

CONDUCT RIGOROUS  
IN-SITU SCIENCE

GEOLOGICALLY DIVERSE SITE

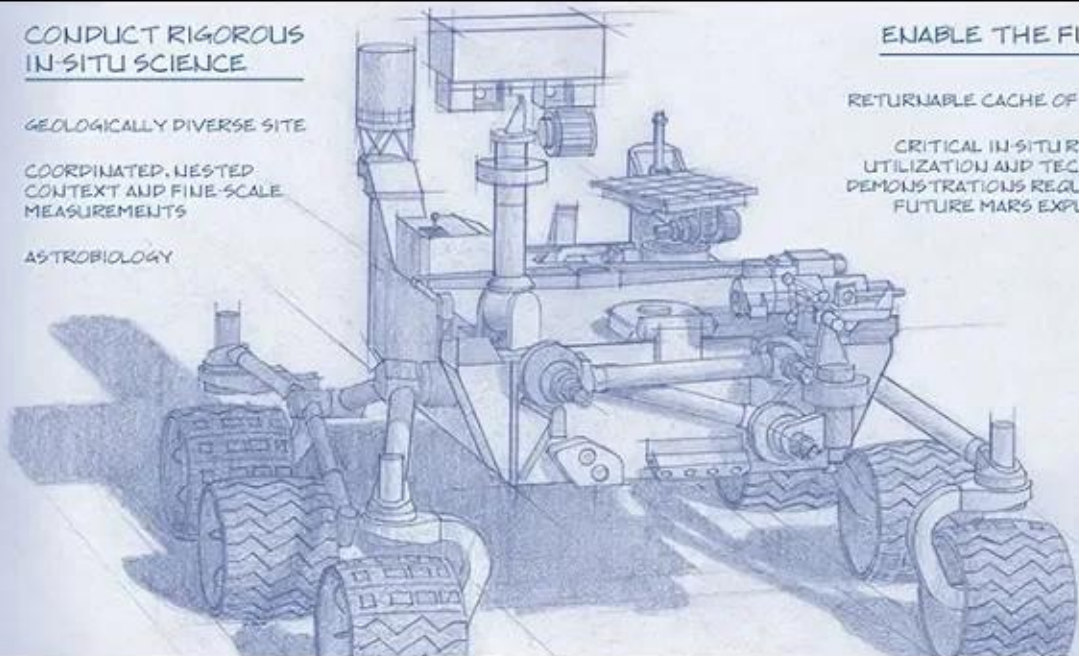
COORDINATED, NESTED  
CONTEXT AND FINE-SCALE  
MEASUREMENTS

ASTROBIOLOGY

ENABLE THE FUTURE

RETURNABLE CACHE OF SAMPLES

CRITICAL IN-SITU RESOURCE  
UTILIZATION AND TECHNOLOGY  
DEMONSTRATIONS REQUIRED FOR  
FUTURE MARS EXPLORATION



1  
00:00:06,410 --> 00:00:02,210  
NASA's Jet Propulsion Laboratory

2  
00:00:08,839 --> 00:00:06,420  
presents the von Karman lecture a series

3  
00:00:11,180 --> 00:00:08,849  
of talks by scientists and engineers who

4  
00:00:13,930 --> 00:00:11,190  
are exploring our planet our solar

5  
00:00:21,140 --> 00:00:13,940  
system and all that lies beyond

6  
00:00:23,030 --> 00:00:21,150  
[Music]

7  
00:00:29,660 --> 00:00:23,040  
hello and good evening to you wherever

8  
00:00:33,020 --> 00:00:30,830  
whether you're in Coatesville

9  
00:00:34,430 --> 00:00:33,030  
Pennsylvania Winona Minnesota or here in

10  
00:00:36,470 --> 00:00:34,440  
California welcome to the von Karman

11  
00:00:38,180 --> 00:00:36,480  
lecture series my name is Brian white I

12  
00:00:40,130 --> 00:00:38,190  
work in the JPL's office of

13  
00:00:43,610 --> 00:00:40,140

communication and education

14

00:00:46,160 --> 00:00:43,620

welcome how do we achieve what we

15

00:00:48,070 --> 00:00:46,170

thought was once impossible and how do

16

00:00:51,770 --> 00:00:48,080

you take that faintest idea the dream

17

00:00:55,000 --> 00:00:51,780

the sketch on the bar napkin how do you

18

00:00:57,410 --> 00:00:55,010

turn that into a flow full-blown mission

19

00:00:59,180 --> 00:00:57,420

where such stuff as dreams are made on

20

00:01:01,579 --> 00:00:59,190

and our little life is rounded with

21

00:01:02,600 --> 00:01:01,589

sleep now you may notice we're doing

22

00:01:04,070 --> 00:01:02,610

something a little different today we're

23

00:01:07,670 --> 00:01:04,080

sitting here on stage it's gonna be more

24

00:01:10,010 --> 00:01:07,680

of a discussion versus a full-blown talk

25

00:01:12,170 --> 00:01:10,020

at you our speaker tonight has been with

26

00:01:14,480 --> 00:01:12,180

JPL since 1984 and has worked with

27

00:01:16,070 --> 00:01:14,490

several mission and program areas he's

28

00:01:18,950 --> 00:01:16,080

been a system engineer in the

29

00:01:22,250 --> 00:01:18,960

astrophysics division has zero sense of

30

00:01:24,500 --> 00:01:22,260

humor whatsoever telecommunications and

31

00:01:25,730 --> 00:01:24,510

mistahs mission systems manager in the

32

00:01:28,640 --> 00:01:25,740

deep space network serving the Mars

33

00:01:30,800 --> 00:01:28,650

missions manager of the Cassini science

34

00:01:33,050 --> 00:01:30,810

planning and operations the Galileo

35

00:01:34,550 --> 00:01:33,060

deputy sequence team chief the Voyager

36

00:01:36,890 --> 00:01:34,560

science sequence coordinator for the

37

00:01:40,490 --> 00:01:36,900

Uranus and Neptune encounter I could go

38

00:01:42,260 --> 00:01:40,500

on and on and on today I won't today he

39

00:01:44,900 --> 00:01:42,270

is the lead study architect of JPL's

40

00:01:51,560 --> 00:01:44,910

innovation foundry 18 please welcome dr.

