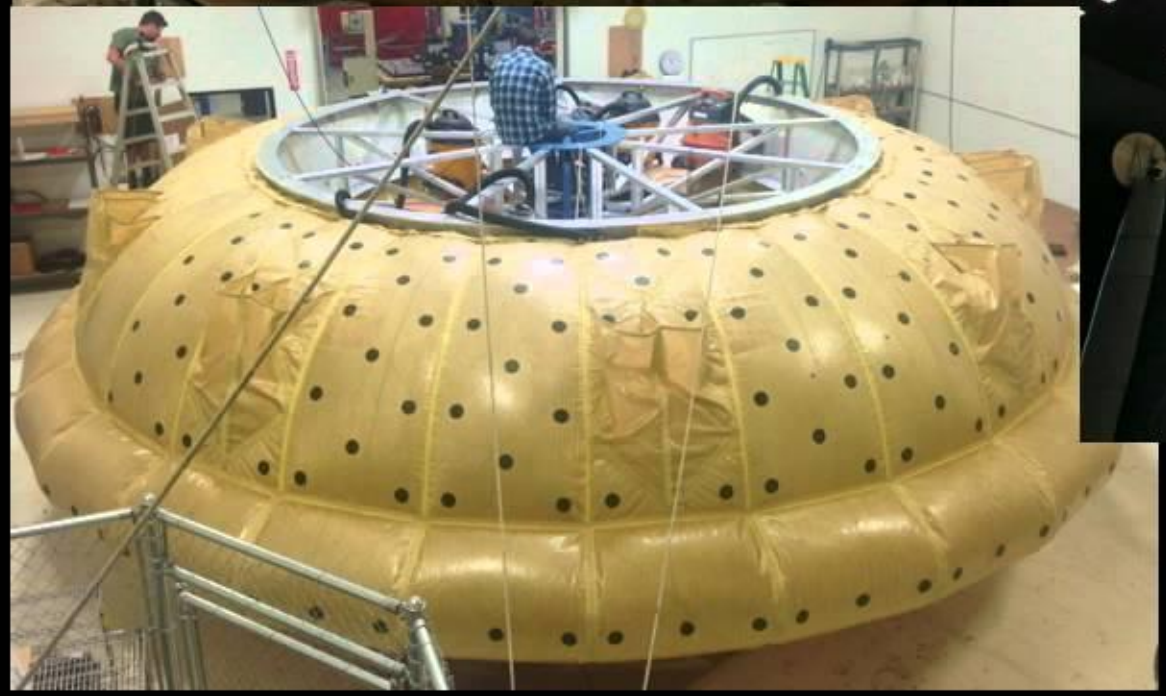
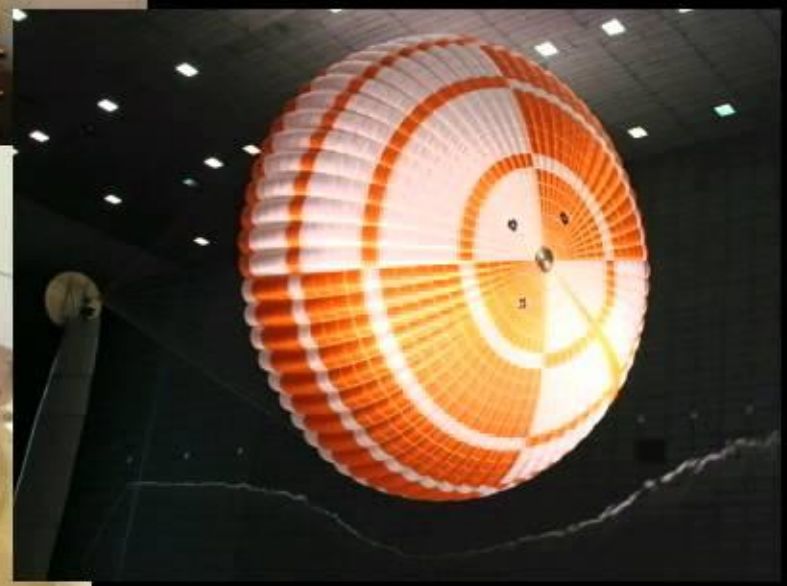
LDSD: Low-Density Supersonic Decelerator





