37,162 --> 00:21:38,096
like a drum.

951
00:21:38,096 --> 00:21:39,131
It may even do a kind of

952
00:21:39,131 --> 00:21:40,265
a potato-chipping.

953
00:21:40,265 --> 00:21:41,033
So if you think of the shape

954
00:21:41,033 --> 00:21:42,234
of a Pringle, where,

955
00:21:42,234 --> 00:21:42,834
you know, maybe

956
00:21:42,834 --> 00:21:43,802
two sides are gonna go up and

957
00:21:43,802 --> 00:21:45,037
two sides are gonna go down.

958
00:21:45,037 --> 00:21:45,837
>> So is this like a melting

959
00:21:45,837 --> 00:21:46,471
heat shield?

960
00:21:46,471 --> 00:21:46,938
Is that what

961
00:21:46,938 --> 00:21:47,606
we're lookin' at here?

962
00:21:47,606 --> 00:21:48,473
>> It's not melting.

963
00:21:48,473 --> 00:21:49,808

It's just, um, changing,

964
00:21:49,808 --> 00:21:50,809
you know-- it's-it's gonna

965
00:21:50,809 --> 00:21:51,910
get bigger in certain points

966
00:21:51,910 --> 00:21:53,311
and smaller in other points

967
00:21:53,311 --> 00:21:54,646
as it's getting-- it's--

968
00:21:54,646 --> 00:21:55,514
you know, it's gonna get

969
00:21:55,514 --> 00:21:56,615
very hot, and the sh--

970
00:21:56,615 --> 00:21:58,216
we know the shape will change.

971
00:21:58,216 --> 00:21:59,918
Um, and so we have this design

972
00:21:59,918 --> 00:22:01,820
of the way we attach

973
00:22:01,820 --> 00:22:03,188
the heat shield to

974
00:22:03,188 --> 00:22:04,556
the spacecraft is, again,

975
00:22:04,556 --> 00:22:07,159
a-- just a breathtaking

976
00:22:07,159 --> 00:22:09,027
piece of technology.

977
00:22:09,027 --> 00:22:10,162
Um, and we have--

978
00:22:10,162 --> 00:22:11,396
they're on rather like

979
00:22:11,396 --> 00:22:12,564
shoulder joints, again.

980
00:22:12,564 --> 00:22:14,666
So you can, um, you can imagine

981
00:22:14,666 --> 00:22:17,102
as the thing is changing,

982
00:22:17,102 --> 00:22:18,537
the whole sort of attachment

983
00:22:18,537 --> 00:22:21,273
fixture is moving with it.

984
00:22:21,273 --> 00:22:22,808
It's kind of-- kind of

985
00:22:22,808 --> 00:22:23,508
giving in to it, and

986
00:22:23,508 --> 00:22:24,810
it's never-- you know,

987
00:22:24,810 --> 00:22:26,111
it's not gonna just snap off.

988
00:22:26,111 --> 00:22:27,579

It's going to kind of move.

989
00:22:27,579 --> 00:22:28,113
>> Sure.

990
00:22:28,113 --> 00:22:28,980
>> As the heat shield deforms

991
00:22:28,980 --> 00:22:30,949
in different ways

992
00:22:30,949 --> 00:22:32,617
at different times and

993
00:22:32,617 --> 00:22:33,418
different distances from

994
00:22:33,418 --> 00:22:34,386
the Sun.

995
00:22:34,386 --> 00:22:35,620
Um, the other thing is

996
00:22:35,620 --> 00:22:37,656
we-we have to minimize

997
00:22:37,656 --> 00:22:39,324
the, uh, the amount of heat

998
00:22:39,324 --> 00:22:40,525
that gets conducted into

999
00:22:40,525 --> 00:22:41,960
the spacecraft.

1000
00:22:41,960 --> 00:22:43,762
And so the whole, um,

1001
00:22:43,762 --> 00:22:45,464
heat shield is, uh, attached

1002
00:22:45,464 --> 00:22:47,299
with six carbon bolts only,

1003
00:22:47,299 --> 00:22:50,068
um, which is amazing to me.

1004
00:22:50,068 --> 00:22:51,336
>> Yeah, that's-- that sounds

1005
00:22:51,336 --> 00:22:52,003
like not a lot for

1006
00:22:52,003 --> 00:22:53,438
a spacecraft headed to the Sun.

1007
00:22:53,438 --> 00:22:54,005
>> Right?

1008
00:22:54,005 --> 00:22:55,040
Um, but you know,

1009
00:22:55,040 --> 00:22:55,907
we've obviously tested

1010
00:22:55,907 --> 00:22:56,908
and tested and tested.

1011
00:22:56,908 --> 00:22:58,510
And, uh, they're-they're

1012
00:22:58,510 --> 00:22:59,377
sort of-- they call them

1013
00:22:59,377 --> 00:23:00,245

pie pan structures.

1014
00:23:00,245 --> 00:23:01,012
They look like inverted

1015
00:23:01,012 --> 00:23:02,681
pie pans that are on the back

1016
00:23:02,681 --> 00:23:03,715
side of the heat shield.

1017
00:23:03,715 --> 00:23:04,583
And you'll see them in

1018
00:23:04,583 --> 00:23:05,884
some of the, uh, the pictures

1019
00:23:05,884 --> 00:23:07,953
of the-- um, when you see

1020
00:23:07,953 --> 00:23:08,687
our heat shield actually

1021
00:23:08,687 --> 00:23:09,654
attached to the spacecraft,

1022
00:23:09,654 --> 00:23:10,889
you can see these pie pans.

1023
00:23:10,889 --> 00:23:12,190
Um, and then we have

1024
00:23:12,190 --> 00:23:14,860
this just beautiful titanium

1025
00:23:14,860 --> 00:23:17,295
welded structure that is, um,

1026
00:23:17,295 --> 00:23:19,498
it's like a-- I don't know,

1027
00:23:19,498 --> 00:23:23,135
s-- like a cone-shaped, um,

1028
00:23:23,135 --> 00:23:24,936
that is attached to the main

1029
00:23:24,936 --> 00:23:25,804
body of the spacecraft,

1030
00:23:25,804 --> 00:23:27,906
and then, um, goes up and out,

1031
00:23:27,906 --> 00:23:28,874
and the heat shield attaches

1032
00:23:28,874 --> 00:23:30,976
on the top of this structure.

1033
00:23:30,976 --> 00:23:32,944
And I can tell you that, um,

1034
00:23:32,944 --> 00:23:35,347
I have-- I'm not-- it will

1035
00:23:35,347 --> 00:23:36,515
probably surprise you--

1036
00:23:36,515 --> 00:23:37,682
I'm not a welder.

1037
00:23:37,682 --> 00:23:40,252
Um, but-but I have engineers

1038
00:23:40,252 --> 00:23:41,453

who I've seen kind of go

1039
00:23:41,453 --> 00:23:43,855
almost weepy at the beautiful

1040
00:23:43,855 --> 00:23:44,890
quality of the welding

1041
00:23:44,890 --> 00:23:45,924
of this structure.

1042
00:23:45,924 --> 00:23:47,793
Um, it is just phenomenal.

1043
00:23:47,793 --> 00:23:49,027
And it's made of titanium,

1044
00:23:49,027 --> 00:23:50,195
and, uh, that's what holds

1045
00:23:50,195 --> 00:23:51,029
our heat shield to

1046
00:23:51,029 --> 00:23:52,097
the spacecraft.

1047
00:23:52,097 --> 00:23:53,298
>> So people who appreciate

1048
00:23:53,298 --> 00:23:55,066
great engineering and

1049
00:23:55,066 --> 00:23:56,368
really cool technology,

1050
00:23:56,368 --> 00:23:57,602
this is a moment to geek out

1051
00:23:57,602 --> 00:23:58,537
on that.

1052
00:23:58,537 --> 00:24:00,205
>> It really is, and, uh,

1053
00:24:00,205 --> 00:24:01,807
not only does this truss

1054
00:24:01,807 --> 00:24:03,275
hold our heat shield in place,

1055
00:24:03,275 --> 00:24:04,242
but it also holds

1056
00:24:04,242 --> 00:24:06,311
the cooling system for

1057
00:24:06,311 --> 00:24:08,313
the solar panels.

1058
00:24:08,313 --> 00:24:09,047
So it's an amazing piece

1059
00:24:09,047 --> 00:24:10,715
of technology.

1060
00:24:10,715 --> 00:24:11,917
>> How should people kind of

1061
00:24:11,917 --> 00:24:12,951
relate to this mission?

1062
00:24:12,951 --> 00:24:13,852
Because there's a sexiness

1063
00:24:13,852 --> 00:24:14,953

to the idea of like flying

1064
00:24:14,953 --> 00:24:15,954
near the sun, but

1065
00:24:15,954 --> 00:24:16,788
what are you learning

1066
00:24:16,788 --> 00:24:17,956
to help people, and why should

1067
00:24:17,956 --> 00:24:19,457
people be really interested

1068
00:24:19,457 --> 00:24:20,926
in this?

1069
00:24:20,926 --> 00:24:22,627
>> So the big mysteries are

1070
00:24:22,627 --> 00:24:24,429
really why the corona is

1071
00:24:24,429 --> 00:24:26,731
so hot, why it's so active.

1072
00:24:26,731 --> 00:24:27,465
So where you see

1073
00:24:27,465 --> 00:24:28,500
this 3 million-degree

1074
00:24:28,500 --> 00:24:30,802
temperature, the plasma itself,

1075
00:24:30,802 --> 00:24:31,603
the coronal material,

1076
00:24:31,603 --> 00:24:33,638
suddenly gets so energized

1077
00:24:33,638 --> 00:24:34,840
that it can move away from

1078
00:24:34,840 --> 00:24:36,541
the Sun, and it sort of

1079
00:24:36,541 --> 00:24:37,576
bathes all the planets,

1080
00:24:37,576 --> 00:24:38,577
that it's a-- it's

1081
00:24:38,577 --> 00:24:39,444
a continual streaming.

1082
00:24:39,444 --> 00:24:41,112
We call it the solar wind.

1083
00:24:41,112 --> 00:24:42,380
And Gene Parker, for whom

1084
00:24:42,380 --> 00:24:43,515
the mission was-- is named

1085
00:24:43,515 --> 00:24:44,716
actually predicted

1086
00:24:44,716 --> 00:24:47,352
there would be a solar wind.

1087
00:24:47,352 --> 00:24:48,753
>> When I first stumbled across

1088
00:24:48,753 --> 00:24:50,488

the mathematics and established

1089
00:24:50,488 --> 00:24:54,693
the solar wind, it was 1957.

1090
00:24:54,693 --> 00:24:56,795
I was 30 years old.

1091
00:24:56,795 --> 00:25:00,899
C over V equals...

1092
00:25:00,899 --> 00:25:02,200
It's so simple.

1093
00:25:02,200 --> 00:25:04,936
Four lines of algebra, and

1094
00:25:04,936 --> 00:25:06,404
it sort of hit me--

1095
00:25:06,404 --> 00:25:08,440
it's a solar wind.

1096
00:25:08,440 --> 00:25:10,275
>> We're essentially a boulder

1097
00:25:10,275 --> 00:25:11,509
in the stream that is

1098
00:25:11,509 --> 00:25:12,844
flowing from the Sun

1099
00:25:12,844 --> 00:25:13,612
all the time.

1100
00:25:13,612 --> 00:25:14,112
>> That's a really interesting

1101
00:25:14,112 --> 00:25:14,713
way to look at it.

1102
00:25:14,713 --> 00:25:15,347
>> And so, you know,

1103
00:25:15,347 --> 00:25:15,914
here we are.

1104
00:25:15,914 --> 00:25:17,082
We are now, um,

1105
00:25:17,082 --> 00:25:18,650
we're interacting with

1106
00:25:18,650 --> 00:25:19,751
this solar wind.

1107
00:25:19,751 --> 00:25:21,620
And so it gets very accelerated.

1108
00:25:21,620 --> 00:25:23,121
It carries with it

1109
00:25:23,121 --> 00:25:24,990
the sun's magnetic field.

1110
00:25:24,990 --> 00:25:26,825
It carries a lot of plasma.

1111
00:25:26,825 --> 00:25:28,560
It carries a lot of particles.

1112
00:25:28,560 --> 00:25:30,028
And the Earth has

1113
00:25:30,028 --> 00:25:31,263

a magnetic field also.

1114
00:25:31,263 --> 00:25:32,297
When those fields are

1115
00:25:32,297 --> 00:25:34,199
in the opposite direction,

1116
00:25:34,199 --> 00:25:36,534
um, just like like poles repel,

1117
00:25:36,534 --> 00:25:38,169
opposite poles attract.

1118
00:25:38,169 --> 00:25:39,404
Um, it will actually allow

1119
00:25:39,404 --> 00:25:40,739
these two magnetic fields

1120
00:25:40,739 --> 00:25:41,606
to kind of join.

1121
00:25:41,606 --> 00:25:43,074
It lets all of this energy

1122
00:25:43,074 --> 00:25:44,376
in from the solar wind.

1123
00:25:44,376 --> 00:25:46,444
Lots of great physics happens

1124
00:25:46,444 --> 00:25:47,812
all around the Earth.

1125
00:25:47,812 --> 00:25:50,048
But the result is space weather.