41

00:01:55,230 --> 00:01:53,280

let's get into it

42

00:01:58,410 --> 00:01:55,240

what's your bio you wrote it for me so I

43

00:02:00,600 --> 00:01:58,420

want to make sure we're talking about

44

00:02:03,240 --> 00:02:00,610

ideas becoming reality more specifically

45

00:02:05,610 --> 00:02:03,250

NASA JPL missions and where do they come

46

00:02:07,980 --> 00:02:05,620

from who gets to decide that's where

47

00:02:10,430 --> 00:02:07,990

we're going and you all are gonna do it

48

00:02:13,100 --> 00:02:10,440

that's right yeah

49

00:02:16,590 --> 00:02:13,110

NASA has changed over the years so

50

00:02:18,270 --> 00:02:16,600

before the mid 1990s NASA would do

51  
00:02:19,980 --> 00:02:18,280  
what's called assigned missions that go

52  
00:02:23,070 --> 00:02:19,990  
OK the Goddard Space Flight Center

53  
00:02:24,390 --> 00:02:23,080  
here's you know 200 million do this Ames

54  
00:02:26,820 --> 00:02:24,400  
Research Center I want you to do this

55  
00:02:28,590 --> 00:02:26,830  
and they JPL do this they would just

56  
00:02:32,010 --> 00:02:28,600  
assign missions to the different NASA

57  
00:02:34,220 --> 00:02:32,020  
centers by the mid-1990s two things

58  
00:02:38,190 --> 00:02:34,230  
happen that led us to where we are today

59  
00:02:40,680 --> 00:02:38,200  
one NASA was getting a little mad at us

60  
00:02:42,600 --> 00:02:40,690  
because they would come to JPL and say I

61  
00:02:44,340 --> 00:02:42,610  
have this great idea about a mission I

62  
00:02:47,220 --> 00:02:44,350  
want a rover on Mars what does it look

63  
00:02:48,900 --> 00:02:47,230

like what it was it cost and we wouldn't

64

00:02:51,590 --> 00:02:48,910

know so we'd actually have to take a

65

00:02:53,910 --> 00:02:51,600

bunch of months develop it it would cost

66

00:02:56,970 --> 00:02:53,920

some money to develop that stuff and

67

00:02:58,440 --> 00:02:56,980

then we do this one at a time it was

68

00:03:02,400 --> 00:02:58,450

just too long and too expensive to do

69

00:03:05,070 --> 00:03:02,410

that so in the mid-1990s they did this

70

00:03:07,800 --> 00:03:05,080

they came up it was called the team X

71

00:03:09,870 --> 00:03:07,810

and it's called concurrent collaborative

72

00:03:11,729 --> 00:03:09,880

engineering and what they do is they

73

00:03:14,040 --> 00:03:11,739

have chairs and each chairs has a title

74

00:03:15,930 --> 00:03:14,050

so they put the eight classical

75

00:03:18,240 --> 00:03:15,940

spacecraft chairs so power thermal

76  
00:03:20,699 --> 00:03:18,250  
structure command data handling and so

77  
00:03:22,170 --> 00:03:20,709  
on they have the science chairs the

78  
00:03:24,300 --> 00:03:22,180  
science and the science instrument

79  
00:03:28,290 --> 00:03:24,310  
they'd have programmatic so you'd have

80  
00:03:29,820 --> 00:03:28,300  
risk cost chairs system engineering and

81  
00:03:32,190 --> 00:03:29,830  
they put them all in a room with

82  
00:03:34,080 --> 00:03:32,200  
connected spreadsheets so now when

83  
00:03:35,490 --> 00:03:34,090  
someone is doing a design and the sign

84  
00:03:38,190 --> 00:03:35,500  
thing that goes you know I need a little

85  
00:03:40,050 --> 00:03:38,200  
bit more coverage he'd lean over until

86  
00:03:42,150 --> 00:03:40,060  
the science instrument chair hey I need

87  
00:03:43,380 --> 00:03:42,160  
more coverage and then she would put in

88  
00:03:45,630 --> 00:03:43,390

a different detector to get that

89

00:03:48,420 --> 00:03:45,640

coverage and as soon as she selected

90

00:03:50,009 --> 00:03:48,430

that chip it would hit the cost chair

91

00:03:52,470 --> 00:03:50,019

the mass chair and the power chair and

92

00:03:54,060 --> 00:03:52,480

it's almost like ordered chaos but we

93

00:03:56,070 --> 00:03:54,070

could come up with a point design in

94

00:03:58,110 --> 00:03:56,080

about three days we can come up with a

95

00:04:00,720 --> 00:03:58,120

full up mission concept to the parts and

96

00:04:02,640 --> 00:04:00,730

get a cost a mass being giving of life

97

00:04:05,160 --> 00:04:02,650

power end of life power in bow

98

00:04:07,110 --> 00:04:05,170

three days so that was team acts in this

99

00:04:09,929 --> 00:04:07,120

collaborative engineering environment so

100

00:04:12,869 --> 00:04:09,939

that solved one problem the next

101  
00:04:15,750 --> 00:04:12,879  
challenge we ran into was the NASA

102  
00:04:18,170 --> 00:04:15,760  
Administrator of the time Dan Goldin he

103  
00:04:20,340 --> 00:04:18,180  
wanted to darken the sky with spacecraft

104  
00:04:23,700 --> 00:04:20,350  
now before that we're doing like a

105  
00:04:26,279 --> 00:04:23,710  
mission once a decade well to darken the

106  
00:04:28,860 --> 00:04:26,289  
sky you're launching one or two a year

107  
00:04:30,659 --> 00:04:28,870  
and you just keep doing it how do you

108  
00:04:32,010 --> 00:04:30,669  
pick the missions for the assigned

109  
00:04:32,939 --> 00:04:32,020  
mission it was easy the Science

110  
00:04:35,219 --> 00:04:32,949  
Committee would say these are the

111  
00:04:37,080 --> 00:04:35,229  
missions I want and the NASA would just

112  
00:04:39,659 --> 00:04:37,090  
assign those based on the priority the

113  
00:04:42,480 --> 00:04:39,669

science community when it came to

114

00:04:44,640 --> 00:04:42,490

competitions what they said is Oh for

115

00:04:46,980 --> 00:04:44,650

discovery I've got 550 million dollars

116

00:04:48,600 --> 00:04:46,990

who wants to do what and they would let

117

00:04:51,180 --> 00:04:48,610

the principal investigator propose

118

00:04:52,710 --> 00:04:51,190

concepts and they'd have to team up with

119

00:04:55,140 --> 00:04:52,720

an industry partner that was going to

120

00:04:56,100 --> 00:04:55,150

build the spacecraft and a NASA center

121

00:04:57,870 --> 00:04:56,110

that was going to manage the whole

122

00:04:59,990 --> 00:04:57,880

contract and those are called

123

00:05:02,640 --> 00:05:00,000

competitions and they were just competed

124

00:05:05,249 --> 00:05:02,650

now in order to handle that we actually

125

00:05:07,950 --> 00:05:05,259

had to generate proposals that responded

126  
00:05:10,050 --> 00:05:07,960  
to what NASA needed so we started

127  
00:05:11,730 --> 00:05:10,060  
generating these we call them war rooms

128  
00:05:13,339 --> 00:05:11,740  
where they're dedicated rooms and you

129  
00:05:15,779 --> 00:05:13,349  
put the whole proposals up there

130  
00:05:18,330 --> 00:05:15,789  
describing what's going on there and you

131  
00:05:20,129 --> 00:05:18,340  
would actually for the first step

132  
00:05:22,370 --> 00:05:20,139  
proposal the first thing on the gate you

133  
00:05:25,320 --> 00:05:22,380  
had three months to write this book and

134  
00:05:27,060 --> 00:05:25,330  
NASA tries to limit the number of books

135  
00:05:28,860 --> 00:05:27,070  
so they're looking for any excuse to

136  
00:05:30,930 --> 00:05:28,870  
reject these things you know you're

137  
00:05:33,029 --> 00:05:30,940  
supposed to do this in 16 pages it's 17

138  
00:05:34,770 --> 00:05:33,039

you're out of there and just they look

139

00:05:36,719 --> 00:05:34,780

for compliance first so we have to make

140

00:05:38,580 --> 00:05:36,729

sure we follow the letter of the law of

141

00:05:40,200 --> 00:05:38,590

the instructions that we get in the

142

00:05:41,850 --> 00:05:40,210

announcement of opportunity to make

143

00:05:43,890 --> 00:05:41,860

these proposals and then we make a

144

00:05:47,909 --> 00:05:43,900

NASA's problem to decide which ones to

145

00:05:51,180 --> 00:05:47,919

select I'm gonna keep going unless you

146

00:05:53,040 --> 00:05:51,190

help no I please one of the problems

147

00:05:57,120 --> 00:05:53,050

that we ran into and now we're getting

148

00:06:01,140 --> 00:05:57,130

into the 2005 time frame people realize

149

00:06:03,240 --> 00:06:01,150

that proposals are now taking more and

150

00:06:05,909 --> 00:06:03,250

more laboratory resources so we better

151

00:06:07,620 --> 00:06:05,919

make our own office to do this so in

152

00:06:08,700 --> 00:06:07,630

2005 they set up what was called the

153

00:06:10,980 --> 00:06:08,710

strategic planning and project

154

00:06:13,830 --> 00:06:10,990

formulation office planning and

155

00:06:15,570 --> 00:06:13,840

formulation the chief engineer at the

156

00:06:15,839 --> 00:06:15,580

time mark Adler recognized that there

157

00:06:18,899 --> 00:06:15,849

was a

158

00:06:20,309 --> 00:06:18,909

problem if somebody comes to me with a

159

00:06:22,649 --> 00:06:20,319

row with two people come to me with a

160

00:06:24,570 --> 00:06:22,659

rover design and this one's got three

161

00:06:26,869 --> 00:06:24,580

years of work behind it and this one was

162

00:06:29,189 --> 00:06:26,879

a good idea in the shower this morning

163

00:06:32,399 --> 00:06:29,199

how do I tell the difference and what

164

00:06:34,829 --> 00:06:32,409

how much sure the idea is so what he did

165

00:06:36,540 --> 00:06:34,839

is modeling after a scale that we

166

00:06:39,719 --> 00:06:36,550

already had called technology readiness

167

00:06:42,269 --> 00:06:39,729

levels of how much you're a widget is he

168

00:06:45,329 --> 00:06:42,279

came up with this TRL's assay we see

169

00:06:46,679 --> 00:06:45,339

males concept maturity levels and I'm

170

00:06:51,859 --> 00:06:46,689

willing to talk about the first four

171

00:06:55,199 --> 00:06:51,869

just to give this a perspective see ml1

172

00:06:57,149 --> 00:06:55,209

consummatory level is the idea

173

00:06:59,449 --> 00:06:57,159

generation or the cocktail napkin stage

174

00:07:03,659 --> 00:06:59,459

this is where you do the brainstorming

175

00:07:07,169 --> 00:07:03,669

CML - this is where you do feasibility

176

00:07:08,999 --> 00:07:07,179

does it violate a law of nature 3 is

177

00:07:11,459 --> 00:07:09,009

trade space exploration and a good

178

00:07:13,980 --> 00:07:11,469

example of a trade space if I got this

179

00:07:16,429 --> 00:07:13,990

great Rover and I think it's gonna go

180

00:07:19,079 --> 00:07:16,439

one kilometer and stop it's six sites

181

00:07:21,600 --> 00:07:19,089

why not go two kilometers and stop at

182

00:07:24,209 --> 00:07:21,610

three sites why not go only 500 meters

183

00:07:25,969 --> 00:07:24,219

and stop at 12 sites what's more

184

00:07:28,259 --> 00:07:25,979

important the driving or the drilling

185

00:07:30,230 --> 00:07:28,269

well there's a trade that has to be made

186

00:07:32,459 --> 00:07:30,240

there and all too often in this business

187

00:07:33,839 --> 00:07:32,469

people fall in love with the concept and

188

00:07:36,199 --> 00:07:33,849

they just go forward they're not looking

189

00:07:39,119 --> 00:07:36,209

for how to make this the optimum content

190

00:07:40,949 --> 00:07:39,129

so what we do is we now force people to

191

00:07:43,109 --> 00:07:40,959

go through the console mature level one

192

00:07:46,049 --> 00:07:43,119

the idea generation - feasibility three

193

00:07:48,839 --> 00:07:46,059

trade space for you scientists out there

194

00:07:51,059 --> 00:07:48,849

I don't believe you start at CML one

195

00:07:54,149 --> 00:07:51,069

that says hey let's do a Mars orbiter in

196

00:07:56,100 --> 00:07:54,159

a polar orbit at 250 kilometers it

197

00:07:58,319 --> 00:07:56,110

really starts with the science question

198

00:08:01,139 --> 00:07:58,329

was there ever long standing water on

199

00:08:03,419 --> 00:08:01,149

the surface well how do I answer that

200

00:08:05,100 --> 00:08:03,429

what measurement will have to make what

201  
00:08:07,709 --> 00:08:05,110  
box makes that measurement where does

202  
00:08:12,029 --> 00:08:07,719  
that box have to be oh that's a 250

203  
00:08:13,949 --> 00:08:12,039  
kilometer orbit in a polar orbit so when

204  
00:08:15,089 --> 00:08:13,959  
you're coming up with those so a lot of

205  
00:08:17,999 --> 00:08:15,099  
these questions are coming from the

206  
00:08:19,919 --> 00:08:18,009  
Decatur survey yes and the table survey

207  
00:08:21,269 --> 00:08:19,929  
decayed old every 10 years every 10

208  
00:08:23,749 --> 00:08:21,279  
years in earth solar systemin

209  
00:08:25,709 --> 00:08:23,759  
astrophysics there's a group of people

210  
00:08:27,269 --> 00:08:25,719  
experts and they say these are the

211  
00:08:28,140 --> 00:08:27,279  
things we want to do for the next 10

212  
00:08:29,790 --> 00:08:28,150  
years

213  
00:08:31,530 --> 00:08:29,800

which can kind of guide those questions

214

00:08:34,950 --> 00:08:31,540

yes so then they bring them to you and

215

00:08:36,959 --> 00:08:34,960

you are you're not team X correct team X

216

00:08:38,940 --> 00:08:36,969

I got confused first time I heard this

217

00:08:42,269 --> 00:08:38,950

because I thought team X is it team X is

218

00:08:45,329 --> 00:08:42,279

number one team X is it CML for they're

219

00:08:48,000 --> 00:08:45,339

doing the point design they realized in

220

00:08:49,710 --> 00:08:48,010

about I think was like 2011 that we

221

00:08:51,690 --> 00:08:49,720

needed some sort of preprocessor some

222

00:08:53,670 --> 00:08:51,700

group of people to work on stuff before

223

00:08:58,410 --> 00:08:53,680

team X so like I'm gonna show you a

224

00:09:00,210 --> 00:08:58,420

picture of a lunar sky light if I want

225

00:09:02,370 --> 00:09:00,220

to study one of these openings into a

226

00:09:05,010 --> 00:09:02,380

planet if I said I want to study a

227

00:09:06,810 --> 00:09:05,020

skylight on Mars or moon how would you

228

00:09:09,480 --> 00:09:06,820

do it if I went to team X they don't

229

00:09:11,850 --> 00:09:09,490

have enough material to start with so

230

00:09:14,010 --> 00:09:11,860

you came to with the a team which is

231

00:09:16,140 --> 00:09:14,020

short for architecture team we get all

232

00:09:19,560 --> 00:09:16,150

these quotes about the kernel and phase

233

00:09:21,180 --> 00:09:19,570

and Bao anyway so we get all those

234

00:09:22,800 --> 00:09:21,190

things but basically this was a way of

235

00:09:25,230 --> 00:09:22,810

putting the right people in the room

236

00:09:27,360 --> 00:09:25,240

that have the right discipline to

237

00:09:29,880 --> 00:09:27,370

actually be the subject matter expert

238

00:09:34,920 --> 00:09:29,890

for this concept and then we brainstorm

239

00:09:36,750 --> 00:09:34,930

ideas so in 2011 we set up this this is

240

00:09:40,650 --> 00:09:36,760

a place where ideas come from we call it

241

00:09:42,780 --> 00:09:40,660

left field so and the patio is

242

00:09:44,190 --> 00:09:42,790

controlled out there I tried to have a

243

00:09:47,490 --> 00:09:44,200

conference called in here but they don't

244

00:09:50,250 --> 00:09:47,500

want that but this is left field okay

245

00:09:52,410 --> 00:09:50,260

and one of the things we do at council

246

00:09:55,140 --> 00:09:52,420

material level one the the cocktail

247

00:09:56,970 --> 00:09:55,150

napkin stage is brainstorming and when

248

00:09:58,829 --> 00:09:56,980

we brainstorm we tell everybody that

249

00:10:01,590 --> 00:09:58,839

when I have a problem and I want you to

250

00:10:04,710 --> 00:10:01,600

