

MARS



1
00:00:05,030 --> 00:00:03,030
all right good afternoon everybody

2
00:00:06,389 --> 00:00:05,040
um as elena said my name is doug litigan

3
00:00:08,070 --> 00:00:06,399
and i'm an engineer in the structural

4
00:00:10,310 --> 00:00:08,080
engineering division which is right next

5
00:00:12,629 --> 00:00:10,320
door here in building 13.

6
00:00:13,990 --> 00:00:12,639
i started at jsc about five years ago

7
00:00:15,110 --> 00:00:14,000
and back then it was a very exciting

8
00:00:16,630 --> 00:00:15,120
time

9
00:00:18,630 --> 00:00:16,640
the space shuttle program was ending and

10
00:00:20,390 --> 00:00:18,640
we had a bright eyed future going back

11
00:00:21,990 --> 00:00:20,400
to the moon and on to mars

12
00:00:25,029 --> 00:00:22,000
i started looking around and i saw a lot

13
00:00:26,470 --> 00:00:25,039

of cool projects i saw lunar landers

14

00:00:27,990 --> 00:00:26,480

lunar rovers

15

00:00:29,830 --> 00:00:28,000

some cool habitats

16

00:00:31,029 --> 00:00:29,840

there was something that i saw common in

17

00:00:31,990 --> 00:00:31,039

all these things that kind of concerned

18

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

me

19

00:00:40,709 --> 00:00:38,960

everyone was still building things out

20

00:00:42,470 --> 00:00:40,719

of metal and yeah i'm talking about

21

00:00:44,630 --> 00:00:42,480

aluminum and steel and titanium and

22

00:00:46,869 --> 00:00:44,640

metallic structures and i know that the

23

00:00:48,389 --> 00:00:46,879

space program has been built on metallic

24

00:00:50,790 --> 00:00:48,399

structures

25

00:00:52,150 --> 00:00:50,800

but we're trying to go beyond low earth

26

00:00:54,229 --> 00:00:52,160

orbit we're trying to go to places we've

27

00:00:55,510 --> 00:00:54,239

never been before in order to do that we

28

00:00:57,270 --> 00:00:55,520

have to do things that we've never been

29

00:00:58,389 --> 00:00:57,280

before

30

00:00:59,830 --> 00:00:58,399

and so

31

00:01:01,990 --> 00:00:59,840

we need to do some other things so i

32

00:01:03,990 --> 00:01:02,000

started to steer my career away from

33

00:01:05,509 --> 00:01:04,000

metals i started looking at composites

34

00:01:06,710 --> 00:01:05,519

and fabric structures

35

00:01:09,109 --> 00:01:06,720

and these are the things that we need to

36

00:01:11,030 --> 00:01:09,119

do we need to innovate we need to change

37

00:01:12,789 --> 00:01:11,040

we need to get out of our comfort zone

38

00:01:15,590 --> 00:01:12,799

and try new things so we need to try

39

00:01:21,190 --> 00:01:15,600

some things like inflatables

40

00:01:24,950 --> 00:01:23,190

this beach ball for example is an

41

00:01:27,270 --> 00:01:24,960

inflatable structure you've seen this

42

00:01:29,270 --> 00:01:27,280

before you've seen a lot of other things

43

00:01:32,149 --> 00:01:29,280

similar to this like rafts air

44

00:01:33,510 --> 00:01:32,159

mattresses party balloons

45

00:01:34,870 --> 00:01:33,520

these are all considered inflatable

46

00:01:37,429 --> 00:01:34,880

structures

47

00:01:39,429 --> 00:01:37,439

in essence they're a massive material

48

00:01:41,830 --> 00:01:39,439

and then they get inflated and they grow

49

00:01:44,310 --> 00:01:41,840

into a larger volume and they occupy the

50

00:01:46,710 --> 00:01:44,320

space that they've been designed for

51
00:01:48,870 --> 00:01:46,720
this beach ball however is considered a

52
00:01:50,389 --> 00:01:48,880
low strength inflatable structure much

53
00:01:52,710 --> 00:01:50,399
like all the other materials and

54
00:01:53,990 --> 00:01:52,720
inflatables that you see on earth

55
00:01:56,069 --> 00:01:54,000
what that means is it takes a low

56
00:01:57,749 --> 00:01:56,079
pressure to inflate this

57
00:02:00,389 --> 00:01:57,759