1126
00:25:50,048 --> 00:25:51,716
Um, so the nice part of

1127
00:25:51,716 --> 00:25:52,517
space weather is

1128
00:25:52,517 --> 00:25:53,251
the beautiful Northern

1129
00:25:53,251 --> 00:25:54,185
and Southern Lights.

1130
00:25:54,185 --> 00:25:55,053
>> Okay.

1131
00:25:55,053 --> 00:25:55,921
>> The Northern and Southern

1132
00:25:55,921 --> 00:25:57,222
Lights are essentially

1133
00:25:57,222 --> 00:25:57,956
a large current system

1134
00:25:57,956 --> 00:25:59,057
flowing in the sky.

1135
00:25:59,057 --> 00:25:59,858
It's like having a big wire

1136
00:25:59,858 --> 00:26:01,192
with a current flowing

1137
00:26:01,192 --> 00:26:02,327
across it.

1138
00:26:02,327 --> 00:26:02,761

>> A really pretty one.

1139
00:26:02,761 --> 00:26:03,728
>> Very pretty.

1140
00:26:03,728 --> 00:26:05,030
Very dangerous one.

1141
00:26:05,030 --> 00:26:06,164
If it happens to be flowing

1142
00:26:06,164 --> 00:26:08,266
over a power grid at the time--

1143
00:26:08,266 --> 00:26:09,234
all currents need to have

1144
00:26:09,234 --> 00:26:11,069
somewhere to close.

1145
00:26:11,069 --> 00:26:12,938
If the ground is not

1146
00:26:12,938 --> 00:26:14,406
conducting, they will look for

1147
00:26:14,406 --> 00:26:14,873
something else to close through.

1148
00:26:14,873 --> 00:26:15,907
Very nice of you--

1149
00:26:15,907 --> 00:26:16,541
you've actually provided

1150
00:26:16,541 --> 00:26:17,575
a power grid for them.

1151
00:26:17,575 --> 00:26:19,277
They can actually flow through

1152
00:26:19,277 --> 00:26:20,111
the power grids, and cause

1153
00:26:20,111 --> 00:26:21,379
big damage.

1154
00:26:21,379 --> 00:26:21,947
>> Interesting.

1155
00:26:21,947 --> 00:26:22,714
>> Um, you know, we've had,

1156
00:26:22,714 --> 00:26:24,349
uh, catastrophic failures

1157
00:26:24,349 --> 00:26:25,150
of power grids.

1158
00:26:25,150 --> 00:26:26,151
We've had burn-outs.

1159
00:26:26,151 --> 00:26:27,052
We've had brown-outs.

1160
00:26:27,052 --> 00:26:28,586
We've had all kinds of issues.

1161
00:26:28,586 --> 00:26:30,889
If you lose your power grid,

1162
00:26:30,889 --> 00:26:32,290
everything goes down now.

1163
00:26:32,290 --> 00:26:33,591

Think how reliant we are

1164
00:26:33,591 --> 00:26:34,926
on technology.

1165
00:26:34,926 --> 00:26:36,027
Um, you can't-- you can't

1166
00:26:36,027 --> 00:26:36,795
move money-- your bank is

1167
00:26:36,795 --> 00:26:38,096
no longer working.

1168
00:26:38,096 --> 00:26:39,397
You can't put gas in your car.

1169
00:26:39,397 --> 00:26:40,665
You can't-- all these things.

1170
00:26:40,665 --> 00:26:42,100
If you lose your power,

1171
00:26:42,100 --> 00:26:43,101
eventually you'll have

1172
00:26:43,101 --> 00:26:44,202
no clean water.

1173
00:26:44,202 --> 00:26:45,770
Um, so these-these are

1174
00:26:45,770 --> 00:26:47,906
big issues that we deal with.

1175
00:26:47,906 --> 00:26:49,374
Of course, satellites get

1176
00:26:49,374 --> 00:26:50,375
damaged because you let

1177
00:26:50,375 --> 00:26:51,376
all these particles in,

1178
00:26:51,376 --> 00:26:52,344
and they can get damaged

1179
00:26:52,344 --> 00:26:53,178
'cause the radiation belts

1180
00:26:53,178 --> 00:26:54,446
pump up.

1181
00:26:54,446 --> 00:26:55,613
Everything is driven by

1182
00:26:55,613 --> 00:26:57,549
the Sun.

1183
00:26:57,549 --> 00:26:58,984
We have great models that

1184
00:26:58,984 --> 00:27:00,085
predict-- you know, you see

1185
00:27:00,085 --> 00:27:01,653
a big event on the Sun,

1186
00:27:01,653 --> 00:27:03,254
and we predict what that's

1187
00:27:03,254 --> 00:27:04,589
going to do to Earth.

1188
00:27:04,589 --> 00:27:05,557

Right now, those models have

1189
00:27:05,557 --> 00:27:06,791
a gap in them.

1190
00:27:06,791 --> 00:27:07,926
It's like the missing piece

1191
00:27:07,926 --> 00:27:09,027
of the puzzle, because

1192
00:27:09,027 --> 00:27:10,929
we don't know, truly,

1193
00:27:10,929 --> 00:27:12,230
what physics is going on

1194
00:27:12,230 --> 00:27:13,631
in that region, because

1195
00:27:13,631 --> 00:27:14,966
we've never been there.

1196
00:27:14,966 --> 00:27:15,967
And so we'll make

1197
00:27:15,967 --> 00:27:17,769
transformational improvements

1198
00:27:17,769 --> 00:27:19,504
in our ability to be able to

1199
00:27:19,504 --> 00:27:21,339
predict how the Earth is

1200
00:27:21,339 --> 00:27:22,440
going to respond to

1201
00:27:22,440 --> 00:27:24,642
our ever-changing Sun.

1202
00:27:24,642 --> 00:27:26,211
And so it's-it's a great

1203
00:27:26,211 --> 00:27:27,545
mission, it's a mission

1204
00:27:27,545 --> 00:27:28,246
of discovery, it's a voyage

1205
00:27:28,246 --> 00:27:29,881
into the unknown that

1206
00:27:29,881 --> 00:27:30,715
we're going to.

1207
00:27:30,715 --> 00:27:31,616
There be dragons.

1208
00:27:31,616 --> 00:27:33,918
Um, it's amazing from

1209
00:27:33,918 --> 00:27:35,387
the scientific point of view.

1210
00:27:35,387 --> 00:27:36,721
But does have a big

1211
00:27:36,721 --> 00:27:37,922
societal impact, because

1212
00:27:37,922 --> 00:27:39,691
that star is there.

1213
00:27:39,691 --> 00:27:40,592

It's doing whatever it wants

1214
00:27:40,592 --> 00:27:41,993
to do, and we have to live

1215
00:27:41,993 --> 00:27:43,661
in the atmosphere of that sun.

1216
00:27:43,661 --> 00:27:44,963
So it-it really does

1217
00:27:44,963 --> 00:27:46,164
affect everybody.

1218
00:27:46,164 --> 00:27:47,699
>> What NASA does is discover

1219
00:27:47,699 --> 00:27:48,933
the unknown, which is, uh,

1220
00:27:48,933 --> 00:27:50,068
a challenging thing to do.

1221
00:27:50,068 --> 00:27:51,102
Dr. Fox, appreciate you,

1222
00:27:51,102 --> 00:27:52,203
and your efforts, and your team,

1223
00:27:52,203 --> 00:27:53,204
and your hard work.

1224
00:27:53,204 --> 00:27:55,407
We wish you all the best.

1225
00:27:55,407 --> 00:27:56,641
Go Parker Solar Probe, and, uh,

1226
00:27:56,641 --> 00:27:57,542
thanks, Dr. Fox.

1227
00:27:57,542 --> 00:27:58,309
>> Coolest hottest mission

1228
00:27:58,309 --> 00:27:59,644
under the sun.

1229
00:27:59,644 --> 00:28:08,686
[music]

1230
00:28:08,686 --> 00:28:09,587
>> As Dr. Fox was talking

1231
00:28:09,587 --> 00:28:10,488
about the coatings for

1232
00:28:10,488 --> 00:28:11,456
the Parker Solar Probe

1233
00:28:11,456 --> 00:28:13,458
heat shield, it reminded me--

1234
00:28:13,458 --> 00:28:14,392
we have some similar work

1235
00:28:14,392 --> 00:28:15,326
happening in our own

1236
00:28:15,326 --> 00:28:17,028
applied physics lab.

1237
00:28:17,028 --> 00:28:17,962
As it turns out,

1238
00:28:17,962 --> 00:28:18,930

this technology is evolving

1239
00:28:18,930 --> 00:28:20,231
really fast.

1240
00:28:20,231 --> 00:28:21,132
>> Yeah, I got a phone call

1241
00:28:21,132 --> 00:28:22,233
recently from one of the big

1242
00:28:22,233 --> 00:28:23,735
aerospace companies.

1243
00:28:23,735 --> 00:28:24,169
>> Okay.

1244
00:28:24,169 --> 00:28:25,370
>> One of the-the big ones.

1245
00:28:25,370 --> 00:28:26,604
And they contacted me

1246
00:28:26,604 --> 00:28:27,939
and they said, "we think

1247
00:28:27,939 --> 00:28:29,774
"this technology is awesome.

1248
00:28:29,774 --> 00:28:31,209
"We wanna see it fast-tracked.

1249
00:28:31,209 --> 00:28:32,844
"We want to store liquid

1250
00:28:32,844 --> 00:28:34,045
"oxygen on the Moon.

1251
00:28:34,045 --> 00:28:35,480
"That's our goal, and we know

1252
00:28:35,480 --> 00:28:36,581
"we can only do that

1253
00:28:36,581 --> 00:28:37,515
"with your coating."

1254
00:28:37,515 --> 00:28:38,583
>> That's Dr. Bob Youngquist

1255
00:28:38,583 --> 00:28:39,784
with me in the booth.

1256
00:28:39,784 --> 00:28:41,019
He spent over 25 years

1257
00:28:41,019 --> 00:28:42,353
solving problems and inventing

1258
00:28:42,353 --> 00:28:43,388
solutions for Shuttle

1259
00:28:43,388 --> 00:28:44,956
ground support.

1260
00:28:44,956 --> 00:28:45,990
Since the Shuttle program ended

1261
00:28:45,990 --> 00:28:47,625
in 2011, he's been freed up

1262
00:28:47,625 --> 00:28:49,727
to do more pure research.

1263
00:28:49,727 --> 00:28:51,029

Today he's here to talk with me

1264
00:28:51,029 --> 00:28:52,697
about radiation protection.

1265
00:28:52,697 --> 00:28:53,832
My understanding is

1266
00:28:53,832 --> 00:28:54,699
you're developing something

1267
00:28:54,699 --> 00:28:56,534
that can-- could potentially

1268
00:28:56,534 --> 00:28:57,702
in the future improve

1269
00:28:57,702 --> 00:28:59,804
the ability of a probe like that

1270
00:28:59,804 --> 00:29:01,139
to get closer to the Sun?

1271
00:29:01,139 --> 00:29:02,440
>> Uh, yes, yes.

1272
00:29:02,440 --> 00:29:03,875
The, um-- right now,

1273
00:29:03,875 --> 00:29:05,710
the state-of-the-art in

1274
00:29:05,710 --> 00:29:07,078
optical solar reflectors is

1275
00:29:07,078 --> 00:29:09,514
based on silver and quartz.

1276
00:29:09,514 --> 00:29:11,049
The best-best reflection of

1277
00:29:11,049 --> 00:29:12,350
solar power that you can buy

1278
00:29:12,350 --> 00:29:13,751
is basically a quartz layer

1279
00:29:13,751 --> 00:29:15,053
on top of silver.

1280
00:29:15,053 --> 00:29:16,554
And that has the astonishing

1281
00:29:16,554 --> 00:29:18,456
result of still absorbing

1282
00:29:18,456 --> 00:29:20,425
6% of the Sun's energy.

1283
00:29:20,425 --> 00:29:21,159
That's a lot of energy

1284
00:29:21,159 --> 00:29:21,926
when you get close.

1285
00:29:21,926 --> 00:29:22,460
>> Sure.

1286
00:29:22,460 --> 00:29:23,294
>> And the Parker Solar Probe

1287
00:29:23,294 --> 00:29:24,762
people couldn't even use that

1288
00:29:24,762 --> 00:29:25,897

because the silver would melt

1289
00:29:25,897 --> 00:29:27,599
with how close they're getting.

1290
00:29:27,599 --> 00:29:29,267
I mean, the Parker Solar Probe

1291
00:29:29,267 --> 00:29:30,201
is, um, outstanding.

1292
00:29:30,201 --> 00:29:30,969
It's an incredible piece

1293
00:29:30,969 --> 00:29:32,070
of engineering.

1294
00:29:32,070 --> 00:29:33,238
Um, and then they have

1295
00:29:33,238 --> 00:29:34,239
a really effective

1296
00:29:34,239 --> 00:29:36,908
and-and-and-- shield that

1297
00:29:36,908 --> 00:29:37,876
they've developed to help

1298
00:29:37,876 --> 00:29:39,244
block the Sun's radiation.

1299
00:29:39,244 --> 00:29:41,379
But-but there's always things

1300
00:29:41,379 --> 00:29:42,280
you can do to improve on

1301
00:29:42,280 --> 00:29:42,847
these things.

1302
00:29:42,847 --> 00:29:43,615
>> Absolutely.

