
AbSciCon
2019

1
00:00:00,790 --> 00:00:07,320
[Music]

2
00:00:12,859 --> 00:00:09,369
[Applause]

3
00:00:14,900 --> 00:00:12,869
good morning my name is Tai Casas I'm

4
00:00:16,400 --> 00:00:14,910
here from Pasadena on behalf of honeybee

5
00:00:19,189 --> 00:00:16,410
robotics the exploration technologies

6
00:00:21,589 --> 00:00:19,199
group chrissa's in Greenland so I'm

7
00:00:23,529 --> 00:00:21,599
doing the talk instead of him so today

8
00:00:25,490 --> 00:00:23,539
I'm going to be talking to you about a

9
00:00:28,400 --> 00:00:25,500
conceptual design of a probe for

10
00:00:30,259 --> 00:00:28,410
penetrating through Europa's crust this

11
00:00:31,880 --> 00:00:30,269
is an exercise in architecting a

12
00:00:35,060 --> 00:00:31,890
solution that is just out of reach of

13
00:00:36,590 --> 00:00:35,070

current technologies and but but those

14
00:00:37,970 --> 00:00:36,600
technologies are just on the horizon so

15
00:00:39,920 --> 00:00:37,980
it allows us to look ahead and sort of

16
00:00:42,170 --> 00:00:39,930
direct our development efforts as we

17
00:00:45,139 --> 00:00:42,180
move forward so here you can see a

18
00:00:47,630 --> 00:00:45,149
section view of this conceptual vehicle

19
00:00:50,900 --> 00:00:47,640
it is literally built around the probe

20
00:00:54,250 --> 00:00:50,910
the probe is a 5 meter long 60

21
00:00:56,540 --> 00:00:54,260
centimeter diameter self-contained

22
00:00:59,470 --> 00:00:56,550
vehicle essentially for going through

23
00:01:02,119 --> 00:00:59,480
the 15 kilometers of ice the fundamental

24
00:01:04,279 --> 00:01:02,129
approach is a thermal mechanical

25
00:01:08,690 --> 00:01:04,289
approach for drilling through the crust

26
00:01:10,790 --> 00:01:08,700
of the the crust of the surface so about

27
00:01:11,990 --> 00:01:10,800
that crust as you guys all know because

28
00:01:14,740 --> 00:01:12,000
you're in the ocean world's technology

29
00:01:17,419 --> 00:01:14,750
section there are three different layers

30
00:01:19,490 --> 00:01:17,429
the brittle layer the ductile layer and

31
00:01:21,559 --> 00:01:19,500
the ocean and while we don't really know

32
00:01:24,350 --> 00:01:21,569
how thick the ice is exactly and it

33
00:01:26,089 --> 00:01:24,360
varies over the surface we estimate

34
00:01:27,740 --> 00:01:26,099
about 15 kilometers although it could be

35
00:01:30,199 --> 00:01:27,750
as much as about 40 kilometers thick of

36
00:01:32,270 --> 00:01:30,209
ice so there are some considerable

37
00:01:33,889 --> 00:01:32,280
challenges with getting through this ice

38
00:01:35,749 --> 00:01:33,899

crust as you can imagine the first one

39
00:01:38,389 --> 00:01:35,759
being how the heck do you even get

40
00:01:40,070 --> 00:01:38,399
through 15 kilometers of ice I don't

41
00:01:43,219 --> 00:01:40,080
know if I drill long enough to do that

42
00:01:44,839 --> 00:01:43,229
and then also how do you power the probe

43
00:01:46,729 --> 00:01:44,849
as it's going through the ice how do you

44
00:01:48,290 --> 00:01:46,739
make sure that it has energy as it

45
00:01:50,089 --> 00:01:48,300
drills and then finally how do you

46
00:01:51,589 --> 00:01:50,099
communicate with it on its journey so

47
00:01:53,570 --> 00:01:51,599
how do you make sure that you can get

48
00:01:55,609 --> 00:01:53,580
telemetry back and get science back etc

49
00:01:58,430 --> 00:01:55,619
so this talk is going to be focused on

50