1
00:00:14,870 --> 00:00:13,190
all right i'd like to welcome all of you

2
00:00:17,109 --> 00:00:14,880
to the smithsonian national air and

3
00:00:18,550 --> 00:00:17,119
space museum and to the moving beyond

4
00:00:20,150 --> 00:00:18,560
earth gallery

5
00:00:21,910 --> 00:00:20,160
today we have our what's new and

6
00:00:24,390 --> 00:00:21,920
aerospace program

7
00:00:26,390 --> 00:00:24,400
sewing machines balloons and rocket fuel

8
00:00:27,429 --> 00:00:26,400
and our program today is sponsored by

9
00:00:29,429 --> 00:00:27,439
boeing

10
00:00:31,669 --> 00:00:29,439
i'd like to welcome all of our online

11
00:00:33,270 --> 00:00:31,679
viewers and our folks from nasa tv as

12
00:00:34,310 --> 00:00:33,280
well as those of you in the audience

13
00:00:39,830 --> 00:00:34,320

today

14
00:00:41,670 --> 00:00:39,840
dr clark is the principal investigator

15
00:00:43,670 --> 00:00:41,680
for the low density supersonic

16
00:00:46,549 --> 00:00:43,680
decelerator project

17
00:00:48,709 --> 00:00:46,559
in 2012 clark received the presidential

18
00:00:50,950 --> 00:00:48,719
early career award for

19
00:00:53,430 --> 00:00:50,960
exceptional leadership and achievement

20
00:00:55,110 --> 00:00:53,440
from president obama at the end of his

21
00:00:57,189 --> 00:00:55,120
presentation we'll have an opportunity

22
00:00:59,590 --> 00:00:57,199
to take questions from the audience as

23
00:01:06,950 --> 00:00:59,600
well as our online viewers so let's give

24
00:01:10,789 --> 00:01:08,950
thank you mark and thank you to the air

25
00:01:12,230 --> 00:01:10,799
and space museum for inviting me today

26
00:01:15,350 --> 00:01:12,240
to give this talk and thank you all for

27
00:01:17,990 --> 00:01:15,360
attending the title of my talk is called

28
00:01:19,429 --> 00:01:18,000
sewing machines balloons and rocket fuel

29
00:01:21,030 --> 00:01:19,439
and you're probably wondering what these

30
00:01:23,190 --> 00:01:21,040
three very disparate objects have to do

31
00:01:26,310 --> 00:01:23,200
with the future of mars exploration in

32
00:01:27,910 --> 00:01:26,320
particular how we land on mars so my

33
00:01:29,429 --> 00:01:27,920
talk will give you a little bit of

34
00:01:32,069 --> 00:01:29,439
overview of technologies that we're

35
00:01:33,429 --> 00:01:32,079
developing here within nasa uh this year

36
00:01:34,469 --> 00:01:33,439
and last year and over the past few

37
00:01:36,789 --> 00:01:34,479
years

38
00:01:39,190 --> 00:01:36,799

that we use for landing uh our missions

39
00:01:41,030 --> 00:01:39,200
on the surface of mars but

40
00:01:42,469 --> 00:01:41,040
we are of course at the world's coolest

41
00:01:43,910 --> 00:01:42,479
museum so i'm actually going to start

42
00:01:46,389 --> 00:01:43,920
off the talk with giving you a little

43
00:01:48,870 --> 00:01:46,399
bit of history about how we've developed

44
00:01:50,469 --> 00:01:48,880
technologies and how we currently land

45
00:01:53,030 --> 00:01:50,479
on mars today

46
00:01:55,670 --> 00:01:53,040
so let's get started

47
00:01:57,910 --> 00:01:55,680
this is the curiosity rover or sometimes

48
00:01:59,670 --> 00:01:57,920
known as the mars science laboratory

49
00:02:02,310 --> 00:01:59,680
it's a little less than a full metric

50
00:02:04,630 --> 00:02:02,320
ton it's about the size of a small suv

51
00:02:06,709 --> 00:02:04,640
for comparison it's about twice as heavy

52
00:02:09,029 --> 00:02:06,719
as the mars lander viking lander

53
00:02:11,110 --> 00:02:09,039
prototype that's just outside

54
00:02:13,430 --> 00:02:11,120
this exhibit gallery you guys can take a

55
00:02:15,990 --> 00:02:13,440
look when i'm done

56
00:02:17,510 --> 00:02:16,000
but at 900 kilograms it is the largest

57
00:02:19,350 --> 00:02:17,520
most massive thing that we've ever

58
00:02:21,270 --> 00:02:19,360
landed on another planet

59
00:02:23,430 --> 00:02:21,280
it's six-wheel drive nuclear powered

60
00:02:25,430 --> 00:02:23,440
laser equipped and putting it safely on

61
00:02:27,190 --> 00:02:25,440
the surface of mars was a tremendous

62
00:02:28,790 --> 00:02:27,200
engineering challenge

63
00:02:29,670 --> 00:02:28,800

so how did we do that

64
00:02:31,430 --> 00:02:29,680
well

65
00:02:33,270 --> 00:02:31,440
we start at the top of the atmosphere

66
00:02:35,430 --> 00:02:33,280
the martian atmosphere

67
00:02:37,270 --> 00:02:35,440
encapsulating the rover inside a very

68
00:02:39,110 --> 00:02:37,280
large blunt body it's about 15 feet in

69
00:02:41,190 --> 00:02:39,120
diameter and it comes screaming into the

70
00:02:43,110 --> 00:02:41,200
martian atmosphere at about 10 000 miles

71
00:02:45,190 --> 00:02:43,120
an hour we use the atmosphere to help

72
00:02:46,949 --> 00:02:45,200
slow down from about ten thousand miles

73
00:02:49,190 --> 00:02:46,959
an hour down to about two thousand miles

74
00:02:51,589 --> 00:02:49,200
an hour where we hit the emergency brake

75
00:02:53,430 --> 00:02:51,599
we deploy a large 65-foot diameter

76
00:02:54,309 --> 00:02:53,440
parachute at over twice the speed of

77
00:02:56,630 --> 00:02:54,319
sound

78
00:02:59,190 --> 00:02:56,640
that slows the capsule down from 2000

79
00:03:00,229 --> 00:02:59,200
miles an hour down to about 200 miles an

80
00:03:01,589 --> 00:03:00,239
hour

81
00:03:03,750 --> 00:03:01,599
at which point we have to turn on our

82
00:03:05,190 --> 00:03:03,760
rocket engines

83
00:03:06,790 --> 00:03:05,200
we use something called the sky crane

84
00:03:08,790 --> 00:03:06,800
system to help slow it down a little bit

85
00:03:10,390 --> 00:03:08,800
further and gently

86
00:03:12,309 --> 00:03:10,400
bring the rover closer and closer

87
00:03:14,790 --> 00:03:12,319
towards the surface of earth bring the

88
00:03:16,790 --> 00:03:14,800

velocity down to zero and then slowly

89
00:03:17,670 --> 00:03:16,800
lower the rover down to the surface of

90
00:03:20,710 --> 00:03:17,680
earth

91
00:03:24,869 --> 00:03:22,790
hit the surface we cut the cables the

92
00:03:27,190 --> 00:03:24,879
sky crane flies off in the distance

93
00:03:29,589 --> 00:03:27,200
crashes in the distance but the rover is

94
00:03:33,270 --> 00:03:29,599
there safely landed and today it's doing

95
00:03:35,190 --> 00:03:33,280
amazing science for us

96
00:03:37,030 --> 00:03:35,200
how we've landed things on mars hasn't

97
00:03:39,030 --> 00:03:37,040
really changed a whole lot in the past

98
00:03:40,869 --> 00:03:39,040
forty years we start at the top of the

99
00:03:42,789 --> 00:03:40,879
atmosphere with very large vehicles that

100
00:03:44,550 --> 00:03:42,799
we use to help slow down but those

101
00:03:45,990 --> 00:03:44,560
aren't adequate enough we have to use

102
00:03:47,910 --> 00:03:46,000
parachutes that are deployed at several

103
00:03:49,750 --> 00:03:47,920
times the speed of sound to slow us a

104
00:03:52,309 --> 00:03:49,760
little bit further and we use rocket

105
00:03:54,470 --> 00:03:52,319
fuel to help sell us the last little bit

106
00:03:57,270 --> 00:03:54,480
and put the payload safely there we have

107
00:03:59,509 --> 00:03:57,280
made some advances uh particularly on

108
00:04:01,030 --> 00:03:59,519
the blunt bodies we can actually steer

109
00:04:02,789 --> 00:04:01,040
these barn doors through the thin

110
00:04:04,470 --> 00:04:02,799
martian atmosphere to try to get a

111
00:04:06,789 --> 00:04:04,480
little bit more altitude and land

112
00:04:08,229 --> 00:04:06,799
heavier payloads some slightly heavier

113
00:04:10,070 --> 00:04:08,239

payloads and also help improve some of

114
00:04:12,229 --> 00:04:10,080
the accuracy of of where we can land

115
00:04:14,309 --> 00:04:12,239
these payloads on mars

116
00:04:16,150 --> 00:04:14,319
on the landing side we've improved some

117
00:04:18,310 --> 00:04:16,160
of our landing technologies we've gone

118
00:04:21,030 --> 00:04:18,320
from the pulse thrusters that the viking

119
00:04:23,030 --> 00:04:21,040
lander like the one outside uh used to

120
00:04:24,390 --> 00:04:23,040
airbags that we've used for some of our

121
00:04:26,550 --> 00:04:24,400
smaller rovers

122
00:04:27,749 --> 00:04:26,560
to more recently the sky crane system

123
00:04:29,430 --> 00:04:27,759
but one of the areas that we haven't

124
00:04:31,510 --> 00:04:29,440
really made any significant advancements

125
00:04:33,030 --> 00:04:31,520
in are these supersonic parachutes

126
00:04:34,790 --> 00:04:33,040
they're still the cornerstone of our

127
00:04:37,830 --> 00:04:34,800
supersonic decelerators that we use for

128
00:04:40,150 --> 00:04:38,870
now

129
00:04:41,990 --> 00:04:40,160
we want to land things that are a little

130
00:04:43,670 --> 00:04:42,000
bit bigger and this is the part where if

131
00:04:44,790 --> 00:04:43,680
you guys could sort of grab onto the

132
00:04:47,909 --> 00:04:44,800
side of your chair and hold tight

133
00:04:49,830 --> 00:04:47,919
because we're about to do some math

134
00:04:51,350 --> 00:04:49,840
how we slow down there's two main things

135
00:04:52,629 --> 00:04:51,360
for as long as we've been accelerating

136
00:04:53,990 --> 00:04:52,639
and sending things into space we've been

137
00:04:55,270 --> 00:04:54,000
trying to figure out how to slow them

138
00:04:57,350 --> 00:04:55,280

down safely

139
00:04:59,510 --> 00:04:57,360
we can either use rocket fuel tends to

140
00:05:01,510 --> 00:04:59,520
be very heavy not particularly efficient

141
00:05:03,350 --> 00:05:01,520
or we try to use the atmosphere to slow

142
00:05:05,350 --> 00:05:03,360
us down and the way we use that is we

143
00:05:06,870 --> 00:05:05,360
generate drag and how do we generate

144
00:05:07,909 --> 00:05:06,880
drag well that's the equation up here at

145
00:05:09,430 --> 00:05:07,919
the top

146
00:05:12,230 --> 00:05:09,440
there's four components to generating

147
00:05:14,150 --> 00:05:12,240
drag the density of the atmosphere the

148
00:05:15,029 --> 00:05:14,160
fluid that i'm traveling through

149
00:05:17,189 --> 00:05:15,039
the

150
00:05:19,430 --> 00:05:17,199
velocity of which i'm traveling through

151
00:05:20,950 --> 00:05:19,440
that fluid or through the atmosphere

152
00:05:22,629 --> 00:05:20,960
something called the drag coefficient

153
00:05:25,430 --> 00:05:22,639
it's the measure of the efficiency or

154
00:05:28,790 --> 00:05:25,440
inefficiency of the shape of the device

155
00:05:30,950 --> 00:05:28,800
and the size of device the a the area

156
00:05:32,390 --> 00:05:30,960
if i take our force of drag and i couple

157
00:05:33,909 --> 00:05:32,400
that with

158
00:05:36,150 --> 00:05:33,919
newton's well-known

159
00:05:39,029 --> 00:05:36,160
second law here f equals m a force

160
00:05:42,150 --> 00:05:39,039
equals mass times acceleration

161
00:05:43,990 --> 00:05:42,160
i have that the deceleration due to drag

162
00:05:46,150 --> 00:05:44,000
is equal to this and there's these two

163
00:05:47,670 --> 00:05:46,160

terms over here the size of the object

164
00:05:49,830 --> 00:05:47,680
and the mass and those are the things

165
00:05:51,909 --> 00:05:49,840
that tend to change the most uh every

166
00:05:54,550 --> 00:05:51,919
time we try to send another probe or

167
00:05:57,830 --> 00:05:54,560
spacecraft to mars so if we think about

168
00:05:58,950 --> 00:05:57,840
as we go larger the length of the size

169
00:06:01,430 --> 00:05:58,960
of the thing

170
00:06:04,150 --> 00:06:01,440
grows well the area is only going to go

171
00:06:06,309 --> 00:06:04,160
roughly with the square of the length

172
00:06:08,070 --> 00:06:06,319
but the volume will go with the cube of

173
00:06:09,990 --> 00:06:08,080
length and since we tend to be very

174
00:06:11,430 --> 00:06:10,000
efficient at stuffing as much things as

175
00:06:13,350 --> 00:06:11,440
we can and whatever volume we have

176
00:06:15,270 --> 00:06:13,360
available that means that the mass of

177
00:06:16,390 --> 00:06:15,280
the object will go with the cube of the

178
00:06:18,469 --> 00:06:16,400
length

179
00:06:20,950 --> 00:06:18,479
so if i look at that acceleration and i

180
00:06:22,870 --> 00:06:20,960
put the ratio of the size in terms of

181
00:06:25,029 --> 00:06:22,880
area to mass

182
00:06:27,110 --> 00:06:25,039
i get a over m i get 1 over l that means

183
00:06:28,870 --> 00:06:27,120
that as l gets bigger as the objects get

184
00:06:31,270 --> 00:06:28,880
bigger as the rovers get bigger it

185
00:06:32,070 --> 00:06:31,280
becomes harder and harder to slow them

186
00:06:33,510 --> 00:06:32,080
down

187
00:06:35,110 --> 00:06:33,520
and that's one of the challenges that we

188
00:06:36,710 --> 00:06:35,120

face today

189
00:06:38,390 --> 00:06:36,720
but it's not a unique challenge it's

190
00:06:41,830 --> 00:06:38,400
actually a challenge similar to one that

191
00:06:44,070 --> 00:06:41,840
we had 40 years ago think back to 1962

192
00:06:46,070 --> 00:06:44,080
nasa's in its infancy nasa is beginning

193
00:06:48,870 --> 00:06:46,080
to develop the saturn v the largest

194
00:06:50,629 --> 00:06:48,880
large launch vehicle largest rocket ever

195
00:06:52,550 --> 00:06:50,639
built and the one that we would use to

196
00:06:55,510 --> 00:06:52,560
send astronauts to the surface of the

197
00:06:56,790 --> 00:06:55,520
moon capable of putting over 100 tons in

198
00:06:58,790 --> 00:06:56,800
low earth orbit

199
00:07:01,189 --> 00:06:58,800
now at that time nasa was planning to

200
00:07:03,189 --> 00:07:01,199
use that largest rocket ever built to

201
00:07:05,110 --> 00:07:03,199
send a probe the first probe to the

202
00:07:07,110 --> 00:07:05,120
surface of mars we had very little

203
00:07:08,550 --> 00:07:07,120
knowledge about what mars was like but

204
00:07:11,350 --> 00:07:08,560
we knew that we wanted to send something

205
00:07:12,469 --> 00:07:11,360
very very massive to mars and so in this

206
00:07:14,950 --> 00:07:12,479
vacuum

207
00:07:17,670 --> 00:07:14,960
of knowledge we began in its infancy to

208
00:07:18,870 --> 00:07:17,680
send spacecraft flying by mars we began

209
00:07:20,469 --> 00:07:18,880
learning more about the martian

210
00:07:21,830 --> 00:07:20,479
atmosphere we had observations from

211
00:07:23,749 --> 00:07:21,840
earth that we could make to try to

212
00:07:25,510 --> 00:07:23,759
understand how thick the atmosphere was

213
00:07:27,350 --> 00:07:25,520

but it wasn't really until we started

214
00:07:29,029 --> 00:07:27,360
until we started doing these flybys of

215
00:07:30,550 --> 00:07:29,039
mars that we began to get getting a

216
00:07:33,270 --> 00:07:30,560
better insight into the martian

217
00:07:34,550 --> 00:07:33,280
atmosphere so this figure here this plot

218
00:07:36,950 --> 00:07:34,560
gives you a little bit of history of our

219
00:07:39,510 --> 00:07:36,960
understanding it's density versus

220
00:07:41,350 --> 00:07:39,520
altitude at mars and so for comparison i

221
00:07:44,710 --> 00:07:41,360
put what sea level density here at earth

222
00:07:47,430 --> 00:07:44,720
is about 1.225 kilograms per cubic meter

223
00:07:49,909 --> 00:07:47,440
is the density of our atmosphere

224
00:07:51,510 --> 00:07:49,919
if we look back in 1964

225
00:07:54,230 --> 00:07:51,520
