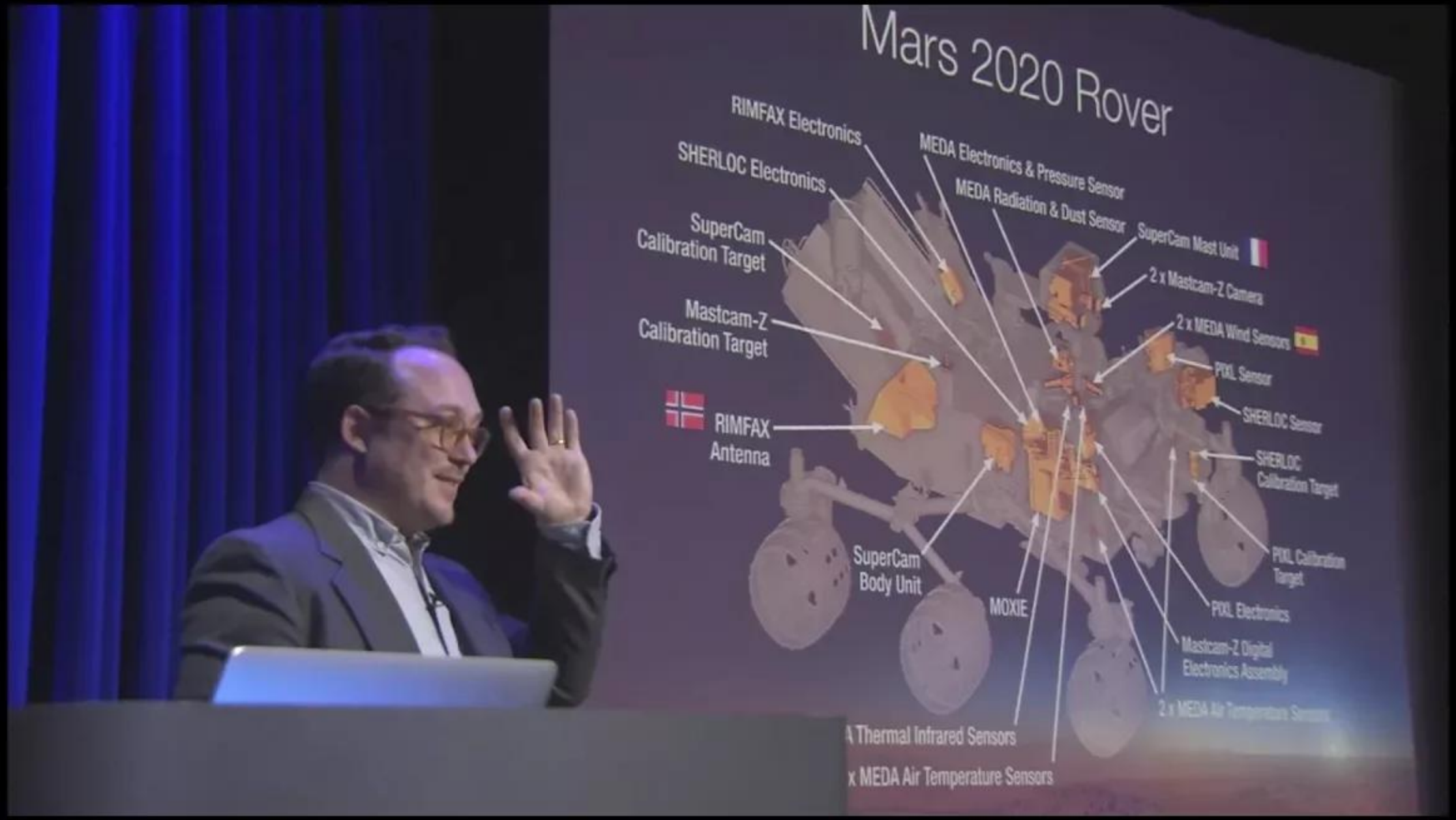
Mars 2020 Rover
RIMFAX Electronics
SHERLOC Electronics
SuperCam Calibration Target
Mastcam-Z Calibration Target
RIMFAX Antenna
MEDA Electronics & Pressure Sensor
MEDA Radiation & Dust Sensor
SuperCam Mast Unit
2 x Mastcam-Z Camera
2 x MEDA Wind Sensors
PIXL Sensor
SHERLOC Sensor
SHERLOC Calibration Target
PIXL Calibration Target
PIXL Electronics
Mastcam-Z Digital Electronics Assembly
2 x MEDA Air Temperature Sensors
SuperCam Body Unit
MOXIE
A Thermal Infrared Sensors
x MEDA Air Temperature Sensors

1
00:00:00,000 --> 00:00:01,469
[ambient electronic music]

2
00:00:01,502 --> 00:00:03,437
- Hey, good evening,
everyone, how's everybody

3
00:00:03,470 --> 00:00:05,206
doing tonight?
[audience applauding]

4
00:00:05,239 --> 00:00:08,376
Woo-hoo [laughs] excellent.