00:01:59,869 --> 00:01:58,440
how to penetrate through or a drilling

51
00:02:03,260 --> 00:01:59,879
and sampling company so this is sort of

52
00:02:04,400 --> 00:02:03,270
our core competency but yeah so let's

53
00:02:06,199 --> 00:02:04,410
start with a couple different deep

54
00:02:08,240 --> 00:02:06,209
drilling approaches this is a pretty

55
00:02:10,669 --> 00:02:08,250
dense chart but I'm gonna have you focus

56
00:02:12,680 --> 00:02:10,679
on slush which is obviously the subject

57
00:02:16,610 --> 00:02:12,690
of my presentation it combines some of

58
00:02:19,009 --> 00:02:16,620
the pros of the two main different types

59
00:02:20,630 --> 00:02:19,019
of penetrating through ice mechanical

60
00:02:21,940 --> 00:02:20,640
which is drilling like you have at your

61
00:02:23,260 --> 00:02:21,950
household drill and thermal

62
00:02:25,210 --> 00:02:23,270
which is basically taking something

63
00:02:29,110 --> 00:02:25,220

super hot and just pushing it through

64
00:02:32,140 --> 00:02:29,120
the ice so the the sort of issues with

65
00:02:33,550 --> 00:02:32,150
thermal of having trouble penetrating

66
00:02:36,220 --> 00:02:33,560
through things that it can't melt

67
00:02:38,740 --> 00:02:36,230
through obviously are of concern because

68
00:02:40,390 --> 00:02:38,750
there are salts in the ice there are

69
00:02:42,729 --> 00:02:40,400
salt layers we may come across like

70
00:02:45,190 --> 00:02:42,739
different sedimentation stuff like that

71
00:02:46,509 --> 00:02:45,200
but it's really robust and it's nice

72
00:02:48,070 --> 00:02:46,519
because you don't have a lot of moving

73
00:02:49,390 --> 00:02:48,080
parts whereas on the mechanical side you

74
00:02:50,589 --> 00:02:49,400
have a lot of moving parts you need

75
00:02:52,119 --> 00:02:50,599
rotary percussive we're talking about

76
00:02:54,479 --> 00:02:52,129
drilling for something like three years

77
00:02:58,839 --> 00:02:54,489
so you need a system that's like pretty

78
00:03:00,729 --> 00:02:58,849
last for a pretty long time and what we

79
00:03:02,350 --> 00:03:00,739
tried to do was take some of the things

80
00:03:04,630 --> 00:03:02,360
from the best of both worlds and combine

81
00:03:06,910 --> 00:03:04,640
them into a single architecture so we

82
00:03:08,890 --> 00:03:06,920
approach this by doing sort of a

83
00:03:11,110 --> 00:03:08,900
scaled-down version of the probe testing

84
00:03:12,789 --> 00:03:11,120
this is a picture of the instrumented

85
00:03:15,280 --> 00:03:12,799
drilling testbed that we use you may

86
00:03:17,170 --> 00:03:15,290
recognize that drill from an early as an

87
00:03:18,280 --> 00:03:17,180
earlier TRL version of the Arad's drill

88
00:03:21,660 --> 00:03:18,290

that's popped up in a couple other

89
00:03:26,500 --> 00:03:21,670
posters around here and essentially we

90
00:03:29,020 --> 00:03:26,510
designed a probe that is about 18 mean

91
00:03:30,940 --> 00:03:29,030
18 inches long the first four inches of

92
00:03:34,330 --> 00:03:30,950
which is a rotating drill bit with an

93
00:03:36,280 --> 00:03:34,340
auger and then the last 14 inches is the

94
00:03:37,599 --> 00:03:36,290
cylinder behind it is on bearing so that

95
00:03:39,340 --> 00:03:37,609
it doesn't rotate through the ice so the

96
00:03:41,620 --> 00:03:39,350
idea is that simulates the sort of

97
00:03:44,800 --> 00:03:41,630
rotating cutting head at the front of

98
00:03:46,390 --> 00:03:44,810