they thought the martian atmosphere near

226
00:07:56,390 --> 00:07:54,240
the surface was maybe

227
00:07:59,029 --> 00:07:56,400
a fraction of that call it one fit in

228
00:08:00,950 --> 00:07:59,039
one tenth or so maybe seven percent of

229
00:08:02,790 --> 00:08:00,960
earth's density but as we started

230
00:08:04,950 --> 00:08:02,800
learning more and more that number got

231
00:08:06,469 --> 00:08:04,960
smaller and smaller our knowledge of the

232
00:08:07,909 --> 00:08:06,479
martian atmosphere particularly at the

233
00:08:10,070 --> 00:08:07,919
altitudes where we do most of our

234
00:08:12,309 --> 00:08:10,080
deceleration started indicating that the

235
00:08:13,670 --> 00:08:12,319
martian atmosphere was very very thin

236
00:08:15,189 --> 00:08:13,680
and today we know that the martian

237
00:08:16,550 --> 00:08:15,199
atmosphere is actually only about one

238
00:08:18,230 --> 00:08:16,560

percent the thickness of earth's

239
00:08:20,150 --> 00:08:18,240
atmosphere so if you think back to that

240
00:08:22,309 --> 00:08:20,160
equation that i showed you where drag

241
00:08:24,390 --> 00:08:22,319
has that row that density variable in

242
00:08:25,430 --> 00:08:24,400
there you realize that to generate drag

243
00:08:26,950 --> 00:08:25,440
you don't really have a whole lot of

244
00:08:29,110 --> 00:08:26,960
density to work with so you need very

245
00:08:31,749 --> 00:08:29,120
very large objects to help create that

246
00:08:33,750 --> 00:08:31,759
drag to slow you down

247
00:08:36,550 --> 00:08:33,760
so in that vacuum of technology of the

248
00:08:38,630 --> 00:08:36,560
early 1960s about how to land on mars we

249
00:08:40,389 --> 00:08:38,640
started developing all kinds of things

250
00:08:42,149 --> 00:08:40,399
inflatable devices that would be stowed

251
00:08:44,470 --> 00:08:42,159
on the back of an aeroshell that we can

252
00:08:45,990 --> 00:08:44,480
inflate at four times the speed of sound

253
00:08:47,670 --> 00:08:46,000
to grow the size of the aeroshell to

254
00:08:49,430 --> 00:08:47,680
create more area to create more drag to

255
00:08:50,710 --> 00:08:49,440
help slow them down things that would be

256
00:08:52,150 --> 00:08:50,720
ram air inflated with these little

257
00:08:53,670 --> 00:08:52,160
scoops on the side

258
00:08:55,590 --> 00:08:53,680
for the first time we started taking

259
00:08:58,389 --> 00:08:55,600
parachutes things that we had been using

260
00:08:59,750 --> 00:08:58,399
reliably for the decades previously uh

261
00:09:01,990 --> 00:08:59,760
people would routinely jump out of

262
00:09:03,750 --> 00:09:02,000
airplanes using cotton or nylon

263
00:09:05,269 --> 00:09:03,760

parachutes or polyester parachutes and

264
00:09:06,870 --> 00:09:05,279
they worked wonderfully we started

265
00:09:08,630 --> 00:09:06,880
pushing them into faster and faster

266
00:09:10,150 --> 00:09:08,640
speed regimes started seeing if

267
00:09:11,590 --> 00:09:10,160
parachutes would work at several times

268
00:09:13,030 --> 00:09:11,600
the speed of sound starting to get our

269
00:09:15,190 --> 00:09:13,040
first understanding of what that was

270
00:09:17,910 --> 00:09:15,200
like some of the very first tests all

271
00:09:19,430 --> 00:09:17,920
occurring in the 1960s

272
00:09:21,829 --> 00:09:19,440
in fact when we did some of those early

273
00:09:23,990 --> 00:09:21,839
tests we began to see that parachutes

274
00:09:25,670 --> 00:09:24,000
operating in a supersonic regime was an

275
00:09:27,750 --> 00:09:25,680
entirely different animal than what we

276
00:09:29,750 --> 00:09:27,760
were used to they tended to inflate

277
00:09:32,389 --> 00:09:29,760
extremely quickly less than a fraction

278
00:09:34,070 --> 00:09:32,399
of a second 0.3 to 0.5 seconds and they

279
00:09:36,389 --> 00:09:34,080
were very very violent in their

280
00:09:38,630 --> 00:09:36,399
inflation once they got open they tended

281
00:09:40,630 --> 00:09:38,640
to collapse and expand and collapse and

282
00:09:42,310 --> 00:09:40,640
expand and they generated a decent

283
00:09:43,590 --> 00:09:42,320
amount of drag but once they slowed down

284
00:09:45,269 --> 00:09:43,600
enough then they were just like

285
00:09:47,350 --> 00:09:45,279
parachutes that we were used to at low

286
00:09:49,350 --> 00:09:47,360
earth altitudes they provided excellent

287
00:09:50,389 --> 00:09:49,360
drag for us so we started pushing

288
00:09:52,150 --> 00:09:50,399

further and further

289
00:09:53,430 --> 00:09:52,160
faster and faster we started

290
00:09:55,350 --> 00:09:53,440
understanding some of the limits of

291
00:09:57,269 --> 00:09:55,360
parachutes we went to several times the

292
00:09:59,030 --> 00:09:57,279
speed of sound and we began to see where

293
00:10:01,350 --> 00:09:59,040
parachutes began beating themselves to

294
00:10:02,949 --> 00:10:01,360
pieces or melting because of the high

295
00:10:05,190 --> 00:10:02,959
mach numbers the aero thermodynamic

296
00:10:06,870 --> 00:10:05,200
heating melting the very thin

297
00:10:10,069 --> 00:10:06,880
polyester material that the parachutes

298
00:10:13,990 --> 00:10:12,150
all of that would eventually go away

299
00:10:15,750 --> 00:10:14,000
once the voyager project which was going

300
00:10:17,829 --> 00:10:15,760
to be using that saturn v rocket would

301
00:10:19,990 --> 00:10:17,839
eventually go away and in its place came

302
00:10:21,910 --> 00:10:20,000
the viking lander something much smaller

303
00:10:23,829 --> 00:10:21,920
still relatively large again you can go

304
00:10:25,350 --> 00:10:23,839
outside and see

305
00:10:26,790 --> 00:10:25,360
but some of the technologies that were

306
00:10:28,230 --> 00:10:26,800
being developed for that program the

307
00:10:30,949 --> 00:10:28,240
voyager program weren't going to be

308
00:10:33,670 --> 00:10:30,959
necessary viking ultimately selected a

309
00:10:37,990 --> 00:10:33,680
parachute as being adequate to land the

310
00:10:40,790 --> 00:10:39,509
so that off ramp from all of that

311
00:10:43,350 --> 00:10:40,800
technology development that occurred in

312
00:10:45,590 --> 00:10:43,360
1960s we took the parachutes and we've

313
00:10:48,069 --> 00:10:45,600

used them for every mars successful mars

314
00:10:49,990 --> 00:10:48,079
mission since so the viking

315
00:10:52,310 --> 00:10:50,000
landers of course the 1970s mars

316
00:10:53,990 --> 00:10:52,320
pathfinder the mars exploration rover

317
00:10:55,509 --> 00:10:54,000
spirit and opportunity

318
00:10:57,590 --> 00:10:55,519
the phoenix lander mars science

319
00:11:00,230 --> 00:10:57,600
laboratory the curiosity

320
00:11:03,269 --> 00:11:00,240
and in the coming years the mars insight

321
00:11:04,630 --> 00:11:03,279
lander and the mars 2020 rover some of

322
00:11:06,230 --> 00:11:04,640
the other technologies that were being

323
00:11:07,269 --> 00:11:06,240
developed would find off ramps in other

324
00:11:09,110 --> 00:11:07,279
areas

325
00:11:10,710 --> 00:11:09,120
we would use them for stabilization

326
00:11:13,590 --> 00:11:10,720
devices on the ejection seats for the

327
00:11:15,269 --> 00:11:13,600
gemini capsules we would use them for

328
00:11:16,710 --> 00:11:15,279
stabilization for meteorological

329
00:11:18,550 --> 00:11:16,720
sounding rockets that we would send high

330
00:11:20,550 --> 00:11:18,560
in the atmosphere to try to understand

331
00:11:22,150 --> 00:11:20,560
what the atmosphere was like at

332
00:11:23,910 --> 00:11:22,160
altitudes well above what an aircraft

333
00:11:25,829 --> 00:11:23,920
can operate at we'd use them for

334
00:11:28,150 --> 00:11:25,839
stabilization and munitions

335
00:11:29,750 --> 00:11:28,160
but ultimately all of that technology

336
00:11:31,110 --> 00:11:29,760
development sort of died down as the

337
00:11:33,110 --> 00:11:31,120
applications and the needs for these

338
00:11:35,350 --> 00:11:33,120

technologies went away and it wasn't

339
00:11:37,190 --> 00:11:35,360
really until a few years ago that we

340
00:11:38,150 --> 00:11:37,200
started having to go back to that and it

341
00:11:39,910 --> 00:11:38,160
was because we were in the same

342
00:11:41,509 --> 00:11:39,920
situation that we were in the 1960s we

343
00:11:43,750 --> 00:11:41,519
want to land even larger things on the

344
00:11:46,710 --> 00:11:43,760
surface of mars and we need technologies

345
00:11:51,350 --> 00:11:48,790
as we look to the future of mars

346
00:11:53,590 --> 00:11:51,360
missions we start thinking about robotic

347
00:11:55,829 --> 00:11:53,600
missions ones that we would use to go

348
00:11:57,590 --> 00:11:55,839
and collect rocks on the surface of mars

349
00:11:59,910 --> 00:11:57,600
or soil samples that we could ultimately

350
00:12:02,230 --> 00:11:59,920
bring back to earth for better analysis

351
00:12:03,910 --> 00:12:02,240
uh perhaps demonstrations that we'd want

352
00:12:05,430 --> 00:12:03,920
to send to the surface of mars to show

353
00:12:07,350 --> 00:12:05,440
that we could take the carbon dioxide of

354
00:12:09,990 --> 00:12:07,360
the martian atmosphere and distill it to

355
00:12:11,590 --> 00:12:10,000
make rocket fuel that we could use

356
00:12:13,269 --> 00:12:11,600
perhaps to land a greenhouse on the

357
00:12:15,509 --> 00:12:13,279
surface of mars to see if we could grow

358
00:12:17,269 --> 00:12:15,519
plants in the martian environment

359
00:12:19,110 --> 00:12:17,279
and ultimately of course as we cast our

360
00:12:20,629 --> 00:12:19,120
eyes to the horizon we start thinking

361
00:12:22,550 --> 00:12:20,639
about that we want to put humans on the

362
00:12:24,150 --> 00:12:22,560
surface of mars that's going to be an

363
00:12:25,990 --> 00:12:24,160

endeavor that takes the one ton

364
00:12:27,430 --> 00:12:26,000
curiosity mass and has to increase it by

365
00:12:29,590 --> 00:12:27,440
at least an order of magnitude you're

366
00:12:31,509 --> 00:12:29,600
looking at putting not just one ton or

367
00:12:34,550 --> 00:12:31,519
ten tons but probably closer to twenty

368
00:12:35,990 --> 00:12:34,560
thirty or forty tons uh i think mark

369
00:12:37,590 --> 00:12:36,000
watney and all the different things that

370
00:12:40,310 --> 00:12:37,600
he had to have to exist on the surface

371
00:12:41,509 --> 00:12:40,320
of mars right his computers his ipads

372
00:12:43,030 --> 00:12:41,519
iphones

373
00:12:44,870 --> 00:12:43,040
food water you know whatever is

374
00:12:49,430 --> 00:12:44,880
necessary to exist on the surface of

375
00:12:50,949 --> 00:12:49,440
mars for days weeks or months at a time

376
00:12:52,870 --> 00:12:50,959
so that's where the project that i'm

377
00:12:54,870 --> 00:12:52,880
working on comes into play low density

378
00:12:56,069 --> 00:12:54,880
supersonic decelerator we're trying to

379
00:12:59,190 --> 00:12:56,079
develop the next generation of

380
00:13:01,590 --> 00:12:59,200
supersonic decelerators for use at mars

381
00:13:03,350 --> 00:13:01,600
for landing those future mars missions

382
00:13:05,350 --> 00:13:03,360
so there's three main decelerator types

383
00:13:07,430 --> 00:13:05,360
that we're developing

384
00:13:09,030 --> 00:13:07,440
the first off is an inflatable drag

385
00:13:11,190 --> 00:13:09,040
device we call these supersonic

386
00:13:13,670 --> 00:13:11,200
inflatable aerodynamic decelerators or

387
00:13:15,190 --> 00:13:13,680
sciats because we love our acronyms

388
00:13:16,790 --> 00:13:15,200

this is the first time that we've really

389
00:13:18,230 --> 00:13:16,800
developed something of this scale and so

390
00:13:19,750 --> 00:13:18,240
when we were going down this path we

391
00:13:20,790 --> 00:13:19,760
wanted something that we thought we

392
00:13:22,870 --> 00:13:20,800
could control and that we could

393
00:13:23,990 --> 00:13:22,880
understand relatively well we wanted a

394
00:13:25,829 --> 00:13:24,000
shape that we thought was very

395
00:13:27,509 --> 00:13:25,839
deterministic that we could help control

396
00:13:28,949 --> 00:13:27,519
with pressure we wanted to be able to

397
00:13:31,910 --> 00:13:28,959
control the pressure in the inside of

398
00:13:33,750 --> 00:13:31,920
device using uh gas generators like

399
00:13:35,590 --> 00:13:33,760
automotive gas generators in fact the

400
00:13:36,790 --> 00:13:35,600
ones that we use for this development

401
00:13:38,389 --> 00:13:36,800
testing were

402
00:13:39,910 --> 00:13:38,399
precisely like the ones that are behind

403
00:13:41,590 --> 00:13:39,920
the steering wheel in your car we didn't

404
00:13:43,990 --> 00:13:41,600
go to a junkyard and rip them out but

405
00:13:45,590 --> 00:13:44,000
they are identical to the ones that

406
00:13:47,509 --> 00:13:45,600
are in your steering wheel

407
00:13:49,110 --> 00:13:47,519
so this is a device that grows the size

408
00:13:51,030 --> 00:13:49,120
of the aeroshell from about 15 feet in

409
00:13:51,829 --> 00:13:51,040
diameter to about 20 feet in diameter

410
00:13:54,150 --> 00:13:51,839
again

411
00:13:56,150 --> 00:13:54,160
bigger area more drag generated and it

412
00:13:59,350 --> 00:13:56,160
does it at several times the speed of

413
00:14:00,790 --> 00:13:59,360

sound about mach 4 mach 5 or so

414
00:14:02,550 --> 00:14:00,800
it's designed to be a very closed

415
00:14:04,790 --> 00:14:02,560
pressure vessel we have moderate

416
00:14:06,389 --> 00:14:04,800
pressure about three to four psi

417
00:14:08,069 --> 00:14:06,399
internals not a whole lot but you don't

418
00:14:11,030 --> 00:14:08,079
really need a whole lot

419
00:14:12,790 --> 00:14:11,040
to maintain a very rigid defined shape

420
00:14:14,230 --> 00:14:12,800
and it's a device that allows us to gain

421
00:14:16,150 --> 00:14:14,240
confidence that when we do things like

422
00:14:17,990 --> 00:14:16,160
our wind tunnel testing or when we

423
00:14:19,990 --> 00:14:18,000
develop small models that we shoot out

424
00:14:21,910 --> 00:14:20,000
of a cannon to see how they fly that the

425
00:14:23,829 --> 00:14:21,920
results from those tests are scalable to

426
00:14:25,829 --> 00:14:23,839
things that are orders of magnitude

427
00:14:27,269 --> 00:14:25,839
larger so we can go from say 2 inches in

428
00:14:28,949 --> 00:14:27,279
diameter to

429
00:14:30,710 --> 00:14:28,959
20 feet in diameter and feel comfortable

430
00:14:32,389 --> 00:14:30,720
that the performance of the device is

431
00:14:34,870 --> 00:14:32,399
scalable that we'll know understand how

432
00:14:36,389 --> 00:14:34,880
to scale it

433
00:14:37,829 --> 00:14:36,399
of course we want to land even larger

434
00:14:40,230 --> 00:14:37,839
things and so we're developing even

435
00:14:41,750 --> 00:14:40,240
larger inflatable decelerators and so

436
00:14:43,189 --> 00:14:41,760
there's another device that actually

437
00:14:45,269 --> 00:14:43,199
harkens back to some of the devices that

438
00:14:47,269 --> 00:14:45,279

were being developed in the 1960s this

439
00:14:49,750 --> 00:14:47,279
one's called an attached isotensioid

440
00:14:52,069 --> 00:14:49,760
it's even bigger it's about 27 almost 30

441
00:14:54,230 --> 00:14:52,079
feet in diameter

442
00:14:56,310 --> 00:14:54,240
and instead of having an internal