write ideas on a post-it which looks

251

00:10:06,060 --> 00:10:04,720

like this we just we just write them

252

00:10:08,370 --> 00:10:06,070

down a board and then we bin them and

253

00:10:10,290 --> 00:10:08,380

then we vote on these things we say we

254

00:10:13,170 --> 00:10:10,300

want everybody to come with at least one

255

00:10:15,690 --> 00:10:13,180

bad idea not because we want to

256

00:10:17,340 --> 00:10:15,700

implement bad ideas but usually you have

257

00:10:19,890 --> 00:10:17,350

a tendency to blinders and say this is

258

00:10:21,480 --> 00:10:19,900

the way we do things and we can't live

259

00:10:23,640 --> 00:10:21,490

that way we need to be able to open up

260

00:10:25,470 --> 00:10:23,650

the boundaries because just because we

261

00:10:30,150 --> 00:10:25,480

haven't done it before doesn't mean you

262

00:10:32,430 --> 00:10:30,160

can't do it bad idea has there been a

263

00:10:34,380 --> 00:10:32,440

moment when the bad idea has actually

264

00:10:36,990 --> 00:10:34,390

been an idea like actually that's not a

265

00:10:38,910 --> 00:10:37,000

bad idea let's stick with that idea well

266

00:10:40,130 --> 00:10:38,920

to me there's no such thing as a bad

267

00:10:43,710 --> 00:10:40,140

idea

268

00:10:45,690 --> 00:10:43,720

yeah yeah well it's something that

269

00:10:48,510 --> 00:10:45,700

pushes the envelope okay all right so

270

00:10:51,810 --> 00:10:48,520

one of the things that what I use to

271

00:10:54,690 --> 00:10:51,820

help me when it comes to idea generation

272

00:10:57,780 --> 00:10:54,700

I like the correct use of the word

273

00:10:59,070 --> 00:10:57,790

impossible now don't ask me about where

274

00:11:00,570 --> 00:10:59,080

I learned this from it was volitional

275

00:11:04,410 --> 00:11:00,580

physics but that's another whole side

276

00:11:06,930 --> 00:11:04,420

line but the depth the true definition I

277

00:11:09,660 --> 00:11:06,940

believe for the word impossible is that

278

00:11:11,310 --> 00:11:09,670

which violates a natural law so as an

279

00:11:13,710 --> 00:11:11,320

example can a spacecraft go faster than

280

00:11:16,110 --> 00:11:13,720

the speed of light no with our color

281

00:11:18,510 --> 00:11:16,120

understanding that's impossible can a

282

00:11:22,230 --> 00:11:18,520

human being live to be 200 or 300 years

283

00:11:24,960 --> 00:11:22,240

old well if I can't point to what it

284

00:11:28,170 --> 00:11:24,970

violates it just means we don't know how

285

00:11:30,990 --> 00:11:28,180

to do it so that's one filter I use for

286

00:11:34,170 --> 00:11:31,000

a good idea and you know people use the

287

00:11:36,630 --> 00:11:34,180

word impossibly poorly all the time

288

00:11:38,760 --> 00:11:36,640

my favorite example and I clicked some

289

00:11:40,350 --> 00:11:38,770

weird space stuff I've got these two

290

00:11:42,600 --> 00:11:40,360

papers that are just bound together

291

00:11:44,250 --> 00:11:42,610

there nothing fancy it was by an

292

00:11:45,360 --> 00:11:44,260

astronomer named Simon Newcomb in the

293

00:11:49,380 --> 00:11:45,370

early 1900s

294

00:11:52,220 --> 00:11:49,390

his first paper in 1902 is titled is the

295

00:11:54,510 --> 00:11:52,230

airship coming and he wrote why it was

296

00:11:56,550 --> 00:11:54,520

impossible to have a heavier than air

297

00:11:59,670 --> 00:11:56,560

craft this was a year before the Wright

298

00:12:01,590 --> 00:11:59,680

brothers the second paper that is

299

00:12:03,290 --> 00:12:01,600

mounted to this thing and to be known

300

00:12:06,210 --> 00:12:03,300

through history for this just kills me

301

00:12:08,310 --> 00:12:06,220

the second paper is entitled the

302

00:12:12,120 --> 00:12:08,320

prospects of aerial navigation it was

303

00:12:13,800 --> 00:12:12,130

written in 1907 why he was wrong

304

00:12:15,660 --> 00:12:13,810

why it is possible to have heavier than

305

00:12:18,330 --> 00:12:15,670

aircraft but why it will never be

306

00:12:21,570 --> 00:12:18,340

commercially viable you know I'm just

307

00:12:23,580 --> 00:12:21,580

gonna man guys that's not how you want

308

00:12:27,120 --> 00:12:23,590

to get known so whenever I hear someone

309

00:12:29,670 --> 00:12:27,130

say that's impossible or that's not the

310

00:12:33,390 --> 00:12:29,680

way you do it warning signals go off in

311

00:12:35,640 --> 00:12:33,400

my mind because I don't care how we did

312

00:12:37,230 --> 00:12:35,650

it we want to do something new and one

313

00:12:39,390 --> 00:12:37,240

of the really wonderful things about the

314

00:12:40,950 --> 00:12:39,400

Jet Propulsion Laboratory is we only

315

00:12:42,930 --> 00:12:40,960

want to do missions that no one else has

316

00:12:45,360 --> 00:12:42,940

ever done before you want to do it over

317

00:12:47,490 --> 00:12:45,370

to Mars go to Lockheed Martin go to ball

318

00:12:49,320 --> 00:12:47,500

brothers because we want to do the

319

00:12:51,150 --> 00:12:49,330

Mobility Systems we want to do the

320

00:12:53,189 --> 00:12:51,160

space-based interferometers we want to

321

00:12:56,879 --> 00:12:53,199

do the subsurface exploration

322

00:12:58,079 --> 00:12:56,889

that's where we won't play yeah these

323

00:13:01,679 --> 00:12:58,089

this is amazing

324

00:13:02,939 --> 00:13:01,689

I love that definition of impossible who

325

00:13:04,829 --> 00:13:02,949

works well we're talking about something

326

00:13:06,119 --> 00:13:04,839

like remember here we got a full scale

327

00:13:08,609 --> 00:13:06,129

model of Voyager we're talking about

328

00:13:12,799 --> 00:13:08,619

these missions that go out there and

329

00:13:14,789 --> 00:13:12,809

beyond what we thought was possible yeah

330

00:13:15,569 --> 00:13:14,799

what would be something that you would

331

00:13:16,829 --> 00:13:15,579

okay

332

00:13:18,299 --> 00:13:16,839

talk me through something right now

333

00:13:20,579 --> 00:13:18,309

let's say let's have a mission out there

334

00:13:22,139 --> 00:13:20,589

I want something like Voyager and I end

335

00:13:25,049 --> 00:13:22,149

up going through you guys through the

336

00:13:27,449 --> 00:13:25,059

very beginning how do I talk about going

337

00:13:28,650 --> 00:13:27,459

out there well the first challenge is

338

00:13:30,720 --> 00:13:28,660

you always want to start with science

339

00:13:32,249 --> 00:13:30,730

requirements we're not doing these to do

340

00:13:34,259 --> 00:13:32,259

engineering we're doing this to do

341

00:13:37,679 --> 00:13:34,269

science we use engineering to enable us

342

00:13:38,879 --> 00:13:37,689

quiring the science okay and so it

343

00:13:40,530 --> 00:13:38,889

really starts with some sort of

344

00:13:42,929 --> 00:13:40,540

scientific question that we want to do

345

00:13:46,650 --> 00:13:42,939

okay so I'm gonna lead into this

346

00:13:50,159 --> 00:13:46,660

interesting concept here if you look at

347

00:13:54,780 --> 00:13:50,169

this this is an interstellar mission

348

00:13:57,659 --> 00:13:54,790

broken up into phases so you've got wow

349

00:13:59,999 --> 00:13:57,669

dad that goes there this is the this is

350

00:14:02,970 --> 00:14:00,009

the acceleration it's all propulsion the

351  
00:14:05,249 --> 00:14:02,980  
long survival the deceleration to the

352  
00:14:07,289 --> 00:14:05,259  
system getting ready for the encounter

353  
00:14:09,989 --> 00:14:07,299  
in that exoplanet system on another

354  
00:14:12,960 --> 00:14:09,999  
world the science to acquire that data

355  
00:14:15,479 --> 00:14:12,970  
and then the playback well everybody in

356  
00:14:16,710 --> 00:14:15,489  
there the mother's brother is all

357  
00:14:19,650 --> 00:14:16,720  
working on trying to figure out how to

358  
00:14:20,759 --> 00:14:19,660  
go faster than Voyager our rule of thumb

359  
00:14:23,039 --> 00:14:20,769  
was would like to be able to go ten

360  
00:14:24,179 --> 00:14:23,049  
times faster than Voyager for you guys

361  
00:14:25,609 --> 00:14:24,189  
that are counting that's a little bit

362  
00:14:27,389 --> 00:14:25,619  
more than a year from here in Neptune

363  
00:14:29,269 --> 00:14:27,399

we're talking about that kind of space

364

00:14:32,699 --> 00:14:29,279

not the 12 years that Voyager did it

365

00:14:34,739 --> 00:14:32,709

even at that speed I mean Voyager right

366

00:14:36,569 --> 00:14:34,749

now at a million miles per day which i

367

00:14:39,419 --> 00:14:36,579

think is pretty not too shabby

368

00:14:40,650 --> 00:14:39,429

that would take 72,000 years to get to

369

00:14:42,119 --> 00:14:40,660

the nearest star and we're not even

370

00:14:44,680 --> 00:14:42,129

going in that direction if stars move

371

00:14:47,050 --> 00:14:44,690

but other than that

372

00:14:49,449 --> 00:14:47,060

and if you go 10 times faster that's

373

00:14:51,100 --> 00:14:49,459

only 7,000 years that's still not in my

374

00:14:54,970 --> 00:14:51,110

lifetime and I'm kind of I'm at the back

375

00:14:56,920 --> 00:14:54,980

nine okay but the question that we

376

00:15:00,879 --> 00:14:56,930

proposed here was and let's let's zoom

377

00:15:04,420 --> 00:15:00,889

in on this thing you can see this is the

378

00:15:06,009 --> 00:15:04,430

tail end is being displayed here let's

379

00:15:08,379 --> 00:15:06,019

say we could take 40 years to go to

380

00:15:09,999 --> 00:15:08,389

Proxima Centuri which is the closest R

381

00:15:11,439 --> 00:15:10,009

we know it's got a we call them

382

00:15:14,170 --> 00:15:11,449

exoplanets planets around other stars

383

00:15:15,340 --> 00:15:14,180

systems let's make it somebody else's

384

00:15:18,519 --> 00:15:15,350

problem figuring out how to speed up

385

00:15:21,460 --> 00:15:18,529

survive and slow down when you get there

386

00:15:24,160 --> 00:15:21,470

after 40 years the science that this

387

00:15:25,449 --> 00:15:24,170

spacecraft was designed for has probably

388

00:15:26,679 --> 00:15:25,459

already been done on the ground because

389

00:15:28,480 --> 00:15:26,689

astronomers on the ground are not

390

00:15:30,490 --> 00:15:28,490

waiting for you guys to get there in 40

391

00:15:33,490 --> 00:15:30,500

years they're so working the problem in

392

00:15:35,980 --> 00:15:33,500

addition the technology is old voyages

393

00:15:39,429 --> 00:15:35,990

41 years is going to be 42 years I think

394

00:15:43,990 --> 00:15:39,439

it's big memory is for four kilobytes of

395

00:15:45,280 --> 00:15:44,000

memory this thing would run doors around

396

00:15:47,829 --> 00:15:45,290

that I would have loved to have this

397

00:15:49,509 --> 00:15:47,839

thing running that spacecraft so the

398

00:15:51,790 --> 00:15:49,519

technology old so now how could you get

399

00:15:53,379 --> 00:15:51,800

around them so one idea that we were

400

00:15:57,009 --> 00:15:53,389

toying with that was really kind of

401  
00:15:58,449 --> 00:15:57,019  
science fiction was 4d printing you've

402  
00:16:00,939 --> 00:15:58,459  
heard of 3d printers doing additive

403  
00:16:02,590 --> 00:16:00,949  
manufacturing you know your printer at

404  
00:16:04,569 --> 00:16:02,600  
home you have a magenta cartridge and a

405  
00:16:06,910 --> 00:16:04,579  
cyan cartridge and a black cartridge

406  
00:16:08,889 --> 00:16:06,920  
head what happens if you have a 3d

407  
00:16:11,769 --> 00:16:08,899  
printer and now you put it in a copper

408  
00:16:13,120 --> 00:16:11,779  
head on a loom head a Teflon head or all

409  
00:16:14,769 --> 00:16:13,130  
the different materials and now you

410  
00:16:16,720 --> 00:16:14,779  
build up all the circuitry and all the

411  
00:16:18,540 --> 00:16:16,730  
functionality of the thing so that when

412  
00:16:20,679 --> 00:16:18,550  
it's done you have something that works

413  
00:16:21,939 --> 00:16:20,689

I'm looking these guys going you're

414

00:16:26,319 --> 00:16:21,949

talking about building a replicator

415

00:16:28,030 --> 00:16:26,329

right is that where I am um and the idea

416

00:16:30,579 --> 00:16:28,040

that we're talking about is wouldn't it

417

00:16:33,340 --> 00:16:30,589

be fun that after you decelerate down

418

00:16:36,129 --> 00:16:33,350

you have a 4d print on your spacecraft

419

00:16:37,540 --> 00:16:36,139

and you eat your propellant tanks to

420

00:16:39,160 --> 00:16:37,550

make your new instruments and optical

421

00:16:41,379 --> 00:16:39,170

system and pointing system and then

422

00:16:44,710 --> 00:16:41,389

after the encounter you eat your

423

00:16:48,249 --> 00:16:44,720

instruments to make your telecom system

424

00:16:50,920 --> 00:16:48,259

there'd be like a 95% you know loss with

425

00:16:55,059 --> 00:16:50,930

each stage but you could evolve the

426

00:16:55,990 --> 00:16:55,069

spacecraft why not right so you know

427

00:16:57,970 --> 00:16:56,000

we're not saying we're gonna do this

428

00:16:59,860 --> 00:16:57,980

tomorrow but it points in the direction

429

00:17:11,409 --> 00:16:59,870

of the things that we might need to try

430

00:17:12,699 --> 00:17:11,419

to enable some future capability so you

431

00:17:14,140 --> 00:17:12,709

start with the science you start with

432

00:17:15,779 --> 00:17:14,150

the science question that's right how do

433

00:17:18,909 --> 00:17:15,789

you come up with a good science question

434

00:17:21,039 --> 00:17:18,919

the science question really first comes

435

00:17:22,449 --> 00:17:21,049

from the takeda surveys again we're

436

00:17:24,309 --> 00:17:22,459

always pointing back to science whether

437

00:17:26,289 --> 00:17:24,319

it's an ass advisor group or dukale

438

00:17:27,640 --> 00:17:26,299

survey we want to find the compelling

439

00:17:29,830 --> 00:17:27,650

science question that we want to go

440

00:17:31,570 --> 00:17:29,840

after and one of the things that we try

441

00:17:34,240 --> 00:17:31,580

to do is in our minds is a difference

442

00:17:38,230 --> 00:17:34,250

between a goal and objective a goal is

443

00:17:40,000 --> 00:17:38,240

something grandiose and qualitative an

444

00:17:44,140 --> 00:17:40,010

objective is something really specific

445

00:17:47,049 --> 00:17:44,150

and quantitative so as an example a goal

446

00:17:49,210 --> 00:17:47,059

in NASA's soulsand kale is I want to

447

00:17:52,450 --> 00:17:49,220

find if there's life or was life in the

448

00:17:53,590 --> 00:17:52,460

solar system that's huge

449

00:17:56,350 --> 00:17:53,600

I mean I mean how do you handle

450

00:17:57,549 --> 00:17:56,360

something like that what you could do is

451  
00:17:59,710 --> 00:17:57,559  
try to make it down more quantifiable

452  
00:18:02,110 --> 00:17:59,720  
and more bite-sized and say okay I'm

453  
00:18:03,970 --> 00:18:02,120  
gonna develop a lander that's gonna land

454  
00:18:05,500 --> 00:18:03,980  
at this latitude and longitude and with

455  
00:18:08,320 --> 00:18:05,510  
in top five centimeters look for

456  
00:18:09,730 --> 00:18:08,330  
organics it's addressing that goal but

457  
00:18:14,100 --> 00:18:09,740  
it's much more specific and something to

458  
00:18:17,500 --> 00:18:14,110  
get my hands around so we make them do

459  
00:18:19,210 --> 00:18:17,510  