the probe and the stationary body that

99
00:03:48,660 --> 00:03:46,400
holds things like avionics and the

100
00:03:51,280 --> 00:03:48,670
tether and whatnot that follows behind

101
00:03:52,720 --> 00:03:51,290
I'm going to show you two videos I just

102
00:03:53,979 --> 00:03:52,730
learned that actually I rotated the

103
00:03:55,960 --> 00:03:53,989
videos the wrong direction so they're

104
00:03:59,979 --> 00:03:55,970
gonna pop up sideways but bear with me

105
00:04:01,840 --> 00:03:59,989
here um on the left is a video of yeah

106
00:04:04,270 --> 00:04:01,850
that's that's a that's one way of doing

107
00:04:08,860 --> 00:04:04,280
it on the left is a video of sloshing

108
00:04:11,710 --> 00:04:08,870
through ice at 240 C 240 Kelvin scuse me

109
00:04:13,089 --> 00:04:11,720
it is just water ice this is how we sort

110
00:04:14,530 --> 00:04:13,099
of did a lot of our baseline tests I'm

111
00:04:16,870 --> 00:04:14,540
going to replay that for you and what I

112
00:04:19,270 --> 00:04:16,880
want you to know is how watery it is so

113
00:04:22,029 --> 00:04:19,280

this is sort of a flushing approach that

114
00:04:23,350 --> 00:04:22,039
favors the thermal side of things so

115
00:04:25,300 --> 00:04:23,360
when you're actually melting most of the

116
00:04:27,040 --> 00:04:25,310
chips that you generate this is nice

117
00:04:28,330 --> 00:04:27,050
because it handles the chip transport

118
00:04:30,279 --> 00:04:28,340
issues that you have when you have to

119
00:04:31,570 --> 00:04:30,289
like actively move dried chips from the

120
00:04:33,190 --> 00:04:31,580
front to the back of the probe and

121
00:04:34,630 --> 00:04:33,200
recompress them but it's obviously not

122
00:04:35,220 --> 00:04:34,640
very energy-efficient because you're

123
00:04:36,780 --> 00:04:35,230
just melting

124
00:04:40,680 --> 00:04:36,790
in the same way that you would with a

125
00:04:43,020 --> 00:04:40,690
mel probe so this other video also

126
00:04:45,240 --> 00:04:43,030
sideways is a much better balanced

127
00:04:47,580 --> 00:04:45,250
version of the thermal and mechanical

128
00:04:49,320 --> 00:04:47,590
power so you're only partially melting

129
00:04:50,940 --> 00:04:49,330
the chips so it helps facilitate the

130
00:04:52,410 --> 00:04:50,950
transport along the probe you actually

131
00:04:53,880 --> 00:04:52,420
can take advantage of the environmental

132
00:04:55,290 --> 00:04:53,890
conditions to refreeze to the same

133
00:04:57,330 --> 00:04:55,300
density behind you so you don't get

134
00:04:59,280 --> 00:04:57,340
stuck however you don't use nearly as

135
00:05:02,490 --> 00:04:59,290
much energy to actually get through all

136
00:05:04,320 --> 00:05:02,500
of the all of the material so sort of at

137
00:05:06,630 --> 00:05:04,330
a high level um we wanted to do

138
00:05:07,860 --> 00:05:06,640

apples-to-apples testing saying what is

139
00:05:10,350 --> 00:05:07,870
the difference between just melting

140
00:05:12,810 --> 00:05:10,360
flushing with a more optimized system

141
00:05:14,220 --> 00:05:12,820
and just drilling so you can see the

142
00:05:15,870 --> 00:05:14,230
difference in the kind of chips that we

143
00:05:17,850 --> 00:05:15,880
make on the left you can see the big

144
00:05:19,350 --> 00:05:17,860
puddle of water that comes from just

145
00:05:21,570 --> 00:05:19,360
melting so this was turning on heat on

146
00:05:23,910 --> 00:05:21,580