443
00:14:58,870 --> 00:14:56,320
pressurization system we actually use

444
00:15:00,790 --> 00:14:58,880
ram air inlets on the side this is a

445
00:15:02,389 --> 00:15:00,800
picture of one of our engineers standing

446
00:15:04,150 --> 00:15:02,399
in front of an inflated version of it

447
00:15:05,590 --> 00:15:04,160
it's upside down these are little ram

448
00:15:06,870 --> 00:15:05,600
air scoops in fact to get this thing

449
00:15:08,389 --> 00:15:06,880
pressurized to

450
00:15:11,030 --> 00:15:08,399
in this case it's about three quarters

451
00:15:12,870 --> 00:15:11,040
of a psi we had to use 27 bounce house

452
00:15:15,110 --> 00:15:12,880
blowers that we supercharged three at a

453
00:15:16,629 --> 00:15:15,120
time so we took the exhaust from one uh

454
00:15:18,230 --> 00:15:16,639
pumped it into the inlet of another and

455
00:15:19,829 --> 00:15:18,240
then took the exhaust to that guy pumped

456
00:15:21,350 --> 00:15:19,839
it into the inlet another

457
00:15:22,870 --> 00:15:21,360
so we could get enough pressure build up

458
00:15:25,350 --> 00:15:22,880
to get this thing going

459
00:15:27,110 --> 00:15:25,360
so 27 of those got that thing up to a

460
00:15:28,710 --> 00:15:27,120
little less than a psi but it took full

461
00:15:30,550 --> 00:15:28,720
shape full geometry so it doesn't take a

462
00:15:32,710 --> 00:15:30,560
whole lot of pressure to get this guy up

463
00:15:34,310 --> 00:15:32,720

to full shape

464
00:15:36,310 --> 00:15:34,320
and lastly we're developing a new

465
00:15:37,990 --> 00:15:36,320
supersonic parachute one that's about

466
00:15:39,189 --> 00:15:38,000
two and a half times the size of any

467
00:15:40,629 --> 00:15:39,199
parachute that we've ever used

468
00:15:42,150 --> 00:15:40,639
successfully

469
00:15:44,550 --> 00:15:42,160
at several times the speed of sound

470
00:15:46,470 --> 00:15:44,560
previously to show some comparison the

471
00:15:47,910 --> 00:15:46,480
phoenix lander a few years ago that

472
00:15:50,389 --> 00:15:47,920
parachute was a little less than 12

473
00:15:52,949 --> 00:15:50,399
meters in diameter the viking was about

474
00:15:55,749 --> 00:15:52,959
16 meters msl the largest supersonic

475
00:15:57,350 --> 00:15:55,759
parachute we've ever used at 21.5 meters

476
00:15:59,749 --> 00:15:57,360
and then here's the parachute that ldsd

477
00:16:01,829 --> 00:15:59,759
is developing about 100 feet in diameter

478
00:16:04,629 --> 00:16:01,839
or the full size of the deceleration

479
00:16:08,150 --> 00:16:04,639
system is about that of a boeing 747

480
00:16:11,670 --> 00:16:10,550
ah sewing machines so

481
00:16:14,150 --> 00:16:11,680
all of these devices that we're

482
00:16:16,230 --> 00:16:14,160
developing are textile devices they're

483
00:16:18,150 --> 00:16:16,240
soft goods they're made from fabrics or

484
00:16:20,870 --> 00:16:18,160
materials that are even woven either

485
00:16:22,550 --> 00:16:20,880
woven or braided together and so we have

486
00:16:25,110 --> 00:16:22,560
to assemble them we have to stitch them

487
00:16:27,110 --> 00:16:25,120
either by hand or more commonly using

488
00:16:29,430 --> 00:16:27,120

sewing machines so i'm not really sure

489
00:16:31,670 --> 00:16:29,440
that elias howe or isaac singer really

490
00:16:33,110 --> 00:16:31,680
understood the fathom of what they were

491
00:16:34,790 --> 00:16:33,120
developing

492
00:16:36,150 --> 00:16:34,800
and that their inventions would become

493
00:16:38,230 --> 00:16:36,160
critical for the future of space

494
00:16:39,829 --> 00:16:38,240
exploration but that very much is the

495
00:16:41,430 --> 00:16:39,839
case these lightweight fabrics that

496
00:16:44,230 --> 00:16:41,440
allow us to pack them into very small

497
00:16:46,069 --> 00:16:44,240
volumes and stow them very easily

498
00:16:50,230 --> 00:16:46,079
really rely on our ability to stitch and

499
00:16:54,150 --> 00:16:52,069
but of course once we've developed the

500
00:16:55,590 --> 00:16:54,160
technologies we have to test them we

501
00:16:57,509 --> 00:16:55,600
want to make sure that the technologies

502
00:16:58,949 --> 00:16:57,519
work the way that they need to that they

503
00:17:00,870 --> 00:16:58,959
have the performance that they have to

504
00:17:02,470 --> 00:17:00,880
have in order to use them at mars and we

505
00:17:04,710 --> 00:17:02,480
want to make sure that they survive the

506
00:17:06,470 --> 00:17:04,720
harsh martian entry environment

507
00:17:08,710 --> 00:17:06,480
that was one of the biggest challenges

508
00:17:09,990 --> 00:17:08,720
of this entire project not so much

509
00:17:11,669 --> 00:17:10,000
although it was difficult to come up

510
00:17:13,110 --> 00:17:11,679
with the technologies

511
00:17:14,549 --> 00:17:13,120
the fabrication the technology is

512
00:17:16,309 --> 00:17:14,559
challenging but we had to figure out

513
00:17:17,669 --> 00:17:16,319

ways in which to test them to stress

514
00:17:19,270 --> 00:17:17,679
them to put them through the environment

515
00:17:20,870 --> 00:17:19,280
that they would see at mars

516
00:17:22,630 --> 00:17:20,880
so when we first started out we started

517
00:17:24,069 --> 00:17:22,640
looking around the country for avenues

518
00:17:25,909 --> 00:17:24,079
or venues that we could do this wind

519
00:17:27,429 --> 00:17:25,919
tunnels that we could put them in

520
00:17:29,909 --> 00:17:27,439
vacuum chambers that we could test them

521
00:17:31,909 --> 00:17:29,919
in we started to realize that none of

522
00:17:34,310 --> 00:17:31,919
the the vacuum chambers or wind tunnels

523
00:17:36,870 --> 00:17:34,320
were big enough that the energies that

524
00:17:38,470 --> 00:17:36,880
the sizes the scales of the devices that

525
00:17:40,230 --> 00:17:38,480
we were developing and the environments

526
00:17:42,710 --> 00:17:40,240
with which we'd have to expose them that

527
00:17:44,710 --> 00:17:42,720
there was no existing way to test them

528
00:17:46,789 --> 00:17:44,720
and that was somewhat of a foundational

529
00:17:48,710 --> 00:17:46,799
moment because we if you think back

530
00:17:50,789 --> 00:17:48,720
right we've been exploring space for

531
00:17:53,029 --> 00:17:50,799
about five decades now right we've gone

532
00:17:54,870 --> 00:17:53,039
to every planet or flown by every planet

533
00:17:57,669 --> 00:17:54,880
in the solar system we've landed things

534
00:17:59,270 --> 00:17:57,679
on mars on venus on moons of saturn

535
00:18:01,510 --> 00:17:59,280
we've sent probes and into the

536
00:18:03,430 --> 00:18:01,520
atmosphere of jupiter

537
00:18:05,430 --> 00:18:03,440
and in that time we've developed all of

538
00:18:07,270 --> 00:18:05,440

this infrastructure things like

539
00:18:08,870 --> 00:18:07,280
wind tunnels that are the size of city

540
00:18:11,190 --> 00:18:08,880
blocks that use more power than a

541
00:18:13,590 --> 00:18:11,200
nuclear aircraft carrier vacuum chambers

542
00:18:15,590 --> 00:18:13,600
that are nearly as large

543
00:18:17,190 --> 00:18:15,600
you know buildings that were for a time

544
00:18:19,430 --> 00:18:17,200
the vehicle assembly building for

545
00:18:20,789 --> 00:18:19,440
example at kennedy the largest building

546
00:18:22,870 --> 00:18:20,799
in the world

547
00:18:24,789 --> 00:18:22,880
in all of that infrastructure we've

548
00:18:26,150 --> 00:18:24,799
essentially outgrown when it came time

549
00:18:27,669 --> 00:18:26,160
to develop these technologies we

550
00:18:29,510 --> 00:18:27,679
couldn't fit our devices and wind

551
00:18:31,669 --> 00:18:29,520
tunnels anymore the biggest in the world

552
00:18:33,830 --> 00:18:31,679
is the 80 by 120 up at nasa ames

553
00:18:35,110 --> 00:18:33,840
research center outside san francisco if

554
00:18:36,630 --> 00:18:35,120
we try to put our parachute in there it

555
00:18:38,710 --> 00:18:36,640
would take up the entire test section

556
00:18:40,549 --> 00:18:38,720
you couldn't even get the wind going

557
00:18:42,710 --> 00:18:40,559
when we started looking at other

558
00:18:44,070 --> 00:18:42,720
alternatives they didn't exist so we had

559
00:18:45,750 --> 00:18:44,080
to come up with our own way of doing

560
00:18:47,350 --> 00:18:45,760
testing

561
00:18:49,190 --> 00:18:47,360
so we do lots of that

562
00:18:50,870 --> 00:18:49,200
for the science for that inflatable drag

563
00:18:52,470 --> 00:18:50,880

device we wanted to make sure that it

564
00:18:54,150 --> 00:18:52,480
would survive the stresses and the

565
00:18:56,230 --> 00:18:54,160
aerodynamic loads that it would see if

566
00:18:57,750 --> 00:18:56,240
it were entering the martian atmosphere

567
00:18:59,430 --> 00:18:57,760
so we scoured the country couldn't find

568
00:19:01,669 --> 00:18:59,440
anything and eventually we went out to

569
00:19:03,909 --> 00:19:01,679
our friends the navy who operate a

570
00:19:05,270 --> 00:19:03,919
facility the china lake naval air weapon

571
00:19:08,150 --> 00:19:05,280
station about two and a half hours

572
00:19:10,070 --> 00:19:08,160
northeast of los angeles they have a

573
00:19:12,470 --> 00:19:10,080
four mile long railroad track standard

574
00:19:13,350 --> 00:19:12,480
gauge railroad track and they let us

575
00:19:16,150 --> 00:19:13,360
with

576
00:19:18,390 --> 00:19:16,160
their help build essentially a 30 foot

577
00:19:19,270 --> 00:19:18,400
tall siege tower it's 40 tons of welded

578
00:19:21,750 --> 00:19:19,280
steel

579
00:19:23,590 --> 00:19:21,760
that sit on top of two standard gauge

580
00:19:25,190 --> 00:19:23,600
railroads

581
00:19:27,430 --> 00:19:25,200
we put a mock aeroshell on the front of

582
00:19:29,190 --> 00:19:27,440
it we pack the side to the periphery of

583
00:19:31,350 --> 00:19:29,200
that air shell like it would be stowed

584
00:19:33,110 --> 00:19:31,360
on a martian entry vehicle and then we

585
00:19:34,789 --> 00:19:33,120
take six solid rocket motors and we

586
00:19:36,630 --> 00:19:34,799
strap them to the back of it these are

587
00:19:39,350 --> 00:19:36,640
solid rocket nike solid rocket motors

588
00:19:40,950 --> 00:19:39,360

these are originally built in the 1950s

589
00:19:42,710 --> 00:19:40,960
and they would be staged around cities

590
00:19:44,630 --> 00:19:42,720
like los angeles or san francisco to

591
00:19:46,390 --> 00:19:44,640
shoot down soviet bombers if they ever

592
00:19:48,150 --> 00:19:46,400
came our way well fortunately they

593
00:19:49,430 --> 00:19:48,160
didn't and so we've got a bunch of these

594
00:19:51,669 --> 00:19:49,440
things sitting out in the bunker in the

595
00:19:53,909 --> 00:19:51,679
desert relatively cheap and economical

596
00:19:56,150 --> 00:19:53,919
to use so we take half a dozen at a time

597
00:19:58,150 --> 00:19:56,160
we light them off we go from zero to 300

598
00:20:00,549 --> 00:19:58,160
miles an hour in two seconds and at

599
00:20:02,390 --> 00:20:00,559
those speeds we're able to replicate the

600
00:20:03,990 --> 00:20:02,400
aerodynamic loading that the device

601
00:20:05,990 --> 00:20:04,000
would see if we were to enter the

602
00:20:07,909 --> 00:20:06,000
martian atmosphere

603
00:20:10,630 --> 00:20:07,919
so what does that look like well we take

604
00:20:13,110 --> 00:20:10,640
lots of video in high definition in slow

605
00:20:14,710 --> 00:20:13,120
motion and we watch the thing inflate we

606
00:20:17,029 --> 00:20:14,720
see how it emerges

607
00:20:18,710 --> 00:20:17,039
we have little dots on it that we use

608
00:20:20,470 --> 00:20:18,720
photogrammetry techniques to measure the

609
00:20:22,789 --> 00:20:20,480
shape and see how much the shape deforms

610
00:20:24,870 --> 00:20:22,799
over time see how it emerges and then we

611
00:20:26,630 --> 00:20:24,880
see if the shape if the the inflatable

612
00:20:28,710 --> 00:20:26,640
device is rigid

613
00:20:30,549 --> 00:20:28,720

at these higher dynamic loads

614
00:20:32,390 --> 00:20:30,559
we did this several times we saw it work

615
00:20:34,390 --> 00:20:32,400
extremely well in fact the deflection of

616
00:20:36,310 --> 00:20:34,400
this device was on the order of a few

617
00:20:38,789 --> 00:20:36,320
centimeters less than an inch for

618
00:20:40,630 --> 00:20:38,799
comparison uh that's about half as much

619
00:20:41,909 --> 00:20:40,640
as the rigid heat shield was for the

620
00:20:45,190 --> 00:20:41,919
curiosity

621
00:20:51,190 --> 00:20:45,200
rover that we landed on the surface of

622
00:20:54,630 --> 00:20:52,950
there's the rockets part of my three

623
00:20:55,990 --> 00:20:54,640
items

624
00:20:57,830 --> 00:20:56,000
of course we also wanted to test the

625
00:20:59,750 --> 00:20:57,840
parachute we're developing a new

626
00:21:01,190 --> 00:20:59,760
supersonic parachute so one of the first

627
00:21:02,549 --> 00:21:01,200
things we did was try to figure out what

628
00:21:04,470 --> 00:21:02,559
does that parachute need to look like

629
00:21:06,070 --> 00:21:04,480
what's the shape what's the geometry

630
00:21:08,149 --> 00:21:06,080
where do we put holes or do we not put

631
00:21:09,510 --> 00:21:08,159
holes so we did go to that wind tunnel

632
00:21:11,350 --> 00:21:09,520
but we had to test subscale about

633
00:21:12,789 --> 00:21:11,360
one-third scale parachutes

634
00:21:14,870 --> 00:21:12,799
in that wind tunnel

635
00:21:17,590 --> 00:21:14,880
we tested over 55 different parachute

636
00:21:19,590 --> 00:21:17,600
designs we would do things like take uh

637
00:21:21,669 --> 00:21:19,600
off-the-shelf paintball smoke grenades

638
00:21:23,029 --> 00:21:21,679

and set them off to watch the smoke

639
00:21:24,470 --> 00:21:23,039
travel around the parachute to try to

640
00:21:27,750 --> 00:21:24,480
get an idea of what the flow field was

641
00:21:28,870 --> 00:21:27,760
like uh streamline visualization on some

642
00:21:30,070 --> 00:21:28,880
of it to again try to get an

643
00:21:31,669 --> 00:21:30,080
understanding of what the aerodynamics

644
00:21:33,750 --> 00:21:31,679
of the parachute would be like

645
00:21:35,110 --> 00:21:33,760
we test a parachute see how it flew see

646
00:21:36,870 --> 00:21:35,120
how much it moved around the tunnel see

647
00:21:38,470 --> 00:21:36,880
how much drag it generated then we turn

648
00:21:39,990 --> 00:21:38,480
off the wind parachute would fall on the

649
00:21:41,669 --> 00:21:40,000
ground we'd take a pair of scissors and

650
00:21:43,430 --> 00:21:41,679
we'd start cutting it put a hole here

651
00:21:45,510 --> 00:21:43,440
put a hole there and then we turn on the

652
00:21:47,350 --> 00:21:45,520
wind see how it flew bring it down try

653
00:21:49,350 --> 00:21:47,360
again we did this over 55 different

654
00:21:51,190 --> 00:21:49,360
times

655
00:21:52,549 --> 00:21:51,200
here's a little snippet of what that

656
00:21:53,669 --> 00:21:52,559
video or what that testing kind of

657
00:21:55,430 --> 00:21:53,679
looked like

658
00:21:56,390 --> 00:21:55,440
so here the winds at about 30 miles an

659
00:21:57,830 --> 00:21:56,400
hour

660
00:22:00,310 --> 00:21:57,840
and we just watched the parachute move

661
00:22:02,230 --> 00:22:00,320
we track it we see how dynamic

662
00:22:03,750 --> 00:22:02,240