1303
00:29:43,615 --> 00:29:44,482
>> And, um, we believe that

1304
00:29:44,482 --> 00:29:45,717
our coatings would allow you

1305
00:29:45,717 --> 00:29:46,951
to reflect away more of

1306
00:29:46,951 --> 00:29:48,586
the Sun's energy, so that

1307
00:29:48,586 --> 00:29:49,420
your shield wouldn't get

1308
00:29:49,420 --> 00:29:51,589
as-as hot.

1309
00:29:51,589 --> 00:29:52,257
And if you can keep

1310
00:29:52,257 --> 00:29:53,258
the shield temperature down,

1311
00:29:53,258 --> 00:29:54,859
you can get closer.

1312
00:29:54,859 --> 00:29:56,895
The Parker Solar Probe,

1313
00:29:56,895 --> 00:29:57,962

the heat shield gets

1314
00:29:57,962 --> 00:29:59,063
really, really hot.

1315
00:29:59,063 --> 00:29:59,831
You don't wanna sit under

1316
00:29:59,831 --> 00:30:00,899
a broiler.

1317
00:30:00,899 --> 00:30:01,799
>> Okay, yeah.

1318
00:30:01,799 --> 00:30:02,600
>> This thing's hotter than

1319
00:30:02,600 --> 00:30:03,201
a broiler.

1320
00:30:03,201 --> 00:30:03,968
>> I don't wanna sit on that.

1321
00:30:03,968 --> 00:30:04,736
>> Don't wanna sit-- right.

1322
00:30:04,736 --> 00:30:05,403
So they put about 4 inches

1323
00:30:05,403 --> 00:30:06,471
of carbon foam in there

1324
00:30:06,471 --> 00:30:07,272
to act as an insulator.

1325
00:30:07,272 --> 00:30:07,805
>> Okay.

1326
00:30:07,805 --> 00:30:08,506
>> And that's great.

1327
00:30:08,506 --> 00:30:09,307
It works.

1328
00:30:09,307 --> 00:30:10,542
What we would rather do

1329
00:30:10,542 --> 00:30:11,676
is let our shield

1330
00:30:11,676 --> 00:30:13,578
radiate that heat backwards.

1331
00:30:13,578 --> 00:30:14,345
>> Okay.

1332
00:30:14,345 --> 00:30:15,547
>> And put in a silver

1333
00:30:15,547 --> 00:30:17,482
reflector, so the infrared

1334
00:30:17,482 --> 00:30:18,616
radiation that would normally

1335
00:30:18,616 --> 00:30:19,984
hit us bounces off of

1336
00:30:19,984 --> 00:30:20,919
that silver reflector and

1337
00:30:20,919 --> 00:30:22,320
gets thrown off to the sides.

1338
00:30:22,320 --> 00:30:22,987

>> I see.

1339
00:30:22,987 --> 00:30:23,855
>> So we would rather use

1340
00:30:23,855 --> 00:30:25,690
a radiative shield than

1341
00:30:25,690 --> 00:30:27,559
a big thick piece of--

1342
00:30:27,559 --> 00:30:28,326
>> Okay.

1343
00:30:28,326 --> 00:30:29,360
>> Of carbon shield.

1344
00:30:29,360 --> 00:30:29,961
>> Okay.

1345
00:30:29,961 --> 00:30:31,829
>> Um, so, assuming that,

1346
00:30:31,829 --> 00:30:32,497
and assuming we have

1347
00:30:32,497 --> 00:30:34,866
a very good reflective surface,

1348
00:30:34,866 --> 00:30:35,934
we believe we can get

1349
00:30:35,934 --> 00:30:38,269
maybe ten times closer

1350
00:30:38,269 --> 00:30:40,271
to the Sun than

1351
00:30:40,271 --> 00:30:41,372
the Parker Solar Probe.

1352
00:30:41,372 --> 00:30:42,173
>> So I think they're getting

1353
00:30:42,173 --> 00:30:43,908
about 4 million miles, so

1354
00:30:43,908 --> 00:30:44,576
you're talking about getting

1355
00:30:44,576 --> 00:30:45,777
in the range of like--

1356
00:30:45,777 --> 00:30:46,544
>> 0.4, 0.4.

1357
00:30:46,544 --> 00:30:47,946
>> 0.4 million miles.

1358
00:30:47,946 --> 00:30:48,379
>> Yeah.

1359
00:30:48,379 --> 00:30:49,113
>> So 400,000 miles,

1360
00:30:49,113 --> 00:30:49,948
which, again--

1361
00:30:49,948 --> 00:30:50,481
>> Yeah, from the surface

1362
00:30:50,481 --> 00:30:51,015
of the Sun.

1363
00:30:51,015 --> 00:30:51,616

>> Coming from here on Earth,

1364
00:30:51,616 --> 00:30:52,283
93 million miles.

1365
00:30:52,283 --> 00:30:52,884
>> Yeah.

1366
00:30:52,884 --> 00:30:53,851
>> That's incredibly close.

1367
00:30:53,851 --> 00:30:54,852
>> Incredibly close.

1368
00:30:54,852 --> 00:30:55,687
>> So future missions

1369
00:30:55,687 --> 00:30:57,121
could-could pull on you guys

1370
00:30:57,121 --> 00:30:58,556
not to create great

1371
00:30:58,556 --> 00:31:00,325
scientific instruments for

1372
00:31:00,325 --> 00:31:01,593
their spacecraft, but

1373
00:31:01,593 --> 00:31:02,393
to help them protect

1374
00:31:02,393 --> 00:31:03,561
those spacecraft even better.

1375
00:31:03,561 --> 00:31:04,862
>> That's-that's exactly right.

1376
00:31:04,862 --> 00:31:05,830
In fact, I was, um, invited

1377
00:31:05,830 --> 00:31:07,098
to go talk to the Science

1378
00:31:07,098 --> 00:31:07,932
Mission directorate

1379
00:31:07,932 --> 00:31:08,733
a couple of weeks ago

1380
00:31:08,733 --> 00:31:10,368
in Washington to-to discuss

1381
00:31:10,368 --> 00:31:11,636
this-this very thing.

1382
00:31:11,636 --> 00:31:13,004
And, uh, they're-they're

1383
00:31:13,004 --> 00:31:14,072
interested in looking,

1384
00:31:14,072 --> 00:31:16,074
down the road, at what a, um,

1385
00:31:16,074 --> 00:31:18,309
a future heliophysics mission

1386
00:31:18,309 --> 00:31:20,078
to the Sun might look like.

1387
00:31:20,078 --> 00:31:21,679
And our-our coatings are

1388
00:31:21,679 --> 00:31:23,047

one option, you know, that

1389
00:31:23,047 --> 00:31:23,948
could be brought to bear

1390
00:31:23,948 --> 00:31:24,882
to help get even closer

1391
00:31:24,882 --> 00:31:25,617
to the Sun than

1392
00:31:25,617 --> 00:31:27,252
the Parker Solar Probe.

1393
00:31:27,252 --> 00:31:28,586
So, so let me talk a little bit

1394
00:31:28,586 --> 00:31:29,654
about some more applications.

1395
00:31:29,654 --> 00:31:30,655
>> Yeah, that'd be awesome.

1396
00:31:30,655 --> 00:31:31,456
I'd love to hear.

1397
00:31:31,456 --> 00:31:34,926
>> Okay, so the original request

1398
00:31:34,926 --> 00:31:36,561
was that we be able to take

1399
00:31:36,561 --> 00:31:37,695
liquid oxygen to Mars.

1400
00:31:37,695 --> 00:31:38,596
>> Okay.

1401
00:31:38,596 --> 00:31:39,697
>> And we-we demonstrated

1402
00:31:39,697 --> 00:31:41,032
theoretically and then

1403
00:31:41,032 --> 00:31:42,166
built our coatings, we put them

1404
00:31:42,166 --> 00:31:43,534
into a-- we actually built

1405
00:31:43,534 --> 00:31:44,669
a chamber that we could

1406
00:31:44,669 --> 00:31:46,104
chill down to 40 Kelvin--

1407
00:31:46,104 --> 00:31:47,739
very-- almost-almost-almost

1408
00:31:47,739 --> 00:31:49,274
absolute zero-- chill things

1409
00:31:49,274 --> 00:31:51,476
down, put our samples in there,

1410
00:31:51,476 --> 00:31:52,877
hit them with-with light,

1411
00:31:52,877 --> 00:31:54,512
and look and see whether

1412
00:31:54,512 --> 00:31:55,480
they were absorbing or not.

1413
00:31:55,480 --> 00:31:56,180

>> Okay.

1414
00:31:56,180 --> 00:31:56,848
>> And so far, we've done

1415
00:31:56,848 --> 00:31:58,216
quite well on those tests.

1416
00:31:58,216 --> 00:31:59,350
The coatings are-are holding up.

1417
00:31:59,350 --> 00:32:00,151
We need to do a little more

1418
00:32:00,151 --> 00:32:01,386
work, but we're demonstrating

1419
00:32:01,386 --> 00:32:02,453
we can keep things cold

1420
00:32:02,453 --> 00:32:03,421
in space.

1421
00:32:03,421 --> 00:32:04,255
>> You kind of blew past this,

1422
00:32:04,255 --> 00:32:05,123
but you built a chamber

1423
00:32:05,123 --> 00:32:06,991
to test things at 40 Kelvin?

1424
00:32:06,991 --> 00:32:08,192
>> Well, yeah, we have

1425
00:32:08,192 --> 00:32:09,093
a cryogenics lab at

1426
00:32:09,093 --> 00:32:09,927
the Kennedy Space Center.

1427
00:32:09,927 --> 00:32:10,461
>> Okay.

1428
00:32:10,461 --> 00:32:10,995
>> And they have something

1429
00:32:10,995 --> 00:32:12,163
called a cryo cooler, which

1430
00:32:12,163 --> 00:32:12,997
will take you down to about

1431
00:32:12,997 --> 00:32:14,032
20 Kelvin, which is

1432
00:32:14,032 --> 00:32:15,466
liquid hydrogen temperature.

1433
00:32:15,466 --> 00:32:16,401
>> Sure.

1434
00:32:16,401 --> 00:32:17,769
>> Um, when we put heat loads

1435
00:32:17,769 --> 00:32:18,770
on it and add structure

1436
00:32:18,770 --> 00:32:20,872
to that surface, it comes up

1437
00:32:20,872 --> 00:32:22,173
to maybe 40 Kelvin.

1438
00:32:22,173 --> 00:32:23,374

So we're really operating at

1439
00:32:23,374 --> 00:32:24,742
about 40 Kelvin, which is

1440
00:32:24,742 --> 00:32:25,843
very, very cold.

1441
00:32:25,843 --> 00:32:26,511
>> Which is an accomplishment

1442
00:32:26,511 --> 00:32:27,412
on its own to be able to test

1443
00:32:27,412 --> 00:32:28,279
with that, but you guys are

1444
00:32:28,279 --> 00:32:29,314
getting a chance to test

1445
00:32:29,314 --> 00:32:30,281
in an actual environment

1446
00:32:30,281 --> 00:32:31,649
your coatings, which is

1447
00:32:31,649 --> 00:32:32,383
fantastic.

1448
00:32:32,383 --> 00:32:33,217
>> That's right, we have

1449
00:32:33,217 --> 00:32:34,185
a chamber that we evacuate

1450
00:32:34,185 --> 00:32:35,520
and chill down to very cold

1451
00:32:35,520 --> 00:32:36,554
temperatures, we paint

1452
00:32:36,554 --> 00:32:37,555
the walls all black.

1453
00:32:37,555 --> 00:32:38,222
>> Okay.

1454
00:32:38,222 --> 00:32:38,990
>> So if you were sitting

1455
00:32:38,990 --> 00:32:39,957
in there, it would be as if

1456
00:32:39,957 --> 00:32:41,259
you were sitting out in,

1457
00:32:41,259 --> 00:32:42,660
you know, deep space.

1458
00:32:42,660 --> 00:32:43,261
>> Wow.

1459
00:32:43,261 --> 00:32:44,495
>> Very cold environment,

1460
00:32:44,495 --> 00:32:45,697
very black environment.

1461
00:32:45,697 --> 00:32:46,597
And then there's a little window

1462
00:32:46,597 --> 00:32:47,432
at the top, and we can

1463
00:32:47,432 --> 00:32:48,633

bring in what radiation we want

1464
00:32:48,633 --> 00:32:50,435
to-to simulate various

1465
00:32:50,435 --> 00:32:51,569
wavelengths, sort of bringing in

1466
00:32:51,569 --> 00:32:52,470
a simulated sun.

1467
00:32:52,470 --> 00:32:53,137
>> Sure.

1468
00:32:53,137 --> 00:32:54,105
>> Now, it's hard to simulate

1469
00:32:54,105 --> 00:32:55,106
the Sun exactly.

1470
00:32:55,106 --> 00:32:56,107
>> Yeah, no doubt.

1471
00:32:56,107 --> 00:32:57,108
>> Yeah, but we can-- we can

1472
00:32:57,108 --> 00:32:59,644
make ballpark simulations.

1473
00:32:59,644 --> 00:33:00,411
So it's-- I don't wanna--

1474
00:33:00,411 --> 00:33:01,746
I don't wanna say this testing

1475
00:33:01,746 --> 00:33:03,014
replaces an actual test

1476
00:33:03,014 --> 00:33:03,781
in space.

1477
00:33:03,781 --> 00:33:04,515
>> Sure.

1478
00:33:04,515 --> 00:33:05,683
>> But it's-it's a good step.

1479
00:33:05,683 --> 00:33:06,351
>> Yeah.