the drill not rotating in the center is

147
00:05:25,380 --> 00:05:23,920
the combination from a reasonably well

148
00:05:27,960 --> 00:05:25,390
balanced slushing just and on the right

149
00:05:30,300 --> 00:05:27,970
is a pure drilling test so drilling as

150
00:05:31,950 --> 00:05:30,310
you would normally with no he you can

151
00:05:34,350 --> 00:05:31,960
see how powdery those cuttings are how

152
00:05:36,870 --> 00:05:34,360
they bind up actually that caused us to

153
00:05:38,400 --> 00:05:36,880
get stuck only shortly after the probe

154
00:05:39,840 --> 00:05:38,410
body entered the ice because we weren't

155
00:05:41,520 --> 00:05:39,850
actively transporting chips that's sort

156
00:05:43,130 --> 00:05:41,530
of what we anticipated and the problem

157
00:05:47,190 --> 00:05:43,140
we're trying to solve with the solution

158
00:05:50,310 --> 00:05:47,200
so this is a chart that summarizes the

159
00:05:52,380 --> 00:05:50,320
testing that we've done so far so each

160
00:05:54,240 --> 00:05:52,390
of these groups of three bars represents

161
00:05:55,890 --> 00:05:54,250
a different method the bar on the left

162
00:05:57,750 --> 00:05:55,900
is the specific energy which is

163
00:06:00,180 --> 00:05:57,760

essentially how much energy per cc you

164
00:06:02,460 --> 00:06:00,190
need to excavate some of the ice the bar

165
00:06:04,440 --> 00:06:02,470
in the middle is the power so the power

166
00:06:06,930 --> 00:06:04,450
consumption and then on the right is our

167
00:06:08,790 --> 00:06:06,940
AP or rate of penetration so you can see

168
00:06:10,440 --> 00:06:08,800
that to draw your attention to the

169
00:06:12,120 --> 00:06:10,450
leftmost bars first we're looking at

170
00:06:14,190 --> 00:06:12,130
approximately an order of magnitude

171
00:06:16,830 --> 00:06:14,200
difference between the specific energies

172
00:06:18,450 --> 00:06:16,840
of melting slushing and drilling note

173
00:06:20,130 --> 00:06:18,460
that the y-axis on the left is

174
00:06:22,230 --> 00:06:20,140
logarithmic and the y-axis on the right

175
00:06:25,140 --> 00:06:22,240
is linear it was the best way of

176
00:06:26,010 --> 00:06:25,150
condensing us into one chart so you can

177
00:06:28,710 --> 00:06:26,020
see the sort of order of magnitude

178
00:06:30,330 --> 00:06:28,720
differences in the specific energy but

179
00:06:31,860 --> 00:06:30,340
you also will notice how the power

180
00:06:34,260 --> 00:06:31,870
difference between melting and slushing

181
00:06:36,030 --> 00:06:34,270
really isn't all that different so why

182
00:06:38,190 --> 00:06:36,040
is that how can we have such lower power

183
00:06:39,930 --> 00:06:38,200
I'm coming up such lower energy than we

184
00:06:41,880 --> 00:06:39,940
can that when we're using some more

185
00:06:43,380 --> 00:06:41,890
power it's because we go way faster so

186
00:06:45,270 --> 00:06:43,390
we were penetrating through ice maybe

187
00:06:47,250 --> 00:06:45,280
five to 10 times faster because we have

188
00:06:48,750 --> 00:06:47,260

this active drilling approach so we just

189
00:06:50,850 --> 00:06:48,760
need less energy overall

190
00:06:53,460 --> 00:06:50,860
and you can see that on the right the

191
00:06:55,440 --> 00:06:53,470
drilling specific energy is even lower

192
00:06:57,120 --> 00:06:55,450
by about another order of magnitude and

193
00:06:59,310 --> 00:06:57,130
it's because we can go super super fast

194