uh is the parachute is the motion and

663
00:22:05,029 --> 00:22:03,760

again how much force is it generating

664
00:22:06,710 --> 00:22:05,039
how much drag

665
00:22:08,470 --> 00:22:06,720
we use that to hone down to a very

666
00:22:10,390 --> 00:22:08,480
specific parachute configuration one

667
00:22:11,990 --> 00:22:10,400
that we felt had a lot of drag and good

668
00:22:14,789 --> 00:22:12,000
stability characteristics associated

669
00:22:18,070 --> 00:22:16,390
but we also have to do structural

670
00:22:19,830 --> 00:22:18,080
testing on the parachute

671
00:22:21,270 --> 00:22:19,840
we couldn't find a way to do that again

672
00:22:23,190 --> 00:22:21,280
can't put it in the wind tunnel can't

673
00:22:25,190 --> 00:22:23,200
push it off the back of the plane or

674
00:22:27,190 --> 00:22:25,200
anything like that so we went back to

675
00:22:28,950 --> 00:22:27,200
our friends out in the desert the navy

676
00:22:30,070 --> 00:22:28,960
and we started working with them on

677
00:22:31,669 --> 00:22:30,080
another

678
00:22:33,669 --> 00:22:31,679
rocket sled idea

679
00:22:35,909 --> 00:22:33,679
using bigger rockets this time so this

680
00:22:37,909 --> 00:22:35,919
is a picture at night before the setup

681
00:22:40,470 --> 00:22:37,919
you have this funnel you have a tripod

682
00:22:42,549 --> 00:22:40,480
standing over the rocket sled track and

683
00:22:44,070 --> 00:22:42,559
you've got four giant solid rocket

684
00:22:45,430 --> 00:22:44,080
motors over here

685
00:22:46,710 --> 00:22:45,440
and rather than go into detail i'll just

686
00:22:48,149 --> 00:22:46,720
cut to the video

687
00:22:49,750 --> 00:22:48,159
so this is a video from a test that we

688
00:22:51,990 --> 00:22:49,760

conducted

689
00:22:53,669 --> 00:22:52,000
earlier this year we start with the navy

690
00:22:55,510 --> 00:22:53,679
seahawk helicopter it's the navy

691
00:22:57,590 --> 00:22:55,520
blackhawk variation

692
00:23:00,390 --> 00:22:57,600
which picks up our parachute out of a

693
00:23:03,990 --> 00:23:00,400
can this is a fairly large parachute

694
00:23:05,350 --> 00:23:04,000
it's got a lot of volume even packed

695
00:23:06,870 --> 00:23:05,360
then there's a rope and a little

696
00:23:08,630 --> 00:23:06,880
measurement load plate that we have so

697
00:23:10,789 --> 00:23:08,640
bend suspended underneath it

698
00:23:11,990 --> 00:23:10,799
and that parachute in that helicopter

699
00:23:14,950 --> 00:23:12,000
the helicopter will take the parachute

700
00:23:25,510 --> 00:23:14,960
to an altitude of about 4000 feet

701
00:23:30,149 --> 00:23:26,870
we release the parachute from the

702
00:23:32,230 --> 00:23:30,159
helicopter it falls out of that bag

703
00:23:34,390 --> 00:23:32,240
the parachute will begin inflating again

704
00:23:36,149 --> 00:23:34,400
it's got 4000 feet of rope and a giant

705
00:23:38,470 --> 00:23:36,159
load plate suspended underneath it to

706
00:23:40,390 --> 00:23:38,480
help pull it down towards the ground

707
00:23:43,510 --> 00:23:40,400
we watch the parachute inflate very

708
00:23:49,269 --> 00:23:45,750
that straight line is the track

709
00:23:53,110 --> 00:23:51,190
we have nature do a little safety check

710
00:23:55,750 --> 00:23:53,120
for us

711
00:23:57,830 --> 00:23:55,760
this is right before the tests go off

712
00:23:59,510 --> 00:23:57,840
that parachute begins coming further and

713
00:24:04,630 --> 00:23:59,520

further towards the ground

714
00:24:08,390 --> 00:24:06,950
eventually it latches up to our rocket

715
00:24:10,230 --> 00:24:08,400
sled

716
00:24:12,789 --> 00:24:10,240
rockets ignite

717
00:24:14,230 --> 00:24:12,799
that rocket sled takes off horizontally

718
00:24:15,830 --> 00:24:14,240
and it pulls the parachute towards the

719
00:24:17,669 --> 00:24:15,840
ground and it generates over a hundred

720
00:24:19,430 --> 00:24:17,679
thousand pounds of force

721
00:24:21,830 --> 00:24:19,440
and we routinely take our parachutes to

722
00:24:23,909 --> 00:24:21,840
failure to see how strong they are and

723
00:24:25,350 --> 00:24:23,919
where they fail to understand how they

724
00:24:27,350 --> 00:24:25,360
fail and to see if it's something that

725
00:24:29,590 --> 00:24:27,360
we can improve easily this one was

726
00:24:32,310 --> 00:24:29,600
designed for a load of 80 000 pounds

727
00:24:34,470 --> 00:24:32,320
went to over 120 000 pounds in this test

728
00:24:36,230 --> 00:24:34,480
for ultimately uh one of the ropes

729
00:24:38,710 --> 00:24:36,240
further down out of the field of view of

730
00:24:40,470 --> 00:24:38,720
this camera failed

731
00:24:42,310 --> 00:24:40,480
we'd see it in slow motion and again see

732
00:24:43,990 --> 00:24:42,320
how the parachute failed and if it's an

733
00:24:49,269 --> 00:24:44,000
area that we think we need to improve

734
00:24:51,909 --> 00:24:50,470
another fun

735
00:24:53,909 --> 00:24:51,919
view this time holding it a little bit

736
00:24:56,149 --> 00:24:53,919
longer so the parachute latches up

737
00:24:57,750 --> 00:24:56,159
rostic rockets ignite

738
00:24:59,430 --> 00:24:57,760

then if the parachute separates from the

739
00:25:01,110 --> 00:24:59,440
rocket sled the rockets take off very

740
00:25:02,950 --> 00:25:01,120
quickly they begin pulling that rope

741
00:25:05,590 --> 00:25:02,960
through there's even a little ant that

742
00:25:14,230 --> 00:25:05,600
got woken up and is now

743
00:25:17,909 --> 00:25:15,590
so those are some of the structural

744
00:25:19,990 --> 00:25:17,919
tests we also want to see other aspects

745
00:25:21,990 --> 00:25:20,000
we want to see these devices deploy and

746
00:25:23,990 --> 00:25:22,000
inflate in a supersonic flow field at

747
00:25:25,430 --> 00:25:24,000
several times the speed of sound we want

748
00:25:27,190 --> 00:25:25,440
to see how much drag they produce in the

749
00:25:28,870 --> 00:25:27,200
supersonic environment we want to see

750
00:25:30,630 --> 00:25:28,880
how they slow down how dynamic they are

751
00:25:33,830 --> 00:25:30,640
how stable they are do they survive a

752
00:25:34,950 --> 00:25:33,840
supersonic inflation uh and do they give

753
00:25:37,750 --> 00:25:34,960
us the performance that we need

754
00:25:38,789 --> 00:25:37,760
subsonically again to operate safely at

755
00:25:39,830 --> 00:25:38,799
mars

756
00:25:41,430 --> 00:25:39,840
so

757
00:25:42,710 --> 00:25:41,440
this is a complicated diagram in fact

758
00:25:44,870 --> 00:25:42,720
i'll skip this

759
00:25:46,390 --> 00:25:44,880
and i'll go straight to another video

760
00:25:48,950 --> 00:25:46,400
and talk about another

761
00:25:50,789 --> 00:25:48,960
test architecture that we had to develop

762
00:25:52,950 --> 00:25:50,799
so we built a test vehicle again looks

763
00:25:54,789 --> 00:25:52,960

very similar to a martian entry vehicle

764
00:25:56,149 --> 00:25:54,799
we put a giant rocket motor on the

765
00:25:58,390 --> 00:25:56,159
inside of it we load it up with

766
00:26:00,470 --> 00:25:58,400
technologies we ship it out to the west

767
00:26:03,590 --> 00:26:00,480
coast of kauai where there's the navy's

768
00:26:05,190 --> 00:26:03,600
pacific missile range facility

769
00:26:07,750 --> 00:26:05,200
and then late in the night the morning

770
00:26:10,070 --> 00:26:07,760
before we launch we hook it up to a

771
00:26:13,110 --> 00:26:10,080
gondola this gondola is at the bottom of

772
00:26:15,029 --> 00:26:13,120
a large helium-filled scientific balloon

773
00:26:17,430 --> 00:26:15,039
all stations the three-word hold

774
00:26:19,190 --> 00:26:17,440
protocol is now in effect only those

775
00:26:21,430 --> 00:26:19,200
with proper hold authority are allowed

776
00:26:24,070 --> 00:26:21,440
to call it hold on the project net from

777
00:26:26,230 --> 00:26:24,080
this point through balloon launch this

778
00:26:28,070 --> 00:26:26,240
balloon fully inflated is 34 million

779
00:26:29,830 --> 00:26:28,080
cubic feet in volume for scale

780
00:26:32,230 --> 00:26:29,840
comparison that's a little bit larger

781
00:26:34,630 --> 00:26:32,240
than a large football stadium so i think

782
00:26:36,470 --> 00:26:34,640
the rose bowl in pasadena or where the

783
00:26:37,750 --> 00:26:36,480
washington redskins play

784
00:26:39,190 --> 00:26:37,760
something that's a little bit larger

785
00:26:40,789 --> 00:26:39,200
than either one of those

786
00:26:42,470 --> 00:26:40,799
it weighs several thousand pounds but

787
00:26:44,149 --> 00:26:42,480
the balloon itself is made from a very

788
00:26:46,230 --> 00:26:44,159

thin material that's even thinner than a

789
00:26:48,870 --> 00:26:46,240
say a garbage bag uh we use several

790
00:26:50,950 --> 00:26:48,880
thousand pounds of helium to inflate it

791
00:26:52,870 --> 00:26:50,960
and it has to be that large to hoist

792
00:26:54,470 --> 00:26:52,880
this full-scale entry vehicle this

793
00:26:56,310 --> 00:26:54,480
15-foot diameter vehicle that weighs

794
00:26:58,310 --> 00:26:56,320
seven thousand pounds itself attention

795
00:27:00,470 --> 00:26:58,320
all stations the test vehicle is go for

796
00:27:01,430 --> 00:27:00,480
drop i repeat test vehicle is go for

797
00:27:02,390 --> 00:27:01,440
drop

798
00:27:03,510 --> 00:27:02,400
or

799
00:27:04,549 --> 00:27:03,520
three

800
00:27:06,710 --> 00:27:04,559
two

801
00:27:08,149 --> 00:27:06,720
one

802
00:27:10,390 --> 00:27:08,159
balloon will carry the test vehicle to

803
00:27:11,830 --> 00:27:10,400
an altitude of 120 000 feet about four

804
00:27:14,070 --> 00:27:11,840
times higher than a typical jetliner

805
00:27:16,070 --> 00:27:14,080
flies we then release from the balloon

806
00:27:18,070 --> 00:27:16,080
we spin the vehicle up for gyroscopic

807
00:27:19,510 --> 00:27:18,080
stability we light that large solid

808
00:27:21,430 --> 00:27:19,520
rocket motor

809
00:27:23,110 --> 00:27:21,440
this is a star 48 it's more typically

810
00:27:24,549 --> 00:27:23,120
used as the third stage of a delta ii

811
00:27:26,149 --> 00:27:24,559
launch vehicle the rocket that would

812
00:27:28,070 --> 00:27:26,159
typically send a spacecraft from earth

813
00:27:29,990 --> 00:27:28,080

orbit to mars orbit but here we're going

814
00:27:32,950 --> 00:27:30,000
to use this rocket motor to accelerate

815
00:27:35,350 --> 00:27:32,960
us from 120 000 to 180 thousand feet and

816
00:27:37,269 --> 00:27:35,360
get us going from zero to four times the

817
00:27:39,830 --> 00:27:37,279
speed of sound there's the balloon in

818
00:27:41,830 --> 00:27:39,840
the background once we release it tears

819
00:27:43,590 --> 00:27:41,840
itself falls down in the pacific ocean

820
00:27:45,029 --> 00:27:43,600
we going to recover it we don't want to

821
00:27:46,230 --> 00:27:45,039
leave that much plastic in the pacific

822
00:27:47,909 --> 00:27:46,240
ocean we like to be good stewards of the

823
00:27:49,269 --> 00:27:47,919
environment

824
00:27:52,389 --> 00:27:49,279
and that rocket motor will burn for

825
00:27:59,909 --> 00:27:53,830
there's the earth the pacific ocean in

826
00:28:05,110 --> 00:28:02,870
once it burns out we despin

827
00:28:07,110 --> 00:28:05,120
and we get ready to conduct our test so

828
00:28:09,669 --> 00:28:07,120
now we're we're going the right speed

829
00:28:11,830 --> 00:28:09,679
for a martian entry and we're in an

830
00:28:13,750 --> 00:28:11,840
atmosphere at 180 000 feet halfway to

831
00:28:16,389 --> 00:28:13,760
the edge of space that is the same

832
00:28:17,909 --> 00:28:16,399
thickness as the martian atmosphere so

833
00:28:20,230 --> 00:28:17,919
we can do our tests we can inflate the

834
00:28:22,389 --> 00:28:20,240
side in a fraction of a second you see

835
00:28:24,310 --> 00:28:22,399
how stable the inflation was how stable

836
00:28:27,990 --> 00:28:24,320
the vehicle is after the inflation

837
00:28:33,190 --> 00:28:29,750
that inflatable decelerator takes us

838
00:28:35,430 --> 00:28:33,200

from about mach 4 down to mach 3

839
00:28:38,470 --> 00:28:35,440
where we deploy another drag device this

840
00:28:39,909 --> 00:28:38,480
time we shoot a 30 pound pack that's

841
00:28:41,830 --> 00:28:39,919
about the density of wood out the back

842
00:28:44,230 --> 00:28:41,840
of the vehicle at 200 feet per second

843
00:28:46,950 --> 00:28:44,240
and inside is about a 15 foot diameter

844
00:28:48,630 --> 00:28:46,960
uh ram air inflated drag device that we

845
00:28:49,830 --> 00:28:48,640
have to use just to pull the parachute

846
00:28:52,230 --> 00:28:49,840
off the back of the vehicle the

847
00:28:54,310 --> 00:28:52,240
parachute itself is 200 pounds of nylon

848
00:28:56,149 --> 00:28:54,320
and kevlar we try to take that and get

849
00:28:58,470 --> 00:28:56,159
it to inflate in a 2000 mile an hour

850
00:29:00,389 --> 00:28:58,480
wind and see what happens

851
00:29:02,710 --> 00:29:00,399
in this case we find out

852
00:29:04,710 --> 00:29:02,720
it doesn't survive that wind very well

853
00:29:07,510 --> 00:29:04,720
it does create some drag helps slow the

854
00:29:09,510 --> 00:29:07,520
vehicle down the the attached inflatable

855
00:29:11,269 --> 00:29:09,520
decelerator begins deflating and all

856
00:29:12,870 --> 00:29:11,279
this comes down in the pacific ocean

857
00:29:14,470 --> 00:29:12,880
where our recovery team is waiting to

858
00:29:18,549 --> 00:29:14,480
scoop it up and bring it back for

859
00:29:22,070 --> 00:29:20,389
that was a test we did last year as a

860
00:29:23,830 --> 00:29:22,080
shakeout for this test architecture to

861
00:29:25,430 --> 00:29:23,840
see if we could even conduct these tests

862
00:29:26,870 --> 00:29:25,440
if we could get to the right conditions

863
00:29:28,470 --> 00:29:26,880

but ultimately it was extremely

864
00:29:30,310 --> 00:29:28,480
successful we had a number of

865
00:29:32,470 --> 00:29:30,320
accomplishments including the largest

866
00:29:34,549 --> 00:29:32,480
inflatable decelerator ever tested at

867
00:29:37,110 --> 00:29:34,559
supersonic conditions that six meter

868
00:29:38,310 --> 00:29:37,120
nearly 20 20 feet diameter inflatable

869
00:29:40,389 --> 00:29:38,320
decelerator

870
00:29:42,470 --> 00:29:40,399
the largest balut that little guy in the

871
00:29:44,149 --> 00:29:42,480
lower right hand corner that would ever

872
00:29:47,110 --> 00:29:44,159
been deflate excuse me ever been

873
00:29:49,430 --> 00:29:47,120
inflated supersonically at 4.4 meters

874
00:29:51,830 --> 00:29:49,440
nearly 15 feet in diameter this was the

875
00:29:53,590 --> 00:29:51,840
first ever supersonic pilot deployment

876
00:29:55,430 --> 00:29:53,600
of a parachute that is using another

877
00:29:58,149 --> 00:29:55,440
device to help pull the parachute out

878
00:29:59,830 --> 00:29:58,159
and a supersonic flow field

879
00:30:01,830 --> 00:29:59,840
and it was the largest supersonic

880
00:30:03,669 --> 00:30:01,840
parachute that had ever been deployed

881
00:30:05,430 --> 00:30:03,679
but the quantity and the quality of the

882
00:30:07,430 --> 00:30:05,440
data this was perhaps the exciting thing

883
00:30:08,789 --> 00:30:07,440
for me as the principal investigator was

884
00:30:10,950 --> 00:30:08,799
the realization that we had been using