and because of that low pressure it has

58
00:02:02,870 --> 00:02:00,399
only one layer of material on it this

59
00:02:04,950 --> 00:02:02,880
layer of material is both a gas barrier

60
00:02:06,709 --> 00:02:04,960
and a structural layer because it has a

61
00:02:08,869 --> 00:02:06,719
low pressure it doesn't need a very high

62
00:02:10,630 --> 00:02:08,879
structural layer but we all know from

63
00:02:12,869 --> 00:02:10,640

experience that things these things are

64

00:02:14,949 --> 00:02:12,879

very fragile they tend to break they

65

00:02:16,630 --> 00:02:14,959

tend to pop they tend to rip and they're

66

00:02:18,229 --> 00:02:16,640

very dangerous

67

00:02:19,350 --> 00:02:18,239

so if i say that i'm going to take this

68

00:02:20,869 --> 00:02:19,360

and i'm going to put it into space and i

69

00:02:22,710 --> 00:02:20,879

want you to live inside of it you're

70

00:02:24,710 --> 00:02:22,720

probably not going to want to do it

71

00:02:27,670 --> 00:02:24,720

but our space structures our space

72

00:02:29,110 --> 00:02:27,680

balloons if you will are not like this

73

00:02:30,550 --> 00:02:29,120

okay we have

74

00:02:32,309 --> 00:02:30,560

numerous layers of protection on the

75

00:02:35,030 --> 00:02:32,319

outside of our balloons that make them

76

00:02:36,550 --> 00:02:35,040

virtually bulletproof

77

00:02:38,550 --> 00:02:36,560

one of the other advantages of our space

78

00:02:41,190 --> 00:02:38,560

structures just like this balloon is

79

00:02:43,509 --> 00:02:41,200

that it can be compressed and compact it

80

00:02:46,070 --> 00:02:43,519

can be fit into a small launch shroud

81

00:02:50,949 --> 00:02:46,080

launched into space and inflated to over

82

00:02:55,430 --> 00:02:53,430

additionally

83

00:02:57,110 --> 00:02:55,440

when we launch an inflatable structure

84

00:02:59,990 --> 00:02:57,120

for the same cost that we can launch a

85

00:03:01,750 --> 00:03:00,000

metallic structure we can get over three

86

00:03:03,750 --> 00:03:01,760

times the volume

87

00:03:04,790 --> 00:03:03,760

that's the same price to launch a

88

00:03:05,990 --> 00:03:04,800

vehicle

89

00:03:07,509 --> 00:03:06,000

instead of a metallic structure you can

90

00:03:08,550 --> 00:03:07,519

launch an inflatable and get three times

91

00:03:10,229 --> 00:03:08,560

the volume

92

00:03:12,070 --> 00:03:10,239

and i want i want you to visualize this

93

00:03:14,070 --> 00:03:12,080

because this is very important so i have

94

00:03:17,110 --> 00:03:14,080

some friends in the second and third

95

00:03:18,710 --> 00:03:17,120

rows if you guys can come up right now

96

00:03:20,949 --> 00:03:18,720

we're gonna do a little demonstration i

97

00:03:22,070 --> 00:03:20,959

need six of you so ron and doug you can

98

00:03:26,309 --> 00:03:22,080

come as well

99

00:03:29,430 --> 00:03:27,430

so there's these

100

00:03:30,789 --> 00:03:29,440

marks on the ground everyone just stand

101
00:03:32,390 --> 00:03:30,799
on one of them

102
00:03:33,830 --> 00:03:32,400
there should be six of them there's one

103
00:03:35,830 --> 00:03:33,840
way over there

104
00:03:38,869 --> 00:03:35,840
and there's one way back there

105
00:03:40,229 --> 00:03:38,879
kelly you can do that one on the front

106
00:03:41,270 --> 00:03:40,239
so what i've done here is i have six

107
00:03:42,390 --> 00:03:41,280
people

108
00:03:43,750 --> 00:03:42,400
and i divided them up into three

109
00:03:45,910 --> 00:03:43,760
different crews they're all going to

110
00:03:47,589 --> 00:03:45,920
mars okay the first crew over here on

111
00:03:49,990 --> 00:03:47,599
the left they're standing in a triangle

112
00:03:51,910 --> 00:03:50,000
can you sit on this triangle

113
00:03:53,830 --> 00:03:51,920

that's me that's you

114

