
AbSciCon
2019

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

2
00:00:13,930 --> 00:00:09,460
[Applause]

3
00:00:19,269 --> 00:00:13,940
thank you it's an opportunity to present

4
00:00:22,130 --> 00:00:19,279
Antony today Antony is based on

5
00:00:24,679 --> 00:00:22,140
primarily microscope that's an atomic

6
00:00:26,900 --> 00:00:24,689
force microscope it was named in honor

7
00:00:29,720 --> 00:00:26,910
of the father of microbiology Anthony

8
00:00:32,030 --> 00:00:29,730
and Meagan Leeuwenhoek I the clever

9
00:00:35,930 --> 00:00:32,040
naming for that as due to brent chris

10
00:00:40,130 --> 00:00:35,940
iners Hey midnite acronym searching

11
00:00:46,120 --> 00:00:40,140
algorithm uh-huh the I'm gonna just get

12
00:00:48,680 --> 00:00:46,130
started in here okay so I as you know

13
00:00:50,090 --> 00:00:48,690

one of the primary goals of the Europe

14
00:00:53,030 --> 00:00:50,100
Lander science definition team was

15
00:00:55,040 --> 00:00:53,040
address to address characterizing bio

16
00:00:57,470 --> 00:00:55,050
signatures in Europe as near subsurface

17
00:00:59,660 --> 00:00:57,480
materials there are a couple of

18
00:01:02,389 --> 00:00:59,670
objectives that we address with a

19
00:01:04,520 --> 00:01:02,399
microscope the first is to identify and

20
00:01:06,650 --> 00:01:04,530
characterize morphological and/or

21
00:01:09,800 --> 00:01:06,660
textural features of Europe this near

22
00:01:12,139 --> 00:01:09,810
subsurface and the investigation that

23
00:01:13,880 --> 00:01:12,149
Anthony accomplishes here is to

24
00:01:17,539 --> 00:01:13,890
characterize particulates and samples

25
00:01:19,969 --> 00:01:17,549
that are 0.2 microns to 1500 microns in

26
00:01:21,950 --> 00:01:19,979
scale the second objective the antony

27
00:01:23,570 --> 00:01:21,960
addresses is to assess the structural

28
00:01:25,520 --> 00:01:23,580
and compositional nature of europe is

29
00:01:27,500 --> 00:01:25,530
near subsurface materials there are two

30
00:01:29,000 --> 00:01:27,510
investigations here one of them is to

31
00:01:31,310 --> 00:01:29,010
measure the mechanical properties of the

32
00:01:32,840 --> 00:01:31,320
sample and the second is to potentially

33
00:01:37,100 --> 00:01:32,850
determine the composition of

34
00:01:41,710 --> 00:01:37,110
particulates afm you may be familiar

35
00:01:44,240 --> 00:01:41,720
with it's been around for about 40 years

36
00:01:46,340 --> 00:01:44,250
works is a pretty simple instrument and

37
00:01:50,210 --> 00:01:46,350
it works by a cantilever interacting

38
00:01:51,590 --> 00:01:50,220

with a sample it raster's over the

39
00:01:54,530 --> 00:01:51,600
sample and it creates a

40
00:01:56,749 --> 00:01:54,540
three-dimensional topographic map if

41
00:01:58,149 --> 00:01:56,759
Emma's tip is often used in material

42
00:02:02,140 --> 00:01:58,159
science in the semiconductor industry

43
00:02:05,420 --> 00:02:02,150
but can also be used to detect biology

44
00:02:08,270 --> 00:02:05,430
particulates such as this cell were

45
00:02:10,520 --> 00:02:08,280
imaged in a 1999 paper if this came from

46
00:02:13,400 --> 00:02:10,530
Lake Vostok accretion ice you can get

47
00:02:17,030 --> 00:02:13,410
really high-resolution image at the sort

48
00:02:18,970 --> 00:02:17,040
of sub sub cell level even looking at

49
00:02:21,409 --> 00:02:18,980
textures that are on the cell surface

50
00:02:23,599 --> 00:02:21,419
but in addition to getting a 3d

51
00:02:25,280 --> 00:02:23,609
topographical map you

52
00:02:28,220 --> 00:02:25,290
also get nanomechanical properties

53
00:02:29,569 --> 00:02:28,230
things such as the sample stiffness the

54
00:02:31,039 --> 00:02:29,579
dissipation of energy when the