00:07:00,960 --> 00:06:59,320
when the whole drill is spinning so when

195
00:07:02,790 --> 00:07:00,970
the whole probe is turning in ice and

196
00:07:05,430 --> 00:07:02,800
excavating chips we can move really

197
00:07:06,870 --> 00:07:05,440
quick but the issue of course is you can

198
00:07:08,520 --> 00:07:06,880
tell by the Asterix next to drilling

199
00:07:10,710 --> 00:07:08,530
the issue of course is that we don't

200
00:07:12,720 --> 00:07:10,720
handle the chips so once you create all

201
00:07:14,610 --> 00:07:12,730
this fluffy powder there's like what we

202
00:07:16,440 --> 00:07:14,620
call a fluff factor basically how much

203
00:07:18,810 --> 00:07:16,450
more the volume of the Powder consumes

204
00:07:20,850 --> 00:07:18,820
than the actual bulk material and it's

205
00:07:23,250 --> 00:07:20,860
bigger I mean powders fluffier than ice

206
00:07:24,750 --> 00:07:23,260
so you need to make sure that behind the

207
00:07:26,220 --> 00:07:24,760
probe when these chips move past you

208
00:07:30,750 --> 00:07:26,230
your recompressing to the same density

209
00:07:32,640 --> 00:07:30,760
or you basically get stuck and so we saw

210
00:07:35,910 --> 00:07:32,650
the slushing as a nice sort of balance

211
00:07:38,190 --> 00:07:35,920
between both the approaches of thermal

212
00:07:39,750 --> 00:07:38,200
and mechanical drilling as well as the

213
00:07:42,960 --> 00:07:39,760

power consumptions between the two of

214
00:07:44,850 --> 00:07:42,970
them so this is a sort of section view

215
00:07:46,050 --> 00:07:44,860
of the probe at a very high level I'm

216
00:07:49,140 --> 00:07:46,060
just going to point out a couple things

217
00:07:51,870 --> 00:07:49,150
the bottom of the probe in the hot

218
00:07:54,390 --> 00:07:51,880
section is what it is where we have a

219
00:07:57,330 --> 00:07:54,400
killer power reactor baselined for the

220
00:07:58,860 --> 00:07:57,340
baseline for the mission the rear part

221
00:08:00,630 --> 00:07:58,870
where the avionics and tether and

222
00:08:03,480 --> 00:08:00,640
batteries live is cold they're separated

223
00:08:05,940 --> 00:08:03,490
by a radiation shield you can see that

224
00:08:08,310 --> 00:08:05,950
we also have these detachable tether

225
00:08:09,750 --> 00:08:08,320
spools with wireless communication at

226
00:08:13,020 --> 00:08:09,760
the back of the probe so the idea is

227
00:08:14,490 --> 00:08:13,030
that if we come across as we're spooling

228
00:08:16,410 --> 00:08:14,500
out if we come across something like a

229
00:08:18,720 --> 00:08:16,420
water body or whatever we can detach and

230
00:08:20,940 --> 00:08:18,730
use acoustic or RF instead of sorry we

231
00:08:22,620 --> 00:08:20,950
can use acoustic instead of just a

232
00:08:24,750 --> 00:08:22,630
tether to sort of make it across and

233
00:08:26,010 --> 00:08:24,760
that way if we see like shifting of the

234
00:08:27,750 --> 00:08:26,020
ice crust or something like that we can

235
00:08:29,630 --> 00:08:27,760
screw leave a tether where it is use

236
00:08:31,620 --> 00:08:29,640
wireless to jump between two repeaters

237
00:08:33,660 --> 00:08:31,630
but since that's not the point of my

238
00:08:36,570 --> 00:08:33,670

talk right now I'm going to jump into a

239
00:08:37,920 --> 00:08:36,580
little promo video that we made to try

240
00:08:59,430 --> 00:08:37,930
and get people excited about this

241
00:09:22,800 --> 00:09:16,760
[Music]