00:03:55,670 --> 00:03:53,840

so the first crew here on the left

115

00:03:57,750 --> 00:03:55,680

standing in this triangle the space in

116

00:04:00,710 --> 00:03:57,760

between these three people represents

117

00:04:02,070 --> 00:04:00,720

the volume of a typical capsule design

118

00:04:03,670 --> 00:04:02,080

something you've probably seen before

119

00:04:05,190 --> 00:04:03,680

it's going to take us to mars or take us

120

00:04:06,789 --> 00:04:05,200

to the moon

121

00:04:07,830 --> 00:04:06,799

and this this is the habitable volume

122

00:04:09,750 --> 00:04:07,840

that they have to work with on their

123

00:04:11,910 --> 00:04:09,760

journey to mars

124

00:04:13,110 --> 00:04:11,920

now this triangle over here and these

125

00:04:14,869 --> 00:04:13,120

three crew members are also going to

126

00:04:16,870 --> 00:04:14,879

mars but they are living in an

127

00:04:18,069 --> 00:04:16,880

inflatable structure this inflatable

128

00:04:19,509 --> 00:04:18,079

structure has

129

00:04:20,870 --> 00:04:19,519

what you see here is just three times

130

00:04:22,469 --> 00:04:20,880

the volume but it can be a lot more

131

00:04:24,150 --> 00:04:22,479

depending on the design

132

00:04:26,629 --> 00:04:24,160

so you can see here

133

00:04:28,870 --> 00:04:26,639

pretty obviously which vehicle would you

134

00:04:30,710 --> 00:04:28,880

rather take to mars

135

00:04:32,230 --> 00:04:30,720

this one you're right all right you guys

136

00:04:37,990 --> 00:04:32,240

can get sit back down

137

00:04:40,950 --> 00:04:39,590

so you're probably wondering you know

138

00:04:42,710 --> 00:04:40,960

like what's the catch

139

00:04:45,510 --> 00:04:42,720

why haven't we done this before this

140

00:04:46,950 --> 00:04:45,520

looks awesome it's amazing let's throw a

141

00:04:48,550 --> 00:04:46,960

bunch of money at it and let's build an

142

00:04:49,830 --> 00:04:48,560

inflatable structure

143

00:04:51,830 --> 00:04:49,840

but one of the big problems with

144

00:04:52,950 --> 00:04:51,840

inflatables is that a lot of people are

145

00:04:54,870 --> 00:04:52,960

afraid of them

146

00:04:56,870 --> 00:04:54,880

as i mentioned before you put a balloon

147

00:04:58,310 --> 00:04:56,880

in space it sounds scary

148

00:04:59,270 --> 00:04:58,320

um i talked to a lot of kids about this

149

00:05:00,870 --> 00:04:59,280

and i tell them that we're going to put

150

00:05:02,550 --> 00:05:00,880

balloons in space and they get a lot of

151
00:05:04,390 --> 00:05:02,560
concerned faces

152
00:05:06,469 --> 00:05:04,400
because of the same reasons they know

153
00:05:08,070 --> 00:05:06,479
that balloons pop i know that you know

154
00:05:09,590 --> 00:05:08,080
that but the balloons that we have on

155
00:05:11,830 --> 00:05:09,600
earth are not the same types of balloons

156
00:05:13,430 --> 00:05:11,840
that we're putting in space

157
00:05:15,110 --> 00:05:13,440
for example

158
00:05:16,629 --> 00:05:15,120
this balloon like i said has a single

159
00:05:23,430 --> 00:05:16,639
gas barrier

160
00:05:25,670 --> 00:05:23,440
resilient to cold temperatures

161
00:05:26,790 --> 00:05:25,680
it can be flexed multiple times without

162
00:05:29,110 --> 00:05:26,800
breaking

163
00:05:30,390 --> 00:05:29,120

we also have redundant barriers

164

00:05:31,830 --> 00:05:30,400

and it could be

165

00:05:34,310 --> 00:05:31,840

made of self-healing materials so if

166

00:05:35,990 --> 00:05:34,320

there is a pinhole break or a leak it

167

00:05:37,909 --> 00:05:36,000

can heal itself

168

00:05:40,150 --> 00:05:37,919

now outside of that gas barrier there's

169

00:05:41,430 --> 00:05:40,160

also a main structural layer because our

170

00:05:42,790 --> 00:05:41,440

inflatables are high strength

171