55
00:02:34,339 --> 00:02:31,049
cantilever interacts with the surface

56
00:02:37,339 --> 00:02:34,349
and adhesive properties and so you can

57
00:02:40,280 --> 00:02:37,349
see how sort of a diagram of the cartoon

58
00:02:44,270 --> 00:02:40,290
and the top figure here on the bottom is

59
00:02:46,940 --> 00:02:44,280
a scale showing the stiffness as a

60
00:02:48,649 --> 00:02:46,950
as measured as kiloPascals over eight

61
00:02:54,220 --> 00:02:48,659
orders of magnitude different between

62
00:02:56,959 --> 00:02:54,230
cells and hard materials like steel so

63
00:02:59,030 --> 00:02:56,969

AFM bio signature detection technology

64
00:03:02,809 --> 00:02:59,040
as we have thought about it builds on

65
00:03:06,140 --> 00:03:02,819
spaceflight heritage there are a number

66
00:03:09,229 --> 00:03:06,150
of assets to using AFM in space in

67
00:03:11,509 --> 00:03:09,239
addition to its submicron 3d resolution

68
00:03:14,330 --> 00:03:11,519
and the potential for nano mechanical

69
00:03:15,830 --> 00:03:14,340
property determinations the these

70
00:03:18,020 --> 00:03:15,840
instruments are lightweight they have a

71
00:03:19,939 --> 00:03:18,030
small footprint and low power

72
00:03:24,349 --> 00:03:19,949
consumption they can operate an air

73
00:03:27,080 --> 00:03:24,359
liquid and in vacuum the they've also

74
00:03:29,330 --> 00:03:27,090
been flown recently in space on two

75
00:03:31,429 --> 00:03:29,340
different missions one of them was flown

76
00:03:34,399 --> 00:03:31,439
on the Phoenix mission and the other on

77
00:03:37,399 --> 00:03:34,409
the Rosetta mission in both cases they

78
00:03:39,229 --> 00:03:37,409
imaged particulates on Mars on the

79
00:03:41,420 --> 00:03:39,239
Phoenix mission in particulates size

80
00:03:43,490 --> 00:03:41,430
distribution and soils on the Phoenix

81
00:03:45,800 --> 00:03:43,500
mint and the rosetta mission they

82
00:03:49,129 --> 00:03:45,810
measured cometary dust and an observed

83
00:03:51,939 --> 00:03:49,139
large particle aggregates mark Bentley

84
00:03:54,439 --> 00:03:51,949
wrote a paper post the Rosetta mission

85
00:03:56,780 --> 00:03:54,449
that was really on lessons learned from

86
00:03:59,390 --> 00:03:56,790
operating AFM's in space which we have

87
00:04:02,030 --> 00:03:59,400
adopted into the design going forward

88
00:04:05,499 --> 00:04:02,040

and thinking about antony some of these

89
00:04:07,429 --> 00:04:05,509
are co registering if you use a no

90
00:04:09,800 --> 00:04:07,439
register ring an optical microscope

91
00:04:12,530 --> 00:04:09,810
image with the atomic force microscope

92
00:04:14,179 --> 00:04:12,540
image including an array of cantilevers

93
00:04:16,520 --> 00:04:14,189
that have different spring constants in

94
00:04:18,589 --> 00:04:16,530
different tip morphologies and then

95
00:04:20,209 --> 00:04:18,599
being able to operate the instrument

96
00:04:22,760 --> 00:04:20,219
both in open and closed loop formats

97
00:04:26,360 --> 00:04:22,770
which they was required on the Rosetta

98
00:04:29,149 --> 00:04:26,370
mission so one of the things that I

99
00:04:31,610 --> 00:04:29,159
think AFM has a real advantage to is

100
00:04:33,080 --> 00:04:31,620
detecting really small bio signatures we

101
00:04:34,730 --> 00:04:33,090
don't know to what to expect and going

102
00:04:36,320 --> 00:04:34,740
to the surface of Europa

103
00:04:38,360 --> 00:04:36,330
and we didn't know what to expect when

104
00:04:41,150 --> 00:04:38,370
we went to Lake Vita which is a lake in

105
00:04:43,279 --> 00:04:41,160
East Antarctica and the like and McMurdo

106
00:04:44,540 --> 00:04:43,289
Dry Valleys where the sand plan I don't

107
00:04:45,499 --> 00:04:44,550