242
00:09:28,020 --> 00:09:25,950
and then finally the reason I'm up here

243
00:09:30,270 --> 00:09:28,030
and Chris isn't is because he is

244
00:09:32,100 --> 00:09:30,280
currently in Greenland testing a

245
00:09:34,500 --> 00:09:32,110
prototype of the slush system so this is

246
00:09:36,450 --> 00:09:34,510
a version of it that's actually a coring

247
00:09:38,220 --> 00:09:36,460
drill instead of a full slushing so it's

248
00:09:39,810 --> 00:09:38,230
pure mechanical and they're removing the

249
00:09:41,460 --> 00:09:39,820
cores every time they drill down the

250
00:09:43,140 --> 00:09:41,470
certain depth I'm so slightly different

251
00:09:44,670 --> 00:09:43,150
architecture but the self-contained

252
00:09:48,390 --> 00:09:44,680
probe idea and a lot of the technologies

253
00:09:50,070 --> 00:09:48,400
are pretty analogous and they drilled on

254
00:09:52,200 --> 00:09:50,080
June 14th actually just the other day

255
00:09:54,870 --> 00:09:52,210
they made it down to 111 meters deep in

256
00:09:57,630 --> 00:09:54,880
in Greenland ice and this is them on the

257
00:10:00,180 --> 00:09:57,640
bottom righthand celebrating with a hot

258
00:10:04,770 --> 00:10:00,190
toddy made with some old ice cores so in

259
00:10:07,470 --> 00:10:04,780
conclusion so in conclusion there is a

260
00:10:09,060 --> 00:10:07,480
bunch of reasons why mechanical and

261
00:10:11,550 --> 00:10:09,070
thermal have advantages in terms of

262
00:10:13,650 --> 00:10:11,560
robustness and in terms of complexity

263
00:10:15,450 --> 00:10:13,660

and in terms of the materials that they

264
00:10:18,450 --> 00:10:15,460
can cut through but we really think that

265
00:10:20,550 --> 00:10:18,460
moving forward with slush is a good is a

266
00:10:22,560 --> 00:10:20,560
good is a good high-level approach as we

267
00:10:24,030 --> 00:10:22,570
start to conceptualize what a probe that

268
00:10:27,150 --> 00:10:24,040
would be able to go through 15

269
00:10:29,030 --> 00:10:27,160
kilometers of cryogenic and warm ice on

270
00:10:33,270 --> 00:10:29,040
Europa would actually have to look like

271
00:10:40,920 --> 00:10:33,280
so with that I'd like to open it up to

272
00:10:43,080 --> 00:10:40,930
any questions thanks Dino we've got a

273
00:10:53,490 --> 00:10:43,090
time for a question if you want to come

274
00:10:55,560 --> 00:10:53,500
to the microphone we did it in about I

275
00:11:00,330 --> 00:10:55,570
think it was 5 days from when we started

276
00:11:02,220 --> 00:11:00,340
drilling I don't think they were working

277
00:11:15,850 --> 00:11:02,230
24/7 though so I can't actually tell you

278
00:11:20,090 --> 00:11:18,170
what difference is would it make when

279
00:11:20,420 --> 00:11:20,100
you operate in vacuum this is the bottom

280
00:11:22,490 --> 00:11:20,430
line

281
00:11:24,440 --> 00:11:22,500
ah that's a really good question so at

282
00:11:26,540 --> 00:11:24,450
the surface obviously the whole starting

283
00:11:29,000 --> 00:11:26,550
is of challenge because you sublimate

284
00:11:30,790 --> 00:11:29,010
all everything that you know and on

285
00:11:33,019 --> 00:11:30,800
Europa that would mean that we have to

286
00:11:35,269 --> 00:11:33,029
before we can start slushing and sort of