00:05:44,550 --> 00:05:42,800

inflatables they have a high pressure on

172

00:05:45,909 --> 00:05:44,560

the inside thanks to the vacuum of space

173

00:05:47,749 --> 00:05:45,919

that's on the outside

174

00:05:49,189 --> 00:05:47,759

so we have a big structural layer that's

175

00:05:51,110 --> 00:05:49,199

made of the same material that you make

176

00:05:53,510 --> 00:05:51,120

bulletproof vest out of it is

177

00:05:55,029 --> 00:05:53,520

bulletproof and it's strong and it's

178

00:05:56,230 --> 00:05:55,039

very stiff

179

00:05:58,230 --> 00:05:56,240

and those are the main two layers

180

00:05:59,830 --> 00:05:58,240

structural layer the gas barrier but

181

00:06:01,430 --> 00:05:59,840

outside of that we have a space

182

00:06:03,590 --> 00:06:01,440

environment that's very dangerous and

183

00:06:05,189 --> 00:06:03,600

very scary and so we have a shell on the

184

00:06:07,029 --> 00:06:05,199

outside of those layers that helps us

185

00:06:09,189 --> 00:06:07,039

protect that protects us from that space

186

00:06:11,029 --> 00:06:09,199

environment for example that shell has

187

00:06:13,189 --> 00:06:11,039

atomic oxygen protection

188

00:06:14,629 --> 00:06:13,199

it's got thermal insulation and it has

189

00:06:17,270 --> 00:06:14,639

multiple layers of micro meteorite

190

00:06:18,950 --> 00:06:17,280

orbital debris protection or mmod

191

00:06:21,270 --> 00:06:18,960

mmod is probably the biggest or the

192

00:06:22,950 --> 00:06:21,280

scariest thing with inflatables but the

193

00:06:26,710 --> 00:06:22,960

mmod shield that we've created for our

194

00:06:29,830 --> 00:06:26,720

inflatable has outperformed the iss mmod

195

00:06:30,870 --> 00:06:29,840

shields in hypervelocity impact testing

196

00:06:33,110 --> 00:06:30,880

so

197

00:06:35,830 --> 00:06:33,120

our inflatable balloon

198

00:06:38,710 --> 00:06:35,840

is actually better prepared for mmod

199

00:06:40,870 --> 00:06:38,720

impacts than the current iss metallic

200

00:06:43,590 --> 00:06:40,880

shields

201
00:06:46,550 --> 00:06:43,600
so one of the other beauties of this

202
00:06:48,230 --> 00:06:46,560
structure and of inflatable structures

203
00:06:49,990 --> 00:06:48,240
is that they can be formed into a

204
00:06:51,830 --> 00:06:50,000
variety of different shapes

205
00:06:53,270 --> 00:06:51,840
they can be used as a long-term transit

206
00:06:55,029 --> 00:06:53,280
vehicle to mars

207
00:06:57,029 --> 00:06:55,039
they can be used as a surface habitat on

208
00:06:58,390 --> 00:06:57,039
the moon or on mars

209
00:06:59,990 --> 00:06:58,400
this isn't the first time that we

210
00:07:01,990 --> 00:07:00,000
thought about this

211
00:07:04,309 --> 00:07:02,000
nasa first investigated inflatable

212
00:07:06,469 --> 00:07:04,319
structures back in 1961 eight years

213
00:07:08,790 --> 00:07:06,479

before we went to the moon

214

00:07:10,469 --> 00:07:08,800

in fact the first ever eva was performed

215

00:07:13,749 --> 00:07:10,479

by the russians and it used an

216

00:07:15,909 --> 00:07:13,759

inflatable airlock

217

00:07:17,909 --> 00:07:15,919

this picture is from 1989 it was a

218

00:07:19,909 --> 00:07:17,919

design concept for inflatable lunar

219

00:07:22,070 --> 00:07:19,919

habitat

220

00:07:23,670 --> 00:07:22,080

most recently back in the late 90s

221

00:07:25,510 --> 00:07:23,680

was a big project here at jc called

222

00:07:26,550 --> 00:07:25,520

transhab most of you probably heard of

223

00:07:27,670 --> 00:07:26,560

it

224

00:07:31,589 --> 00:07:27,680

transhab

225

00:07:33,270 --> 00:07:31,599

was essentially the birth of common or

226

00:07:35,189 --> 00:07:33,280

today's design

227

00:07:37,110 --> 00:07:35,199

for inflatable structures

228

00:07:38,469 --> 00:07:37,120