know that you can see very well from the

108
00:04:50,719 --> 00:04:45,509
back that you can see they're really

109
00:04:52,010 --> 00:04:50,729
bright images here these these are what

110
00:04:54,680 --> 00:04:52,020
I would call kind of normal-sized

111
00:04:57,710 --> 00:04:54,690
bacterial cells and this background sort

112
00:04:59,120 --> 00:04:57,720
of starry night barely shows up when

113
00:05:00,980 --> 00:04:59,130

you're looking at really what we have is

114
00:05:02,499 --> 00:05:00,990
like one of the brightest DNA stains

115
00:05:06,890 --> 00:05:02,509
under epi fluorescent microbes

116
00:05:09,290 --> 00:05:06,900
microscope if we look using an AFM you

117
00:05:11,420 --> 00:05:09,300
can see really really what these what

118
00:05:13,730 --> 00:05:11,430
these particles look like you can zoom

119
00:05:15,110 --> 00:05:13,740
in at higher resolution and and start

120
00:05:19,730 --> 00:05:15,120
looking at the surface textures of the

121
00:05:21,730 --> 00:05:19,740
cells so we have also been interested in

122
00:05:25,930 --> 00:05:21,740
can asking the question can we discern

123
00:05:28,760 --> 00:05:25,940
bio signatures from abiotic particles

124
00:05:32,000 --> 00:05:28,770
using AFM based on their nano mechanical

125
00:05:38,360 --> 00:05:32,010
properties this is a image that we

126
00:05:44,360 --> 00:05:38,370
collected where the we we mixed silica

127
00:05:46,100 --> 00:05:44,370
beads so if I go back here so the round

128
00:05:48,529 --> 00:05:46,110
features which you may or may not be

129
00:05:51,980 --> 00:05:48,539
able to see our silica beads that we

130
00:05:54,560 --> 00:05:51,990
mixed with bacterial cells and if we

131
00:05:56,899 --> 00:05:54,570
look at the forest curves from these

132
00:05:59,029 --> 00:05:56,909
particles we can see that this is on a

133
00:06:03,320 --> 00:05:59,039
glass slide so the black dots are the

134
00:06:05,060 --> 00:06:03,330
are plotted here on the graph the glass

135
00:06:09,200 --> 00:06:05,070
background is not different from the

136
00:06:11,930 --> 00:06:09,210
glass beads that are in blue and we have

137
00:06:13,750 --> 00:06:11,940
particulate organic matter that is as

138
00:06:18,710 --> 00:06:13,760

Roger calls the schmutz from the cells

139
00:06:20,510 --> 00:06:18,720
that is in green this is softer and then

140
00:06:25,159 --> 00:06:20,520
even softer yet are the cells that are

141
00:06:27,320 --> 00:06:25,169
in the and the figure we did a second

142
00:06:31,279 --> 00:06:27,330
kind of similar experiment but in this

143
00:06:32,870 --> 00:06:31,289
case due to a conversation we were

144
00:06:35,029 --> 00:06:32,880
inspired that we had with Mitch Schulte

145
00:06:37,219 --> 00:06:35,039
a few months ago he asked us a question

146
00:06:39,379 --> 00:06:37,229
could you actually discern the

147
00:06:43,070 --> 00:06:39,389
difference between carbonaceous

148
00:06:45,610 --> 00:06:43,080
chondrite meteorite and bio and cells

149
00:06:48,129 --> 00:06:45,620
and so we obtained some i-n

150
00:06:50,409 --> 00:06:48,139
crushed powdered meteorite sample we

151
00:06:52,960 --> 00:06:50,419
screened it through a 5 micron sieve and

152
00:06:56,590 --> 00:06:52,970
mixed it with three different bacterial

153
00:06:59,080 --> 00:06:56,600
cell types in this case the meteorite

154
00:07:03,670 --> 00:06:59,090
which is here in the particle in the

155
00:07:06,460 --> 00:07:03,680
middle of this aggregate of cells shows

156
00:07:10,150 --> 00:07:06,470
up to be quite stiffer not as stiff as

157
00:07:13,480 --> 00:07:10,160
the background of glass and then the

158
00:07:16,000 --> 00:07:13,490
cells have different they are softer yet

159
00:07:17,350 --> 00:07:16,010