1480
00:33:06,351 --> 00:33:07,185
>> And the people up at

1481
00:33:07,185 --> 00:33:07,952
the Glenn Research Center

1482
00:33:07,952 --> 00:33:09,020
are working with us, building

1483
00:33:09,020 --> 00:33:10,321
a higher fidelity version

1484
00:33:10,321 --> 00:33:11,389
of that system.

1485
00:33:11,389 --> 00:33:11,789
>> Cool.

1486
00:33:11,789 --> 00:33:12,490
So you were talking about

1487
00:33:12,490 --> 00:33:13,024
applications-- I wanna

1488
00:33:13,024 --> 00:33:13,658

get back to that.

1489
00:33:13,658 --> 00:33:15,026
>> Yeah, so there-- the people

1490
00:33:15,026 --> 00:33:16,494
at Glenn that we're working

1491
00:33:16,494 --> 00:33:17,362
with, they're very interested

1492
00:33:17,362 --> 00:33:19,364
in taking propellants

1493
00:33:19,364 --> 00:33:20,998
into space and storing them.

1494
00:33:20,998 --> 00:33:22,100
There's a lot of interest

1495
00:33:22,100 --> 00:33:23,701
out there in taking liquid

1496
00:33:23,701 --> 00:33:26,237
natural gas into space

1497
00:33:26,237 --> 00:33:28,039
and preserving it, you know,

1498
00:33:28,039 --> 00:33:29,474
liquid oxygen into space

1499
00:33:29,474 --> 00:33:30,408
and preserving it without

1500
00:33:30,408 --> 00:33:31,576
active cooling-- being able

1501
00:33:31,576 --> 00:33:32,543
to take this stuff on a long--

1502
00:33:32,543 --> 00:33:33,845
a long mission.

1503
00:33:33,845 --> 00:33:34,412
Rather than having to take

1504
00:33:34,412 --> 00:33:35,580
nitrogen tetroxide, you actually

1505
00:33:35,580 --> 00:33:37,281
take liquid oxygen.

1506
00:33:37,281 --> 00:33:38,316
And liquid oxygen has

1507
00:33:38,316 --> 00:33:39,851
much more oxygen in it

1508
00:33:39,851 --> 00:33:42,153
than nitrogen tetroxide,

1509
00:33:42,153 --> 00:33:43,054
which is the other material

1510
00:33:43,054 --> 00:33:44,088
that's often used as

1511
00:33:44,088 --> 00:33:45,323
an oxidizer.

1512
00:33:45,323 --> 00:33:46,591
So you gain a lot of weight

1513
00:33:46,591 --> 00:33:47,525

advantage if you can kick

1514
00:33:47,525 --> 00:33:49,026
liquid oxygen and not have to

1515
00:33:49,026 --> 00:33:50,027
add a lot of cryo coolers

1516
00:33:50,027 --> 00:33:51,129
and, you know, active cooling

1517
00:33:51,129 --> 00:33:52,230
kind of systems.

1518
00:33:52,230 --> 00:33:53,931
You could put a tank

1519
00:33:53,931 --> 00:33:55,266
out in space and it would

1520
00:33:55,266 --> 00:33:56,300
get cold.

1521
00:33:56,300 --> 00:33:57,235
It would just emit away

1522
00:33:57,235 --> 00:33:59,470
radiation into the background

1523
00:33:59,470 --> 00:34:00,371
of the-- of the universe

1524
00:34:00,371 --> 00:34:01,773
and get colder, and colder,

1525
00:34:01,773 --> 00:34:02,874
and colder.

1526
00:34:02,874 --> 00:34:04,041
And you'd be able to store

1527
00:34:04,041 --> 00:34:05,877
liquid oxygen in space.

1528
00:34:05,877 --> 00:34:07,345
>> Which is pretty cold.

1529
00:34:07,345 --> 00:34:08,112
>> Which is really cold.

1530
00:34:08,112 --> 00:34:09,347
Yeah, 90 Kelvin.

1531
00:34:09,347 --> 00:34:09,947
>> Okay.

1532
00:34:09,947 --> 00:34:11,048
>> Yeah, very, very cold.

1533
00:34:11,048 --> 00:34:11,949
>> Which is roughly, like,

1534
00:34:11,949 --> 00:34:14,519
-350 Fahrenheit?

1535
00:34:14,519 --> 00:34:15,353
>> Yeah, something like that.

1536
00:34:15,353 --> 00:34:16,053
>> In that area?

1537
00:34:16,053 --> 00:34:16,854
>> In that area, yeah.

1538
00:34:16,854 --> 00:34:18,122

>> Okay.

1539
00:34:18,122 --> 00:34:18,956
>> But right now, we can't

1540
00:34:18,956 --> 00:34:19,924
do that because we don't have

1541
00:34:19,924 --> 00:34:21,592
any coatings that reflect away

1542
00:34:21,592 --> 00:34:23,528
enough of the Sun's energy.

1543
00:34:23,528 --> 00:34:24,395
So a few years back,

1544
00:34:24,395 --> 00:34:26,397
I approached what's called

1545
00:34:26,397 --> 00:34:28,132
NIAC, the NASA Institute

1546
00:34:28,132 --> 00:34:29,534
for Advanced Concepts.

1547
00:34:29,534 --> 00:34:31,202
And they agreed to fund me

1548
00:34:31,202 --> 00:34:31,969
to see if I could come up with

1549
00:34:31,969 --> 00:34:33,171
a better coating.

1550
00:34:33,171 --> 00:34:34,672
And we soon realized

1551
00:34:34,672 --> 00:34:36,841
the answer to this problem

1552
00:34:36,841 --> 00:34:37,942
had been achieved by

1553
00:34:37,942 --> 00:34:38,776
the optics community

1554
00:34:38,776 --> 00:34:40,311
in the 1960s.

1555
00:34:40,311 --> 00:34:42,180
They-they actually-- the optics

1556
00:34:42,180 --> 00:34:42,847
community had the same

1557
00:34:42,847 --> 00:34:43,714
problem-- they couldn't

1558
00:34:43,714 --> 00:34:44,682
come up with a good reflective

1559
00:34:44,682 --> 00:34:46,217
coating, and they realized

1560
00:34:46,217 --> 00:34:48,486
the way to make a good coating

1561
00:34:48,486 --> 00:34:51,022
is to use white scatterers.

1562
00:34:51,022 --> 00:34:52,523
Think of snow, clouds.

1563
00:34:52,523 --> 00:34:53,090

>> Okay.

1564
00:34:53,090 --> 00:34:53,891
>> You know, these things are

1565
00:34:53,891 --> 00:34:55,159
bright white, and they're

1566
00:34:55,159 --> 00:34:56,160
bright white because

1567
00:34:56,160 --> 00:34:58,129
they don't absorb the visible

1568
00:34:58,129 --> 00:34:59,497
light that your eyes can see.

1569
00:34:59,497 --> 00:35:00,998
They just bounce it all around,

1570
00:35:00,998 --> 00:35:01,799
by little particles, and

1571
00:35:01,799 --> 00:35:02,633
they scatter that light

1572
00:35:02,633 --> 00:35:03,601
back at you.

1573
00:35:03,601 --> 00:35:04,735
And they're very, very

1574
00:35:04,735 --> 00:35:06,270
efficient at that.

1575
00:35:06,270 --> 00:35:07,305
They don't absorb-- essentially

1576
00:35:07,305 --> 00:35:09,474
absorb almost nothing.

1577
00:35:09,474 --> 00:35:10,208
And so all that light

1578
00:35:10,208 --> 00:35:11,108
has to go somewhere, so

1579
00:35:11,108 --> 00:35:11,843
eventually it all gets

1580
00:35:11,843 --> 00:35:12,910
scattered back.

1581
00:35:12,910 --> 00:35:13,878
Big snowbank, you know,

1582
00:35:13,878 --> 00:35:15,279
a salt-salt shaker, you know,

1583
00:35:15,279 --> 00:35:16,814
cotton fibers-- all these things

1584
00:35:16,814 --> 00:35:17,548
are white because

1585
00:35:17,548 --> 00:35:18,783
they're scatterers.

1586
00:35:18,783 --> 00:35:19,750
So if you wanna make

1587
00:35:19,750 --> 00:35:21,719
a really good reflector of

1588
00:35:21,719 --> 00:35:24,489

energy, what you do is

1589
00:35:24,489 --> 00:35:25,323
you say to yourself,

1590
00:35:25,323 --> 00:35:27,058
"over what spectral band

1591
00:35:27,058 --> 00:35:28,192
"am I interested?"

1592
00:35:28,192 --> 00:35:28,926
Do I wanna scatter ultraviolet

1593
00:35:28,926 --> 00:35:29,961
as well?

1594
00:35:29,961 --> 00:35:31,262
Do I wanna scatter infrared?

1595
00:35:31,262 --> 00:35:32,196
You know, how-- what do I want

1596
00:35:32,196 --> 00:35:33,030
to scatter?

1597
00:35:33,030 --> 00:35:34,532
You find a material that

1598
00:35:34,532 --> 00:35:35,867
won't absorb that energy.

1599
00:35:35,867 --> 00:35:37,201
You know, some-some

1600
00:35:37,201 --> 00:35:38,035
base material--

1601
00:35:38,035 --> 00:35:38,703
>> Sure, makes sense.

1602
00:35:38,703 --> 00:35:39,770
>> Grind it up into a powder.

1603
00:35:39,770 --> 00:35:40,571
>> Okay.

1604
00:35:40,571 --> 00:35:42,406
>> And maybe sinter it,

1605
00:35:42,406 --> 00:35:43,207
mix a little water,

1606
00:35:43,207 --> 00:35:44,141
make a clay.

1607
00:35:44,141 --> 00:35:45,142
>> And-and-- sorry--

1608
00:35:45,142 --> 00:35:46,410
sintering is heating it?

1609
00:35:46,410 --> 00:35:47,845
>> Yeah, basically, what you did

1610
00:35:47,845 --> 00:35:49,013
when you were in, um,

1611
00:35:49,013 --> 00:35:50,681
7th, 8th grade when you baked

1612
00:35:50,681 --> 00:35:52,350
clay and put it into a kiln

1613
00:35:52,350 --> 00:35:53,684

and you fired it up--

1614
00:35:53,684 --> 00:35:54,385
that kind of thing.

1615
00:35:54,385 --> 00:35:55,119
>> Okay.

1616
00:35:55,119 --> 00:35:55,753
>> So you're basically just

1617
00:35:55,753 --> 00:35:57,154
taking this stuff, making

1618
00:35:57,154 --> 00:35:58,422
a powder, add a little water,

1619
00:35:58,422 --> 00:35:59,524
make a paste, squeeze it

1620
00:35:59,524 --> 00:36:01,359
into a mold, put it in an oven,

1621
00:36:01,359 --> 00:36:03,294
a kiln, fire it, pull it out,

1622
00:36:03,294 --> 00:36:04,161
and you're done-- you've got

1623
00:36:04,161 --> 00:36:05,596
a tile that will scatter

1624
00:36:05,596 --> 00:36:07,532
energy over whatever band

1625
00:36:07,532 --> 00:36:08,933
you chose.

1626
00:36:08,933 --> 00:36:09,800
>> And so you could make

1627
00:36:09,800 --> 00:36:10,501
your own shape, essentially.

1628
00:36:10,501 --> 00:36:11,302
>> Exactly, you make your own

1629
00:36:11,302 --> 00:36:12,136
shape, and you can make

1630
00:36:12,136 --> 00:36:13,304
this stuff arbitrarily thick,

1631
00:36:13,304 --> 00:36:14,539
and you can make it out of

1632
00:36:14,539 --> 00:36:15,640
pretty much whatever material

1633
00:36:15,640 --> 00:36:16,340
that you want.

1634
00:36:16,340 --> 00:36:16,974
>> Okay.

1635
00:36:16,974 --> 00:36:17,642
>> So we chose a material

1636
00:36:17,642 --> 00:36:18,643
originally called

1637
00:36:18,643 --> 00:36:20,144
barium fluoride, which is

1638
00:36:20,144 --> 00:36:21,546

an optical material that

1639
00:36:21,546 --> 00:36:23,281
is transparent from

1640
00:36:23,281 --> 00:36:24,682
the ultraviolet through

1641
00:36:24,682 --> 00:36:25,983
the visible, to the near

1642
00:36:25,983 --> 00:36:27,151
infrared, the mid-infrared,

1643
00:36:27,151 --> 00:36:28,486
even into the full-- even

1644
00:36:28,486 --> 00:36:29,787
where-- the heat your body's

1645
00:36:29,787 --> 00:36:30,655
giving off goes right through

1646
00:36:30,655 --> 00:36:31,289
this stuff.

1647
00:36:31,289 --> 00:36:31,856
>> Interesting.

1648
00:36:31,856 --> 00:36:32,323
>> Yeah, so it's very

1649
00:36:32,323 --> 00:36:32,890
broad-band.

1650
00:36:32,890 --> 00:36:33,858
So you grind-- we actually

1651
00:36:33,858 --> 00:36:35,092
buy it as a powder, make

1652
00:36:35,092 --> 00:36:36,827
these tiles out of it,

1653
00:36:36,827 --> 00:36:39,664
and these things should

1654
00:36:39,664 --> 00:36:40,998
theoretically-- and so far,

1655
00:36:40,998 --> 00:36:41,866
to the best of our

1656
00:36:41,866 --> 00:36:43,434
measurements-- scatter away

1657
00:36:43,434 --> 00:36:44,368
the majority of

1658
00:36:44,368 --> 00:36:45,536
the Sun's energy.