885
00:30:12,389 --> 00:30:10,960
these devices for four decades but our

886
00:30:13,909 --> 00:30:12,399
understanding of them was very little

887
00:30:15,990 --> 00:30:13,919
because we didn't have great data sets

888
00:30:18,470 --> 00:30:16,000

associated with them the instrumentation

889
00:30:20,230 --> 00:30:18,480
the cameras high speed high resolution

890
00:30:22,470 --> 00:30:20,240
the amount of data we got the gigabytes

891
00:30:24,470 --> 00:30:22,480
of data were several orders of magnitude

892
00:30:26,630 --> 00:30:24,480
more than we had had and again the 40

893
00:30:27,669 --> 00:30:26,640
years of actually using these devices so

894
00:30:29,590 --> 00:30:27,679
we started to get a much better

895
00:30:31,669 --> 00:30:29,600
understanding of how they operate

896
00:30:33,269 --> 00:30:31,679
but that was all last year so what did

897
00:30:35,510 --> 00:30:33,279
we do this year well we built two more

898
00:30:37,590 --> 00:30:35,520
test vehicles and again we loaded one of

899
00:30:39,750 --> 00:30:37,600
them up with a new parachute design new

900
00:30:41,830 --> 00:30:39,760
technologies new instrumentation and we

901
00:30:44,230 --> 00:30:41,840
shipped that out to kauai with some of

902
00:30:46,149 --> 00:30:44,240
our engineers and we did another test

903
00:30:48,549 --> 00:30:46,159
but before we got to that we actually

904
00:30:50,870 --> 00:30:48,559
took that larger device that eight meter

905
00:30:53,430 --> 00:30:50,880
uh in ram air inflated device and we got

906
00:30:54,870 --> 00:30:53,440
to do some testing on that one as well

907
00:30:56,630 --> 00:30:54,880
so i'll show you some of the rocket sled

908
00:30:59,190 --> 00:30:56,640
videos from that

909
00:31:01,990 --> 00:30:59,200
we did deployment tests not so much not

910
00:31:04,630 --> 00:31:02,000
without a wind going just to see how the

911
00:31:06,470 --> 00:31:04,640
side emerged was it uniform did it go

912
00:31:07,830 --> 00:31:06,480
since this device is much bigger how

913
00:31:08,870 --> 00:31:07,840

quickly could we get it out from the

914
00:31:10,789 --> 00:31:08,880
vehicle

915
00:31:12,549 --> 00:31:10,799
we did lots of analysis

916
00:31:14,789 --> 00:31:12,559
computational fluid dynamics to see the

917
00:31:16,389 --> 00:31:14,799
flow field around the device to help

918
00:31:18,549 --> 00:31:16,399
predict the drag before we actually did

919
00:31:24,950 --> 00:31:18,559
the test then we integrated it to our

920
00:31:24,960 --> 00:31:33,990
we got ready to test

921
00:31:37,029 --> 00:31:35,590
you can really accelerate 40 tons of

922
00:31:44,549 --> 00:31:37,039
steel pretty quickly if you've got

923
00:31:48,230 --> 00:31:46,149
again we got to see how these devices

924
00:31:50,710 --> 00:31:48,240
inflate this was something that really

925
00:31:52,549 --> 00:31:50,720
relied more on scooping air around it to

926
00:31:54,470 --> 00:31:52,559
help pressurize and that was something

927
00:31:55,430 --> 00:31:54,480
that was very new very experimental for

928
00:31:57,430 --> 00:31:55,440
us

929
00:31:59,590 --> 00:31:57,440
but we see those inlets emerge very

930
00:32:01,110 --> 00:31:59,600
cleanly very uniformly begin to scoop up

931
00:32:02,950 --> 00:32:01,120
the air ingest the air and help

932
00:32:06,470 --> 00:32:02,960
pressurize this device and here we're

933
00:32:08,310 --> 00:32:06,480
going a little over 200 miles an hour

934
00:32:10,149 --> 00:32:08,320
we also see if the device is stable

935
00:32:11,430 --> 00:32:10,159
there's some oscillations going on we're

936
00:32:12,950 --> 00:32:11,440
beginning to understand that the flow

937
00:32:14,230 --> 00:32:12,960
field around these inflated structures

938
00:32:15,990 --> 00:32:14,240

and how they interact with that flow

939
00:32:17,669 --> 00:32:16,000
field is different we've got some

940
00:32:19,750 --> 00:32:17,679
engineers the two engineers in charge of

941
00:32:23,110 --> 00:32:19,760
the test and the device watching one of

942
00:32:23,120 --> 00:32:26,630
they're excited when it works

943
00:32:29,269 --> 00:32:28,149
they were in a room that we couldn't go

944
00:32:30,630 --> 00:32:29,279
in

945
00:32:33,110 --> 00:32:30,640
so it's just them and a couple other

946
00:32:34,870 --> 00:32:33,120
folks we get to have fun with cameras

947
00:32:36,630 --> 00:32:34,880
if you've ever wondered what it would be

948
00:32:39,590 --> 00:32:36,640
like to have 40 tons of steel fly over

949
00:32:43,190 --> 00:32:39,600
you at 200 miles an hour

950
00:32:46,789 --> 00:32:45,110
the the two engineers another story

951
00:32:47,990 --> 00:32:46,799
about that uh

952
00:32:49,990 --> 00:32:48,000
we were in another room that was

953
00:32:51,509 --> 00:32:50,000
adjacent watching the test and the one

954
00:32:53,269 --> 00:32:51,519
on the left who looked very skeptical

955
00:32:55,590 --> 00:32:53,279
and got very excited once it worked he

956
00:32:59,190 --> 00:32:55,600
came out and the first thing he said was

957
00:32:59,200 --> 00:33:02,070
he was right

958
00:33:05,990 --> 00:33:04,149
but of course we had the parachute still

959
00:33:08,710 --> 00:33:06,000
the test and that new test vehicle that

960
00:33:15,350 --> 00:33:08,720
we built so we ship that out

961
00:33:15,360 --> 00:33:19,269
so this is june of this year

962
00:33:23,750 --> 00:33:21,669
there it is being transported out to the

963
00:33:25,669 --> 00:33:23,760

area where it will attach to the balloon

964
00:33:31,590 --> 00:33:25,679
pushing it out interfacing it with the

965
00:33:31,600 --> 00:33:42,549
bleeding the balloon

966
00:33:42,559 --> 00:33:52,630
see the large helium tanks on the side

967
00:33:56,870 --> 00:33:54,470
once we release for the balloon the

968
00:33:59,350 --> 00:33:56,880
balloon has to carry up up up and it

969
00:34:00,710 --> 00:33:59,360
carries over this tower or the launch

970
00:34:02,630 --> 00:34:00,720
vehicle excuse me where the test vehicle

971
00:34:04,389 --> 00:34:02,640
is attached and the balloon ideally

972
00:34:06,389 --> 00:34:04,399
keeps going over but the wind was so

973
00:34:08,310 --> 00:34:06,399
calm this day that we were trying to see

974
00:34:09,990 --> 00:34:08,320
if the balloon would carry past so that

975
00:34:11,909 --> 00:34:10,000
when we released it the test vehicle

976
00:34:13,990 --> 00:34:11,919
would push off

977
00:34:15,909 --> 00:34:14,000
background chatter there's the two

978
00:34:17,430 --> 00:34:15,919
engineers talking to each other one of

979
00:34:18,710 --> 00:34:17,440
them saying we don't think it's going

980
00:34:20,869 --> 00:34:18,720
any further in fact it's starting to

981
00:34:23,190 --> 00:34:20,879
come back and the second one saying

982
00:34:25,109 --> 00:34:23,200
release release release

983
00:34:29,430 --> 00:34:25,119
launch it

984
00:34:33,510 --> 00:34:31,990
releases there's the pacific ocean it

985
00:34:34,950 --> 00:34:33,520
was such a clear day when we conducted

986
00:34:36,629 --> 00:34:34,960
this test that we could actually see the

987
00:34:38,550 --> 00:34:36,639
balloon the entire time and you could

988
00:34:40,710 --> 00:34:38,560

see the contrail from the the large

989
00:34:41,909 --> 00:34:40,720
rocket motor as the vehicle was being

990
00:34:43,990 --> 00:34:41,919
accelerated to higher and higher

991
00:34:47,030 --> 00:34:44,000
altitudes and faster and faster

992
00:34:47,040 --> 00:34:52,790
there's balloon beginning to tear

993
00:34:52,800 --> 00:35:03,910
streaking across the sky

994
00:35:07,270 --> 00:35:05,270
something different with this test is

995
00:35:09,109 --> 00:35:07,280
that right after we spun down there was

996
00:35:10,150 --> 00:35:09,119
a disturbance on the vehicle something

997
00:35:12,630 --> 00:35:10,160
pitched it

998
00:35:14,790 --> 00:35:12,640
started rocking at fairly high rates and

999
00:35:16,550 --> 00:35:14,800
fairly large angles we're still not

1000
00:35:18,069 --> 00:35:16,560
positive what it was but atmospheric

1001
00:35:20,069 --> 00:35:18,079
scientists sometimes calls this region

1002
00:35:21,430 --> 00:35:20,079
the atmosphere the ignore sphere because

1003
00:35:22,790 --> 00:35:21,440
there's so little that we understand

1004
00:35:24,550 --> 00:35:22,800
about it so one of the ideas is that

1005
00:35:26,630 --> 00:35:24,560
there's these potholes in the sky of

1006
00:35:28,470 --> 00:35:26,640
pockets of density that we may have hit

1007
00:35:30,390 --> 00:35:28,480
that pitched the vehicle and disturbed

1008
00:35:32,230 --> 00:35:30,400
it but once we inflated the scion the

1009
00:35:34,310 --> 00:35:32,240
side helped damp those oscillations out

1010
00:35:36,550 --> 00:35:34,320
considerably the side worked flawlessly

1011
00:35:38,950 --> 00:35:36,560
for us again inflated

1012
00:35:40,470 --> 00:35:38,960
held its shape and gave us very

1013
00:35:44,150 --> 00:35:40,480

very good aerodynamic performance to

1014
00:35:46,069 --> 00:35:44,160
help slow the vehicle down

1015
00:35:48,150 --> 00:35:46,079
we deployed the blue at about mach 3

1016
00:35:51,030 --> 00:35:48,160
three times the speed of sound 2500

1017
00:35:53,030 --> 00:35:51,040
miles an hour or so

1018
00:35:54,950 --> 00:35:53,040
it worked flawlessly for us one of the

1019
00:35:57,030 --> 00:35:54,960
scariest aspects of the entire test was

1020
00:35:59,270 --> 00:35:57,040
would this balloon even inflate it's got

1021
00:36:01,589 --> 00:35:59,280
ram air inlets on the side and nobody

1022
00:36:03,190 --> 00:36:01,599
had gotten previously last year balut

1023
00:36:04,790 --> 00:36:03,200
this large to work in the environment

1024
00:36:06,550 --> 00:36:04,800
that we were testing it but it worked

1025
00:36:08,150 --> 00:36:06,560
flawlessly for us helped pull the

1026
00:36:09,750 --> 00:36:08,160
parachute we took this new parachute

1027
00:36:11,109 --> 00:36:09,760
design

1028
00:36:13,109 --> 00:36:11,119
one that we had structurally

1029
00:36:15,349 --> 00:36:13,119
strengthened uh considerably that we had

1030
00:36:16,550 --> 00:36:15,359
tested over 120 000 pounds that we had

1031
00:36:18,310 --> 00:36:16,560
analyzed

1032
00:36:20,950 --> 00:36:18,320
and predicted that it should drive loads

1033
00:36:22,870 --> 00:36:20,960
of in excess of 300 000 pounds and we

1034
00:36:24,069 --> 00:36:22,880
saw that it got all the way up to full

1035
00:36:27,270 --> 00:36:24,079
inflation

1036
00:36:29,190 --> 00:36:27,280
and then a large tear developed

1037
00:36:38,230 --> 00:36:29,200
and once that tear developed the

1038
00:36:43,030 --> 00:36:39,670

so again it comes down to the pacific

1039
00:36:45,589 --> 00:36:43,040
ocean we go and we scoop everything up

1040
00:36:47,510 --> 00:36:45,599
some divers from the navy

1041
00:36:48,630 --> 00:36:47,520
explosive ordnance disposal team that's

1042
00:36:50,470 --> 00:36:48,640
the balut

1043
00:36:52,310 --> 00:36:50,480
still inflated on the surface in fact

1044
00:36:53,670 --> 00:36:52,320
that was several miles away when they

1045
00:36:55,589 --> 00:36:53,680
finally caught up to it they realized

1046
00:36:57,349 --> 00:36:55,599
that it was sailing on the surface of

1047
00:36:59,270 --> 00:36:57,359
the ocean that had stayed inflated that

1048
00:37:01,030 --> 00:36:59,280
those little inlets were scooping up the

1049
00:37:03,910 --> 00:37:01,040
wind and the wind was just pushing it

1050
00:37:07,270 --> 00:37:03,920
along at several miles an hour

1051
00:37:09,829 --> 00:37:07,280
so what happened to the parachute well

1052
00:37:11,430 --> 00:37:09,839
we uh we made it a lot stronger

1053
00:37:14,069 --> 00:37:11,440
and the areas that we had seen it failed

1054
00:37:15,750 --> 00:37:14,079
we changed the shape of it uh we used

1055
00:37:17,430 --> 00:37:15,760
all of our state-of-the-art analysis

1056
00:37:19,430 --> 00:37:17,440
tools to try to predict the loads and

1057
00:37:21,589 --> 00:37:19,440
that it would see at full inflation it

1058
00:37:23,670 --> 00:37:21,599
said it should be perfectly fine

1059
00:37:26,150 --> 00:37:23,680
we tested it using those rocket sleds

1060
00:37:28,630 --> 00:37:26,160
and it survived over 120 000 pounds but

1061
00:37:30,950 --> 00:37:28,640
what we found out was that at in

1062
00:37:32,150 --> 00:37:30,960
supersonic inflation those very rapid

1063
00:37:34,150 --> 00:37:32,160

inflation and the shape and the

1064
00:37:36,069 --> 00:37:34,160
transients that occur during that rapid

1065
00:37:38,310 --> 00:37:36,079
inflation that even though we were only

1066
00:37:39,670 --> 00:37:38,320
measuring about 80 000 pounds of drag

1067
00:37:41,109 --> 00:37:39,680
that the stresses and the forces

1068
00:37:42,470 --> 00:37:41,119
associated with those inflation were

1069
00:37:44,550 --> 00:37:42,480
well beyond anything that we could

1070
00:37:46,069 --> 00:37:44,560
predict anything that we could test to

1071
00:37:48,630 --> 00:37:46,079
and so we start to realize that there's

1072
00:37:50,390 --> 00:37:48,640
a huge disconnect between how we analyze

1073
00:37:52,950 --> 00:37:50,400
and how we test our parachutes and how

1074
00:37:54,710 --> 00:37:52,960
they seem to perform supersonically

1075
00:37:56,870 --> 00:37:54,720
if you think about that i mean it can be

1076
00:37:58,310 --> 00:37:56,880
a you know as an engineer who's been

1077
00:38:00,710 --> 00:37:58,320
spending years trying to develop these

1078
00:38:02,870 --> 00:38:00,720
things that can be a very uh

1079
00:38:05,910 --> 00:38:02,880
humbling experience when something that

1080
00:38:07,990 --> 00:38:05,920
you predict to work so well doesn't

1081
00:38:10,710 --> 00:38:08,000
but that can also be a very exciting

1082
00:38:12,710 --> 00:38:10,720
time right this is like you know

1083
00:38:14,550 --> 00:38:12,720
navigators of old starting to realize

1084
00:38:15,990 --> 00:38:14,560
that the earth isn't flat anymore it

1085
00:38:17,829 --> 00:38:16,000
gives you an entirely new world of

1086
00:38:19,910 --> 00:38:17,839
opportunity to understand to predict to

1087
00:38:21,910 --> 00:38:19,920
analyze there's so much more that we can

1088
00:38:24,150 --> 00:38:21,920

learn that we can test to that's really

1089
00:38:26,230 --> 00:38:24,160
why we're doing these tests we don't do

1090
00:38:27,750 --> 00:38:26,240
them just to succeed this is technology

1091
00:38:29,510 --> 00:38:27,760
development right

1092
00:38:31,109 --> 00:38:29,520
if everything works the right the first

1093
00:38:33,030 --> 00:38:31,119
time then that tells us that we're not

1094
00:38:35,510 --> 00:38:33,040
pushing the envelope far enough fast

1095
00:38:38,069 --> 00:38:35,520
enough uh or hard enough so the fact

1096
00:38:39,349 --> 00:38:38,079
that we uh saw the parachute fail in

1097
00:38:41,109 --> 00:38:39,359
fact the two parachute failures that

1098
00:38:42,790 --> 00:38:41,119
we've had in the past two years have

1099
00:38:43,910 --> 00:38:42,800
given us more insight into supersonic

1100
00:38:46,550 --> 00:38:43,920
parachutes than we've had in the

1101
00:38:48,710 --> 00:38:46,560
previous 40 years of actually using them

1102
00:38:50,310 --> 00:38:48,720