and they have different curves for the

160
00:07:19,210 --> 00:07:17,360
different types of cells that we had in

161
00:07:21,100 --> 00:07:19,220
in this case we mixed an Antarctic

162
00:07:25,480 --> 00:07:21,110
bacterium called pseudo Vibrio with

163
00:07:27,730 --> 00:07:25,490

bacillus and s worse in equine so we

164
00:07:30,610 --> 00:07:27,740
think we can discern particles of

165
00:07:33,969 --> 00:07:30,620
different types of properties from from

166
00:07:36,520 --> 00:07:33,979
life you could imagine then that if we

167
00:07:38,500 --> 00:07:36,530
went and got a library of different

168
00:07:40,360 --> 00:07:38,510
types of cells and particles that we

169
00:07:42,340 --> 00:07:40,370
might be able to just separate these in

170
00:07:44,140 --> 00:07:42,350
in three dimensions or in here in two

171
00:07:49,240 --> 00:07:44,150
dimensions on a on a graph based on

172
00:07:51,760 --> 00:07:49,250
their biophysical properties as Peter

173
00:07:53,860 --> 00:07:51,770
talked about a little bit in his talk

174
00:07:56,080 --> 00:07:53,870
but identifying morphological features

175
00:07:57,909 --> 00:07:56,090
of particulates and I see potentially

176
00:08:00,790 --> 00:07:57,919
salty samples is going to require sample

177
00:08:03,010 --> 00:08:00,800
processing and along these lines we

178
00:08:06,730 --> 00:08:03,020
partnered with the Monterey Bay Aquarium

179
00:08:08,350 --> 00:08:06,740
Research Institute to develop a concept

180
00:08:12,190 --> 00:08:08,360
for this instrument which would be a

181
00:08:13,840 --> 00:08:12,200
sample handling system Ambari has a lot

182
00:08:16,180 --> 00:08:13,850
of history and experience in operating

183
00:08:20,140 --> 00:08:16,190
remote autonomous platforms in the ocean

184
00:08:21,940 --> 00:08:20,150
on earth this is the 2g ESP that was

185
00:08:25,330 --> 00:08:21,950
originally funded by a NASA a step

186
00:08:27,640 --> 00:08:25,340
project with the the concept they would

187
00:08:31,120 --> 00:08:27,650
evolve this design into space based

188
00:08:33,459 --> 00:08:31,130

operations and the - 2g ESP here is very

189
00:08:35,949 --> 00:08:33,469
large but this is actually a functional

190
00:08:37,959 --> 00:08:35,959
molecular biology platform where it's

191
00:08:40,540 --> 00:08:37,969
not only processing collecting samples

192
00:08:43,240 --> 00:08:40,550
and analyzing them but also doing real

193
00:08:45,730 --> 00:08:43,250
molecular biology DNA extractions PCR

194
00:08:48,280 --> 00:08:45,740
and and remotely communicating that

195
00:08:52,930 --> 00:08:48,290
information back to the lab they use

196
00:08:55,380 --> 00:08:52,940
titanium pucks which are inert for

197
00:08:59,250 --> 00:08:55,390
sample processing and

198
00:09:02,550 --> 00:08:59,260
this system is is again complete and

199
00:09:05,340 --> 00:09:02,560
remotely operated they have a new system

200
00:09:07,590 --> 00:09:05,350
that they have integrated into this

201
00:09:11,130 --> 00:09:07,600
submersible which is based on

202
00:09:14,850 --> 00:09:11,140
microfluidic cartridges which has a it

203
00:09:18,090 --> 00:09:14,860
rotates around and as actuator driven

204
00:09:20,340 --> 00:09:18,100
inside the head of the submersible so we

205
00:09:23,130 --> 00:09:20,350
have adopted elements from from both of

206
00:09:26,340 --> 00:09:23,140
these designs into the concept for

207
00:09:28,980 --> 00:09:26,350
Antony in which the titanium puck would

208
00:09:32,160 --> 00:09:28,990
be delivered to the instrument the

209
00:09:36,500 --> 00:09:32,170
central processing unit here then would

210
00:09:38,880 --> 00:09:36,510
accept the sample and process take it

211
00:09:41,340 --> 00:09:38,890