the science we make sure they have a

460  
00:18:21,250 --> 00:18:19,220  
hypothesis and a prediction you know if

461  
00:18:23,529 --> 00:18:21,260  
I'm if I'm Newton I go I drop an apple

462  
00:18:25,240 --> 00:18:23,539  
it falls well my hypothesis is a

463  
00:18:27,760 --> 00:18:25,250

gravitational force it's  $1$  over  $R$

464

00:18:29,230 --> 00:18:27,770

squared my prediction is if I drop the

465

00:18:31,750 --> 00:18:29,240

cart over there which I have never done

466

00:18:33,039 --> 00:18:31,760

ever before that it'll fall at  $1$  over  $R$

467

00:18:35,230 --> 00:18:33,049

squared so then I go over there and I

468

00:18:37,810 --> 00:18:35,240

drop it and if it works I go ooh

469

00:18:40,299 --> 00:18:37,820

coincidence three times there's a trend

470

00:18:41,649 --> 00:18:40,309

for I mean it just keeps going and each

471

00:18:44,710 --> 00:18:41,659

time you're trying to validate these

472

00:18:46,899 --> 00:18:44,720

things okay so we make them come up with

473

00:18:49,330 --> 00:18:46,909

a hypothesis in the prediction and one

474

00:18:50,830 --> 00:18:49,340

of my co-workers dr. al Nash that I love

475

00:18:53,039 --> 00:18:50,840

he says when you're coming up with a

476

00:18:55,990 --> 00:18:53,049

hypothesis it has to be a barroom brawl

477

00:18:57,740 --> 00:18:56,000

and I look at my gold barroom brawl he

478

00:19:00,740 --> 00:18:57,750

goes yeah if I say more snow

479

00:19:03,560 --> 00:19:00,750

leads to more snow runoff that's kind of

480

00:19:06,500 --> 00:19:03,570

a statement I mean it doesn't if I said

481

00:19:09,680 --> 00:19:06,510

that lack of snow on the mountains is

482

00:19:11,930 --> 00:19:09,690

gonna cause rebounding in Greenland ooh

483

00:19:14,240 --> 00:19:11,940

not everybody's gonna buy that so now we

484

00:19:16,460 --> 00:19:14,250

have we can have a fight over that so to

485

00:19:17,870 --> 00:19:16,470

make a compelling hypothesis it's it's

486

00:19:20,120 --> 00:19:17,880

got to have the barroom brawls out of a

487

00:19:22,400 --> 00:19:20,130

bowl right yeah then the next thing we

488

00:19:24,290 --> 00:19:22,410

do is we find that scientists are

489

00:19:27,050 --> 00:19:24,300

phenomenal at writing peer-reviewed

490

00:19:28,490 --> 00:19:27,060

journal articles they're not so hot at

491

00:19:31,850 --> 00:19:28,500

communicating to the general public and

492

00:19:35,060 --> 00:19:31,860

making people care about it so what we

493

00:19:35,990 --> 00:19:35,070

try to do is we actually use techniques

494

00:19:37,460 --> 00:19:36,000

because we've been going to all

495

00:19:40,040 --> 00:19:37,470

different entries to find ways to do it

496

00:19:42,650 --> 00:19:40,050

we went to Disney for this one this is

497

00:19:44,890 --> 00:19:42,660

Pixar storytelling and what they do is

498

00:19:47,750 --> 00:19:44,900

they make everybody writing a story

499

00:19:50,240 --> 00:19:47,760

complete these segments segments of a

500

00:19:53,270 --> 00:19:50,250

fragments of a sentence once upon time

501  
00:19:56,840 --> 00:19:53,280  
there was every day one day because of

502  
00:19:59,720 --> 00:19:56,850  
that because of that until finally so

503  
00:20:01,640 --> 00:19:59,730  
let me show you how this thing works

504  
00:20:05,300 --> 00:20:01,650  
this is Finding Nemo you can find this

505  
00:20:07,090 --> 00:20:05,310  
on the internet it's great just just I

506  
00:20:09,920 --> 00:20:07,100  
mean it's all out there

507  
00:20:11,240 --> 00:20:09,930  
this is Nemo once upon a time there was

508  
00:20:12,950 --> 00:20:11,250  
a widow fish named Marlin who was

509  
00:20:15,440 --> 00:20:12,960  
extremely protective his only son Nemo

510  
00:20:17,150 --> 00:20:15,450  
every day Marlin Warren Nemo of the

511  
00:20:19,370 --> 00:20:17,160  
oceans dangers and implored him not to

512  
00:20:20,780 --> 00:20:19,380  
swim far away one day in an act of

513  
00:20:22,660 --> 00:20:20,790

defiance Nemo ignored his father's

514

00:20:24,620 --> 00:20:22,670

warnings and swam into the open water

515

00:20:26,150 --> 00:20:24,630

because of that he is captured by a

516

00:20:27,890 --> 00:20:26,160

diver and ends up in a fish tank of a

517

00:20:29,330 --> 00:20:27,900

dentist and Disney because of that

518

00:20:30,620 --> 00:20:29,340

Marlin sets off on a journey to recover

519

00:20:32,420 --> 00:20:30,630

Nemo and loosing the help but the other

520

00:20:33,950 --> 00:20:32,430

sea creatures along the way until

521

00:20:35,450 --> 00:20:33,960

finally Marlin Nemo find each other

522

00:20:40,130 --> 00:20:35,460

reunite and learned that love depends on

523

00:20:42,410 --> 00:20:40,140

trust yeah really spoiler alert that is

524

00:20:45,290 --> 00:20:42,420

the movie you could say there go yes

525

00:20:46,010 --> 00:20:45,300

that is it now you go what does it have

526

00:20:48,920 --> 00:20:46,020

to do with NASA

527

00:20:51,380 --> 00:20:48,930

well this same technique works for us to

528

00:20:53,480 --> 00:20:51,390

get the science community to answer to

529

00:20:55,100 --> 00:20:53,490

tell us their story so what we'll do is

530

00:20:56,870 --> 00:20:55,110

we'll bring a science team into the room

531

00:20:58,580 --> 00:20:56,880

we'll give them these six fragments of a

532

00:21:00,110 --> 00:20:58,590

sentence and we have each guy write

533

00:21:02,960 --> 00:21:00,120

their own story and surprise surprise

534

00:21:05,510 --> 00:21:02,970

they're all writing their own story well

535

00:21:07,730 --> 00:21:05,520

then we make them work on one story and

536

00:21:09,230 --> 00:21:07,740

the story could look like this this is

537

00:21:11,360 --> 00:21:09,240

about Europa it's a moon of Jupiter that

538

00:21:12,530 --> 00:21:11,370

has an ice field it was

539

00:21:14,570 --> 00:21:12,540

that's advisor group and look what they

540

00:21:16,010 --> 00:21:14,580

did once upon a time scientist saw

541

00:21:18,260 --> 00:21:16,020

evidence of a liquid water ocean on

542

00:21:20,660 --> 00:21:18,270

Europa everyday scientists wondered to

543

00:21:22,130 --> 00:21:20,670

this ocean could support life one day

544

00:21:23,540 --> 00:21:22,140

studies indicated that to support life

545

00:21:24,980 --> 00:21:23,550

there must be some evidence of an

546

00:21:27,560 --> 00:21:24,990

exchange of material between the ocean

547

00:21:29,120 --> 00:21:27,570

and surface because of that NASA decides

548

00:21:31,460 --> 00:21:29,130

to send a lander to Europa to look for

549

00:21:32,900 --> 00:21:31,470

bio signatures because of that a seismic

550

00:21:34,730 --> 00:21:32,910

network was established on Europa to

551

00:21:36,170 --> 00:21:34,740

listen to the moon's quakes until

552

00:21:37,310 --> 00:21:36,180

finally scientists were able determine

553

00:21:39,320 --> 00:21:37,320

the thickness of moon's cross the

554

00:21:43,340 --> 00:21:39,330

activity of its ocean and in turn its

555

00:21:47,270 --> 00:21:43,350

habitability that's a compelling science

556

00:21:48,710 --> 00:21:47,280

story everybody understands that so we

557

00:21:50,360 --> 00:21:48,720

make them come up with their science

558

00:21:51,470 --> 00:21:50,370

question my hypothesis prediction and we

559

00:21:54,500 --> 00:21:51,480

make them do this too

560

00:21:56,720 --> 00:21:54,510

and what happens is this can actually

561

00:21:58,669 --> 00:21:56,730

lead to different things now I'm not

562

00:22:00,680 --> 00:21:58,679

saying that the a team is the

563

00:22:02,960 --> 00:22:00,690

brainstorms of every idea that comes to

564

00:22:04,480 --> 00:22:02,970

the left it does not we have a lot of

565

00:22:06,410 --> 00:22:04,490

brilliant and creative minds out there

566

00:22:07,669 --> 00:22:06,420

people may come with us just to

567

00:22:09,200 --> 00:22:07,679

understand the feasibility of their

568

00:22:10,490 --> 00:22:09,210

concept they may come to us just to

569

00:22:12,919 --> 00:22:10,500

understand the trade to make sure they

570

00:22:14,360 --> 00:22:12,929

have the optimum design so as an example

571

00:22:19,040 --> 00:22:14,370

of one thing that came through us was

572

00:22:21,169 --> 00:22:19,050

this this is something that were

573

00:22:23,570 --> 00:22:21,179

actually doing in 2020 which is so cool

574

00:22:26,750 --> 00:22:23,580

if you look at 97 we had a little

575

00:22:28,100 --> 00:22:26,760

Sojourner Rover that rover the

576

00:22:29,570 --> 00:22:28,110

Pathfinder team didn't want it was

577

00:22:32,450 --> 00:22:29,580

sitting on their solar arrays blocking

578

00:22:36,140 --> 00:22:32,460

the light but having mobility was so

579

00:22:37,970 --> 00:22:36,150

cool that we actually were able to do it

580

00:22:40,790 --> 00:22:37,980

and with that led to Spirit Opportunity

581

00:22:42,830 --> 00:22:40,800

curiosity in Mars 2020 Rover x' well

582

00:22:45,410 --> 00:22:42,840

what you're seeing this animation of is

583

00:22:47,660 --> 00:22:45,420

we've got the go-ahead that on 2020

584

00:22:48,680 --> 00:22:47,670

we're putting a two kilogram helicopter

585

00:22:52,430 --> 00:22:48,690

on that vehicle

586

00:22:54,919 --> 00:22:52,440

so once the rover lands we're gonna pull

587

00:22:57,140 --> 00:22:54,929

out this helicopter we're gonna drive

588

00:22:59,120 --> 00:22:57,150

away and look at it and we're gonna

589

00:23:01,100 --> 00:22:59,130

watch to see if this thing lifts and to

590

00:23:04,130 --> 00:23:01,110

prove ourselves we get to work we went

591

00:23:05,210 --> 00:23:04,140

to our high base we we tied this thing

592

00:23:08,090 --> 00:23:05,220

to the floor we sucked out the

593

00:23:10,460 --> 00:23:08,100

atmosphere 7,000 carbon dioxide and the

594

00:23:11,600 --> 00:23:10,470

thing was able to generate lift it's the

595

00:23:14,830 --> 00:23:11,610

wrong gravity field it's the wrong

596

00:23:17,750 --> 00:23:14,840

temperature but it flies

597

00:23:21,710 --> 00:23:17,760

we've already had eight team studies

598

00:23:23,870 --> 00:23:21,720

that say hey if you had a 35 to 45

599

00:23:26,060 --> 00:23:23,880

kilogram helicopter what could you do

600

00:23:27,140 --> 00:23:26,070

could you fly in the big Canyon Valles

601  
00:23:29,360 --> 00:23:27,150  
Marineris and get a look at the

602  
00:23:32,690 --> 00:23:29,370  
sidewalls maybe see a femur sticking out

603  
00:23:41,990 --> 00:23:32,700  
of a strata so cool I mean that would be

604  
00:23:44,150 --> 00:23:42,000  
great but this stuff does work this is

605  
00:23:45,860 --> 00:23:44,160  
yeah we can talk about ideas and these

606  
00:23:48,440 --> 00:23:45,870  
things that you want to go out there and

607  
00:23:49,760 --> 00:23:48,450  
do these things but what is some of the

608  
00:23:51,310 --> 00:23:49,770  
stuff that's gone through you already

609  
00:23:53,510 --> 00:23:51,320  
what are some of these ideas that

610  
00:23:56,390 --> 00:23:53,520  
missions people might have even heard of

611  
00:23:57,560 --> 00:23:56,400  
or not yet and what is that that's what

612  
00:23:58,910 --> 00:23:57,570  
I think people are here to see as well

613  
00:24:00,260 --> 00:23:58,920

well one idea that to come through us

614

00:24:04,730 --> 00:24:00,270

from a feasibility point of view so it

615

00:24:07,100 --> 00:24:04,740

wasn't our idea was related to this this

616

00:24:09,080 --> 00:24:07,110

is an image of the surface of Mars and

617

00:24:11,870 --> 00:24:09,090

you'll notice there's two big black dots

618

00:24:14,690 --> 00:24:11,880

and you look at yourself and you go what

619

00:24:16,190 --> 00:24:14,700

the heck is that so you bring Mars

620

00:24:18,260 --> 00:24:16,200

reconnaissance over there with the big

621

00:24:22,000 --> 00:24:18,270

camera the highrise instrument and we go

622

00:24:25,100 --> 00:24:22,010

photograph those and it looks like that

623

00:24:26,510 --> 00:24:25,110

they're cave openings we call these

624

00:24:31,280 --> 00:24:26,520

things skylights which I alluded to

625

00:24:32,600 --> 00:24:31,290

before so picture a lava tube that you

626  
00:24:34,370 --> 00:24:32,610  
know what's flowing billions of years

627  
00:24:37,400 --> 00:24:34,380  
ago and yet all these episodic flows

628  
00:24:39,380 --> 00:24:37,410  
through coding the this tube and then

629  
00:24:41,090 --> 00:24:39,390  
after the court turned off and the lava

630  
00:24:44,240 --> 00:24:41,100  
flows turned off you got this tunnel

631  
00:24:47,330 --> 00:24:44,250  
there and then over the eons a piece of

632  
00:24:48,860 --> 00:24:47,340  
the top caves in that's what we think

633  
00:24:49,659 --> 00:24:48,870  
these things are but these are these are

634  
00:24:53,090 --> 00:24:49,669  
these are

635  
00:24:54,890 --> 00:24:53,100  
skylights to these cave openings and we

636  
00:24:56,510 --> 00:24:54,900  
think the tube itself may not be that

637  
00:24:59,419 --> 00:24:56,520  
interesting because it should be uniform

638  
00:25:02,720 --> 00:24:59,429

with the last flow what we want to see

639

00:25:04,760 --> 00:25:02,730

is the strata as you go through this so

640

00:25:09,810 --> 00:25:04,770

we're working on some technologies like

641

00:25:14,940 --> 00:25:11,669

you know right now that's pretty teeny

642

00:25:16,619 --> 00:25:14,950

but that's also in a gravity feel but

643

00:25:18,539 --> 00:25:16,629

one of the proposals we're doing for the

644

00:25:22,499 --> 00:25:18,549

moon because the moon has skylights too

645

00:25:24,479 --> 00:25:22,509

is this this is called moon divert we're

646

00:25:27,180 --> 00:25:24,489

gonna land next to the opening and take

647

00:25:30,330 --> 00:25:27,190

that axial which is on a cable and roll

648

00:25:35,009 --> 00:25:30,340

it down the sidewalls now to first order

649

00:25:37,680 --> 00:25:35,019

we might have you know it was like a

650

00:25:39,450 --> 00:25:37,690

kilometer no it's probably a hundred

651  
00:25:41,789 --> 00:25:39,460  
meters to the opening 100 meters down a

652  
00:25:43,709 --> 00:25:41,799  
hundred meters in through the tube but

653  
00:25:46,409 --> 00:25:43,719  
the thing that's cool is as you're going

654  
00:25:47,909 --> 00:25:46,419  
down the the side walls you have

655  
00:25:50,549 --> 00:25:47,919  
instruments on the axle of that

656  
00:25:52,799 --> 00:25:50,559  
instrument so that now you can see the

657  
00:25:54,629 --> 00:25:52,809  
stratification and the trapped solar

658  
00:25:59,039 --> 00:25:54,639  
wind particles of how the Sun was

659  
00:26:00,749 --> 00:25:59,049  
behaving billions of years ago so this

660  
00:26:04,560 --> 00:26:00,759  
is one that we did feasibility on and

661  
00:26:08,759 --> 00:26:04,570  
it's going to going to to NASA this this

662  
00:26:11,369 --> 00:26:08,769  
fall well brilliant now another one that

663  
00:26:13,320 --> 00:26:11,379

just kills us that we just love this is

664

00:26:15,869 --> 00:26:13,330

Jupiter it's it's nice and fun it's got

665

00:26:18,299 --> 00:26:15,879

a just a horrific radiation environment

666

00:26:20,430 --> 00:26:18,309

it's got scads moon's you got the four

667

00:26:23,159 --> 00:26:20,440

big Galilean ones there's one called

668