1659
00:36:45,536 --> 00:36:46,671
Theory says if you coat

1660
00:36:46,671 --> 00:36:48,172
a tank with this stuff,

1661
00:36:48,172 --> 00:36:50,074
at the Earth's distance from

1662
00:36:50,074 --> 00:36:51,175
the Sun, the tank should get

1663
00:36:51,175 --> 00:36:52,677

well below liquid oxygen

1664
00:36:52,677 --> 00:36:53,711
temperatures.

1665
00:36:53,711 --> 00:36:55,713
>> So can I coat my house

1666
00:36:55,713 --> 00:36:56,514
in this?

1667
00:36:56,514 --> 00:36:57,048
Like, it's Florida.

1668
00:36:57,048 --> 00:36:57,582
It's hot.

1669
00:36:57,582 --> 00:36:58,382
Summertime is coming.

1670
00:36:58,382 --> 00:36:59,684
Can I-- can I keep my house

1671
00:36:59,684 --> 00:37:00,484
cool with this stuff?

1672
00:37:00,484 --> 00:37:01,519
>> You-you could.

1673
00:37:01,519 --> 00:37:02,587
You could, but there are

1674
00:37:02,587 --> 00:37:03,788
cheaper approaches.

1675
00:37:03,788 --> 00:37:06,223
Yeah, here on Earth,

1676
00:37:06,223 --> 00:37:07,858
here on Earth, the ozone layer

1677
00:37:07,858 --> 00:37:09,026
blocks a lot of the UV.

1678
00:37:09,026 --> 00:37:09,427
>> Okay.

1679
00:37:09,427 --> 00:37:10,127
>> So you don't have to

1680
00:37:10,127 --> 00:37:11,295
worry about that stuff.

1681
00:37:11,295 --> 00:37:12,563
The atmosphere won't transmit

1682
00:37:12,563 --> 00:37:14,699
a lot of that infrared.

1683
00:37:14,699 --> 00:37:15,900
So people have come up with

1684
00:37:15,900 --> 00:37:18,703
cheaper white coatings

1685
00:37:18,703 --> 00:37:19,637
than barium fluoride.

1686
00:37:19,637 --> 00:37:20,171
>> Gotcha.

1687
00:37:20,171 --> 00:37:21,739
>> Barium fluoride is ideal

1688
00:37:21,739 --> 00:37:22,640

for when you're above

1689
00:37:22,640 --> 00:37:23,774
the ozone layer and you get

1690
00:37:23,774 --> 00:37:25,076
that really-- there's a lot

1691
00:37:25,076 --> 00:37:26,644
of really harsh ultraviolet

1692
00:37:26,644 --> 00:37:28,312
coming off the Sun, you know,

1693
00:37:28,312 --> 00:37:28,980
that doesn't make it through

1694
00:37:28,980 --> 00:37:29,647
the ozone layer.

1695
00:37:29,647 --> 00:37:30,314
>> Sure.

1696
00:37:30,314 --> 00:37:31,816
>> And so down here on Earth,

1697
00:37:31,816 --> 00:37:33,050
at ground level, you know,

1698
00:37:33,050 --> 00:37:34,385
things aren't quite as bad.

1699
00:37:34,385 --> 00:37:35,419
It's not quite the spectral

1700
00:37:35,419 --> 00:37:37,154
extent of the Sun that

1701
00:37:37,154 --> 00:37:38,155
we have to worry about--

1702
00:37:38,155 --> 00:37:39,056
that we have to worry about

1703
00:37:39,056 --> 00:37:39,890
in space.

1704
00:37:39,890 --> 00:37:40,791
>> So if my house is

1705
00:37:40,791 --> 00:37:41,759
on the Moon...

1706
00:37:41,759 --> 00:37:42,660
>> Oh.

1707
00:37:42,660 --> 00:37:43,661
>> Is this what I want?

1708
00:37:43,661 --> 00:37:44,528
>> Yep, this is what you want.

1709
00:37:44,528 --> 00:37:45,496
>> Okay, so this is-- this is--

1710
00:37:45,496 --> 00:37:46,897
beyond Earth, this is

1711
00:37:46,897 --> 00:37:48,332
kind of the right solution

1712
00:37:48,332 --> 00:37:48,966
for what we want.

1713
00:37:48,966 --> 00:37:49,967

>> Yeah, but let me-- let me

1714
00:37:49,967 --> 00:37:51,535
talk about-- I got talking

1715
00:37:51,535 --> 00:37:52,603
to some of the people from

1716
00:37:52,603 --> 00:37:53,771
the Jet Propulsion Lab.

1717
00:37:53,771 --> 00:37:55,006
>> Okay-- one of our centers

1718
00:37:55,006 --> 00:37:56,107
out in California.

1719
00:37:56,107 --> 00:37:57,842
>> That's right, and I-I gave

1720
00:37:57,842 --> 00:37:59,310
a presentation to them

1721
00:37:59,310 --> 00:38:00,811
concerning my-my coating

1722
00:38:00,811 --> 00:38:02,647
and its ability to get closer

1723
00:38:02,647 --> 00:38:03,948
to the Sun, you know, than

1724
00:38:03,948 --> 00:38:05,516
the Parker Solar Probe

1725
00:38:05,516 --> 00:38:06,951
currently will reach.

1726
00:38:06,951 --> 00:38:08,419
And they raised two

1727
00:38:08,419 --> 00:38:10,187
very interesting issues,

1728
00:38:10,187 --> 00:38:11,455
or possibilities.

1729
00:38:11,455 --> 00:38:13,024
The first one is they would

1730
00:38:13,024 --> 00:38:15,192
like to better test

1731
00:38:15,192 --> 00:38:16,794
Einstein's general theory

1732
00:38:16,794 --> 00:38:17,862
of relativity.

1733
00:38:17,862 --> 00:38:18,562
>> Okay.

1734
00:38:18,562 --> 00:38:20,131
>> And they need a very strong

1735
00:38:20,131 --> 00:38:22,099
gravitational field to do that.

1736
00:38:22,099 --> 00:38:22,733
>> Okay.

1737
00:38:22,733 --> 00:38:23,367
>> So they would like to

1738
00:38:23,367 --> 00:38:24,101

get close to the Sun

1739
00:38:24,101 --> 00:38:26,637
and park like an atomic clock,

1740
00:38:26,637 --> 00:38:27,371
and watch and see

1741
00:38:27,371 --> 00:38:28,839
how times passes close to

1742
00:38:28,839 --> 00:38:29,607
the Sun--

1743
00:38:29,607 --> 00:38:30,341
>> Interesting.

1744
00:38:30,341 --> 00:38:31,375
>> And try to help continue to

1745
00:38:31,375 --> 00:38:33,077
validate Einstein's theories.

1746
00:38:33,077 --> 00:38:34,078
>> Interesting.

1747
00:38:34,078 --> 00:38:35,246
>> But the other topic they

1748
00:38:35,246 --> 00:38:38,049
raised is truly fascinating.

1749
00:38:38,049 --> 00:38:40,017
They would like mankind

1750
00:38:40,017 --> 00:38:41,352
to begin its first

1751
00:38:41,352 --> 00:38:43,387
interstellar missions.

1752
00:38:43,387 --> 00:38:44,188
They would like us

1753
00:38:44,188 --> 00:38:45,423
to build a launch, uh,

1754
00:38:45,423 --> 00:38:46,657
not a Pioneer and a Voyager

1755
00:38:46,657 --> 00:38:48,225
to take, you know, 100 years

1756
00:38:48,225 --> 00:38:50,161
to get any substantial distance.

1757
00:38:50,161 --> 00:38:51,629
They would like an actual

1758
00:38:51,629 --> 00:38:54,165
mission that's going so fast

1759
00:38:54,165 --> 00:38:55,132
that it flies out of

1760
00:38:55,132 --> 00:38:56,200
the solar system

1761
00:38:56,200 --> 00:38:57,735
and can reach some point

1762
00:38:57,735 --> 00:38:58,936
between the stars,

1763
00:38:58,936 --> 00:38:59,804

between our star

1764
00:38:59,804 --> 00:39:00,871
and say Alpha Centauri.

1765
00:39:00,871 --> 00:39:01,639
>> Sure.

1766
00:39:01,639 --> 00:39:02,473
>> So it can look back at us.

1767
00:39:02,473 --> 00:39:03,207
>> Sure.

1768
00:39:03,207 --> 00:39:04,008
>> And we can start to image

1769
00:39:04,008 --> 00:39:05,376
our actual solar system

1770
00:39:05,376 --> 00:39:07,078
from some distance out.

1771
00:39:07,078 --> 00:39:07,812
>> Okay.

1772
00:39:07,812 --> 00:39:08,579
>> And see what things

1773
00:39:08,579 --> 00:39:09,380
really look like out there

1774
00:39:09,380 --> 00:39:10,081
and what the environment

1775
00:39:10,081 --> 00:39:10,881
is truly like.

1776
00:39:10,881 --> 00:39:12,049
We're just conjecturing now,

1777
00:39:12,049 --> 00:39:13,084
but this is a mission to get

1778
00:39:13,084 --> 00:39:14,018
out there and really do it.

1779
00:39:14,018 --> 00:39:14,919
>> Okay.

1780
00:39:14,919 --> 00:39:16,854
>> The only way right now

1781
00:39:16,854 --> 00:39:17,955
with current technology

1782
00:39:17,955 --> 00:39:20,858
to go that fast is to slingshot

1783
00:39:20,858 --> 00:39:22,059
around the Sun.

1784
00:39:22,059 --> 00:39:23,527
>> Oh, interesting.

1785
00:39:23,527 --> 00:39:24,395
>> They have to get

1786
00:39:24,395 --> 00:39:25,162
closer than--

1787
00:39:25,162 --> 00:39:25,896
>> Interesting.

1788
00:39:25,896 --> 00:39:26,597

>> Yeah, than about

1789
00:39:26,597 --> 00:39:28,199
a million miles from

1790
00:39:28,199 --> 00:39:29,433
the surface of the Sun.

1791
00:39:29,433 --> 00:39:30,434
>> That's-- That is

1792
00:39:30,434 --> 00:39:31,135
terribly interesting.

1793
00:39:31,135 --> 00:39:31,802
>> Yeah.

1794
00:39:31,802 --> 00:39:32,503
>> So will you see

1795
00:39:32,503 --> 00:39:33,170
gravity assist with missions

1796
00:39:33,170 --> 00:39:33,838
like New Horizons?

1797
00:39:33,838 --> 00:39:34,505
>> Mm-hmm.

1798
00:39:34,505 --> 00:39:35,673
>> Uh, even Parker Solar Probe

1799
00:39:35,673 --> 00:39:36,841
is gonna do a few with Venus.

1800
00:39:36,841 --> 00:39:37,608
>> Yup. Yes.

1801
00:39:37,608 --> 00:39:38,375
>> But we're talking about

1802
00:39:38,375 --> 00:39:39,143
doing it off of the Sun.

1803
00:39:39,143 --> 00:39:40,678
>> Off of the Sun itself.

1804
00:39:40,678 --> 00:39:41,645
So you take the biggest

1805
00:39:41,645 --> 00:39:43,047
gravitational field you have

1806
00:39:43,047 --> 00:39:44,515
in the solar system and you're

1807
00:39:44,515 --> 00:39:46,050
gonna slingshot around it.

1808
00:39:46,050 --> 00:39:46,851
You're gonna use it

1809
00:39:46,851 --> 00:39:47,952
as your gravity assist.

1810
00:39:47,952 --> 00:39:48,953
>> Do you know-- Did-did they

1811
00:39:48,953 --> 00:39:49,787
give you a sense of

1812
00:39:49,787 --> 00:39:50,755
how fast they're talking,

1813
00:39:50,755 --> 00:39:52,022

if they can pull this off,

1814
00:39:52,022 --> 00:39:53,457
how fast they're-- that-that

1815
00:39:53,457 --> 00:39:54,458
slingshot will give them,

1816
00:39:54,458 --> 00:39:55,459
what speed they'll get?

1817
00:39:55,459 --> 00:39:56,360
>> Oh, I mean, it comes to

1818
00:39:56,360 --> 00:39:58,229
hundreds of kilometers a second.

1819
00:39:58,229 --> 00:40:00,331
I-I-I-- Don't quote me--

1820
00:40:00,331 --> 00:40:01,065
Well, you are gonna

1821
00:40:01,065 --> 00:40:03,234
quote me, but--

1822
00:40:03,234 --> 00:40:04,068
>> We won't hold you to it.

1823
00:40:04,068 --> 00:40:04,835
>> Well, we'll just say--

1824
00:40:04,835 --> 00:40:05,603
>> We won't quote you.

1825
00:40:05,603 --> 00:40:06,437
>> Hun-hun-hundreds of

1826
00:40:06,437 --> 00:40:07,204
kilometers a second.

1827
00:40:07,204 --> 00:40:07,805
>> Okay.

1828
00:40:07,805 --> 00:40:08,372
>> As you--

1829
00:40:08,372 --> 00:40:08,939
>> So really, really fast.

1830
00:40:08,939 --> 00:40:09,840
>> It's really, really fast.

1831
00:40:09,840 --> 00:40:10,508
>> Okay.