pressurize the sample in order to be

212
00:09:43,680 --> 00:09:41,350
able to melt it without adding heat or

213
00:09:45,980 --> 00:09:43,690

very much heat and then it would be

214
00:09:49,020 --> 00:09:45,990
passed through different screen sizes

215
00:09:50,820 --> 00:09:49,030
and then those samples can then be

216
00:09:54,720 --> 00:09:50,830
rotated and passed by an optical

217
00:09:57,210 --> 00:09:54,730
microscope an afm and potentially a

218
00:10:00,240 --> 00:09:57,220
third instrument that is on the lander

219
00:10:03,330 --> 00:10:00,250
this all the design fits in the ten

220
00:10:06,240 --> 00:10:03,340
centimeter by 10 centimeter space that

221
00:10:08,430 --> 00:10:06,250
was described in the PIP so there are

222
00:10:09,990 --> 00:10:08,440
several elements that even though we're

223
00:10:11,280 --> 00:10:10,000
basing this on the heritage design of

224
00:10:13,200 --> 00:10:11,290
what has flown before there are a couple

225
00:10:15,090 --> 00:10:13,210
of upgrades that we can do 20 years

226
00:10:19,650 --> 00:10:15,100
later than when these developments were

227
00:10:22,230 --> 00:10:19,660
made the so piezo resistive probes can

228
00:10:27,840 --> 00:10:22,240
be upgraded as well as the actuator and

229
00:10:30,450 --> 00:10:27,850
fine XY scan range to move the sample we

230
00:10:32,190 --> 00:10:30,460
think calibration targets are needed for

231
00:10:34,920 --> 00:10:32,200
every sample processed so that you can

232
00:10:38,960 --> 00:10:34,930
get tip shape on each sample as well as

233
00:10:41,820 --> 00:10:38,970
the XYZ and mechanical force scales

234
00:10:43,950 --> 00:10:41,830
autonomous impressions are going to

235
00:10:46,350 --> 00:10:43,960
require image analysis some of this can

236
00:10:47,490 --> 00:10:46,360
be adopted from heritage algorithms that

237
00:10:49,800 --> 00:10:47,500
were developed from the Phoenix mission

238
00:10:51,990 --> 00:10:49,810

but we also have ideas for how to

239
00:10:55,080 --> 00:10:52,000
compress the data to preserve the high

240
00:10:57,710 --> 00:10:55,090
information aspects of it as well as for

241
00:11:00,480 --> 00:10:57,720
developing neural networks for particle

242
00:11:02,400 --> 00:11:00,490
classification this is based on work

243
00:11:05,610 --> 00:11:02,410
that was done at Oakridge and published

244
00:11:09,090 --> 00:11:05,620
several years ago with a project

245
00:11:11,400 --> 00:11:09,100
collaborator Steven Jesse we also have

246
00:11:14,640 --> 00:11:11,410
there's preliminary work that has been

247
00:11:17,280 --> 00:11:14,650
done with where you can use the AFM to

248
00:11:19,200 --> 00:11:17,290
do correlative mass spectrometry with

249
00:11:21,630 --> 00:11:19,210
particles by heating up the tip of the

250
00:11:23,760 --> 00:11:21,640
AFM you can volatilize the sample and

251
00:11:25,260 --> 00:11:23,770
bring it into a mass spectrometer and so

252
00:11:26,700 --> 00:11:25,270
this could potentially really give us a

253
00:11:31,170 --> 00:11:26,710
lot of information about particles being

254
00:11:33,180 --> 00:11:31,180
observed the advantages of Antony then

255
00:11:35,430 --> 00:11:33,190
are that this is a system as we've

256
00:11:37,290 --> 00:11:35,440
designed it has flexible architecture we

257
00:11:39,680 --> 00:11:37,300
can partner with other instruments it's

258
00:11:42,060 --> 00:11:39,690
integrated sample preparation system

259
00:11:44,130 --> 00:11:42,070
affords us to have high resolution image

260
00:11:48,900 --> 00:11:44,140
and proper image and property

261
00:11:51,000 --> 00:11:48,910
determinations the topographic maps will

262
00:11:52,710 --> 00:11:51,010
be useful information regardless of