they invented a lot of new technology

229

00:07:40,629 --> 00:07:38,479

mainly because they finally had the

230

00:07:43,510 --> 00:07:40,639

materials required to build these high

231

00:07:45,670 --> 00:07:43,520

strength inflatables

232

00:07:47,830 --> 00:07:45,680

one transhab module was designed to fit

233

00:07:49,110 --> 00:07:47,840

in the payload bay of the space shuttle

234

00:07:50,950 --> 00:07:49,120

it was intended to be birthed to the

235

00:07:53,189 --> 00:07:50,960

international space station and it will

236

00:07:55,670 --> 00:07:53,199

provide 1500 square feet of livable

237

00:07:57,270 --> 00:07:55,680

space in one module that's about half

238

00:07:59,510 --> 00:07:57,280

the livable space of the entire space

239

00:08:01,589 --> 00:07:59,520

station

240

00:08:04,309 --> 00:08:01,599

now after transhab a technology was

241

00:08:06,309 --> 00:08:04,319

taken and used by nasa to advance

242

00:08:08,390 --> 00:08:06,319

it was also used by bigelow aerospace to

243

00:08:11,110 --> 00:08:08,400

work on inflatable structures

244

00:08:12,390 --> 00:08:11,120

and this year 2015 we will put the first

245

00:08:14,070 --> 00:08:12,400

inflatable module

246

00:08:16,230 --> 00:08:14,080

on the iss

247

00:08:18,550 --> 00:08:16,240

this new module known as beam will be a

248

00:08:20,150 --> 00:08:18,560

significant demonstration and advocacy

249

00:08:22,230 --> 00:08:20,160

towards the future use of inflatable

250

00:08:23,749 --> 00:08:22,240

structures

251
00:08:29,029 --> 00:08:23,759
it will be the beginning of a new

252
00:08:34,469 --> 00:08:31,909
so besides those uses there are also a

253
00:08:36,389 --> 00:08:34,479
number of other potential applications

254
00:08:38,070 --> 00:08:36,399
for inflatables

255
00:08:39,029 --> 00:08:38,080
i hope you've got your mind thinking a

256
00:08:41,509 --> 00:08:39,039
little bit

257
00:08:44,070 --> 00:08:41,519
we can have this very large very strong

258
00:08:45,350 --> 00:08:44,080
structure and it can be compressed you

259
00:08:47,590 --> 00:08:45,360
could fit something in a suitcase and

260
00:08:50,550 --> 00:08:47,600
then open it up and have a large volume

261
00:08:51,829 --> 00:08:50,560
there's a lot of potential applications

262
00:08:53,590 --> 00:08:51,839
some of those applications are used in

263
00:08:55,990 --> 00:08:53,600

space some of them are being used now

264

00:08:58,470 --> 00:08:56,000

for new technologies and a lot even more

265

00:09:00,230 --> 00:08:58,480

applications that can be used on earth

266

00:09:02,710 --> 00:09:00,240

some of the space applications you may

267

00:09:03,670 --> 00:09:02,720

have heard of is like a deployable solar

268

00:09:07,030 --> 00:09:03,680

sail

269

00:09:09,509 --> 00:09:07,040

a deployable antenna

270

00:09:10,790 --> 00:09:09,519

hypersonic decelerator that's also

271

00:09:12,550 --> 00:09:10,800

deployable

272

00:09:15,350 --> 00:09:12,560

and i know you've heard of spacesuits

273

00:09:17,110 --> 00:09:15,360

spacesuit is a life-saving example of an

274

00:09:18,790 --> 00:09:17,120

inflatable structure

275

00:09:20,710 --> 00:09:18,800

it's a fabric structure that takes its

276

00:09:22,710 --> 00:09:20,720

shape when it's pressurized it's the

277

00:09:24,389 --> 00:09:22,720

definition of inflatable

278

00:09:26,389 --> 00:09:24,399

there's also a lot of applications on

279

00:09:28,310 --> 00:09:26,399

earth for inflatables

280

00:09:30,470 --> 00:09:28,320

so inflatables could be used for example

281

00:09:32,949 --> 00:09:30,480

as a fuel collection device or storage

282

00:09:34,710 --> 00:09:32,959

device to prevent or to clean up an oil

283

00:09:36,870 --> 00:09:34,720

spill offshore

284

00:09:39,110 --> 00:09:36,880