287
00:11:37,220 --> 00:11:35,279
make taking advantage of this transport

288
00:11:38,840 --> 00:11:37,230

method we would have to get fully buried

289
00:11:40,819 --> 00:11:38,850
and ice so you would have to have the

290
00:11:43,250 --> 00:11:40,829
top of the borehole crl over us

291
00:11:45,230 --> 00:11:43,260
essentially once we're inside that's a

292
00:11:47,509 --> 00:11:45,240
challenge that we are looking into right

293
00:11:50,240 --> 00:11:47,519
now actually with these slush prototypes

294
00:11:51,530 --> 00:11:50,250
we are trying to figure out do some

295
00:11:53,269 --> 00:11:51,540
testing in our Mars chamber we have this

296
00:11:54,650 --> 00:11:53,279
like cool like five meter chamber and

297
00:11:56,269 --> 00:11:54,660
we're gonna pump it down and see what

298
00:11:57,290 --> 00:11:56,279
happens when you start when you start

299
00:11:58,790 --> 00:11:57,300
drilling there's also a lot of

300
00:12:00,410 --> 00:11:58,800
challenges with a hole starting in terms

301
00:12:01,519 --> 00:12:00,420
of thermal management and how you make

302
00:12:03,139 --> 00:12:01,529
sure that you're actually directing as

303
00:12:04,610 --> 00:12:03,149
much of the heat into the ice as

304
00:12:09,740 --> 00:12:04,620
possible instead of just radiating out

305
00:12:12,290 --> 00:12:09,750
the sides yeah last question do you need

306
00:12:14,329 --> 00:12:12,300
to drill with the gravity vector or can

307
00:12:16,100 --> 00:12:14,339
you drill up like to these technology

308
00:12:22,449 --> 00:12:16,110
require the weight of the trailer um

309
00:12:25,310 --> 00:12:22,459
that's also a very good question so this

310
00:12:27,500 --> 00:12:25,320
the technology this technology requires

311
00:12:31,160 --> 00:12:27,510
the gravity vector because we don't have

312
00:12:32,870 --> 00:12:31,170
active transport in Lachie however these

313
00:12:34,370 --> 00:12:32,880

anti torque features these anti torque

314
00:12:36,410 --> 00:12:34,380
blades that I talked about that sort of

315
00:12:40,040 --> 00:12:36,420
a counteract the rotational forces of

316
00:12:42,079 --> 00:12:40,050
the auger um can be active as well as

317
00:12:43,910 --> 00:12:42,089
passive and so for example the drill

318
00:12:46,160 --> 00:12:43,920
that we just tested in Greenland has an

319
00:12:48,829 --> 00:12:46,170
active feed stage so while we can't

320
00:12:50,510 --> 00:12:48,839
steer so maybe looping around would be

321
00:12:51,590 --> 00:12:50,520
pretty difficult if we started upside

322
00:12:52,880 --> 00:12:51,600
down there isn't a reason that we

323
00:12:54,769 --> 00:12:52,890
wouldn't be able to just lift ourselves

324
00:12:56,360 --> 00:12:54,779
forward essentially it depends on

325
00:12:59,180 --> 00:12:56,370
whether or not the anti torque features

326
00:13:01,069 --> 00:12:59,190
glide in rails so you're just leaning

327
00:13:02,900 --> 00:13:01,079
forward on the bit or whether or not

328
00:13:04,460 --> 00:13:02,910
you're actually actively engaging with

329
00:13:08,569 --> 00:13:04,470
the borehole walls and stabilizing

330
00:13:11,410 --> 00:13:08,579
yourself to push forward all right let's

331
00:13:12,230 --> 00:13:11,420
think tie for a great presentation