5
00:00:08,409 --> 00:00:11,078
Well, as always, thank
you all very, very much

6
00:00:11,111 --> 00:00:12,780
for coming out to
join us tonight.

7
00:00:12,813 --> 00:00:15,182
Packed the house
tonight, this is amazing.

8
00:00:15,215 --> 00:00:17,885
Good job, you guys, so let's
jump right in, shall we?

9
00:00:17,918 --> 00:00:19,453
Four years from now,

10
00:00:19,486 --> 00:00:23,224
NASA and JPL will once
again rove the Red Planet

11
00:00:23,257 --> 00:00:26,327
with the NASA

Mars 2020 Mission.

12
00:00:26,360 --> 00:00:29,030
This time, mission objectives
include exploration

13
00:00:29,063 --> 00:00:32,033
of extremely ancient habitats
to enable the collection

14
00:00:32,066 --> 00:00:35,603
of samples that could one
day be returned to Earth.

15
00:00:35,636 --> 00:00:38,339
Analysis of these
carefully selected samples,

16
00:00:38,372 --> 00:00:41,809
in laboratories on Earth, would
transform planetary science

17
00:00:41,842 --> 00:00:44,245
and the search for
extraterrestrial life.

18
00:00:44,278 --> 00:00:46,347
Tonight's speaker will
discuss the evolving

19
00:00:46,380 --> 00:00:48,749
scientific strategy
for Mars 2020,

20
00:00:48,782 --> 00:00:51,953
including the impending
selection of a landing site.

21
00:00:51,986 --> 00:00:55,222
Tonight's guest serves as

the deputy project scientist

22
00:00:55,255 --> 00:00:57,892
for the Mars 2020 Lab
and is the director

23
00:00:57,925 --> 00:01:02,029
of the JPL Astro
Biogeochemistry

24
00:01:02,062 --> 00:01:03,698
Laboratory or ABC Lab.

25
00:01:03,731 --> 00:01:06,367
Research in the ABC Lab
is broadly concerned

26
00:01:06,400 --> 00:01:10,037
with tracing the flow of
biologically important elements

27
00:01:10,070 --> 00:01:13,507
through Earth's systems; in
recent years, his research

28
00:01:13,540 --> 00:01:16,644
has focused on developing
analytical techniques to search

29
00:01:16,677 --> 00:01:18,946
for signs of life
and environment

30
00:01:18,979 --> 00:01:21,015
in some of the
oldest rocks on Earth

31
00:01:21,048 --> 00:01:23,217
and then looking to
understand how we can apply

32
00:01:23,250 --> 00:01:25,619
similar techniques to the
search for evidence of life

33
00:01:25,652 --> 00:01:28,889
on other planets, in
rocks, return to Earth

34
00:01:28,922 --> 00:01:32,226
from the surface of
Mars, for example.

35
00:01:32,259 --> 00:01:33,794
Ladies and gentlemen,
please help me welcome

36
00:01:33,827 --> 00:01:36,497
tonight's guest,
Dr. Ken Williford.

37
00:01:36,530 --> 00:01:42,737
[audience applauding]

38
00:01:42,770 --> 00:01:49,043
- Thanks.

39
00:01:49,076 --> 00:01:51,746
Thanks very much and
good evening, everybody.

40
00:01:51,779 --> 00:01:55,750
Thanks also for me for coming
tonight, for coming out.

41
00:01:55,783 --> 00:02:00,054
It's great to see a
full room of people.

42

00:02:00,087 --> 00:02:02,456
Thanks also to the organizers

43
00:02:02,489 --> 00:02:03,858
of the von Karman
Series were inviting

44
00:02:03,891 --> 00:02:06,360
me to give this
lecture tonight.

45
00:02:06,393 --> 00:02:08,596
It's such a pleasure to be able

46
00:02:08,629 --> 00:02:11,265
to stand in front
of you all tonight

47
00:02:11,298 --> 00:02:13,401
and share what
were doing to get

48
00:02:13,434 --> 00:02:17,505
the next NASA rover under
the surface of Mars.

49
00:02:17,538 --> 00:02:21,042
So as as Mark said, my
name's Ken Williford.

50
00:02:21,075 --> 00:02:23,744
I'm the deputy project
scientist for Mars 2020

51
00:02:23,777 --> 00:02:25,980
and I see some JPL folks here.