so i want to end the talk with a quote

1103
00:38:51,910 --> 00:38:50,320
that i think is appropriate

1104
00:38:54,390 --> 00:38:51,920
for technology development it's from

1105
00:38:56,870 --> 00:38:54,400
theodore roosevelt it says far better it

1106
00:38:58,390 --> 00:38:56,880
is to dare mighty things to win glorious

1107
00:39:00,310 --> 00:38:58,400
triumphs even though checkered by

1108
00:39:02,230 --> 00:39:00,320
failure than to rank with those timid

1109
00:39:03,990 --> 00:39:02,240
spirits who neither enjoy nor suffer

1110
00:39:06,390 --> 00:39:04,000
much because they live in the great

1111
00:39:08,150 --> 00:39:06,400
twilight that knows neither victory nor

1112
00:39:09,589 --> 00:39:08,160
defeat

1113
00:39:11,430 --> 00:39:09,599

most of the technologies that we've been

1114
00:39:13,030 --> 00:39:11,440
developing have worked flawlessly for us

1115
00:39:14,870 --> 00:39:13,040
we have further to go to understand the

1116
00:39:16,950 --> 00:39:14,880
supersonic parachutes but in those

1117
00:39:18,630 --> 00:39:16,960
defeats we'll learn more we will make

1118
00:39:20,150 --> 00:39:18,640
corrections and we'll come back and

1119
00:39:21,589 --> 00:39:20,160
we'll continue to develop these and get

1120
00:39:23,109 --> 00:39:21,599
them right because these are the

1121
00:39:25,670 --> 00:39:23,119
technologies that will be critical for

1122
00:39:27,030 --> 00:39:25,680
the next decades of mars exploration

1123
00:39:28,790 --> 00:39:27,040
looking at the next opportunity of

1124
00:39:30,470 --> 00:39:28,800
robotic missions and looking all the way

1125
00:39:32,390 --> 00:39:30,480
out to the horizon for human missions to

1126
00:39:34,069 --> 00:39:32,400
mars

1127
00:39:40,310 --> 00:39:34,079
so that's my talk i can take any

1128
00:39:44,550 --> 00:39:42,790
i think we have oh yes

1129
00:39:46,390 --> 00:39:44,560
another banks in a and i'm from what are

1130
00:39:48,390 --> 00:39:46,400
your education campus

1131
00:39:50,390 --> 00:39:48,400
um and my question is how long did it

1132
00:39:53,589 --> 00:39:50,400
take you to make all the parachutes

1133
00:39:55,910 --> 00:39:53,599
ah the parachutes themselves months

1134
00:39:57,829 --> 00:39:55,920
there's uh you know just the cords that

1135
00:39:59,990 --> 00:39:57,839
connect this the parachute down to the

1136
00:40:01,990 --> 00:40:00,000
test vehicle if i take all 96 and i

1137
00:40:05,589 --> 00:40:02,000
added them up there's about three miles

1138
00:40:07,190 --> 00:40:05,599

of a very small diameter technora cord

1139
00:40:09,349 --> 00:40:07,200
that's strong enough to lift a car but

1140
00:40:10,470 --> 00:40:09,359
also very small in diameter the fabric

1141
00:40:13,430 --> 00:40:10,480
itself

1142
00:40:15,349 --> 00:40:13,440
that parachute had nearly 2000 panels

1143
00:40:16,870 --> 00:40:15,359
about this big by this big each one of

1144
00:40:18,230 --> 00:40:16,880
those had to be stitched together and

1145
00:40:20,470 --> 00:40:18,240
each one of those had to be stitched to

1146
00:40:22,790 --> 00:40:20,480
kevlar reinforcements to provide the

1147
00:40:24,630 --> 00:40:22,800
structural skeleton to the parachute so

1148
00:40:27,990 --> 00:40:24,640
each parachute overall takes months to

1149
00:40:32,150 --> 00:40:28,000
build probably three to four months

1150
00:40:36,230 --> 00:40:34,069
hi my name is damian i'm from whittier

1151
00:40:38,790 --> 00:40:36,240
education campus i wanted to know

1152
00:40:40,309 --> 00:40:38,800
how long did it does it take for a rover

1153
00:40:43,109 --> 00:40:40,319
to scan

1154
00:40:44,630 --> 00:40:43,119
the atmosphere or the surface of mars

1155
00:40:46,630 --> 00:40:44,640
well uh

1156
00:40:48,710 --> 00:40:46,640
the rover can only travel so far over

1157
00:40:50,230 --> 00:40:48,720
mars mars is still a very large planet

1158
00:40:52,150 --> 00:40:50,240
it's not quite as big as earth but it's

1159
00:40:53,510 --> 00:40:52,160
still relatively large and so when it

1160
00:40:55,829 --> 00:40:53,520
scans the atmosphere it's really just

1161
00:40:57,589 --> 00:40:55,839
doing a very local sampling

1162
00:40:59,750 --> 00:40:57,599
something like the curiosity rover can

1163
00:41:02,309 --> 00:40:59,760

look up into the sky and for example

1164
00:41:03,589 --> 00:41:02,319
take a picture and look at how much dust

1165
00:41:06,550 --> 00:41:03,599
is in the atmosphere and use that to

1166
00:41:08,230 --> 00:41:06,560
predict how thick the atmosphere is but

1167
00:41:10,069 --> 00:41:08,240
that measurement can occur in a fraction

1168
00:41:11,990 --> 00:41:10,079
of a second and it can take several

1169
00:41:13,829 --> 00:41:12,000
measurements over the course of its its

1170
00:41:15,510 --> 00:41:13,839
operational lifetime and then begin to

1171
00:41:17,349 --> 00:41:15,520
push piece those elements together in

1172
00:41:19,750 --> 00:41:17,359
conjunction with other measurements by

1173
00:41:21,430 --> 00:41:19,760
spacecraft that we have orbiting mars to

1174
00:41:23,510 --> 00:41:21,440
try to get a better understanding of the

1175
00:41:25,750 --> 00:41:23,520
martian atmosphere so it takes years and

1176
00:41:31,670 --> 00:41:25,760
years to develop that full martian

1177
00:41:35,670 --> 00:41:33,750
hi my name is kimberly iannamorato and

1178
00:41:36,710 --> 00:41:35,680
i'm from radio education campus and my

1179
00:41:39,109 --> 00:41:36,720
question is

1180
00:41:40,790 --> 00:41:39,119
the if the material from the parachute

1181
00:41:42,550 --> 00:41:40,800
that you made is it going to be the same

1182
00:41:46,390 --> 00:41:42,560
material that they're going to use for

1183
00:41:48,309 --> 00:41:46,400
the astronauts to go to mars

1184
00:41:50,390 --> 00:41:48,319
so the parachutes are predominantly made

1185
00:41:52,790 --> 00:41:50,400
from nylon like nylon that you would

1186
00:41:54,390 --> 00:41:52,800
find in your camping tin rip stop nylon

1187
00:41:55,589 --> 00:41:54,400
very similar to that a little bit

1188
00:41:58,069 --> 00:41:55,599

lighter

1189
00:41:59,510 --> 00:41:58,079
but similar strength and kevlar the

1190
00:42:01,430 --> 00:41:59,520
nylon really is just there to provide

1191
00:42:04,069 --> 00:42:01,440
area the kevlar provides most of the

1192
00:42:05,430 --> 00:42:04,079
structural skeleton of the parachute and

1193
00:42:07,589 --> 00:42:05,440
those are the materials that we've been

1194
00:42:09,430 --> 00:42:07,599
using since the mid-90s on parachutes

1195
00:42:12,069 --> 00:42:09,440
before that the viking landers actually

1196
00:42:13,430 --> 00:42:12,079
used polyester for their parachutes so

1197
00:42:15,109 --> 00:42:13,440
we've gotten a little bit more advanced

1198
00:42:16,550 --> 00:42:15,119
in our materials but

1199
00:42:18,870 --> 00:42:16,560
it is likely that we will continue to

1200
00:42:20,630 --> 00:42:18,880
use nylon and kevlar or some variant of

1201
00:42:22,069 --> 00:42:20,640
kevlar like technora

1202
00:42:25,670 --> 00:42:22,079
in our parachutes even in the coming

1203
00:42:30,550 --> 00:42:27,430
my name is tamari from whittier

1204
00:42:34,150 --> 00:42:30,560
education campus and my question is is

1205
00:42:37,510 --> 00:42:34,160
the um parachutes an example of how the

1206
00:42:39,670 --> 00:42:37,520
astronauts are going to land on mars

1207
00:42:41,030 --> 00:42:39,680
uh your question is are parachutes an

1208
00:42:43,109 --> 00:42:41,040
example of how astronauts will land on

1209
00:42:45,430 --> 00:42:43,119
mars parachutes will definitely be used

1210
00:42:47,349 --> 00:42:45,440
for mars exploration whether we use them

1211
00:42:49,270 --> 00:42:47,359
to land humans on the surface of mars is

1212
00:42:50,630 --> 00:42:49,280
still to be determined there are other

1213
00:42:52,710 --> 00:42:50,640

technology out there that i mentioned we

1214
00:42:54,790 --> 00:42:52,720
can try to use rocket fuel it's nice

1215
00:42:56,470 --> 00:42:54,800
it's relatively simple not particularly

1216
00:42:58,870 --> 00:42:56,480
efficient from a mass perspective you

1217
00:43:00,630 --> 00:42:58,880
know i can take 200 pounds of of nylon

1218
00:43:02,550 --> 00:43:00,640
and kevlar and have it generate 100 000

1219
00:43:04,390 --> 00:43:02,560
pounds of drag where i can't get nearly

1220
00:43:06,870 --> 00:43:04,400
that much deceleration out of 200 pounds

1221
00:43:08,309 --> 00:43:06,880
of rocket fuel but because the mass

1222
00:43:10,390 --> 00:43:08,319
associated with landing humans on the

1223
00:43:12,550 --> 00:43:10,400
surface of mars might be so large you

1224
00:43:14,069 --> 00:43:12,560
might need too many parachutes and so it

1225
00:43:15,750 --> 00:43:14,079
may not be feasible to continue to use

1226
00:43:17,430 --> 00:43:15,760
parachutes so parachutes will get us so

1227
00:43:18,870 --> 00:43:17,440
far we don't know if it'll get us all

1228
00:43:24,390 --> 00:43:18,880
the way up to the masses necessary to

1229
00:43:38,710 --> 00:43:25,990
next question is from our online

1230
00:43:42,069 --> 00:43:40,790
the online question is does a parachute

1231
00:43:43,190 --> 00:43:42,079
work differently in the martian

1232
00:43:44,230 --> 00:43:43,200
atmosphere

1233
00:43:45,670 --> 00:43:44,240
well

1234
00:43:47,990 --> 00:43:45,680
than it does in the earth atmosphere i'm

1235
00:43:50,630 --> 00:43:48,000
assuming if you can replicate things

1236
00:43:53,030 --> 00:43:50,640
like density and mach number then you

1237
00:43:54,390 --> 00:43:53,040
can replicate generally the performance

1238
00:43:56,390 --> 00:43:54,400

of the parachute

1239
00:43:58,550 --> 00:43:56,400
there are subtle differences the martian

1240
00:43:59,990 --> 00:43:58,560
atmosphere is composed of carbon dioxide

1241
00:44:02,710 --> 00:44:00,000
the earth atmosphere is predominantly

1242
00:44:04,390 --> 00:44:02,720
nitrogen with a lot of oxygen as well

1243
00:44:06,470 --> 00:44:04,400
that creates some subtle differences but

1244
00:44:07,910 --> 00:44:06,480
in general yes they do behave very

1245
00:44:09,589 --> 00:44:07,920
similar i'd say one of the biggest

1246
00:44:11,109 --> 00:44:09,599
differences is actually how fast the

1247
00:44:13,190 --> 00:44:11,119
parachute inflates

1248
00:44:15,670 --> 00:44:13,200
the speed of sound here at earth in

1249
00:44:17,829 --> 00:44:15,680
earth's atmosphere is about 50 faster

1250
00:44:20,550 --> 00:44:17,839
than it is at mars that means that our

1251
00:44:22,390 --> 00:44:20,560
parachutes inflate about 50 faster here

1252
00:44:24,790 --> 00:44:22,400
at earth than they do at mars but that's

1253
00:44:26,790 --> 00:44:24,800
50 of a fraction of a second so for

1254
00:44:28,950 --> 00:44:26,800
example if i were to take that same size

1255
00:44:30,630 --> 00:44:28,960
parachute that inflated in 0.6 seconds

1256
00:44:32,790 --> 00:44:30,640
here at earth it would inflate in a

1257
00:44:35,030 --> 00:44:32,800
little less than one second at mars it's

1258
00:44:36,950 --> 00:44:35,040
still incredibly fast to take about all

1259
00:44:38,710 --> 00:44:36,960
of that nylon and kevlar from a very

1260
00:44:42,710 --> 00:44:38,720
small volume and get it out a hundred

1261
00:44:47,750 --> 00:44:45,109
my name is kasira pravitz and i'm from

1262
00:44:48,790 --> 00:44:47,760
woody education campuses and my question

1263
00:44:50,870 --> 00:44:48,800

is that

1264
00:44:53,750 --> 00:44:50,880
when the rover

1265
00:44:55,270 --> 00:44:53,760
hit the surface of mars did it damage

1266
00:44:56,870 --> 00:44:55,280
did it get damaged

1267
00:44:58,630 --> 00:44:56,880
when the rover hit the surface of mars

1268
00:45:00,470 --> 00:44:58,640
did it get damaged no

1269
00:45:02,950 --> 00:45:00,480
all of the technologies that we used to

1270
00:45:05,430 --> 00:45:02,960
help land it safely worked flawlessly

1271
00:45:07,109 --> 00:45:05,440
for us you know the it's some people

1272
00:45:08,950 --> 00:45:07,119
refer to that whole martian entry

1273
00:45:10,390 --> 00:45:08,960
sequence as seven minutes of terror

1274
00:45:12,309 --> 00:45:10,400
because that's how long it takes to go

1275
00:45:14,390 --> 00:45:12,319
from the top of the martian atmosphere

1276
00:45:15,829 --> 00:45:14,400
all the way down to the surface and all

1277
00:45:18,230 --> 00:45:15,839
of the different things that have to

1278
00:45:20,390 --> 00:45:18,240
work to land that rover successfully

1279
00:45:21,750 --> 00:45:20,400
worked for us the hundreds and hundreds

1280
00:45:23,510 --> 00:45:21,760
of different events that have to occur

1281
00:45:28,550 --> 00:45:23,520
at exactly the right time all worked

1282
00:45:32,950 --> 00:45:30,790
hello my name is tevani and i'm from

1283
00:45:35,109 --> 00:45:32,960
whittier education campus how long did

1284
00:45:36,230 --> 00:45:35,119
it take the rover to get to

1285
00:45:37,750 --> 00:45:36,240
mars

1286
00:45:40,390 --> 00:45:37,760
how long did it take the rover to get to

1287
00:45:42,150 --> 00:45:40,400
mars once it leaves earth it takes about

1288
00:45:47,030 --> 00:45:42,160

nine months to go from earth all the way

1289
00:45:51,030 --> 00:45:48,550
next question is from our online

1290
00:45:54,309 --> 00:45:52,710
in the online question what kind of

1291
00:45:56,790 --> 00:45:54,319
stitch do you use to sew the parachute

1292
00:46:00,150 --> 00:45:58,790
lots of different kinds of stitches lots

1293
00:46:01,430 --> 00:46:00,160
of different kinds of seams lots of

1294
00:46:03,990 --> 00:46:01,440
different kind of joints it depends on

1295
00:46:05,109 --> 00:46:04,000
what aspect of the the parachute you're

1296
00:46:07,270 --> 00:46:05,119
talking about

1297
00:46:08,870 --> 00:46:07,280
different types of zigzag stitches

1298
00:46:11,910 --> 00:46:08,880
box x's

1299
00:46:13,910 --> 00:46:11,920
french fell seams normal seams

1300
00:46:15,910 --> 00:46:13,920
you name it and depending on the element

1301
00:46:17,190 --> 00:46:15,920
of the parachute it's probably got you

1302
00:46:19,430 --> 00:46:17,200
know just about any kind of stitch that

1303
00:46:21,910 --> 00:46:19,440
you can think of

1304
00:46:23,829 --> 00:46:21,920
what was your difference between the psi

1305
00:46:25,829 --> 00:46:23,839
when you was testing the

1306
00:46:26,790 --> 00:46:25,839
probes and stuff on earth then it wasn't

1307
00:46:28,950 --> 00:46:26,800
mars

1308
00:46:30,309 --> 00:46:28,960
what's the difference in psi between the

1309
00:46:32,710 --> 00:46:30,319
earth testing and what we would use at

1310
00:46:34,390 --> 00:46:32,720
mars well when we test at very high

1311
00:46:35,910 --> 00:46:34,400
altitudes the atmospheric pressure at

1312
00:46:37,670 --> 00:46:35,920
earth is very low just like it is at

1313
00:46:39,910 --> 00:46:37,680

mars so you don't need a whole lot of

1314
00:46:43,030 --> 00:46:39,920
pressure uh when we are inflating these

1315
00:46:45,030 --> 00:46:43,040
devices that six meter diameter yellow

1316
00:46:47,270 --> 00:46:45,040
donut that we inflated that was inflated

1317
00:46:48,630 --> 00:46:47,280
to about three and a half psi and that's

1318
00:46:49,990 --> 00:46:48,640
about as much pressure as you would need

1319