00:26:25,109 --> 00:26:23,169

Europa it looks like a cue ball that you

669

00:26:27,239 --> 00:26:25,119

did a felt to pen to draw lines on it so

670

00:26:28,649 --> 00:26:27,249

it's very smooth and it's ice it's got

671

00:26:31,049 --> 00:26:28,659

the density pretty close to that of an

672

00:26:34,049 --> 00:26:31,059

ice cube so we know it's mostly water

673

00:26:37,979 --> 00:26:34,059

but the Galileo spacecraft went by and

674

00:26:39,629 --> 00:26:37,989

it's our weak magnetic signature and you

675

00:26:42,239 --> 00:26:39,639

go how do you get a ice cube to have a

676

00:26:44,639 --> 00:26:42,249

little bit of a magnetic signature the

677

00:26:48,089 --> 00:26:44,649

best theory is that we have liquid water

678

00:26:51,509 --> 00:26:48,099

salt oceans circulating under that ice

679

00:26:54,389 --> 00:26:51,519

field so we think it looks like this now

680

00:26:57,479 --> 00:26:54,399

we don't know if that ice field is a

681

00:26:58,639 --> 00:26:57,489

meter thick or a hundred kilometers

682

00:27:01,079 --> 00:26:58,649

thick we have no idea how thick it is

683

00:27:04,649 --> 00:27:01,089

but we think the amount of liquid water

684

00:27:07,859 --> 00:27:04,659

in there is twice the amount of all the

685

00:27:10,700 --> 00:27:07,869

water on the oceans on earth so there's

686

00:27:13,940 --> 00:27:10,710

a lot of it so then

687

00:27:17,930 --> 00:27:13,950

yeah you could have a party and never

688

00:27:20,270 --> 00:27:17,940

run out of ice right the question was

689

00:27:22,010 --> 00:27:20,280

say you could get to jute well we can't

690

00:27:23,980 --> 00:27:22,020

get to Jupiter say you can survive the

691

00:27:26,840 --> 00:27:23,990

environment and he'd get through the ice

692

00:27:29,420 --> 00:27:26,850

where would be the best place to explore

693

00:27:31,850 --> 00:27:29,430

is it along the ocean bottom looking at

694

00:27:35,450 --> 00:27:31,860

hydrothermal vents is it being a fishy

695

00:27:38,560 --> 00:27:35,460

and swimming through the water or would

696

00:27:40,700 --> 00:27:38,570

it be where the ice and water meet and

697

00:27:42,020 --> 00:27:40,710

to our science community it's this

698

00:27:44,270 --> 00:27:42,030

interface between the ice and water

699

00:27:46,970 --> 00:27:44,280

because heat from the thermal vents

700

00:27:48,590 --> 00:27:46,980

circulates stuff up and Jupiter's

701

00:27:50,330 --> 00:27:48,600

radiation is radiating the ice on the

702

00:27:52,580 --> 00:27:50,340

top which is falling down so that

703

00:27:55,490 --> 00:27:52,590

interface is really interesting so now

704

00:27:58,610 --> 00:27:55,500

the question is how do you explore that

705

00:27:59,990 --> 00:27:58,620

as a National Research Laboratory we get

706

00:28:03,260 --> 00:28:00,000

to work on technologies that really

707

00:28:04,910 --> 00:28:03,270

don't have a mission funded but is

708

00:28:06,770 --> 00:28:04,920

developing capability for some future

709

00:28:10,040 --> 00:28:06,780

mission so one of the things we worked

710

00:28:12,440 --> 00:28:10,050

on for this particular problem this is

711

00:28:14,180 --> 00:28:12,450

up in Alaska it's a frozen lake there's

712

00:28:15,680 --> 00:28:14,190

a square yellow box in the right corner

713

00:28:18,260 --> 00:28:15,690

because National Geographic dumped a

714

00:28:20,750 --> 00:28:18,270

camera in the bottom of this lake we

715

00:28:22,790 --> 00:28:20,760

take out this little Rover it's named

716

00:28:26,030 --> 00:28:22,800

brewery and and if you have good eyes

717

00:28:28,570 --> 00:28:26,040

just in the bottom we turn it on and we

718

00:28:33,320 --> 00:28:28,580

let it go and the cool thing about it is

719

00:28:35,210 --> 00:28:33,330

this bad boy is buoyant so it floats up

720

00:28:40,160 --> 00:28:35,220

to the ice and now it drives on the

721

00:28:41,270 --> 00:28:40,170

bottom of the ice and now let's get this

722

00:28:43,460 --> 00:28:41,280

straight you know we're able to command

723

00:28:44,930 --> 00:28:43,470

this from JPL but you still got to

724

00:28:46,730 --> 00:28:44,940

figure out how to get it 1/2 billion

725

00:28:49,070 --> 00:28:46,740

miles out how to get it through

726

00:28:51,620 --> 00:28:49,080

kilometers of ice how to get it to go

727

00:28:54,680 --> 00:28:51,630

through how to get power commands to it

728

00:28:56,150 --> 00:28:54,690

how to get data from it how to power it

729

00:28:58,160 --> 00:28:56,160

but right now we're working on the

730

00:29:00,470 --> 00:28:58,170

mobility system

731

00:29:03,770 --> 00:29:00,480

so so this is coming to a theater near

732

00:29:06,460 --> 00:29:03,780

you probably in your lifetime but I mean

733

00:29:09,620 --> 00:29:06,470

it's something really pretty wild and

734

00:29:11,810 --> 00:29:09,630

not every concept goes to the architects

735

00:29:12,950 --> 00:29:11,820

team because they may not need to we're

736

00:29:16,340 --> 00:29:12,960

kind of like a service organization

737

00:29:18,140 --> 00:29:16,350

where we provide a capability where we

738

00:29:20,900 --> 00:29:18,150

have our folks on the architecture team

739

00:29:22,490 --> 00:29:20,910

and we just tell people that if you have

740

00:29:24,200 --> 00:29:22,500

a problem and either coming up with an

741

00:29:28,130 --> 00:29:24,210

idea for something or want to check out

742

00:29:29,420 --> 00:29:28,140

feasibility or want to look at the

743

00:29:32,240 --> 00:29:29,430

trades to make sure you haven't design

744

00:29:33,980 --> 00:29:32,250

you can come to us we initially thought

745

00:29:38,450 --> 00:29:33,990

when we developed this capability in

746

00:29:40,970 --> 00:29:38,460

2012 you know we do about 12 a year two

747

00:29:44,600 --> 00:29:40,980

years ago we did 61 studies last year we

748

00:29:45,110 --> 00:29:44,610

did 66 the my boss is doing this talk

749

00:29:47,300 --> 00:29:45,120

tomorrow

750

00:29:49,190 --> 00:29:47,310

Steve Mateus AK he claims that we're now

751  
00:29:52,100 --> 00:29:49,200  
going to be doing 60 studies every year

752  
00:29:55,550 --> 00:29:52,110  
which is just a lot but we do not have a

753  
00:30:00,880 --> 00:29:55,560  
shortage of ideas one of the other last

754  
00:30:08,270 --> 00:30:04,790  
okay exoplanets are planets around other

755  
00:30:10,310 --> 00:30:08,280  
stars systems okay the problem is

756  
00:30:12,320 --> 00:30:10,320  
they're really dim compared to the

757  
00:30:14,630 --> 00:30:12,330  
sunlight coming to start this starlight

758  
00:30:16,550 --> 00:30:14,640  
coming off of That star we think it's

759  
00:30:18,440 --> 00:30:16,560  
about and you know your your mileage

760  
00:30:22,370 --> 00:30:18,450  
will vary but it's like 10 billion to

761  
00:30:25,130 --> 00:30:22,380  
one they say trying to see the light

762  
00:30:28,730 --> 00:30:25,140  
reflected off an exoplanet is like

763  
00:30:31,940 --> 00:30:28,740

trying to image a firefly an inch away

764

00:30:33,830 --> 00:30:31,950

from a lighthouse at night and because

765

00:30:35,480 --> 00:30:33,840

of the dial dust the dust in our sole

766

00:30:37,670 --> 00:30:35,490

'some and the dust that's probably in

767

00:30:39,950 --> 00:30:37,680

that solar system you have to do this on

768

00:30:43,220 --> 00:30:39,960

a foggy night that's the problem we're

769

00:30:44,690 --> 00:30:43,230

trying to solve so one way of doing this

770

00:30:46,850 --> 00:30:44,700

is you take your finger and you put it

771

00:30:49,100 --> 00:30:46,860

in front of the light bulb so you can

772

00:30:51,230 --> 00:30:49,110

see stuff next to it these are called

773

00:30:53,570 --> 00:30:51,240

coronagraphs we have this a cultic disc

774

00:30:55,220 --> 00:30:53,580

inside the telescope but because the

775

00:30:56,750 --> 00:30:55,230

disc is small is this a telescope you

776

00:31:00,020 --> 00:30:56,760

still get diffraction of light around

777

00:31:01,100 --> 00:31:00,030

that and if it's 10 billion to 1 I mean

778

00:31:02,810 --> 00:31:01,110

think about what you're doing you say

779

00:31:05,270 --> 00:31:02,820

okay I'm gonna take these 10 billion

780

00:31:06,570 --> 00:31:05,280

photons I'm gonna take nine billion nine

781

00:31:08,940 --> 00:31:06,580

hundred nine million nine

782

00:31:11,070 --> 00:31:08,950

99 put them over there and put the one I

783

00:31:13,409 --> 00:31:11,080

need there and then I'm taking the next

784

00:31:15,269 --> 00:31:13,419

10 billion and put the one there and

785

00:31:16,470 --> 00:31:15,279

it's got to be the right one right take

786

00:31:17,759 --> 00:31:16,480

the next 10 billion I put that there

787

00:31:20,039 --> 00:31:17,769

until you build up enough signal to see

788

00:31:22,380 --> 00:31:20,049

this so you can't tolerate a little bit

789

00:31:26,190 --> 00:31:22,390

of scattered light around this occulting

790

00:31:27,450 --> 00:31:26,200

disk so we find that exoplanets come in

791

00:31:30,509 --> 00:31:27,460

many different flavors you can think of

792

00:31:32,880 --> 00:31:30,519

it as a zoo of these things there are

793

00:31:35,039 --> 00:31:32,890

over 4,000 of these things detected and

794

00:31:36,779 --> 00:31:35,049

I can't keep up with it so I'm just you

795

00:31:38,430 --> 00:31:36,789

have a bunch of numbers because first

796

00:31:40,169 --> 00:31:38,440

you gotta have a detection of them and

797

00:31:43,350 --> 00:31:40,179

then you know if I detected I say Brian

798

00:31:45,419 --> 00:31:43,360

there's an exoplanet you gotta go hey

799

00:31:47,310 --> 00:31:45,429

Randy you're right I go uh it's

800

00:31:48,570 --> 00:31:47,320

confirmed somebody independent has to

801  
00:31:50,340 --> 00:31:48,580  
confirm it so there's what you detected

802  
00:31:51,629 --> 00:31:50,350  
and what's confirmed and then what's in

803  
00:31:54,169 --> 00:31:51,639  
the habitable zone just goes on and on

804  
00:31:57,419 --> 00:31:54,179  
but we initially started finding these

805  
00:31:59,580 --> 00:31:57,429  
we call hot Jupiters picture Jupiter's

806  
00:32:00,740 --> 00:31:59,590  
that are in their system well inside the

807  
00:32:04,830 --> 00:32:00,750  
orbit of where mercury would have been

808  
00:32:06,539 --> 00:32:04,840  
the year is a day long or so so we call

809  
00:32:08,610 --> 00:32:06,549  
them hot Jupiter so they're just hauling

810  
00:32:12,389 --> 00:32:08,620  
buns and they're really hot and really

811  
00:32:15,269 --> 00:32:12,399  
close we find these guys these are

812  
00:32:17,009 --> 00:32:15,279  
called orphan worlds picture a Jupiter

813  
00:32:19,860 --> 00:32:17,019

sized object gets thrown to that solar

814

00:32:21,899 --> 00:32:19,870

system and it just coasts forever in the

815

00:32:23,789 --> 00:32:21,909

darkness of space between stars it's

816

00:32:25,080 --> 00:32:23,799

probably still warm from its the helium

817

00:32:28,289 --> 00:32:25,090

sticky in this atmosphere and it's just

818

00:32:30,210 --> 00:32:28,299

floating through interstellar space

819

00:32:31,379 --> 00:32:30,220

we found ones based on the density so

820

00:32:34,080 --> 00:32:31,389

this is kind of made up

821

00:32:36,240 --> 00:32:34,090

we call them ocean worlds not the Kevin

822

00:32:37,889 --> 00:32:36,250

Costner canto ssin world's ocean ocean

823

00:32:39,060 --> 00:32:37,899

kind of worlds where we really think

824

00:32:40,230 --> 00:32:39,070

it's just the whole surface is covered

825

00:32:43,110 --> 00:32:40,240

with water based on our density

826  
00:32:46,049 --> 00:32:43,120  
arguments so the question is how do you

827  
00:32:47,460 --> 00:32:46,059  
put a bigger thumb over the star to

828  
00:32:49,680 --> 00:32:47,470  
limit the light that comes around it so

829  
00:32:51,350 --> 00:32:49,690  
you can see things near it so one of the

830  
00:32:55,769 --> 00:32:51,360  
things we're working on it's up the hill

831  
00:32:57,180 --> 00:32:55,779  
it's called a star shade so here you

832  
00:32:59,730 --> 00:32:57,190  
have a telescope the yellow thing is the

833  
00:33:01,860 --> 00:32:59,740  
star shade you open up a band and it

834  
00:33:03,389 --> 00:33:01,870  
does its first deploy and then it's

835  
00:33:06,840 --> 00:33:03,399  
second deploy this thing could be as

836  
00:33:09,149 --> 00:33:06,850  
much as 75 feet across the pedals are

837  
00:33:11,519 --> 00:33:09,159  
like you know 812 feet long 60 feet long

838  
00:33:13,470 --> 00:33:11,529

two micron Collins colleges you can cut

839

00:33:15,240 --> 00:33:13,480

yourself on this thing sharply you then

840

00:33:17,519 --> 00:33:15,250

send it 23,000 miles and you let it

841

00:33:18,580 --> 00:33:17,529

slide in front of the star system so you

842

00:33:22,080 --> 00:33:18,590

can directly in

843

00:33:24,399 --> 00:33:22,090

stars planets around other stars systems

844

00:33:26,310 --> 00:33:24,409

we actually had to hire an origami

845

00:33:29,409 --> 00:33:26,320

expert to help us work that thing out

846

00:33:31,409 --> 00:33:29,419

how do you pack that I mean it was just

847

00:33:33,669 --> 00:33:31,419

nuts

848

00:33:35,260 --> 00:33:33,679

ideas and these things can come from

849

00:33:38,350 --> 00:33:35,270

anywhere you've talked about yeah how

850

00:33:40,690 --> 00:33:38,360

these teams not always are just you oh

851  
00:33:43,240 --> 00:33:40,700  
you can bring in people from all over we

852  
00:33:45,070 --> 00:33:43,250  
don't have the expert in everything yeah

853  
00:33:46,899 --> 00:33:45,080  
and it's something that I also

854  
00:33:48,820 --> 00:33:46,909  
appreciate you talked about you've told

855  
00:33:51,789 --> 00:33:48,830  
me before you're okay saying the words I

856  
00:33:54,310 --> 00:33:51,799  
don't know oh yeah absolutely

857  
00:33:56,019 --> 00:33:54,320  
we don't know most of this stuff you

858  
00:33:57,700 --> 00:33:56,029  
know we have little pink meat here and

859  
00:34:00,490 --> 00:33:57,710  
we try to understand our order of the

860  
00:34:03,220 --> 00:34:00,500  
universe but think about what we're

861  
00:34:06,399 --> 00:34:03,230  
doing you're guys we are trying to get

862  
00:34:07,109 --> 00:34:06,409  
out of our solar system Neptune is four

863  
00:34:09,760 --> 00:34:07,119

light hours

864

00:34:11,470 --> 00:34:09,770

what's Voyager 16 hours 20 hours

865

00:34:15,220 --> 00:34:11,480

somewhere in that ballpark light hours

866

00:34:17,379 --> 00:34:15,230

away in our star system and our galaxy

867

00:34:20,859 --> 00:34:17,389

you have depending on how you count 200

868

00:34:22,990 --> 00:34:20,869

to 400 billion suns and for every Sun

869

00:34:24,760 --> 00:34:23,000

there's hundreds to thousands of

870

00:34:27,220 --> 00:34:24,770

galaxies each with hundreds of billions

871

00:34:31,599 --> 00:34:27,230

of Suns and now we're finding that in

872

00:34:33,220 --> 00:34:31,609

our so in our part of the galaxy the

873

00:34:35,800 --> 00:34:33,230

Milky Way galaxy it seems like every

874

00:34:38,349 --> 00:34:35,810

star has planets we're not saying

875

00:34:40,030 --> 00:34:38,359

they're all habitable but there's a

876

00:34:42,760 --> 00:34:40,040