52
00:02:26,013 --> 00:02:28,149
You still have your
badges on but I know

53
00:02:28,182 --> 00:02:30,151
there are some people
in the room, hopefully,

54
00:02:30,184 --> 00:02:32,153
a lot of people in the
room who don't work at JPL

55
00:02:32,186 --> 00:02:34,722
and aren't as familiar
with this kind of thing

56
00:02:34,755 --> 00:02:37,992
and what it means to be the
deputy project scientist,

57
00:02:38,025 --> 00:02:40,528
of course, is to work with
the project scientist.

58
00:02:40,561 --> 00:02:43,397
You can't have a deputy
without that guy.

59
00:02:43,430 --> 00:02:46,033
There's two of us,
deputy project scientist

60
00:02:46,066 --> 00:02:48,936
and a project scientist
and three of us together

61
00:02:48,969 --> 00:02:53,307
work to coordinate the efforts
of a very large science team,

62
00:02:53,340 --> 00:02:56,744
hundreds of people we
have already on the team

63
00:02:56,777 --> 00:02:59,580
that came to us through
a competitive selection

64
00:02:59,613 --> 00:03:02,283
of investigations
that we usually talk

65
00:03:02,316 --> 00:03:04,485
about as instruments
on the payload.

66
00:03:04,518 --> 00:03:07,288
So we have a number of
instruments that I'll tell

67
00:03:07,321 --> 00:03:09,690
you about later
that were selected

68
00:03:09,723 --> 00:03:14,495
from over 50, I
think, proposals.

69
00:03:14,528 --> 00:03:17,064
Rides to the surface
of Mars are very few

70
00:03:17,097 --> 00:03:19,967
and far between so lots
of people like to propose

71
00:03:20,000 --> 00:03:22,436
to put their scientific
instrument on the rover.

72
00:03:22,469 --> 00:03:26,073
Several of those were selected
and each of those instruments

73
00:03:26,106 --> 00:03:29,643
or investigations have a
team associated with them

74
00:03:29,676 --> 00:03:33,881
so a principal investigator and
a number of co-investigators

75
00:03:33,914 --> 00:03:36,917
who write the proposal
together and if selected,

76
00:03:36,950 --> 00:03:38,786
they become part of
the science team,

77
00:03:38,819 --> 00:03:40,488
so that's our science
team currently:

78
00:03:40,521 --> 00:03:42,990
all those people who
wrote those proposals

79
00:03:43,023 --> 00:03:45,526
and had their instruments
selected for inclusion

80
00:03:45,559 --> 00:03:49,463
on the rover, so that
large science team

81
00:03:49,496 --> 00:03:52,199
needs some help keeping
itself coordinated

82
00:03:52,232 --> 00:03:56,303
and managed and on task
and that's our job.

83
00:03:56,336 --> 00:03:58,472
We try to help the science team

84
00:03:58,505 --> 00:04:00,708
be as efficient and
functional as possible

85
00:04:00,741 --> 00:04:03,444
and we try to provide a
synthetic scientific view

86
00:04:03,477 --> 00:04:06,447
or a vision, a guiding
vision for the mission

87
00:04:06,480 --> 00:04:09,116
and some of that I'll
share with you tonight.

88
00:04:09,149 --> 00:04:12,153
So my other job here at JPL,

89
00:04:12,186 --> 00:04:14,989
the job I came here
to do was to set up

90
00:04:15,022 --> 00:04:17,892
an organic geochemistry
lab that we now call

91
00:04:17,925 --> 00:04:21,529
the ABC Lab and I did
that several years ago

92
00:04:21,562 --> 00:04:24,131
and it's now a functioning lab

93
00:04:24,164 --> 00:04:28,102

and the kind of work we do
is we work to understand

94
00:04:28,135 --> 00:04:31,572
some of the oldest
records of life on Earth,

95
00:04:31,605 --> 00:04:35,042
the earliest records of life
on Earth, if we can find them,

96
00:04:35,075 --> 00:04:38,012
and then how living systems
and nonliving systems

97
00:04:38,045 --> 00:04:41,849
have co-evolved on the planet
Earth over its long history

98
00:04:41,882 --> 00:04:45,352
and as we do that, we
develop and apply methods

99
00:04:45,385 --> 00:04:48,622
to study those questions
that would be relevant.

100
00:04:48,655 --> 00:04:50,624
They're the same types
of methods that we hope

101
00:04:50,657 --> 00:04:55,596
to apply someday on samples
that we bring back from Mars.