00:46:52,150 --> 00:46:50,000
at mars

1320
00:46:53,829 --> 00:46:52,160
that big ram air inflated device that

1321
00:46:55,109 --> 00:46:53,839
was inflated to a little less than one

1322
00:46:56,950 --> 00:46:55,119
psi

1323
00:47:01,190 --> 00:46:56,960
and it still helped get that shape fully

1324
00:47:05,109 --> 00:47:02,870
hi my name is ashley i'm visiting from

1325
00:47:06,710 --> 00:47:05,119
georgia thank you for your talk

1326
00:47:08,950 --> 00:47:06,720
i had a question about

1327
00:47:10,950 --> 00:47:08,960
since the parachute seemed to be ripping

1328
00:47:12,470 --> 00:47:10,960
at these altitudes are you guys looking

1329
00:47:14,470 --> 00:47:12,480
into developing any kind of textiles

1330
00:47:16,710 --> 00:47:14,480
that could work better at those

1331
00:47:18,470 --> 00:47:16,720
conditions or anything

1332
00:47:19,910 --> 00:47:18,480
the question is since the parachute was

1333
00:47:21,910 --> 00:47:19,920
ripping at these altitudes are there

1334
00:47:22,950 --> 00:47:21,920
textiles that were developing

1335
00:47:25,589 --> 00:47:22,960
that would work better in those

1336
00:47:27,030 --> 00:47:25,599
environments in general we use the most

1337
00:47:29,109 --> 00:47:27,040
state-of-the-art textiles that we have

1338
00:47:30,390 --> 00:47:29,119

there's lots of trades that you

1339
00:47:32,870 --> 00:47:30,400
have to make one of the things that we

1340
00:47:35,109 --> 00:47:32,880
began learning was nylon for example is

1341
00:47:37,270 --> 00:47:35,119
very elastic it stretches

1342
00:47:39,190 --> 00:47:37,280
when it's stretching because of load you

1343
00:47:42,549 --> 00:47:39,200
can pull it to about 20 to 30 percent

1344
00:47:44,630 --> 00:47:42,559
its length before it fails kevlar by

1345
00:47:46,390 --> 00:47:44,640
comparison is extremely stiff it will

1346
00:47:48,630 --> 00:47:46,400
only stretch about two to three percent

1347
00:47:50,870 --> 00:47:48,640
maybe four percent before it breaks when

1348
00:47:52,230 --> 00:47:50,880
you mix the two materials there's

1349
00:47:54,549 --> 00:47:52,240
subtleties associated with how the

1350
00:47:56,470 --> 00:47:54,559
materials interact when the nylon begins

1351
00:47:57,990 --> 00:47:56,480
loading it begins stretching and it'll

1352
00:48:00,150 --> 00:47:58,000
take all of the stress and it will just

1353
00:48:01,910 --> 00:48:00,160
dump it to the kevlar and so if you're

1354
00:48:03,430 --> 00:48:01,920
not understanding how these materials

1355
00:48:05,109 --> 00:48:03,440
behave and interact with each other

1356
00:48:07,270 --> 00:48:05,119
that's one of the challenges that was

1357
00:48:08,630 --> 00:48:07,280
something that we generally had an idea

1358
00:48:10,069 --> 00:48:08,640
about but we didn't understand the

1359
00:48:11,349 --> 00:48:10,079
sensitivity to

1360
00:48:12,790 --> 00:48:11,359
when we've looked at other materials

1361
00:48:15,190 --> 00:48:12,800
that are out there

1362
00:48:17,030 --> 00:48:15,200
things like kevlar and technora are

1363
00:48:18,549 --> 00:48:17,040

pretty much the

1364
00:48:20,549 --> 00:48:18,559
the most state of the art in terms of

1365
00:48:22,710 --> 00:48:20,559
weight per strength of materials that

1366
00:48:24,950 --> 00:48:22,720
you can use in devices like this

1367
00:48:27,190 --> 00:48:24,960
nylon for the broadcloth they're all

1368
00:48:28,870 --> 00:48:27,200
there are alternatives out there but

1369
00:48:30,549 --> 00:48:28,880
generally you have to make sacrifices in

1370
00:48:32,470 --> 00:48:30,559
other areas maybe they don't survive

1371
00:48:33,990 --> 00:48:32,480
some of the temperatures as well

1372
00:48:35,829 --> 00:48:34,000
maybe they have other things that they

1373
00:48:37,430 --> 00:48:35,839
don't respond to for example you know

1374
00:48:39,589 --> 00:48:37,440
the cold environment from the transit

1375
00:48:41,430 --> 00:48:39,599
from earth to mars uh maybe they begin

1376
00:48:43,349 --> 00:48:41,440
to brittle so in general we think that

1377
00:48:45,589 --> 00:48:43,359
we've got the right materials it's

1378
00:48:50,390 --> 00:48:45,599
mixing them in the right combination

1379
00:48:54,630 --> 00:48:53,190
next up is an online question

1380
00:48:56,230 --> 00:48:54,640
online question is it disappointing to

1381
00:48:59,190 --> 00:48:56,240
watch the parachute shred after so much

1382
00:49:03,270 --> 00:49:00,829
you know as i said it can be very

1383
00:49:05,430 --> 00:49:03,280
humbling experience

1384
00:49:07,750 --> 00:49:05,440
but i i think the initial disappointment

1385
00:49:09,510 --> 00:49:07,760
gets replaced with the realization that

1386
00:49:11,670 --> 00:49:09,520
uh you're going to learn from that

1387
00:49:13,430 --> 00:49:11,680
you're going to have to pick yourself up

1388
00:49:15,670 --> 00:49:13,440

figure out why it failed and through

1389
00:49:17,349 --> 00:49:15,680
that understanding then beginning to

1390
00:49:18,549 --> 00:49:17,359
apply that that's something that we

1391
00:49:20,630 --> 00:49:18,559
haven't it's knowledge that we haven't

1392
00:49:22,150 --> 00:49:20,640
had and so that's an exciting aspect is

1393
00:49:24,710 --> 00:49:22,160
that you are beginning to push the

1394
00:49:26,790 --> 00:49:24,720
frontiers you're again on the very edge

1395
00:49:29,030 --> 00:49:26,800
and cutting edge of the envelope for

1396
00:49:31,510 --> 00:49:29,040
these technologies and you're getting

1397
00:49:32,710 --> 00:49:31,520
the the know-how to push that envelope

1398
00:49:33,510 --> 00:49:32,720
and to get these things to eventually

1399
00:49:35,190 --> 00:49:33,520
work

1400
00:49:36,630 --> 00:49:35,200
so there is an element of disappointment

1401
00:49:38,230 --> 00:49:36,640
but there is also an element of

1402
00:49:39,670 --> 00:49:38,240
excitement uh

1403
00:49:40,870 --> 00:49:39,680
because you're learning something new

1404
00:49:43,750 --> 00:49:40,880
something that nobody else has seen

1405
00:49:47,109 --> 00:49:43,760
before and that means that yeah you're

1406
00:49:50,390 --> 00:49:48,710
my name is tom from woody education

1407
00:49:52,470 --> 00:49:50,400
campus and i was going to ask how does

1408
00:49:53,510 --> 00:49:52,480
the aerodynamics of the parachute affect

1409
00:49:55,109 --> 00:49:53,520
the drag

1410
00:49:56,870 --> 00:49:55,119
how do the aerodynamics of the parachute

1411
00:49:57,829 --> 00:49:56,880
affect the drag well depends on the

1412
00:49:59,750 --> 00:49:57,839
environment that you're in so

1413
00:50:01,670 --> 00:49:59,760

supersonically right the parachute is

1414
00:50:03,109 --> 00:50:01,680
inflating behind this blunt body this

1415
00:50:04,549 --> 00:50:03,119
blunt body is screaming through the

1416
00:50:06,630 --> 00:50:04,559
atmosphere it's essentially punching a

1417
00:50:08,390 --> 00:50:06,640
hole in the atmosphere and in that hole

1418
00:50:10,150 --> 00:50:08,400
all of the air is rushing around it and

1419
00:50:11,430 --> 00:50:10,160
it's a very turbulent very chaotic

1420
00:50:13,430 --> 00:50:11,440
environment and so that's what the

1421
00:50:15,190 --> 00:50:13,440
parachute is beginning to inflate in and

1422
00:50:17,030 --> 00:50:15,200
how it interacts well there's a tight

1423
00:50:18,470 --> 00:50:17,040
coupling because the shape of the

1424
00:50:20,069 --> 00:50:18,480
parachute determines the flow field

1425
00:50:21,990 --> 00:50:20,079
around it and the flow field in front of

1426
00:50:24,230 --> 00:50:22,000
it determines the shape of the parachute

1427
00:50:25,829 --> 00:50:24,240
so there's this interaction that goes on

1428
00:50:27,270 --> 00:50:25,839
and because the environment in front of

1429
00:50:29,109 --> 00:50:27,280
it's so turbulent it creates a very

1430
00:50:30,870 --> 00:50:29,119
turbulent acting parachute

1431
00:50:32,470 --> 00:50:30,880
so the aerodynamics things like you know

1432
00:50:34,069 --> 00:50:32,480
how much pressure is inside how stable

1433
00:50:36,069 --> 00:50:34,079
is that pressure distribution all affect

1434
00:50:37,750 --> 00:50:36,079
the shape uh and then the drag of the

1435
00:50:40,470 --> 00:50:37,760
parachute can fluctuate at high mach

1436
00:50:42,230 --> 00:50:40,480
numbers it can be a fraction one-tenth

1437
00:50:45,030 --> 00:50:42,240
the amount of drag it generates at mach

1438
00:50:46,870 --> 00:50:45,040

3 that it would at say

1439
00:50:48,630 --> 00:50:46,880
something less than mach 1

1440
00:50:50,549 --> 00:50:48,640
you know 100 miles an hour so the

1441
00:50:52,230 --> 00:50:50,559
difference between drag at 3 000 miles

1442
00:50:54,069 --> 00:50:52,240
an hour and 100 miles an hour can be an

1443
00:50:55,349 --> 00:50:54,079
order of magnitude it can be very very

1444
00:50:58,230 --> 00:50:55,359
large

1445
00:51:02,470 --> 00:51:00,309
my name is jalani sheppard from video

1446
00:51:04,230 --> 00:51:02,480
education campus my question is

1447
00:51:06,710 --> 00:51:04,240
how does the rover and parachutes land

1448
00:51:08,630 --> 00:51:06,720
in the right destination on mars

1449
00:51:10,870 --> 00:51:08,640
how does the rover land at more

1450
00:51:12,630 --> 00:51:10,880
destinations on mars

1451
00:51:14,549 --> 00:51:12,640
how do you guys know if it's going to

1452
00:51:15,750 --> 00:51:14,559
land in the right destination ah how do

1453
00:51:18,309 --> 00:51:15,760
we know that it's going to land in the

1454
00:51:20,470 --> 00:51:18,319
right destination well

1455
00:51:22,870 --> 00:51:20,480
it's a very challenging problem you're

1456
00:51:24,549 --> 00:51:22,880
trying to go you know

1457
00:51:26,710 --> 00:51:24,559
millions and millions of miles from

1458
00:51:28,870 --> 00:51:26,720
earth to mars you're trying to enter the

1459
00:51:31,430 --> 00:51:28,880
martian atmosphere at a very small

1460
00:51:33,190 --> 00:51:31,440
window say you know a few kilometers in

1461
00:51:34,549 --> 00:51:33,200
in size and then you're trying to put

1462
00:51:36,870 --> 00:51:34,559
that rover

1463
00:51:38,790 --> 00:51:36,880

down on a relatively small area

1464
00:51:39,829 --> 00:51:38,800
back when we landed the viking

1465
00:51:42,870 --> 00:51:39,839
landers

1466
00:51:45,270 --> 00:51:42,880
that area was about 160 to 200

1467
00:51:46,870 --> 00:51:45,280
kilometers long we actually didn't have

1468
00:51:48,309 --> 00:51:46,880
a great idea we knew that there was a

1469
00:51:50,390 --> 00:51:48,319
lot of uncertainty in terms of how much

1470
00:51:52,390 --> 00:51:50,400
drag how thick the atmosphere was how

1471
00:51:54,150 --> 00:51:52,400
the vehicle would fly

1472
00:51:55,510 --> 00:51:54,160
if there are winds would they begin to

1473
00:51:58,870 --> 00:51:55,520
push the vehicle while it was on the

1474
00:52:01,510 --> 00:51:58,880
parachute and drift it off course

1475
00:52:03,270 --> 00:52:01,520
from viking to 200 kilometers of viking

1476
00:52:05,349 --> 00:52:03,280
when we landed curiosity we got that

1477
00:52:07,349 --> 00:52:05,359
down to less than 10 kilometers we'd

1478
00:52:09,030 --> 00:52:07,359
actually shrunk our uncertainty down to

1479
00:52:11,430 --> 00:52:09,040
about 10 kilometers so there's still

1480
00:52:13,589 --> 00:52:11,440
some uncertainty about six miles or so

1481
00:52:14,870 --> 00:52:13,599
in terms of where it will land but we've

1482
00:52:19,670 --> 00:52:14,880
been able to make some significant

1483
00:52:24,309 --> 00:52:22,309
i wanted to know how long did it take to

1484
00:52:25,510 --> 00:52:24,319
make the rover how long did it take to

1485
00:52:28,309 --> 00:52:25,520
make the rover

1486
00:52:30,390 --> 00:52:28,319
years years and years uh you know we're

1487
00:52:32,790 --> 00:52:30,400
planning a rover very similar to that

1488
00:52:34,710 --> 00:52:32,800

that we'll launch in 2020

1489
00:52:36,549 --> 00:52:34,720
and the engineering development of that

1490
00:52:38,470 --> 00:52:36,559
is actually going on today five years

1491
00:52:40,630 --> 00:52:38,480
ahead of schedule you know all of the

1492
00:52:42,230 --> 00:52:40,640
design the testing the analysis that all

1493
00:52:44,829 --> 00:52:42,240
takes years to conduct and then actually

1494
00:52:47,430 --> 00:52:44,839
fabricating uh the materials that put it

1495
00:52:49,109 --> 00:52:47,440
together that takes years

1496
00:52:50,309 --> 00:52:49,119
and then finally assembling it generally

1497
00:52:52,470 --> 00:52:50,319
will take

1498
00:52:53,910 --> 00:52:52,480
over the course of a year so doing the

1499
00:52:58,150 --> 00:52:53,920
the integration the assembling and all

1500
00:53:02,950 --> 00:52:59,910
hi i'm david o'brien visiting for

1501
00:53:05,109 --> 00:53:02,960
chicago area i was wondering if the the

1502
00:53:06,870 --> 00:53:05,119
cfd simulations you had

1503
00:53:09,349 --> 00:53:06,880
were they able to predict some sort of

1504
00:53:11,750 --> 00:53:09,359
possibility the probability of the

1505
00:53:14,470 --> 00:53:11,760
tearing of the parachute and how

1506
00:53:17,510 --> 00:53:14,480
you might use the tearing event to help

1507
00:53:19,270 --> 00:53:17,520
shape your future safety simulations

1508
00:53:21,430 --> 00:53:19,280
the question is did our computational

1509
00:53:23,349 --> 00:53:21,440
fluid dynamics are our computer models

1510
00:53:25,829 --> 00:53:23,359
of the aerodynamics around the parachute

1511
00:53:28,150 --> 00:53:25,839
did those predict anything associated uh

1512
00:53:30,390 --> 00:53:28,160
with the the tearing on the parachute

1513
00:53:32,309 --> 00:53:30,400

and then the second part was sorry could

1514
00:53:34,790 --> 00:53:32,319
we use them to predict future make

1515
00:53:35,990 --> 00:53:34,800
modifications uh

1516
00:53:38,069 --> 00:53:36,000
in general the answer to the first

1517
00:53:39,510 --> 00:53:38,079
question is no not really

1518
00:53:41,109 --> 00:53:39,520
we've used pretty much the state of the

1519
00:53:43,030 --> 00:53:41,119
art the same tools that we've used

1520
00:53:45,430 --> 00:53:43,040
successfully but when we begin applying

1521
00:53:46,230 --> 00:53:45,440
them to much larger parachutes inflated

1522
00:53:52,390 --> 00:53:46,240
at

1523
00:53:55,589 --> 00:53:52,400
all of the stresses pressures forces

1524
00:53:57,190 --> 00:53:55,599
that are going on inside the canopy

1525
00:53:58,950 --> 00:53:57,200
so there's a deficit there we're in the

1526
00:54:00,710 --> 00:53:58,960
process of taking the data that we're

1527
00:54:01,990 --> 00:54:00,720
generating from these tests and using

1528
00:54:08,470 --> 00:54:02,000
that to improve our modeling

1529
00:54:13,190 --> 00:54:10,710
and i think that's all for questions it

1530
00:54:15,510 --> 00:54:13,200
is uh we would like to thank dr ian

1531
00:54:17,510 --> 00:54:15,520
clark for coming to the museum today and

1532
00:54:20,230 --> 00:54:17,520
uh presenting the findings uh that

1533
00:54:22,470 --> 00:54:20,240
they've they've uncovered so far uh we'd

1534
00:54:23,829 --> 00:54:22,480
also like to thank our sponsor boeing

1535
00:54:25,829 --> 00:54:23,839
thank those of you that are watching

1536
00:54:27,510 --> 00:54:25,839
online nasa tv and those of you in the