they could be used as a emergency

285

00:09:41,750 --> 00:09:39,120

hyperbaric chamber you're a deepsea

286

00:09:43,190 --> 00:09:41,760

diver and you were on a ship you did a

287

00:09:44,949 --> 00:09:43,200

dive you came up too fast and you need a

288

00:09:47,030 --> 00:09:44,959

hyperbaric chamber and you're far away

289

00:09:48,550 --> 00:09:47,040

from any medical attention

290

00:09:50,790 --> 00:09:48,560

the ship doesn't have a hyperbaric

291

00:09:52,949 --> 00:09:50,800

chamber but we have an inflatable one

292

00:09:54,870 --> 00:09:52,959

it's been compact into a bag and now we

293

00:09:57,430 --> 00:09:54,880

can inflate it open it up and it can be

294

00:09:59,509 --> 00:09:57,440

used to save your life

295

00:10:01,269 --> 00:09:59,519

this technology can also be used

296

00:10:02,550 --> 00:10:01,279

under extreme conditions and extreme

297

00:10:03,590 --> 00:10:02,560

environments

298

00:10:06,790 --> 00:10:03,600

it could be

299

00:10:08,870 --> 00:10:06,800

used as a safety shelter in antarctica

300

00:10:10,949 --> 00:10:08,880

it could potentially be used

301
00:10:12,949 --> 00:10:10,959
as a shelter for firemen who are caught

302
00:10:14,550 --> 00:10:12,959
in a wildfire

303
00:10:16,230 --> 00:10:14,560
it could also be used as a quick

304
00:10:17,509 --> 00:10:16,240
deployed shelter during a natural

305
00:10:18,630 --> 00:10:17,519
disaster

306
00:10:21,509 --> 00:10:18,640
in fact

307
00:10:23,110 --> 00:10:21,519
during hurricane sandy a few years ago

308
00:10:24,870 --> 00:10:23,120
most of the new york city subway tunnels

309
00:10:26,870 --> 00:10:24,880
became flooded with water

310
00:10:28,230 --> 00:10:26,880
this was a big problem for the city

311
00:10:30,470 --> 00:10:28,240
and since then

312
00:10:33,269 --> 00:10:30,480
the inflatable technology the same type

313
00:10:35,110 --> 00:10:33,279

of structural layer gas pair that we use

314

00:10:37,350 --> 00:10:35,120

that we've designed

315

00:10:39,030 --> 00:10:37,360

has been used and commercialized to

316

00:10:40,870 --> 00:10:39,040

build what's called a tunnel plug for

317

00:10:42,630 --> 00:10:40,880

the new york city subway system

318

00:10:45,750 --> 00:10:42,640

these devices

319

00:10:47,430 --> 00:10:45,760

like i said is a big mass of fabric

320

00:10:49,110 --> 00:10:47,440

it's packed up into a nice pretty

321

00:10:51,350 --> 00:10:49,120

package and then when needed it can be

322

00:10:53,110 --> 00:10:51,360

deployed fill up and plug a subway

323

00:10:55,190 --> 00:10:53,120

tunnel this is an excellent

324

00:10:56,949 --> 00:10:55,200

commercialization use of inflatable

325

00:10:58,949 --> 00:10:56,959

technology

326

00:11:00,870 --> 00:10:58,959

these are just a few things

327

00:11:02,790 --> 00:11:00,880

that i know about i'm hoping that you

328

00:11:04,310 --> 00:11:02,800

guys can think about some more and think

329

00:11:06,150 --> 00:11:04,320

about some future potential applications

330

00:11:07,910 --> 00:11:06,160

that we can use for inflatables

331

00:11:09,829 --> 00:11:07,920

they truly can be a life-saving

332

00:11:12,550 --> 00:11:09,839

technology

333

00:11:14,310 --> 00:11:12,560

so as i close today this was a very

334

00:11:16,069 --> 00:11:14,320

brief overview but i hope it got you

335

00:11:17,829 --> 00:11:16,079

thinking and i want to reiterate the

336

00:11:20,150 --> 00:11:17,839

point that this is very important

337

00:11:23,430 --> 00:11:20,160

you know we want to explore

338

00:11:25,430 --> 00:11:23,440

i want my kids to see mars one day

339

00:11:26,389 --> 00:11:25,440

and we can't get to mars with metallic

340

00:11:28,550 --> 00:11:26,399

structures

341

00:11:30,389 --> 00:11:28,560

we need to get out of our comfort zone