whole lot of real estate out there I

877

00:34:44,800 --> 00:34:42,770

mean it's a great quote by a artha see

878

00:34:46,750 --> 00:34:44,810

Clark that goes sometimes I think we're

879

00:34:51,230 --> 00:34:46,760

alone in the universe sometimes I think

880

00:34:53,510 --> 00:34:51,240

or not either answer is terrifying

881

00:34:55,430 --> 00:34:53,520

I mean and you know we're sticking our

882

00:34:57,980 --> 00:34:55,440

little cosmic toe out just trying to

883

00:34:59,960 --> 00:34:57,990

just see where we are in our place I

884

00:35:02,390 --> 00:34:59,970

mean there really is this pale blue dot

885

00:35:05,089 --> 00:35:02,400

where it's just us in the void of space

886

00:35:07,700 --> 00:35:05,099

and one of the burning questions of NASA

887

00:35:10,099 --> 00:35:07,710

is are we alone and how did life start

888

00:35:12,230 --> 00:35:10,109

here we don't even have good definitions

889

00:35:14,150 --> 00:35:12,240

for the word life I mean I know you

890

00:35:15,230 --> 00:35:14,160

carry it a cell with with with

891

00:35:18,200 --> 00:35:15,240

organelles and nucleic

892

00:35:20,060 --> 00:35:18,210

that's definitely alive and prokaryotes

893

00:35:22,609 --> 00:35:20,070

stuff you know bags of goo I'm pretty

894

00:35:23,990 --> 00:35:22,619

sure those are alive viruses that need

895

00:35:27,020 --> 00:35:24,000

these guys machinery to make more of

896

00:35:29,450 --> 00:35:27,030

themselves I'm not sure if that's alive

897

00:35:31,720 --> 00:35:29,460

and a-prayin which is just a molecule

898

00:35:33,829 --> 00:35:31,730

I'm pretty sure that's not alive

899

00:35:36,400 --> 00:35:33,839

but and this is getting really way off

900

00:35:39,500 --> 00:35:36,410

topic but I mean if you think about it

901  
00:35:42,140 --> 00:35:39,510  
when I went to school the old days

902  
00:35:44,270 --> 00:35:42,150  
life was starts with plants they take

903  
00:35:46,130 --> 00:35:44,280  
sunlight make sugars animals eat the

904  
00:35:51,050 --> 00:35:46,140  
plants animals eat the animals we go to

905  
00:35:53,329 --> 00:35:51,060  
McDonald's there was right well then in

906  
00:35:56,690 --> 00:35:53,339  
1977 by the mid-atlantic ridge we found

907  
00:35:58,460 --> 00:35:56,700  
organisms living off a heat depending on

908  
00:36:00,320 --> 00:35:58,470  
you know what you prescribed to either

909  
00:36:03,079 --> 00:36:00,330  
call that pyro synthesis or chemo

910  
00:36:03,760 --> 00:36:03,089  
synthesis if you're a physicist energy

911  
00:36:06,470 --> 00:36:03,770  
is energy

912  
00:36:09,020 --> 00:36:06,480  
why not acoustic synthesis why not

913  
00:36:11,000 --> 00:36:09,030

magneto synthesis you could argue that

914

00:36:12,380 --> 00:36:11,010

the early Earth had many different types

915

00:36:13,820 --> 00:36:12,390

of primary producers but the

916

00:36:14,359 --> 00:36:13,830

photosynthetic plants were most

917

00:36:15,829 --> 00:36:14,369

efficient

918

00:36:17,300 --> 00:36:15,839

they took over the whole tops of the

919

00:36:19,010 --> 00:36:17,310

ocean they crawled out on land took

920

00:36:20,570 --> 00:36:19,020

everything over there when they ran out

921

00:36:21,890 --> 00:36:20,580

of real estate they tried to go to the

922

00:36:23,150 --> 00:36:21,900

bottom of the ocean to go after the

923

00:36:25,490 --> 00:36:23,160

pyrrha synthetic guys because they're

924

00:36:26,870 --> 00:36:25,500

just so efficient at using sunlight but

925

00:36:29,660 --> 00:36:26,880

they ran out of light before they got

926  
00:36:32,960 --> 00:36:29,670  
down there so if we're looking for life

927  
00:36:35,750 --> 00:36:32,970  
again again talk about impossible or

928  
00:36:38,540 --> 00:36:35,760  
possible if it's got an energy gradient

929  
00:36:43,339 --> 00:36:38,550  
if it's got liquid water and it's got

930  
00:36:44,839 --> 00:36:43,349  
carbons why not and as we get out there

931  
00:36:45,770 --> 00:36:44,849  
we're gonna that's these are more of

932  
00:36:47,150 --> 00:36:45,780  
these science questions that we're

933  
00:36:49,670 --> 00:36:47,160  
absolutely got to go through the Nemo

934  
00:36:50,599 --> 00:36:49,680  
thing yeah yeah they're the last thing I

935  
00:36:52,220 --> 00:36:50,609  
want sorry but before we get to your

936  
00:36:53,630 --> 00:36:52,230  
final slides are actually this rock

937  
00:36:55,339 --> 00:36:53,640  
that's sitting right in front of us it's

938  
00:36:58,509 --> 00:36:55,349

not a rock I apologize for calling it a

939

00:37:01,370 --> 00:37:00,710

you mind telling everybody what it

940

00:37:05,630 --> 00:37:01,380

actually is

941

00:37:07,730 --> 00:37:05,640

I needed a prop to hide the monitor so I

942

00:37:09,289 --> 00:37:07,740

brought a meteorite

943

00:37:10,519 --> 00:37:09,299

remember it's media rides in space a

944

00:37:12,740 --> 00:37:10,529

meteor through the atmosphere it's a

945

00:37:15,140 --> 00:37:12,750

meteorite it's kind of big enough to

946

00:37:15,799 --> 00:37:15,150

hide the monitor meteorites come in

947

00:37:18,019 --> 00:37:15,809

three flavors

948

00:37:19,789 --> 00:37:18,029

there's the iron nickel kind there's the

949

00:37:22,730 --> 00:37:19,799

iron nickel with rock and then there's

950

00:37:24,650 --> 00:37:22,740

just the rock and what happens is if I

951  
00:37:26,299 --> 00:37:24,660  
have an asteroid out there any another

952  
00:37:29,390 --> 00:37:26,309  
guy slams into it either breaks into

953  
00:37:31,160 --> 00:37:29,400  
pieces or it sticks if it sticks it

954  
00:37:34,519 --> 00:37:31,170  
deposits its energy into it so it heats

955  
00:37:36,799 --> 00:37:34,529  
up as more and more rocks hit each other

956  
00:37:37,819 --> 00:37:36,809  
I call them rocks as they as they hit

957  
00:37:38,809 --> 00:37:37,829  
each other to think it's bigger and

958  
00:37:41,299 --> 00:37:38,819  
bigger and hotter and hotter

959  
00:37:45,440 --> 00:37:41,309  
the heavy stuff starts to sink so the

960  
00:37:48,200 --> 00:37:45,450  
iron or nickel sinks and the the rocky

961  
00:37:50,180 --> 00:37:48,210  
stuff floats so you're making a proto

962  
00:37:53,660 --> 00:37:50,190  
world your iron is going to be your

963  
00:37:56,329 --> 00:37:53,670

proto core your metal Rocky is your

964

00:37:58,730 --> 00:37:56,339

mantle and your your rock is the crust

965

00:38:00,349 --> 00:37:58,740

it starts to differentiate as this thing

966

00:38:02,059 --> 00:38:00,359

is growing up trying to become a planet

967

00:38:03,710 --> 00:38:02,069

something mash into it and this time

968

00:38:06,079 --> 00:38:03,720

rather than any heat it just broke the

969

00:38:08,269 --> 00:38:06,089

whole thing up so this is iron nickel

970

00:38:10,519 --> 00:38:08,279

meteorite it's a campo del Cielo from

971

00:38:13,069 --> 00:38:10,529

Argentina found in the 1500s they think

972

00:38:16,789 --> 00:38:13,079

it hit 5,000 years ago this is all iron

973

00:38:19,460 --> 00:38:16,799

so this is the proto core of a world

974

00:38:21,380 --> 00:38:19,470

wannabe that got disrupted and the

975

00:38:22,519 --> 00:38:21,390

reason why it's here is one of the

976  
00:38:24,890 --> 00:38:22,529  
missions that went through us for

977  
00:38:27,440 --> 00:38:24,900  
feasibility was a mission called psyche

978  
00:38:29,839 --> 00:38:27,450  
it's the 16th one that was known in the

979  
00:38:33,279 --> 00:38:29,849  
asteroid belt it's about a hundred and

980  
00:38:35,630 --> 00:38:33,289  
twenty miles across it's an iron nickel

981  
00:38:38,599 --> 00:38:35,640  
asteroid with the crust blown off so we

982  
00:38:40,490 --> 00:38:38,609  
think it's a naked core so just picture

983  
00:38:42,799 --> 00:38:40,500  
this rock about a hundred twenty miles

984  
00:38:45,589 --> 00:38:42,809  
across something would fit between here

985  
00:38:49,370 --> 00:38:45,599  
and San Diego that's what we're going to

986  
00:38:51,259 --> 00:38:49,380  
explore with the psychie mission now I'm

987  
00:38:53,240 --> 00:38:51,269  
gonna do the final please do what I want

988  
00:38:56,240 --> 00:38:53,250

to end with a series of images that that

989

00:38:58,660 --> 00:38:56,250

just just blow me away they're not that

990

00:39:01,730 --> 00:38:58,670

fancy but just just look at this on your

991

00:39:05,420 --> 00:39:01,740

left that is a picture of the earth from

992

00:39:08,240 --> 00:39:05,430

low Earth orbit the middle is a picture

993

00:39:10,940 --> 00:39:08,250

of the earth as seen from the moon on

994

00:39:11,760 --> 00:39:10,950

the right you don't know that so I'm

995

00:39:13,950 --> 00:39:11,770

going to tell you

996

00:39:16,650 --> 00:39:13,960

that is a picture from the surface of

997

00:39:19,890 --> 00:39:16,660

Mars and DC that red circle oops that

998

00:39:22,290 --> 00:39:19,900

red circle yeah okay I'm just make sure

999

00:39:24,060 --> 00:39:22,300

it's the right that that white dot is

1000

00:39:28,260 --> 00:39:24,070

the earth as seen from the surface of

1001  
00:39:29,609 --> 00:39:28,270  
Mars here is Saturn and you're behind it

1002  
00:39:31,920 --> 00:39:29,619  
so you're looking towards the Sun the

1003  
00:39:34,140 --> 00:39:31,930  
disc itself is blocking the sunlight and

1004  
00:39:36,030 --> 00:39:34,150  
you just get the glow of the Rings we

1005  
00:39:39,990 --> 00:39:36,040  
really had to punch this thing up but in

1006  
00:39:43,470 --> 00:39:40,000  
that circle that's the Earth from a

1007  
00:39:45,480 --> 00:39:43,480  
billion miles away so I want to end with

1008  
00:39:47,250 --> 00:39:45,490  
a quote by one of my heroes Constantina

1009  
00:39:49,560 --> 00:39:47,260  
voted avid Sewell Kooskia one of the

1010  
00:39:51,870 --> 00:39:49,570  
fathers of astronautics the earth is the

1011  
00:39:54,690 --> 00:39:51,880  
cradle of the mind but one cannot live

1012  
00:40:10,180 --> 00:39:54,700  
in the cradle forever thank you very

1013  
00:40:14,140 --> 00:40:12,039

we are gonna open it up for some

1014

00:40:15,730 --> 00:40:14,150

questions now now if you're here I got

1015

00:40:16,509 --> 00:40:15,740

questions you've got wedge against

1016

00:40:18,519 --> 00:40:16,519

hundreds

1017

00:40:20,819 --> 00:40:18,529

nobody's enjoying watching some people's

1018

00:40:24,190 --> 00:40:20,829

face your face in particular we're just

1019

00:40:25,720 --> 00:40:24,200

watching this was amazing cuz that's

1020

00:40:27,339 --> 00:40:25,730

what this place is about if you have

1021

00:40:28,599 --> 00:40:27,349

questions this microphone right over

1022

00:40:32,079 --> 00:40:28,609

here if you're here on the lab if you're

1023

00:40:33,430 --> 00:40:32,089

joining us at home on Ustream or YouTube

1024

00:40:35,589 --> 00:40:33,440

if you ask your questions

1025

00:40:37,329 --> 00:40:35,599

we've got people up there monitoring

1026  
00:40:39,519 --> 00:40:37,339  
those they'll be able to burn them in so

1027  
00:40:42,730 --> 00:40:39,529  
who's got the first question so let's go

1028  
00:40:43,930 --> 00:40:42,740  
ahead and step on it so you can if

1029  
00:40:45,339 --> 00:40:43,940  
you've got questions you can line up

1030  
00:40:46,480 --> 00:40:45,349  
right behind the microphone right over

1031  
00:40:48,099 --> 00:40:46,490  
there if you like because if you don't

1032  
00:40:50,289 --> 00:40:48,109  
line up I'll ask you guys questions and

1033  
00:40:52,930 --> 00:40:50,299  
then we're really in trouble Randy never

1034  
00:40:54,279 --> 00:40:52,940  
stops teaching either we were setting up

1035  
00:40:56,440 --> 00:40:54,289  
and talking about this and Randy was

1036  
00:41:00,029 --> 00:40:56,450  
telling everybody all about any but

1037  
00:41:03,579 --> 00:41:00,039  
doesn't just a big fan so first question

1038  
00:41:07,690 --> 00:41:03,589

lots of questions edited down to two

1039

00:41:11,470 --> 00:41:07,700

is there an engineering or science

1040

00:41:13,900 --> 00:41:11,480

discipline for origami so that you can

1041

00:41:17,200 --> 00:41:13,910

fold this stuff up open it and the

1042

00:41:20,319 --> 00:41:17,210

circuits all connect is there specific

1043

00:41:21,789 --> 00:41:20,329

discipline for that is not here at the

1044

00:41:25,089 --> 00:41:21,799

laboratory that's what we had to go to

1045

00:41:27,370 --> 00:41:25,099

campus to Caltech to find an expert or

1046

00:41:28,809 --> 00:41:27,380

Gami guy and I'm sure they have a fancy

1047

00:41:30,339 --> 00:41:28,819

word for it but there there is a

1048

00:41:32,140 --> 00:41:30,349

discipline but it's probably more of an

1049

00:41:33,220 --> 00:41:32,150

art form than an engineering form even

1050

00:41:38,019 --> 00:41:33,230

though we're if they get insulted by

1051

00:41:44,440 --> 00:41:38,029

that it's probably both now my second of

1052

00:41:47,019 --> 00:41:44,450

many but my last I now there's a new

1053

00:41:49,990 --> 00:41:47,029

science mission that wants to put

1054

00:41:56,950 --> 00:41:50,000

another over on Mars we work twenty data

1055

00:41:59,109 --> 00:41:56,960

for C I paid attention have they ever

1056

00:42:03,730 --> 00:41:59,119

worked at putting some kind of a

1057

00:42:06,970 --> 00:42:03,740

compressed gas blower on the Rovers now

1058

00:42:09,930 --> 00:42:06,980

so that if there is a dust storm the

1059

00:42:12,700 --> 00:42:09,940

solar panels can be blown Queen and

1060

00:42:14,529 --> 00:42:12,710

extend the wife even more than the great

1061

00:42:16,569 --> 00:42:14,539

extensions you guys have already done

1062

00:42:18,880 --> 00:42:16,579

well here's the issue here there's a

1063

00:42:20,740 --> 00:42:18,890

number challenges with that one the 2020

1064

00:42:22,280 --> 00:42:20,750

Rover is nuclear power not solar powered

1065

00:42:24,560 --> 00:42:22,290

so you don't want to put a blower on

1066

00:42:26,870 --> 00:42:24,570

if you put a blower on a solar-powered

1067

00:42:29,660 --> 00:42:26,880

vehicle now your anymore mass and

1068

00:42:30,829 --> 00:42:29,670

complexity the rovers Spirit and

1069

00:42:32,420 --> 00:42:30,839

Opportunity were designed for 90 days

1070

00:42:33,650 --> 00:42:32,430

because we've looked at the rate of dust

1071

00:42:35,540 --> 00:42:33,660

deposition and tried to figure out how

1072

00:42:37,849 --> 00:42:35,550

long we could go and make the pan is

1073

00:42:39,440 --> 00:42:37,859

long enough but the dust devils just

1074

00:42:40,700 --> 00:42:39,450

would you know you are powered decrease

1075

00:42:42,470 --> 00:42:40,710

each day and then a dust devil drone

1076

00:42:44,359 --> 00:42:42,480

over so the power you know peak back up

1077

00:42:46,609 --> 00:42:44,369

you go thanks for the fish I mean it was

1078

00:42:48,560 --> 00:42:46,619

just it was just great so adding more

1079

00:42:51,290 --> 00:42:48,570

mass and complexity to do something that

1080

00:42:53,480 --> 00:42:51,300

may be done naturally is one issue

1081

00:42:55,520 --> 00:42:53,490

the next question is and this is kind of

1082

00:42:57,680 --> 00:42:55,530

a heretical I mean how long do you want

1083

00:42:59,270 --> 00:42:57,690

a mission to last for if you keep paying

1084

00:43:00,800 --> 00:42:59,280