1832
00:40:10,508 --> 00:40:11,242
>> They're-- They actually

1833
00:40:11,242 --> 00:40:12,576
give their distances,

1834
00:40:12,576 --> 00:40:14,044
their-their speeds in terms

1835
00:40:14,044 --> 00:40:17,114
of astronomical units.

1836
00:40:17,114 --> 00:40:18,315
In other words, the distance

1837
00:40:18,315 --> 00:40:19,583
from the Sun to the Earth

1838
00:40:19,583 --> 00:40:21,619

astronomical units per year

1839
00:40:21,619 --> 00:40:22,887
and what they want to do

1840
00:40:22,887 --> 00:40:24,021
is leave Pluto.

1841
00:40:24,021 --> 00:40:24,955
>> Sure.

1842
00:40:24,955 --> 00:40:26,357
>> Well, flying past Pluto

1843
00:40:26,357 --> 00:40:27,591
and still be moving at about

1844
00:40:27,591 --> 00:40:30,194
20 astronomical units a year.

1845
00:40:30,194 --> 00:40:31,462
>> We heard from

1846
00:40:31,462 --> 00:40:32,930
the Parker Solar Probe folks

1847
00:40:32,930 --> 00:40:35,866
that the corona, which

1848
00:40:35,866 --> 00:40:37,034
comes out a great distance

1849
00:40:37,034 --> 00:40:38,402
from the Sun and is hotter

1850
00:40:38,402 --> 00:40:39,970
than the Sun itself,

1851
00:40:39,970 --> 00:40:41,372
so how does this kinda coating

1852
00:40:41,372 --> 00:40:43,040
help you get even closer?

1853
00:40:43,040 --> 00:40:44,175
'Cause obviously you're talking

1854
00:40:44,175 --> 00:40:45,676
about the ability to get closer

1855
00:40:45,676 --> 00:40:46,677
under a million miles.

1856
00:40:46,677 --> 00:40:47,678
>> Mm-hmm.

1857
00:40:47,678 --> 00:40:49,213
>> Is the corona not an issue?

1858
00:40:49,213 --> 00:40:50,347
>> Yeah, the-the corona

1859
00:40:50,347 --> 00:40:51,615
under-- at least the analysis

1860
00:40:51,615 --> 00:40:52,683
that-that I've done--

1861
00:40:52,683 --> 00:40:54,418
the-the corona is not

1862
00:40:54,418 --> 00:40:55,686
a serious issue because

1863
00:40:55,686 --> 00:40:56,987

the density of material

1864
00:40:56,987 --> 00:40:59,123
is very, very low.

1865
00:40:59,123 --> 00:40:59,957
There's really very

1866
00:40:59,957 --> 00:41:01,292
little material there.

1867
00:41:01,292 --> 00:41:02,259
You know, the-the Sun

1868
00:41:02,259 --> 00:41:03,894
has a photosphere that's

1869
00:41:03,894 --> 00:41:06,363
very dense and, you know,

1870
00:41:06,363 --> 00:41:08,365
6,000 degrees Kelvin.

1871
00:41:08,365 --> 00:41:09,333
So it's, you know, it's hot

1872
00:41:09,333 --> 00:41:10,601
but not incredibly hot.

1873
00:41:10,601 --> 00:41:11,435
But you got this trans--

1874
00:41:11,435 --> 00:41:12,136
>> Oh, that sounds

1875
00:41:12,136 --> 00:41:12,736
really hot to me.

1876
00:41:12,736 --> 00:41:13,370
>> Yeah, I know. But then

1877
00:41:13,370 --> 00:41:14,638
you got this transition region.

1878
00:41:14,638 --> 00:41:15,506
They call it the transition

1879
00:41:15,506 --> 00:41:16,507
region and above that,

1880
00:41:16,507 --> 00:41:17,374
the corona starts.

1881
00:41:17,374 --> 00:41:18,142
>> Okay.

1882
00:41:18,142 --> 00:41:18,876
>> And the corona's

1883
00:41:18,876 --> 00:41:20,377
around-around a million degrees.

1884
00:41:20,377 --> 00:41:21,111
>> Okay.

1885
00:41:21,111 --> 00:41:22,046
>> Much, much hotter.

1886
00:41:22,046 --> 00:41:24,048
But it's very, very sparse.

1887
00:41:24,048 --> 00:41:24,849
>> Okay.

1888
00:41:24,849 --> 00:41:25,616

>> There's very few

1889
00:41:25,616 --> 00:41:26,283
particles there.

1890
00:41:26,283 --> 00:41:27,418
In fact, the solar wind,

1891
00:41:27,418 --> 00:41:28,285
when you go out and leave

1892
00:41:28,285 --> 00:41:29,253
the Earth's magnetic field

1893
00:41:29,253 --> 00:41:30,321
the solar wind is composed

1894
00:41:30,321 --> 00:41:31,889
of particles that have

1895
00:41:31,889 --> 00:41:33,557
an effective temperature on

1896
00:41:33,557 --> 00:41:35,759
the order of a million degrees,

1897
00:41:35,759 --> 00:41:37,394
but there's only one particle

1898
00:41:37,394 --> 00:41:38,462
per cubic centimeter.

1899
00:41:38,462 --> 00:41:39,196
There's almost

1900
00:41:39,196 --> 00:41:40,331
no particles there.

1901
00:41:40,331 --> 00:41:41,832
You're seeing the-the emission

1902
00:41:41,832 --> 00:41:43,100
from the Sun of these particles

1903
00:41:43,100 --> 00:41:44,768
that have a lot of energy

1904
00:41:44,768 --> 00:41:46,203
but there's not a lot of them.

1905
00:41:46,203 --> 00:41:48,239
So the-the corona, it does

1906
00:41:48,239 --> 00:41:49,340
extend out from the Sun

1907
00:41:49,340 --> 00:41:50,674
and it is very high temperature

1908
00:41:50,674 --> 00:41:51,475
but there's very little

1909
00:41:51,475 --> 00:41:52,910
energy content to it.

1910
00:41:52,910 --> 00:41:53,744
>> I wanted to ask you,

1911
00:41:53,744 --> 00:41:54,645
so we-we've talked about

1912
00:41:54,645 --> 00:41:55,779
repelling the heat

1913
00:41:55,779 --> 00:41:56,647

and radiation.

1914
00:41:56,647 --> 00:41:57,381
>> Mm-hmm.

1915
00:41:57,381 --> 00:41:58,148
>> Is this enough

1916
00:41:58,148 --> 00:41:59,383
to protect humans?

1917
00:41:59,383 --> 00:42:01,485
If I take a capsule to Mars,

1918
00:42:01,485 --> 00:42:02,419
one of the challenges

1919
00:42:02,419 --> 00:42:03,320
we know of is the radiation

1920
00:42:03,320 --> 00:42:04,188
from the Sun.

1921
00:42:04,188 --> 00:42:05,556
Can I protect myself with this?

1922
00:42:05,556 --> 00:42:06,523
>> Okay, oh-- Well, they're

1923
00:42:06,523 --> 00:42:07,358
different kinds of radiation.

1924
00:42:07,358 --> 00:42:08,158
>> Okay.

1925
00:42:08,158 --> 00:42:08,826
>> Yeah.

1926
00:42:08,826 --> 00:42:09,460
>> That's-- Man, that's

1927
00:42:09,460 --> 00:42:10,194
so important to know.

1928
00:42:10,194 --> 00:42:11,028
>> Yeah, the-the radiation

1929
00:42:11,028 --> 00:42:12,263
that we're trying to block

1930
00:42:12,263 --> 00:42:14,231
is the stuff you see.

1931
00:42:14,231 --> 00:42:16,400
It's the-- mostly the visible

1932
00:42:16,400 --> 00:42:17,635
light coming off the Sun,

1933
00:42:17,635 --> 00:42:20,771
the-the-the, um, visible

1934
00:42:20,771 --> 00:42:21,906
and ultraviolet

1935
00:42:21,906 --> 00:42:24,008
and infrared irradiance,

1936
00:42:24,008 --> 00:42:25,409
the light that's hitting you.

1937
00:42:25,409 --> 00:42:26,443
>> Sure.

1938
00:42:26,443 --> 00:42:27,478

>> Now the Sun also has

1939
00:42:27,478 --> 00:42:29,046
solar wind coming off,

1940
00:42:29,046 --> 00:42:30,180
which are particles,

1941
00:42:30,180 --> 00:42:31,181
protons and electrons.

1942
00:42:31,181 --> 00:42:31,949
>> Sure.

1943
00:42:31,949 --> 00:42:32,650
>> And that's a source

1944
00:42:32,650 --> 00:42:33,417
of radiation.

1945
00:42:33,417 --> 00:42:34,351
That's easily blocked,

1946
00:42:34,351 --> 00:42:35,853
unless there's a solar flare.

1947
00:42:35,853 --> 00:42:36,587
>> Right.

1948
00:42:36,587 --> 00:42:37,354
>> If there's a solar flare

1949
00:42:37,354 --> 00:42:38,589
then you get a lot of particles

1950
00:42:38,589 --> 00:42:39,456
in the high density

1951
00:42:39,456 --> 00:42:40,357
with a lot of energy, and now

1952
00:42:40,357 --> 00:42:41,759
you have to go to a safe room.

1953
00:42:41,759 --> 00:42:42,526
>> Okay.

1954
00:42:42,526 --> 00:42:43,360
>> You have to block yourself.

1955
00:42:43,360 --> 00:42:44,295
Our coatings don't help

1956
00:42:44,295 --> 00:42:45,029
with that.

1957
00:42:45,029 --> 00:42:46,363
Now you're talking, you know,

1958
00:42:46,363 --> 00:42:47,998
high-high irradiant--

1959
00:42:47,998 --> 00:42:49,733
h-high-high levels of particles

1960
00:42:49,733 --> 00:42:50,601
with high energies.

1961
00:42:50,601 --> 00:42:51,335
>> Okay.

1962
00:42:51,335 --> 00:42:52,069
>> And then there's

1963
00:42:52,069 --> 00:42:53,570

galactic cosmic radiation.

1964
00:42:53,570 --> 00:42:54,305
>> Which just sounds awesome

1965
00:42:54,305 --> 00:42:54,939
to say that.

1966
00:42:54,939 --> 00:42:55,572
Like, that just sounds

1967
00:42:55,572 --> 00:42:56,173
really cool.

1968
00:42:56,173 --> 00:42:56,774
>> Yeah.

1969
00:42:56,774 --> 00:42:57,374
>> I'm sure it's

1970
00:42:57,374 --> 00:42:58,008
probably dangerous.

1971
00:42:58,008 --> 00:42:58,575
>> Well, it v--

1972
00:42:58,575 --> 00:42:59,543
It's the remnants of supernova.

1973
00:42:59,543 --> 00:43:00,377
>> Okay.

1974
00:43:00,377 --> 00:43:01,979
>> And so they're bad.

1975
00:43:01,979 --> 00:43:03,514
And the Sun's magnetic field

1976
00:43:03,514 --> 00:43:04,715
gets rid of a lot of it,

1977
00:43:04,715 --> 00:43:06,350
but the really nasty stuff

1978
00:43:06,350 --> 00:43:07,818
still reaches the Earth.

1979
00:43:07,818 --> 00:43:09,386
The Earth's magnetic field

1980
00:43:09,386 --> 00:43:10,721
blocks most of the rest,

1981
00:43:10,721 --> 00:43:11,789
but when you're above

1982
00:43:11,789 --> 00:43:13,457
the Earth's magnetic field

1983
00:43:13,457 --> 00:43:14,892
you're subject to being hit

1984
00:43:14,892 --> 00:43:16,560
by galactic cosmic radiation.

1985
00:43:16,560 --> 00:43:18,028
And these are the nuclei

1986
00:43:18,028 --> 00:43:19,463
of things like iron,

1987
00:43:19,463 --> 00:43:20,798
like an iron nuclei

1988
00:43:20,798 --> 00:43:22,232

that's coming at you so fast

1989
00:43:22,232 --> 00:43:23,133
there's no electrons

1990
00:43:23,133 --> 00:43:24,001
stuck to it anymore.

1991
00:43:24,001 --> 00:43:24,902
It's just a-a bullet

1992
00:43:24,902 --> 00:43:25,536
coming at you.

1993
00:43:25,536 --> 00:43:26,236
>> See, that doesn't sound.

1994
00:43:26,236 --> 00:43:26,937
It just sounds scary now.

1995
00:43:26,937 --> 00:43:28,038
>> It is sc-- Yup, yeah.

1996
00:43:28,038 --> 00:43:29,106
Galactic cosmic radiation

1997
00:43:29,106 --> 00:43:30,407
is scary and-- but that's

1998
00:43:30,407 --> 00:43:32,309
a whole 'nother-'nother world.

1999
00:43:32,309 --> 00:43:33,711
There-there-there's actually,

2000
00:43:33,711 --> 00:43:34,845
uh, multiple directions

2001
00:43:34,845 --> 00:43:35,779
that we're going

2002
00:43:35,779 --> 00:43:37,247
and a lot of that is based on

2003
00:43:37,247 --> 00:43:38,449
a variety of customers

2004
00:43:38,449 --> 00:43:39,683
that are coming to the door.

2005
00:43:39,683 --> 00:43:41,752
Um, for example, the, uh,

2006
00:43:41,752 --> 00:43:43,153
Nuclear Thermal Propulsion

2007
00:43:43,153 --> 00:43:44,755
Program needs to take

2008
00:43:44,755 --> 00:43:46,090
liquid hydrogen to Mars.