263
00:11:55,260 --> 00:11:52,720

whether the particles are biogenic or

264
00:11:57,750 --> 00:11:55,270
abiotic in nature and the Nano

265
00:12:00,780 --> 00:11:57,760
mechanical forces can potentially help

266
00:12:02,850 --> 00:12:00,790
us inform between life-forms and and

267
00:12:04,740 --> 00:12:02,860
those that are that are not life in

268
00:12:07,440 --> 00:12:04,750
terms of stiffness adhesion dissipation

269
00:12:08,730 --> 00:12:07,450
of energy and even in the absence of

270
00:12:10,290 --> 00:12:08,740
life I think that this kind of a

271
00:12:12,540 --> 00:12:10,300
platform can yield invaluable

272
00:12:14,160 --> 00:12:12,550
information about microscope materials

273
00:12:18,480 --> 00:12:14,170
and features in the near subsurface of

274
00:12:21,120 --> 00:12:18,490
Europa the the team here is large and

275
00:12:23,220 --> 00:12:21,130
great and I have learned a ton from

276
00:12:25,680 --> 00:12:23,230
working with all of them Roger approach

277
00:12:30,390 --> 00:12:25,690
is sort of the mastermind behind the AFM

278
00:12:33,630 --> 00:12:30,400
design crystal and is the chief and

279
00:12:37,110 --> 00:12:33,640
president of Ambari and with Jim birch

280
00:12:41,450 --> 00:12:37,120
and Doug market have designed the Europa

281
00:12:51,930 --> 00:12:41,460
generation ESP thank you

282
00:12:57,010 --> 00:12:55,480
yeah given that you're looking at very

283
00:12:58,720 --> 00:12:57,020
tiny scales with AFM how do you deal

284
00:13:00,790 --> 00:12:58,730
with searching for things that are

285
00:13:02,440 --> 00:13:00,800
extremely low concentration that you're

286
00:13:03,490 --> 00:13:02,450
likely to see 100 per milliliter or

287
00:13:06,840 --> 00:13:03,500
something like that see if the search

288
00:13:10,120 --> 00:13:06,850

throw a big haystack refer so we have an

289
00:13:12,160 --> 00:13:10,130
the the concept is that we would

290
00:13:15,190 --> 00:13:12,170
concentrate the sample onto a pretty

291
00:13:19,030 --> 00:13:15,200
into a pretty small surface but also

292
00:13:21,070 --> 00:13:19,040
that we would first inspect the the

293
00:13:23,590 --> 00:13:21,080
sample with an optical microscope and

294
00:13:27,370 --> 00:13:23,600
you have a larger scale and then be able

295
00:13:30,640 --> 00:13:27,380
to identify the high entropy areas of

296
00:13:32,560 --> 00:13:30,650
that image and then localize the AFM to

297
00:13:34,450 --> 00:13:32,570
where to go do the work and you can even

298
00:13:36,460 --> 00:13:34,460
still do nested scans like they've done

299
00:13:38,500 --> 00:13:36,470
on both of the other missions with AFM

300
00:13:40,480 --> 00:13:38,510
so you can start at larger and then go

301
00:13:46,510 --> 00:13:40,490
in and a higher resolution at a smaller

302
00:13:48,040 --> 00:13:46,520
area another way of distinguishing

303
00:13:50,380 --> 00:13:48,050
between whether you're looking at

304
00:13:52,930 --> 00:13:50,390
inorganic material or organic or bio

305
00:13:55,120 --> 00:13:52,940
material would be to do a tip enhance

306
00:13:57,850 --> 00:13:55,130
spectroscopy such as tip enhanced Raman

307
00:14:00,400 --> 00:13:57,860
or chip enhanced infrared and I know

308
00:14:02,640 --> 00:14:00,410
it's probably at a lower TRL but what do

309
00:14:05,470 --> 00:14:02,650
you think about the possibilities of

310
00:14:07,420 --> 00:14:05,480
eventually moving to such an enhancement

311
00:14:10,330 --> 00:14:07,430
of the technology yeah I think that's a

312
00:14:13,570 --> 00:14:10,340
super super super interesting an area to

313
00:14:16,600 --> 00:14:13,580

develop for the future and to get that

314
00:14:18,790 --> 00:14:16,610
kind of instrumentation into the sort of