out for these extended missions that's

1085

00:43:03,470 --> 00:43:00,810

money your take away from the next

1086

00:43:04,910 --> 00:43:03,480

mission so the way to think about is say

1087

00:43:06,170 --> 00:43:04,920

you put money away for vacation every

1088

00:43:08,359 --> 00:43:06,180

two week you're having one every two

1089

00:43:10,130 --> 00:43:08,369

years gonna go on vacation you're gonna

1090

00:43:11,780 --> 00:43:10,140

do it for two weeks you're now in a

1091

00:43:14,480 --> 00:43:11,790

place you go I'm gonna stay here a third

1092

00:43:17,089 --> 00:43:14,490

week you're now taking money from your

1093

00:43:19,579 --> 00:43:17,099

next vacation so you're delaying that

1094

00:43:21,020 --> 00:43:19,589

one so when we say something should last

1095

00:43:23,810 --> 00:43:21,030

a certain length we really want it to

1096

00:43:25,339 --> 00:43:23,820

last that long that being said most

1097

00:43:27,470 --> 00:43:25,349

missions that have succeeded that didn't

1098

00:43:29,570 --> 00:43:27,480

have an issue have already gone three

1099

00:43:31,820 --> 00:43:29,580

five times more than its primary mission

1100

00:43:33,800 --> 00:43:31,830

anyway so so lifetime hasn't been an

1101

00:43:37,460 --> 00:43:33,810

issue for our missions we'd like to do

1102

00:43:39,170 --> 00:43:37,470

the more and more capable stuff not now

1103

00:43:40,250 --> 00:43:39,180

later we're gonna line that and Brandi

1104

00:43:46,510 --> 00:43:40,260

let's stick around I'll stick around

1105

00:43:52,700 --> 00:43:50,120

hey it seems as though that there is a

1106

00:43:54,500 --> 00:43:52,710

lag or latency between the time that a

1107

00:43:56,270 --> 00:43:54,510

scientific instrument is deployed and

1108

00:44:00,050 --> 00:43:56,280

the time that it arrives to any

1109

00:44:02,599 --> 00:44:00,060

particular time maybe 30 40 years how

1110

00:44:04,490 --> 00:44:02,609

does NASA predict what society would

1111

00:44:06,920 --> 00:44:04,500

likely want to use that particular

1112

00:44:08,300 --> 00:44:06,930

instrument 30 years down the line maybe

1113

00:44:10,820 --> 00:44:08,310

10 years down the line you mentioned

1114

00:44:15,770 --> 00:44:10,830

earlier that sometimes scientists on

1115

00:44:17,500 --> 00:44:15,780

earth end up discovering ideas yes one

1116

00:44:22,220 --> 00:44:17,510

of the interesting that we face is that

1117

00:44:24,349 --> 00:44:22,230

technology it's got a clock on it the

1118

00:44:25,730 --> 00:44:24,359

technology of now is the technology you

1119

00:44:27,920 --> 00:44:25,740

can use now and is only good for a

1120

00:44:29,990 --> 00:44:27,930

certain finite period of time I would

1121

00:44:31,820 --> 00:44:30,000

not use saturn v technology to Rawkus

1122

00:44:33,859 --> 00:44:31,830

those guys were using vacuum tubes and

1123

00:44:34,730 --> 00:44:33,869

and copper plated wire memory and also

1124

00:44:37,010 --> 00:44:34,740

it's a really horrific

1125

00:44:38,870 --> 00:44:37,020

so it's really what you have the tekneq

1126  
00:44:40,310 --> 00:44:38,880  
technology now so you don't want to deal

1127  
00:44:42,710 --> 00:44:40,320  
with stuff that's going to be 40 years

1128  
00:44:43,910 --> 00:44:42,720  
in the future because all the technology

1129  
00:44:46,940 --> 00:44:43,920  
that you're working with is going to be

1130  
00:44:48,829 --> 00:44:46,950  
outdated so there's this dance between

1131  
00:44:51,230 --> 00:44:48,839  
what is the burning science question of

1132  
00:44:53,540 --> 00:44:51,240  
the day and what's the best technology

1133  
00:44:55,370 --> 00:44:53,550  
that's flight proven that we know works

1134  
00:44:56,930 --> 00:44:55,380  
in space that can actually survive the

1135  
00:45:01,160 --> 00:44:56,940  
rigors of space to actually get you some

1136  
00:45:03,020 --> 00:45:01,170  
of those answers so we don't go that far

1137  
00:45:06,079 --> 00:45:03,030  
in advance we're you know I say we're

1138  
00:45:08,270 --> 00:45:06,089

good for 10 maybe 20 years we'll work on

1139

00:45:09,770 --> 00:45:08,280

technologies for the next 20 years but

1140

00:45:13,640 --> 00:45:09,780

the technology of the day is only good

1141

00:45:15,770 --> 00:45:13,650

for the near-term right now thanks I've

1142

00:45:17,329 --> 00:45:15,780

actually got a good online follow-up

1143

00:45:19,099 --> 00:45:17,339

question from that was from Trevor oh

1144

00:45:22,130 --> 00:45:19,109

and they asked is NASA planning on using

1145

00:45:23,930 --> 00:45:22,140

reusable spacecraft in the future yes I

1146

00:45:26,120 --> 00:45:23,940

mean here again people would say well is

1147

00:45:28,430 --> 00:45:26,130

it impossible to reuse spacecraft launch

1148

00:45:29,990 --> 00:45:28,440

vehicles well come on when you fly from

1149

00:45:33,260 --> 00:45:30,000

New York to DC you don't throw a the

1150

00:45:35,060 --> 00:45:33,270

plane when you get to DC why did people

1151

00:45:37,670 --> 00:45:35,070

say you couldn't reuse space launch

1152

00:45:39,859 --> 00:45:37,680

vehicles so one of the things that

1153

00:45:41,540 --> 00:45:39,869

SpaceX has done that no one has ever

1154

00:45:43,609 --> 00:45:41,550

done before and we're curious about is

1155

00:45:46,190 --> 00:45:43,619

it's called supersonic retropropulsion

1156

00:45:50,750 --> 00:45:46,200

so here you'll launch your rocket you're

1157

00:45:53,030 --> 00:45:50,760

going at Mach lots you do your first

1158

00:45:55,040 --> 00:45:53,040

stage cut off you turn it around your

1159

00:45:56,960 --> 00:45:55,050

start falling and now you're firing your

1160

00:45:59,359 --> 00:45:56,970

engines in the direction that you're

1161

00:46:00,950 --> 00:45:59,369

moving at high Mach numbers so you're

1162

00:46:03,740 --> 00:46:00,960

blowing your engine into the direction

1163

00:46:05,420 --> 00:46:03,750

of travel NASA never does it we launch

1164

00:46:08,320 --> 00:46:05,430

one way we go the other way to actually

1165

00:46:10,940 --> 00:46:08,330

do retro supersonic propulsion it's nuts

1166

00:46:11,540 --> 00:46:10,950

but they showing us how to do it so we

1167

00:46:14,599 --> 00:46:11,550

think it's great

1168

00:46:17,870 --> 00:46:14,609

so NASA what NASA does which is really

1169

00:46:20,720 --> 00:46:17,880

lovely is we try to develop capability

1170

00:46:22,310 --> 00:46:20,730

and then push it out to the the US and

1171

00:46:25,160 --> 00:46:22,320

the businesses as fast as we can because

1172

00:46:26,570 --> 00:46:25,170

we want to set up new markets in our

1173

00:46:27,560 --> 00:46:26,580

Charter we're supposed to train the next

1174

00:46:29,599 --> 00:46:27,570

generation of scientists and engineers

1175

00:46:32,120 --> 00:46:29,609

and help the economic competitors the

1176

00:46:34,010 --> 00:46:32,130

United States NASA doesn't do launch

1177

00:46:36,710 --> 00:46:34,020

vehicles anymore those are your those

1178

00:46:37,849 --> 00:46:36,720

your Boeing's those are your SpaceX's

1179

00:46:41,030 --> 00:46:37,859

they're all these other guys that are

1180

00:46:42,560 --> 00:46:41,040

doing it we want that to be their

1181

00:46:45,560 --> 00:46:42,570

business and we'll do the same thing

1182

00:46:47,089 --> 00:46:45,570

with human transportation in space right

1183

00:46:48,620 --> 00:46:47,099

now nASA has four vehicles coming online

1184

00:46:50,930 --> 00:46:48,630

we're always going to try to

1185

00:46:52,580 --> 00:46:50,940

stuff as far down as we can so NASA is

1186

00:46:54,050 --> 00:46:52,590

not going to do retro supersonic

1187

00:46:55,790 --> 00:46:54,060

propulsion less maybe we're landing on a

1188

00:46:58,130 --> 00:46:55,800

world as we come in and we're trying to

1189

00:47:02,390 --> 00:46:58,140

fire exhaust into that but we want to

1190

00:47:05,870 --> 00:47:02,400

set up commercial sectors to do that hi

1191

00:47:07,580 --> 00:47:05,880

so you mentioned earlier about how there

1192

00:47:10,310 --> 00:47:07,590

are many concepts that could seem really

1193

00:47:12,560 --> 00:47:10,320

crazy but not necessarily be impossible

1194

00:47:14,780 --> 00:47:12,570

are there any concepts that you heard

1195

00:47:17,240 --> 00:47:14,790

that are you know really crazy and out

1196

00:47:18,830 --> 00:47:17,250

there but not impossible that fascinated

1197

00:47:20,810 --> 00:47:18,840

you but never became mission concepts

1198

00:47:22,160 --> 00:47:20,820

the one I love and they keep modifying

1199

00:47:23,660 --> 00:47:22,170

it so I'm going to tell you about a

1200

00:47:27,730 --> 00:47:23,670

design they had a year ago and they've

1201  
00:47:31,700 --> 00:47:27,740  
now changed it but the idea was nuts

1202  
00:47:33,170 --> 00:47:31,710  
Marco I love you for this one he you

1203  
00:47:35,780 --> 00:47:33,180  
know astronomers like bigger and bigger

1204  
00:47:36,950 --> 00:47:35,790  
primary mirrors for their telescopes you

1205  
00:47:40,070 --> 00:47:36,960  
know the big er the further you can see

1206  
00:47:41,930 --> 00:47:40,080  
the dimmer objects you can detect Hubble

1207  
00:47:44,690 --> 00:47:41,940  
is 2.4 meters it's about an 8-foot

1208  
00:47:46,820 --> 00:47:44,700  
primary piece of glass astronomers want

1209  
00:47:48,260 --> 00:47:46,830  
to get bigger so James Webb and infrared

1210  
00:47:51,500 --> 00:47:48,270  
it's like six and a half meters it's

1211  
00:47:56,150 --> 00:47:51,510  
really like 21 feet across stron Murs

1212  
00:48:00,140 --> 00:47:56,160  
want to get bigger one idea is the guy

1213  
00:48:01,790 --> 00:48:00,150

wants to make fine grains shiny dust put

1214

00:48:03,950 --> 00:48:01,800

the dust in a spacecraft send the

1215

00:48:05,240 --> 00:48:03,960

spacecraft out to like I1 where the

1216

00:48:08,060 --> 00:48:05,250

gravity's bounce between the earth and

1217

00:48:09,650 --> 00:48:08,070

the moon dump out the dust which is fun

1218

00:48:10,890 --> 00:48:09,660

to do in zero-g to get that stuff out of

1219

00:48:13,230 --> 00:48:10,900

there

1220

00:48:14,790 --> 00:48:13,240

they have this undulating cloud and dust

1221

00:48:16,410 --> 00:48:14,800

particles just kind of sitting there in

1222

00:48:19,320 --> 00:48:16,420

this gravity well between the earth and

1223

00:48:22,230 --> 00:48:19,330

the moon then with six lasers three on

1224

00:48:24,030 --> 00:48:22,240

the side you don't want to melt the

1225

00:48:26,310 --> 00:48:24,040

grains you want to use photon pressure

1226

00:48:31,620 --> 00:48:26,320

to shape it into a primary mirror of any

1227

00:48:33,240 --> 00:48:31,630

size oh wait it gets better then they

1228

00:48:34,680 --> 00:48:33,250

want to have the lasers interfere with

1229

00:48:36,420 --> 00:48:34,690

each other so you can change the average

1230

00:48:38,100 --> 00:48:36,430

spacing between the grains so now you

1231

00:48:41,310 --> 00:48:38,110

can tune it to what wavelength it'll

1232

00:48:43,230 --> 00:48:41,320

reflect that's the granular imager

1233

00:48:44,460 --> 00:48:43,240

concept I love that one and now they're

1234

00:48:46,380 --> 00:48:44,470

getting away from lasers and they're

1235

00:48:49,200 --> 00:48:46,390

trying to do electrostatically but I

1236

00:48:50,700 --> 00:48:49,210

just love the concept I mean again I'm

1237

00:48:52,950 --> 00:48:50,710

not sure that's in your a lifetime but I

1238

00:48:54,660 --> 00:48:52,960

just think this is it's just great so so

1239

00:48:56,640 --> 00:48:54,670

that one is really to me on the edge of

1240

00:48:59,540 --> 00:48:56,650

something that's that's not Daisy

1241

00:49:02,850 --> 00:48:59,550

shooting lasers but it's still out there

1242

00:49:04,260 --> 00:49:02,860

thank you you got it next person is

1243

00:49:07,650 --> 00:49:04,270

stepping up to the microphone Giancarlo

1244

00:49:09,750 --> 00:49:07,660

Estevez asked if the a-team if your team

1245

00:49:12,000 --> 00:49:09,760

publishes things on methods do you

1246

00:49:13,560 --> 00:49:12,010

publish anything that we do so the

1247

00:49:16,500 --> 00:49:13,570

science storytelling stuff is out there

1248

00:49:18,180 --> 00:49:16,510

are just how we organize the structure

1249

00:49:19,500 --> 00:49:18,190

because we're trying to get this stuff

1250

00:49:21,900 --> 00:49:19,510

out there and we're also trying to

1251

00:49:23,910 --> 00:49:21,910

attract other people's attentions to

1252

00:49:27,420 --> 00:49:23,920

find out how they do stuff we've already

1253

00:49:30,510 --> 00:49:27,430

been to Google X there's Pixar Procter &

1254

00:49:32,730 --> 00:49:30,520

Gamble we're not proud in terms of what

1255

00:49:34,470 --> 00:49:32,740

you're out there but any brainstorming

1256

00:49:36,330 --> 00:49:34,480

organization we'd like to learn from

1257

00:49:38,400 --> 00:49:36,340

because we have not cornered the market

1258

00:49:40,530 --> 00:49:38,410

in this stuff but this is what we do on

1259

00:49:42,090 --> 00:49:40,540

a day to day basis and if there are

1260

00:49:44,340 --> 00:49:42,100

other ways of doing it you know Disney

1261

00:49:46,440 --> 00:49:44,350

Imagineering is it you know you as

1262

00:49:48,420 --> 00:49:46,450

cinema labs or Carnegie Mellon whatever

1263

00:49:50,100 --> 00:49:48,430

we'd like to hear how they do their

1264

00:49:52,260 --> 00:49:50,110

brainstorming just to just to keep

1265

00:49:56,580 --> 00:49:52,270

improving our process so we do work with

1266

00:49:59,280 --> 00:49:56,590

others first of all I disagree with the

1267

00:50:06,930 --> 00:49:59,290

introduction your cohort gave of you you

1268

00:50:09,060 --> 00:50:06,940

do have a sense of humor when I tell a

1269

00:50:11,190 --> 00:50:09,070

joke to a woman and she doesn't laugh I

1270

00:50:14,789 --> 00:50:11,200

tell her well that's an engineering joke

1271

00:50:20,219 --> 00:50:14,799

they always find that work

1272

00:50:23,009 --> 00:50:20,229

but you're alive to tell it so you're

1273

00:50:25,650 --> 00:50:23,019

still talking to the sky out there yes

1274

00:50:28,410 --> 00:50:25,660

how what is the range of the technology

1275

00:50:30,660 --> 00:50:28,420

of receivers and transmitters how far

1276

00:50:33,569 --> 00:50:30,670

out are you gonna be able to communicate

1277

00:50:36,989 --> 00:50:33,579

with a probe referring to Voyager

1278

00:50:39,539 --> 00:50:36,999

Voyager here at home it will die before

1279

00:50:41,370 --> 00:50:39,549

we can't hear it the trick we have to do

1280

00:50:45,359 --> 00:50:41,380

is since we can't change the hardware on

1281

00:50:47,999 --> 00:50:45,369

the spacecraft we have to talk slower

1282

00:50:50,609 --> 00:50:48,009

and slower to make sure we hear those

1283

00:50:52,199 --> 00:50:50,619

zeros and ones so as we get further and

1284

00:50:54,509 --> 00:50:52,209

further away we do a lower lower data

1285

00:50:56,039 --> 00:50:54,519

rate we've turned off the really hog of

1286

00:50:58,469 --> 00:50:56,049

instruments so like the imager and the

1287

00:51:00,239 --> 00:50:58,479

guys that take high data volumes so it's

1288

00:51:02,339 --> 00:51:00,249

really feels in particles the protons

1289