2009
00:43:46,090 --> 00:43:46,924
>> Okay.

2010
00:43:46,924 --> 00:43:48,125
>> I mean, liquid hydrogen.

2011
00:43:48,125 --> 00:43:49,126
Hydrogen has to be down

2012
00:43:49,126 --> 00:43:50,094
to 20 Kelvin.

2013
00:43:50,094 --> 00:43:51,095

I mean, you're talking getting--

2014
00:43:51,095 --> 00:43:51,895
You're getting close to

2015
00:43:51,895 --> 00:43:52,863
absolute zero when you talk

2016
00:43:52,863 --> 00:43:53,630
liquid hydrogen.

2017
00:43:53,630 --> 00:43:54,398
>> Okay.

2018
00:43:54,398 --> 00:43:55,966
>> Even with our coating,

2019
00:43:55,966 --> 00:43:57,835
even optimally with our coating

2020
00:43:57,835 --> 00:43:58,969
we cannot block enough of

2021
00:43:58,969 --> 00:44:00,204
the Sun's energy to maintain

2022
00:44:00,204 --> 00:44:01,238
liquid hydrogen.

2023
00:44:01,238 --> 00:44:02,106
So you have to have

2024
00:44:02,106 --> 00:44:03,107
active cooling on board.

2025
00:44:03,107 --> 00:44:03,974
>> Okay.

2026
00:44:03,974 --> 00:44:05,242
>> But we can make it better.

2027
00:44:05,242 --> 00:44:06,076
>> Sure.

2028
00:44:06,076 --> 00:44:06,977
>> And we can lower

2029
00:44:06,977 --> 00:44:08,078
the heat load on these

2030
00:44:08,078 --> 00:44:09,013
liquid hydrogen tanks

2031
00:44:09,013 --> 00:44:09,913
with our coating.

2032
00:44:09,913 --> 00:44:10,748
>> Sure.

2033
00:44:10,748 --> 00:44:12,082
>> And the Nuclear Thermal

2034
00:44:12,082 --> 00:44:13,017
Propulsion people

2035
00:44:13,017 --> 00:44:13,851
have come to us and have

2036
00:44:13,851 --> 00:44:15,219
talked to us about flexible

2037
00:44:15,219 --> 00:44:16,520
versions of our coatings,

2038
00:44:16,520 --> 00:44:17,654

very thin layers

2039
00:44:17,654 --> 00:44:19,289
that could be just sprayed on,

2040
00:44:19,289 --> 00:44:20,824
and we're currently making

2041
00:44:20,824 --> 00:44:22,259
significant advance in that

2042
00:44:22,259 --> 00:44:23,961
direction with some funding

2043
00:44:23,961 --> 00:44:24,862
from the Nuclear Thermal

2044
00:44:24,862 --> 00:44:25,929
Propulsion agency.

2045
00:44:25,929 --> 00:44:27,231
So that's one direction

2046
00:44:27,231 --> 00:44:28,065
that we're going,

2047
00:44:28,065 --> 00:44:28,966
is coming up with a thin

2048
00:44:28,966 --> 00:44:30,267
versions of the coating.

2049
00:44:30,267 --> 00:44:31,335
The performance is not as good

2050
00:44:31,335 --> 00:44:32,803
as a very thick coating.

2051
00:44:32,803 --> 00:44:33,570
Now--

2052
00:44:33,570 --> 00:44:34,338
>> So, h-how does that work?

2053
00:44:34,338 --> 00:44:35,039
'Cause you've talked about

2054
00:44:35,039 --> 00:44:36,140
it's just kinda reflecting

2055
00:44:36,140 --> 00:44:36,774
that energy.

2056
00:44:36,774 --> 00:44:37,908
>> Yup, yup.

2057
00:44:37,908 --> 00:44:38,776
>> So do you still need

2058
00:44:38,776 --> 00:44:40,377
a thickness there to-to

2059
00:44:40,377 --> 00:44:42,046
really be-be effective?

2060
00:44:42,046 --> 00:44:43,047
>> What we're doing is

2061
00:44:43,047 --> 00:44:44,715
no different from white paint.

2062
00:44:44,715 --> 00:44:45,582
>> Okay.

2063
00:44:45,582 --> 00:44:46,417

>> In-in the fundamental

2064
00:44:46,417 --> 00:44:47,251
understanding.

2065
00:44:47,251 --> 00:44:48,152
>> Okay, so a thicker coat

2066
00:44:48,152 --> 00:44:49,253
covers up the darker colors.

2067
00:44:49,253 --> 00:44:50,687
>> Yup, go-go to Home Depot,

2068
00:44:50,687 --> 00:44:51,822
buy the best quality

2069
00:44:51,822 --> 00:44:52,723
white paint you got,

2070
00:44:52,723 --> 00:44:53,657
put it on the wall

2071
00:44:53,657 --> 00:44:54,825
and paint over a black surface.

2072
00:44:54,825 --> 00:44:55,626
>> Yeah.

2073
00:44:55,626 --> 00:44:56,393
>> And you paint it and you

2074
00:44:56,393 --> 00:44:57,227
look at it and you go,

2075
00:44:57,227 --> 00:44:57,961
"Is that good enough?"

2076
00:44:57,961 --> 00:44:58,929
>> Now it's kinda brownish.

2077
00:44:58,929 --> 00:44:59,730
>> Yeah, so you put

2078
00:44:59,730 --> 00:45:01,131
another layer and it's whiter.

2079
00:45:01,131 --> 00:45:01,932
>> Okay, I got ya.

2080
00:45:01,932 --> 00:45:02,699
>> Well it turns out

2081
00:45:02,699 --> 00:45:03,434
the more layers you put,

2082
00:45:03,434 --> 00:45:04,268
the whiter it gets.

2083
00:45:04,268 --> 00:45:04,968
>> Okay.

2084
00:45:04,968 --> 00:45:05,636
>> There's no--

2085
00:45:05,636 --> 00:45:06,703
there's never an end to that.

2086
00:45:06,703 --> 00:45:07,671
>> Okay, interesting.

2087
00:45:07,671 --> 00:45:08,505
>> If you can keep on thicker

2088
00:45:08,505 --> 00:45:09,506

and thicker and thicker,

2089
00:45:09,506 --> 00:45:10,441
but there's of course a place

2090
00:45:10,441 --> 00:45:12,176
where you have so little.

2091
00:45:12,176 --> 00:45:13,043
>> Sure.

2092
00:45:13,043 --> 00:45:14,445
>> You know, lost-- you know,

2093
00:45:14,445 --> 00:45:15,312
of light actually getting

2094
00:45:15,312 --> 00:45:16,213
through all that white paint

2095
00:45:16,213 --> 00:45:16,980
and being absorbed by

2096
00:45:16,980 --> 00:45:18,015
that black underlayer that

2097
00:45:18,015 --> 00:45:18,949
you don't care anymore.

2098
00:45:18,949 --> 00:45:19,850
Sure, and this--

2099
00:45:19,850 --> 00:45:20,684
>> And we talk about a layer,

2100
00:45:20,684 --> 00:45:21,418
what are we talking about

2101
00:45:21,418 --> 00:45:22,486
thickness-wise?

2102
00:45:22,486 --> 00:45:24,321
>> Well, the spray-on coatings

2103
00:45:24,321 --> 00:45:25,289
that we're doing are

2104
00:45:25,289 --> 00:45:27,891
probably 100 microns,

2105
00:45:27,891 --> 00:45:29,393
uh, 4,000th of an inch,

2106
00:45:29,393 --> 00:45:30,961
5,000th of an inch.

2107
00:45:30,961 --> 00:45:32,496
>> 5,000th of an inch?

2108
00:45:32,496 --> 00:45:33,363
>> Yeah, for the--

2109
00:45:33,363 --> 00:45:34,064
for the thin ones.

2110
00:45:34,064 --> 00:45:34,932
>> For-for a coat.

2111
00:45:34,932 --> 00:45:35,766
>> Yeah, for the--

2112
00:45:35,766 --> 00:45:36,500
for spray-on coating.

2113
00:45:36,500 --> 00:45:37,468

For the-- But that's not--

2114
00:45:37,468 --> 00:45:38,635
If you wanna get the really

2115
00:45:38,635 --> 00:45:40,437
good performance we're talking

2116
00:45:40,437 --> 00:45:41,472
a couple of millimeters.

2117
00:45:41,472 --> 00:45:42,539
>> Okay.

2118
00:45:42,539 --> 00:45:43,273
>> Tenth of an inch.

2119
00:45:43,273 --> 00:45:44,141
>> So a 10th of an inch

2120
00:45:44,141 --> 00:45:45,642
gives you really, really--

2121
00:45:45,642 --> 00:45:46,677
>> Yeah, good performance.

2122
00:45:46,677 --> 00:45:47,544
>> --effective--

2123
00:45:47,544 --> 00:45:48,946
>> Yeah, yeah.

2124
00:45:48,946 --> 00:45:50,080
>> --resistance to Sun's energy?

2125
00:45:50,080 --> 00:45:50,948
>> Yeah.

2126
00:45:50,948 --> 00:45:51,648
>> That's awesome.

2127
00:45:51,648 --> 00:45:52,416
>> With the-- with the new

2128
00:45:52,416 --> 00:45:53,183
materials that we're look--

2129
00:45:53,183 --> 00:45:53,951
hopefully that gets

2130
00:45:53,951 --> 00:45:54,585
improved a little bit.

2131
00:45:54,585 --> 00:45:55,285
We still have some

2132
00:45:55,285 --> 00:45:56,620
optimization going on,

2133
00:45:56,620 --> 00:45:57,888
but somewhere in that ballpark.

2134
00:45:57,888 --> 00:45:59,223
>> So with fast tracking,

2135
00:45:59,223 --> 00:46:00,057
what does that timeline

2136
00:46:00,057 --> 00:46:00,724
look like?

2137
00:46:00,724 --> 00:46:01,425
Are we talking like

2138
00:46:01,425 --> 00:46:02,126

a couple years?

2139
00:46:02,126 --> 00:46:02,860
Ten years?

2140
00:46:02,860 --> 00:46:04,628
>> Probably-- You know,

2141
00:46:04,628 --> 00:46:05,529
the problem with doing

2142
00:46:05,529 --> 00:46:07,030
research and-and-and development

2143
00:46:07,030 --> 00:46:08,398
is you tend to make

2144
00:46:08,398 --> 00:46:10,000
these long several months

2145
00:46:10,000 --> 00:46:11,034
not much happens

2146
00:46:11,034 --> 00:46:12,236
and then there's this leapfrog

2147
00:46:12,236 --> 00:46:13,170
and suddenly you have

2148
00:46:13,170 --> 00:46:14,171
things work better, especially

2149
00:46:14,171 --> 00:46:15,105
if you step back a bit.

2150
00:46:15,105 --> 00:46:17,207
So I-I-I'm hesitant to say

2151
00:46:17,207 --> 00:46:18,642
in a year we'll have it work.

2152
00:46:18,642 --> 00:46:19,543
>> Sure.

2153
00:46:19,543 --> 00:46:20,210
>> You know, like-like

2154
00:46:20,210 --> 00:46:20,978
the barium fluoride we

2155
00:46:20,978 --> 00:46:21,812
started off with,

2156
00:46:21,812 --> 00:46:23,113
we discovered and found

2157
00:46:23,113 --> 00:46:24,081
experimentally.

2158
00:46:24,081 --> 00:46:26,350
We can't get water off of it

2159
00:46:26,350 --> 00:46:28,118
very easily and so we're

2160
00:46:28,118 --> 00:46:29,052
actually changing to

2161
00:46:29,052 --> 00:46:30,354
a different material right now.

2162
00:46:30,354 --> 00:46:31,121
>> Okay.

2163
00:46:31,121 --> 00:46:31,822

>> And we're looking at

2164
00:46:31,822 --> 00:46:32,589
other options because

2165
00:46:32,589 --> 00:46:33,357
the barium fluoride,

2166
00:46:33,357 --> 00:46:34,691
even though it's great

2167
00:46:34,691 --> 00:46:35,692
and we-we'd be really good

2168
00:46:35,692 --> 00:46:36,460
to go to the Sun

2169
00:46:36,460 --> 00:46:37,227
because the Sun's heat

2170
00:46:37,227 --> 00:46:38,562
would bake off the water,

2171
00:46:38,562 --> 00:46:39,997
it's not the appropriate

2172
00:46:39,997 --> 00:46:41,331
material to use to get

2173
00:46:41,331 --> 00:46:42,633
really cold because of that.

2174
00:46:42,633 --> 00:46:44,368
Water is-is something that

2175
00:46:44,368 --> 00:46:45,836
absorbs some ultraviolet

2176
00:46:45,836 --> 00:46:47,171
and some infrared, and it's not

2177
00:46:47,171 --> 00:46:48,872
the material of choice.

2178
00:46:48,872 --> 00:46:49,606
So we don't want

2179
00:46:49,606 --> 00:46:50,541
that water in there.

2180
00:46:50,541 --> 00:46:52,009
>> So obviously some-some

2181
00:46:52,009 --> 00:46:53,377
details and some hurdles

2182
00:46:53,377 --> 00:46:55,379
along the way, what's the--

2183
00:46:55,379 --> 00:46:56,313
what's the process of

2184
00:46:56,313 --> 00:46:57,080
developing a technology

2185
00:46:57,080 --> 00:46:57,781
like this?