00:51:02,819 --> 00:51:02,349

electrons the plasma waves the magnetic

1290

00:51:04,559 --> 00:51:02,829

field

1291

00:51:07,279 --> 00:51:04,569

so basically we're taking weather

1292

00:51:10,410 --> 00:51:07,289

forecasts and we'll be able to hear it

1293

00:51:16,529 --> 00:51:10,420

till it dies which will be a sad day

1294

00:51:18,239 --> 00:51:16,539

because that was my first spacecraft so

1295

00:51:20,849 --> 00:51:18,249

I was really intrigued at how many

1296

00:51:22,650 --> 00:51:20,859

projects you guys are kind of

1297

00:51:24,660 --> 00:51:22,660

researching at any given period of time

1298

00:51:26,189 --> 00:51:24,670

yeah you know 12 a year seems like it's

1299

00:51:28,620 --> 00:51:26,199

somewhat manageable but then you know

1300

00:51:32,160 --> 00:51:28,630

you're talking 6070 whatever we can be

1301  
00:51:33,870 --> 00:51:32,170  
ambitious right oh yeah I think I can

1302  
00:51:35,429 --> 00:51:33,880  
see how a problem can arise when you're

1303  
00:51:38,429 --> 00:51:35,439  
working on so many of these at a time

1304  
00:51:40,769 --> 00:51:38,439  
how do you kind of just document for

1305  
00:51:42,719 --> 00:51:40,779  
posterity sake and for the next person

1306  
00:51:45,479 --> 00:51:42,729  
but also for your own sakes to keep

1307  
00:51:47,519 --> 00:51:45,489  
track of which ideas work which ideas

1308  
00:51:48,809 --> 00:51:47,529  
you like that sort of thing so that's

1309  
00:51:50,009 --> 00:51:48,819  
the one and then the short follow-up

1310  
00:51:52,019 --> 00:51:50,019  
question which I was just curious about

1311  
00:51:53,759 --> 00:51:52,029  
on the starshade there were these little

1312  
00:51:55,650 --> 00:51:53,769  
petals on the side I was just curious

1313  
00:51:56,910 --> 00:51:55,660

what those were about their petals if

1314

00:51:58,229 --> 00:51:56,920

you think about what you're trying to do

1315

00:52:00,929 --> 00:51:58,239

is you're trying to make it transparent

1316

00:52:02,729 --> 00:52:00,939

on the tips and getting more and more

1317

00:52:05,239 --> 00:52:02,739

opaque as you get there and that's shape

1318

00:52:07,979 --> 00:52:05,249

a teardrop shape actually is wavy

1319

00:52:10,319 --> 00:52:07,989

because we're trying to suppress every

1320

00:52:12,569 --> 00:52:10,329

photon that's trying to diffract around

1321

00:52:13,829 --> 00:52:12,579

the edge of this thing but you know when

1322

00:52:16,079 --> 00:52:13,839

we do is studies to address your first

1323

00:52:17,939 --> 00:52:16,089

point we have a facilitator that leaves

1324

00:52:20,069 --> 00:52:17,949

the conversation we have an agenda down

1325

00:52:21,329 --> 00:52:20,079

to five minute resolution we have a

1326

00:52:22,620 --> 00:52:21,339

study lead and assistant side lead

1327

00:52:24,359 --> 00:52:22,630

that's responsible making sure this is

1328

00:52:26,249 --> 00:52:24,369

documented correctly on a wiki page and

1329

00:52:28,079 --> 00:52:26,259

we hire a documentarian to take the

1330

00:52:28,320 --> 00:52:28,089

notes that the study lead in assistance

1331

00:52:30,210 --> 00:52:28,330

either

1332

00:52:32,700 --> 00:52:30,220

read because we want to be able to farm

1333

00:52:34,440 --> 00:52:32,710

this for the next study so I'm gonna do

1334

00:52:35,850 --> 00:52:34,450

another little Segway real quick one of

1335

00:52:38,640 --> 00:52:35,860

the things that was fun did you guys see

1336

00:52:41,610 --> 00:52:38,650

Star Trek was it for with the whales

1337

00:52:43,230 --> 00:52:41,620

whales okay you remember when Scotty is

1338

00:52:45,450 --> 00:52:43,240

looking for transparent aluminum to make

1339

00:52:46,950 --> 00:52:45,460

the fish tank for the whales well that

1340

00:52:49,620 --> 00:52:46,960

stuff actually exists today it's

1341

00:52:52,080 --> 00:52:49,630

aluminum oxynitride and they came to us

1342

00:52:53,370 --> 00:52:52,090

and said this material is transparent in

1343

00:52:56,210 --> 00:52:53,380

all wavelengths except for a little bit

1344

00:52:58,770 --> 00:52:56,220

of the mid IR what could you do with it

1345

00:53:01,260 --> 00:52:58,780

so we did a brainstorming session and

1346

00:53:03,660 --> 00:53:01,270

you're not the winning solution was we

1347

00:53:05,160 --> 00:53:03,670

want to make sample canisters out of

1348

00:53:06,870 --> 00:53:05,170

this stuff so when you put the sample in

1349

00:53:09,060 --> 00:53:06,880

it and seal it up you can still study it

1350

00:53:10,590 --> 00:53:09,070

for the years it takes to go home and if

1351  
00:53:12,630 --> 00:53:10,600  
you die in route or you burned up at

1352  
00:53:15,330 --> 00:53:12,640  
least you got something right now you're

1353  
00:53:16,790 --> 00:53:15,340  
putting a can and it disappears so we're

1354  
00:53:22,200 --> 00:53:16,800  
always looking at these new technologies

1355  
00:53:28,650 --> 00:53:25,440  
so we know you are working on the new

1356  
00:53:29,820 --> 00:53:28,660  
helicopter for for the Mars 2020 Rover

1357  
00:53:31,860 --> 00:53:29,830  
yep

1358  
00:53:35,670 --> 00:53:31,870  
what other new components did you add on

1359  
00:53:37,080 --> 00:53:35,680  
it that were new besides curiosity one

1360  
00:53:40,080 --> 00:53:37,090  
of the fun instruments on it that I

1361  
00:53:42,330 --> 00:53:40,090  
really love one of our fantasies is the

1362  
00:53:44,070 --> 00:53:42,340  
way to reduce cost is to have a smaller

1363  
00:53:46,710 --> 00:53:44,080

payload so you use a smaller rock and

1364

00:53:49,230 --> 00:53:46,720

use less fuel one of our and it is a

1365

00:53:51,570 --> 00:53:49,240

fantasy we want to do a two-way mission

1366

00:53:54,360 --> 00:53:51,580

that goes to Mars and lands with its

1367

00:53:57,300 --> 00:53:54,370

tanks bone-dry well then how do you get

1368

00:54:00,420 --> 00:53:57,310

back the idea was you would suck in the

1369

00:54:04,140 --> 00:54:00,430

atmosphere crack the co2 in two carbons

1370

00:54:07,230 --> 00:54:04,150

and oxygens dig up ice melt the water

1371

00:54:09,150 --> 00:54:07,240

ice split into hydrogen oxygens put the

1372

00:54:12,840 --> 00:54:09,160

oxygens together liquefy it fill up the

1373

00:54:15,120 --> 00:54:12,850

oxidizer tank then take the carbon from

1374

00:54:18,450 --> 00:54:15,130

the atmosphere with a hydrogen from the

1375

00:54:19,680 --> 00:54:18,460

ice make methane liquefy it and fill up

1376

00:54:21,750 --> 00:54:19,690

your fuel tank

1377

00:54:25,590 --> 00:54:21,760

that's why Elon Musk is working on

1378

00:54:27,510 --> 00:54:25,600

methane engines okay on the 2020 Rover

1379

00:54:31,170 --> 00:54:27,520

we have a little baby instrument called

1380

00:54:33,840 --> 00:54:31,180

moxie it's very very simple its job is

1381

00:54:36,330 --> 00:54:33,850

to just do a proof-of-concept this bad

1382

00:54:38,120 --> 00:54:36,340

boy is gonna suck in co2 crack it and

1383

00:54:40,890 --> 00:54:38,130

just see how much oxygen it can make

1384

00:54:43,850 --> 00:54:40,900

moxie and that's that's coming to a

1385

00:54:48,270 --> 00:54:46,950

yeah okay great we're gonna ask one more

1386

00:54:50,160 --> 00:54:48,280

from online and then we're gonna finish

1387

00:54:51,810 --> 00:54:50,170

up with these three final questions here

1388

00:54:53,220 --> 00:54:51,820

and I'll stay here afterwards so if you

1389

00:54:56,450 --> 00:54:53,230

have any last kind of questions come up

1390

00:54:59,430 --> 00:54:56,460

and ask as he said touch the rock

1391

00:55:01,560 --> 00:54:59,440

what about moon regolith as outer

1392

00:55:03,180 --> 00:55:01,570

protection coating to protect the

1393

00:55:06,210 --> 00:55:03,190

spacecraft from radiation this is from

1394

00:55:07,650 --> 00:55:06,220

james belts regolith is okay but it's

1395

00:55:09,900 --> 00:55:07,660

not nearly as good with things with

1396

00:55:11,220 --> 00:55:09,910

hydrogen's or water products okay so

1397

00:55:13,770 --> 00:55:11,230

we're looking at things that are

1398

00:55:16,710 --> 00:55:13,780

hydrated we also think and don't get

1399

00:55:18,390 --> 00:55:16,720

grossed out that waste products from

1400

00:55:24,030 --> 00:55:18,400

astronauts would be great to fill the

1401

00:55:25,830 --> 00:55:24,040

walls with you've got to do something

1402

00:55:27,540 --> 00:55:25,840

with it right okay so but that that

1403

00:55:29,490 --> 00:55:27,550

makes a better insulation than regular

1404

00:55:32,610 --> 00:55:29,500

doesn't have any Hutchins in it put it

1405

00:55:35,010 --> 00:55:32,620

to use okay yeah last three questions so

1406

00:55:37,200 --> 00:55:35,020

you mentioned working with SpaceX Google

1407

00:55:41,120 --> 00:55:37,210

Disney and whatnot what other companies

1408

00:55:43,740 --> 00:55:41,130

do outsource to to get technology and

1409

00:55:45,180 --> 00:55:43,750

products to help with missions you've

1410

00:55:48,300 --> 00:55:45,190

got to be careful when it's outsourcing

1411

00:55:50,580 --> 00:55:48,310

technology because stuff has to be space

1412

00:55:53,400 --> 00:55:50,590

proven and when we're doing stuff that

1413

00:55:55,440 --> 00:55:53,410

hasn't been done before it makes us a

1414

00:55:56,730 --> 00:55:55,450

little squeamish making something that

1415

00:55:58,140 --> 00:55:56,740

you're dependent on that's made by

1416

00:56:00,360 --> 00:55:58,150

somebody else that may not have flown

1417

00:56:02,400 --> 00:56:00,370

before so we're not really necessary

1418

00:56:04,470 --> 00:56:02,410

using technology from other people per

1419

00:56:06,930 --> 00:56:04,480

se I mean there may be subsystem or

1420

00:56:09,240 --> 00:56:06,940

instruments you know hemispherical

1421

00:56:12,270 --> 00:56:09,250

resonator gyroscopes or something that

1422

00:56:13,620 --> 00:56:12,280

will use what we try to do when we're

1423

00:56:15,240 --> 00:56:13,630

building spacecraft so we try to get as

1424

00:56:17,430 --> 00:56:15,250

much of the United States involved in it

1425

00:56:18,840 --> 00:56:17,440

but there are some pieces that people

1426  
00:56:21,090 --> 00:56:18,850  
can't make either because they don't the

1427  
00:56:22,560 --> 00:56:21,100  
technology or it's too expensive so we

1428  
00:56:25,350 --> 00:56:22,570  
have our own machine shop that'll make

1429  
00:56:27,060 --> 00:56:25,360  
them to spec here you know I mean when

1430  
00:56:29,520 --> 00:56:27,070  
your billion spacecraft say you wanted

1431  
00:56:32,010 --> 00:56:29,530  
to build a Camry but you were gonna

1432  
00:56:33,480 --> 00:56:32,020  
build each part yourself think how long

1433  
00:56:34,800 --> 00:56:33,490  
how hard it would be to do that and

1434  
00:56:37,200 --> 00:56:34,810  
that's what we're kind of doing these

1435  
00:56:39,060 --> 00:56:37,210  
spacecraft everyone is one-of-a-kind we

1436  
00:56:40,560 --> 00:56:39,070  
try to get as much contractors to reduce

1437  
00:56:42,830 --> 00:56:40,570  
the price of stuff but it's one of these

1438  
00:56:46,160 --> 00:56:42,840

stuff that they we know they can make

1439

00:56:49,050 --> 00:56:46,170

thank you you got it

1440

00:56:50,970 --> 00:56:49,060

this question is related to your earlier

1441

00:56:54,240 --> 00:56:50,980

one about making fuel on Mars right

1442

00:56:55,940 --> 00:56:54,250

about 15 or 20 years ago there was a

1443

00:56:59,210 --> 00:56:55,950

group call I think the O'Neill

1444

00:57:02,180 --> 00:56:59,220

at Princeton or somewhere I hope you

1445

00:57:03,440 --> 00:57:02,190

people don't forget what they were doing

1446

00:57:05,420 --> 00:57:03,450

because they were told those guys did

1447

00:57:08,720 --> 00:57:05,430

great stuff it goes even further back

1448

00:57:12,140 --> 00:57:08,730

see Wachowski Oberth goddard so so for

1449

00:57:14,300 --> 00:57:12,150

one idea from that area was was you you

1450

00:57:16,910 --> 00:57:14,310

make fuel on the moon which is a low

1451

00:57:19,280 --> 00:57:16,920

gravity well and maybe there's not very

1452

00:57:22,490 --> 00:57:19,290

much hydrogen there not maybe using as

1453

00:57:24,530 --> 00:57:22,500

fuel well you make fuel to go to Mars

1454

00:57:26,360 --> 00:57:24,540

well no I don't know the purpose but you

1455

00:57:32,210 --> 00:57:26,370

know are you talking about water ice

1456

00:57:34,490 --> 00:57:32,220

that's you baked the the lunar soil has

1457

00:57:36,500 --> 00:57:34,500

like one or two percent oxygen you just

1458

00:57:38,720 --> 00:57:36,510

use the oxygen you make out the oxygen

1459

00:57:40,370 --> 00:57:38,730

and you reacted with hydrogen need to

1460

00:57:41,750 --> 00:57:40,380

bring forward so basically you're

1461

00:57:43,790 --> 00:57:41,760

getting the hydrogen you're gonna bring

1462

00:57:46,580 --> 00:57:43,800

that from Earth so but the hydras only

1463

00:57:48,560 --> 00:57:46,590

weighs one-eighth as much so it reduces

1464

00:57:50,810 --> 00:57:48,570

the weight for if you want to move a lot

1465

00:57:53,090 --> 00:57:50,820

of people to Mars you would you could

1466

00:57:56,210 --> 00:57:53,100

you could get make a lot of fuel up

1467

00:58:02,270 --> 00:57:56,220

there there's some people I'd like to

1468

00:58:05,240 --> 00:58:02,280

send to Mars Thank You Michelle craters

1469

00:58:11,240 --> 00:58:05,250

I was actually fascinated by the Mars

1470

00:58:13,730 --> 00:58:11,250

2020 helicopter you had I got a question

1471

00:58:17,450 --> 00:58:13,740

you know Mars has very little atmosphere

1472

00:58:19,730 --> 00:58:17,460

and low pressure you know when you try

1473

00:58:22,550 --> 00:58:19,740

to take off a helicopter on earth you

1474

00:58:24,710 --> 00:58:22,560

got like the pressure lifted how do you

1475

00:58:29,710 --> 00:58:24,720

overcome the problem with low pressure

1476

00:58:31,280 --> 00:58:29,720

and minimal lift we have - not one

1477

00:58:33,410 --> 00:58:31,290

propeller on it

1478

00:58:36,080 --> 00:58:33,420

they're counter rotating and they're

1479

00:58:46,160 --> 00:58:36,090

going on like 27 or 28 rpms I mean it's

1480

00:58:47,990 --> 00:58:46,170

we it's no sound ten seconds of love

1481

00:58:50,120 --> 00:58:48,000

time it's not going to be long we're

1482

00:58:52,610 --> 00:58:50,130

just this is a technology demonstrator

1483

00:58:54,740 --> 00:58:52,620

but we just go really fast and you do

1484

00:58:58,790 --> 00:58:54,750

the biggest span that you can on those

1485

00:59:01,910 --> 00:58:58,800

things and just just whirling and we'll

1486

00:59:05,730 --> 00:59:01,920

let you know in the year how they do

1487

00:59:08,040 --> 00:59:05,740

well thank you very much more than that

1488

00:59:11,400 --> 00:59:08,050

is all the time that we have for tonight

1489

00:59:13,050 --> 00:59:11,410

and I before we thank him one last time

1490

00:59:15,600 --> 00:59:13,060

I would like you to join us next month

1491

00:59:17,640 --> 00:59:15,610

July 11th and 12th for moonstruck we'll

1492

00:59:19,230 --> 00:59:17,650

be celebrating Apollo's 50th anniversary

1493

00:59:28,410 --> 00:59:19,240

can we get a big round of applause for

1494

00:59:33,980 --> 00:59:30,269

thank you so much for joining us folks