2186
00:46:57,781 --> 00:46:58,849
Obviously, like, you've made

2187
00:46:58,849 --> 00:46:59,783
some really good progress,

2188
00:46:59,783 --> 00:47:00,617

you're learning more,

2189
00:47:00,617 --> 00:47:01,985
you're adapting and adjusting

2190
00:47:01,985 --> 00:47:03,487
the-the approach, so where

2191
00:47:03,487 --> 00:47:05,022
do you go from here?

2192
00:47:05,022 --> 00:47:06,290
>> Well, there-there-there's

2193
00:47:06,290 --> 00:47:07,191
actually, uh, multiple

2194
00:47:07,191 --> 00:47:08,458
directions that we're going

2195
00:47:08,458 --> 00:47:10,260
and a lot of that is based on

2196
00:47:10,260 --> 00:47:11,395
a variety of customers

2197
00:47:11,395 --> 00:47:12,629
that are coming to the door.

2198
00:47:12,629 --> 00:47:14,531
Um, for example, within

2199
00:47:14,531 --> 00:47:16,633
10 years there are 200, uh,

2200
00:47:16,633 --> 00:47:17,901
more astronomical units.

2201
00:47:17,901 --> 00:47:18,735
They start getting

2202
00:47:18,735 --> 00:47:19,803
substantial distances.

2203
00:47:19,803 --> 00:47:20,704
>> Yeah, that's awesome.

2204
00:47:20,704 --> 00:47:21,572
Man, that's so cool.

2205
00:47:21,572 --> 00:47:22,673
Hey, is it possible to block out

2206
00:47:22,673 --> 00:47:23,974
too much radiation?

2207
00:47:23,974 --> 00:47:25,075
Can I-- Can I create something

2208
00:47:25,075 --> 00:47:26,243
that's too effective?

2209
00:47:26,243 --> 00:47:26,944
Is there a problem with

2210
00:47:26,944 --> 00:47:27,611
doing that?

2211
00:47:27,611 --> 00:47:28,579
>> Well-Well, like in

2212
00:47:28,579 --> 00:47:29,980
our earlier analysis we show

2213
00:47:29,980 --> 00:47:31,782

that as you're flying to Mars

2214
00:47:31,782 --> 00:47:32,716
and you're blocking all

2215
00:47:32,716 --> 00:47:33,884
the Sun's-- uh, substantial

2216
00:47:33,884 --> 00:47:35,219
amounts of the Sun's energy,

2217
00:47:35,219 --> 00:47:36,386
there's a possibility that

2218
00:47:36,386 --> 00:47:38,622
the liquid oxygen can freeze.

2219
00:47:38,622 --> 00:47:39,389
>> Okay.

2220
00:47:39,389 --> 00:47:40,090
>> And people don't

2221
00:47:40,090 --> 00:47:40,824
want it to freeze.

2222
00:47:40,824 --> 00:47:41,425
>> Sure.

2223
00:47:41,425 --> 00:47:42,326
>> And you can't get at it.

2224
00:47:42,326 --> 00:47:42,960
>> Sure.

2225
00:47:42,960 --> 00:47:43,961
>> So we've actually had people

2226
00:47:43,961 --> 00:47:44,928
come back to us and say,

2227
00:47:44,928 --> 00:47:46,129
"Don't get too cold.

2228
00:47:46,129 --> 00:47:47,764
We-we want some pressure

2229
00:47:47,764 --> 00:47:49,199
so we can pull out that oxygen

2230
00:47:49,199 --> 00:47:50,200
as we need it."

2231
00:47:50,200 --> 00:47:50,901
>> But it's probably easier

2232
00:47:50,901 --> 00:47:52,736
to just not put as many layers.

2233
00:47:52,736 --> 00:47:53,570
>> Yeah, yeah.

2234
00:47:53,570 --> 00:47:54,338
>> So that's an easy problem

2235
00:47:54,338 --> 00:47:55,005
probably to deal with.

2236
00:47:55,005 --> 00:47:55,672
>> It-it is.

2237
00:47:55,672 --> 00:47:56,306
Also, there's other

2238
00:47:56,306 --> 00:47:57,007

sources of heat.

2239
00:47:57,007 --> 00:47:57,674
>> Okay.

2240
00:47:57,674 --> 00:47:58,342
>> You conduct heat from

2241
00:47:58,342 --> 00:47:59,343
other parts of your spacecraft.

2242
00:47:59,343 --> 00:48:00,744
You can actually pick up

2243
00:48:00,744 --> 00:48:02,779
infrared warmth from planets,

2244
00:48:02,779 --> 00:48:04,314
from Mars or from the Earth.

2245
00:48:04,314 --> 00:48:05,582
They give-- The Earth gives off

2246
00:48:05,582 --> 00:48:07,451
a huge amount of heat, you know,

2247
00:48:07,451 --> 00:48:09,419
as radiating warm body.

2248
00:48:09,419 --> 00:48:10,821
So when you're up in orbit--

2249
00:48:10,821 --> 00:48:12,122
When-when The Orbiter was

2250
00:48:12,122 --> 00:48:14,358
in orbit they had a radiative

2251
00:48:14,358 --> 00:48:15,826
heat rejection system

2252
00:48:15,826 --> 00:48:16,827
that works when they're

2253
00:48:16,827 --> 00:48:17,961
facing the Sun.

2254
00:48:17,961 --> 00:48:19,129
It does not work

2255
00:48:19,129 --> 00:48:20,197
when they face the Earth.

2256
00:48:20,197 --> 00:48:21,098
>> Interesting.

2257
00:48:21,098 --> 00:48:21,999
>> So-so they turn and face

2258
00:48:21,999 --> 00:48:23,000
the Earth there's so much

2259
00:48:23,000 --> 00:48:24,368
infrared heat coming off

2260
00:48:24,368 --> 00:48:25,402
the Earth, The Orbiter

2261
00:48:25,402 --> 00:48:26,436
starts heating up.

2262
00:48:26,436 --> 00:48:27,137
>> Interesting.

2263
00:48:27,137 --> 00:48:27,838

>> And they can't

2264
00:48:27,838 --> 00:48:28,705
keep it cool inside.

2265
00:48:28,705 --> 00:48:29,573
They have to actually turn

2266
00:48:29,573 --> 00:48:30,707
and face away from the Earth,

2267
00:48:30,707 --> 00:48:32,376
towards the Sun or space.

2268
00:48:32,376 --> 00:48:33,477
So, I mean, these-these things

2269
00:48:33,477 --> 00:48:34,745
are all kinda counterintuitive.

2270
00:48:34,745 --> 00:48:35,846
I mean, you would think

2271
00:48:35,846 --> 00:48:37,381
the Sun is your big source

2272
00:48:37,381 --> 00:48:38,348
of heat, but when you're

2273
00:48:38,348 --> 00:48:39,616
in low Earth orbit,

2274
00:48:39,616 --> 00:48:40,851
the Earth is radiating

2275
00:48:40,851 --> 00:48:42,419
from this huge extent.

2276
00:48:42,419 --> 00:48:43,320
>> Sure.

2277
00:48:43,320 --> 00:48:44,354
>> It's a huge object,

2278
00:48:44,354 --> 00:48:45,255
so the heat is coming from

2279
00:48:45,255 --> 00:48:46,556
all directions at you.

2280
00:48:46,556 --> 00:48:47,824
The Sun is just one point in

2281
00:48:47,824 --> 00:48:50,661
the sky so that-that-that-that

2282
00:48:50,661 --> 00:48:51,662
heat issue is something you

2283
00:48:51,662 --> 00:48:52,996
really have to keep in-in mind

2284
00:48:52,996 --> 00:48:54,231
when you're orbiting Mars

2285
00:48:54,231 --> 00:48:55,365
or orbiting the Earth.

2286
00:48:55,365 --> 00:48:57,234
>> Yeah, that's-- It's crazy

2287
00:48:57,234 --> 00:48:58,735
to kinda make the mental leap

2288
00:48:58,735 --> 00:49:00,904

from understanding the world

2289
00:49:00,904 --> 00:49:01,772
and kinda how heat

2290
00:49:01,772 --> 00:49:02,873
and things work around us

2291
00:49:02,873 --> 00:49:03,774
in an atmosphere.

2292
00:49:03,774 --> 00:49:04,775
But when you get to

2293
00:49:04,775 --> 00:49:05,642
a vacuum of space,

2294
00:49:05,642 --> 00:49:06,410
it's a different game.

2295
00:49:06,410 --> 00:49:08,078
>> E-everything is radiative--

2296
00:49:08,078 --> 00:49:08,812
The temperatures

2297
00:49:08,812 --> 00:49:09,513
of the planets,

2298
00:49:09,513 --> 00:49:10,414
the temperatures, you know,

2299
00:49:10,414 --> 00:49:11,882
of the moons-- You-you

2300
00:49:11,882 --> 00:49:12,783
work out the temperature of

2301
00:49:12,783 --> 00:49:14,084
the moon itself and all you

2302
00:49:14,084 --> 00:49:15,085
really need to know is

2303
00:49:15,085 --> 00:49:16,219
that the Sun is hitting it

2304
00:49:16,219 --> 00:49:18,088
with radiation.

2305
00:49:18,088 --> 00:49:18,889
And you can work all

2306
00:49:18,889 --> 00:49:19,589
the numbers and you get

2307
00:49:19,589 --> 00:49:20,390
a really good estimate for

2308
00:49:20,390 --> 00:49:21,892
the temperature of the moon

2309
00:49:21,892 --> 00:49:23,593
on the side facing the Sun.

2310
00:49:23,593 --> 00:49:24,995
The same with the Earth.

2311
00:49:24,995 --> 00:49:25,829
You got the Earth's temperature

2312
00:49:25,829 --> 00:49:27,164
is heavily dictated,

2313
00:49:27,164 --> 00:49:28,265

you know, by its interaction

2314
00:49:28,265 --> 00:49:29,232
of the Sun.

2315
00:49:29,232 --> 00:49:30,100
There's a little bit of

2316
00:49:30,100 --> 00:49:31,234
internal heat coming up

2317
00:49:31,234 --> 00:49:32,803
from the-- from the core,

2318
00:49:32,803 --> 00:49:34,037
but for the most part

2319
00:49:34,037 --> 00:49:34,938
the Earth's temp-- the Earth

2320
00:49:34,938 --> 00:49:35,806
and the Moon and the planets,

2321
00:49:35,806 --> 00:49:37,107
their temperatures are set by

2322
00:49:37,107 --> 00:49:38,375
their interaction of the Sun.

2323
00:49:38,375 --> 00:49:40,444
And that's all radiative.

2324
00:49:40,444 --> 00:49:41,178
>> Awesome.

2325
00:49:41,178 --> 00:49:42,212
Dr. Youngquist I appreciate

2326
00:49:42,212 --> 00:49:43,080
your time today.

2327
00:49:43,080 --> 00:49:43,947
This has been phenomenal.

2328
00:49:43,947 --> 00:49:45,549
Good luck to you and your team

2329
00:49:45,549 --> 00:49:46,850
as you guys help to shape

2330
00:49:46,850 --> 00:49:48,452
the future of-of our life

2331
00:49:48,452 --> 00:49:49,820
beyond Earth on the Moon

2332
00:49:49,820 --> 00:49:50,787
and Mars and beyond.

2333
00:49:50,787 --> 00:49:51,455
>> Well, thank you so much

2334
00:49:51,455 --> 00:49:52,155
for having me.

2335
00:49:52,155 --> 00:49:53,657
I appreciate it.

2336
00:49:56,993 --> 00:49:58,061
>> That's our show.

2337
00:49:58,061 --> 00:49:58,762
Thanks for stopping by

2338
00:49:58,762 --> 00:49:59,930

the Rocket Ranch.

2339
00:49:59,930 --> 00:50:00,697
And special thanks to

2340
00:50:00,697 --> 00:50:02,332
our guests, our Sun scientist,

2341
00:50:02,332 --> 00:50:03,500
Dr. Nicky Fox,

2342
00:50:03,500 --> 00:50:04,901
and cryo coatings extraordinaire

2343
00:50:04,901 --> 00:50:06,737
Dr. Bob Youngquist.

2344
00:50:06,737 --> 00:50:07,604
To learn more about

2345
00:50:07,604 --> 00:50:08,939
all things Sun, you can head

2346
00:50:08,939 --> 00:50:11,675
to nasa.gov/sun.

2347
00:50:11,675 --> 00:50:12,509
There are also several

2348
00:50:12,509 --> 00:50:13,810
NASA podcasts you can check out

2349
00:50:13,810 --> 00:50:14,578
to learn more about

2350
00:50:14,578 --> 00:50:15,312
the science happening

2351
00:50:15,312 --> 00:50:16,113
all over our centers

2352
00:50:16,113 --> 00:50:18,749
at nasa.gov/podcasts.

2353
00:50:18,749 --> 00:50:20,117
And shout out to our sound man,

2354
00:50:20,117 --> 00:50:21,151
Lorne Maythree,

2355
00:50:21,151 --> 00:50:22,386
Editor Frankie Martin,

2356
00:50:22,386 --> 00:50:24,354
and our Producer, Jessica Londa.

2357
00:50:24,354 --> 00:50:25,989
Tune in next month as we hear

2358
00:50:25,989 --> 00:50:27,090
how experts are working

2359
00:50:27,090 --> 00:50:28,592
to insure failure isn't