102
00:04:55,629 --> 00:04:59,667
And so that leads me
to one of the things,

103
00:04:59,700 --> 00:05:03,270

maybe the biggest thing that's
distinct about this mission

104
00:05:03,303 --> 00:05:05,706
compared to previous
missions and that

105
00:05:05,739 --> 00:05:07,741
is that we have an
objective to collect

106
00:05:07,774 --> 00:05:11,745
a set of samples that
if we're successful

107
00:05:11,778 --> 00:05:15,649
collecting a high-value
set of samples

108
00:05:15,682 --> 00:05:18,719
and NASA decides to
do so in the future

109
00:05:18,752 --> 00:05:20,688
or the international
community decides to do so

110
00:05:20,721 --> 00:05:24,058
in the future, could one
day be returned to Earth

111
00:05:24,091 --> 00:05:27,728
for future study
and as Mark said,

112
00:05:27,761 --> 00:05:30,331
that could be really
transformative

113
00:05:30,364 --> 00:05:31,499

to planetary science

114
00:05:31,532 --> 00:05:34,568
and the study of life in the
universe, to astrobiology.

115
00:05:34,601 --> 00:05:37,605
That's the kind of science
that I like to focus on.

116
00:05:37,638 --> 00:05:40,307
So we call that
potential effort, we call

117
00:05:40,340 --> 00:05:42,910
that Mars Sample Return
and it's a concept

118
00:05:42,943 --> 00:05:45,846
that's existed for
quite a while, in fact,

119
00:05:45,879 --> 00:05:49,984
it goes back at least to
Pathfinder to Sojourner,

120
00:05:50,017 --> 00:05:53,320
the first rover, I'll show
you a picture of in a moment.

121
00:05:53,353 --> 00:05:56,624
As soon as NASA was
successful roving the surface

122
00:05:56,657 --> 00:05:59,293
of Mars, it became
apparent that we can start

123
00:05:59,326 --> 00:06:01,095
to think about

Mars Sample Return,

124
00:06:01,128 --> 00:06:04,431
but that's been a
long time ago now

125
00:06:04,464 --> 00:06:08,002
and we're just now taking
that big critical first step

126
00:06:08,035 --> 00:06:10,804
of Mars Sample Return, which
is the careful scientific

127
00:06:10,837 --> 00:06:14,441
selection of the samples that
could one day be returned.

128
00:06:14,474 --> 00:06:17,511
So that brings me to, that
was the businesslike title

129
00:06:17,544 --> 00:06:20,147
that I usually show when
I do this talk this.

130
00:06:20,180 --> 00:06:23,117
This is the cheeky subtitle
year for the Tolkien fans

131
00:06:23,150 --> 00:06:25,552
in the audience,
There and Back Again,

132
00:06:25,585 --> 00:06:28,622
so that's what I'm
talking about there.

133
00:06:28,655 --> 00:06:31,792
So, hopefully, we get

to come back again.

134
00:06:31,825 --> 00:06:36,530
I'd like to take a couple
moments now just for you

135
00:06:36,563 --> 00:06:40,200
to all of gaze lovingly at
this photograph of Mars.

136
00:06:40,233 --> 00:06:44,305
It's really a mosaic put
together quite a while ago now.

137
00:06:44,338 --> 00:06:47,408
It's a very beautiful
image of Mars put together

138
00:06:47,441 --> 00:06:52,179
by the Viking mission
and so take a moment.

139
00:06:52,212 --> 00:06:54,948
I'm gonna stop talking
but I'd like you

140
00:06:54,981 --> 00:06:58,218
to just when I when I am
quiet, all the thoughts

141
00:06:58,251 --> 00:07:00,321
about Mars that rush into
your head, all the things

142
00:07:00,354 --> 00:07:03,023
that you know about Mars or
think you know about Mars,

143
00:07:03,056 --> 00:07:05,025
the images you've see,

the beautiful pictures

144
00:07:05,058 --> 00:07:08,395
from the rovers and
the orbiters on Mars,

145
00:07:08,428 --> 00:07:12,032
this included, think about
how much we already know

146
00:07:12,065 --> 00:07:21,642
about her planetary
neighbor Mars.

147
00:07:21,675 --> 00:07:24,411
Right, it's amazing, we
know an incredible amount

148
00:07:24,444 --> 00:07:28,015
about Mars but now
that we've done that,

149
00:07:28,048 --> 00:07:29,983
I'd like you to do the opposite

150
00:07:30,016 --> 00:07:31,885
and wipe all of that clean.

151
00:07:31,918 --> 00:07:34,655
Let's roll back the
clock 1,000 years,

152
00:07:34,688 --> 00:07:37,291
and take a look at what
Mars would've looked like

153
00:07:37,324 --> 00:07:41,295
for the vast majority
of human history.

154
00:07:41,328 --> 00:07:43,897
[audience laughing]

155
00:07:43,930 --> 00:07:48,135
Yeah, so it's a tiny spot,

156
00:07:48,168 --> 00:07:50,904
if you're really lucky,
a tiny, tiny disk

157
00:07:50,937 --> 00:07:54,908
of light in the night
sky, slightly reddish

158
00:07:54,941 --> 00:07:57,511
had a movement that
was strange relative

159
00:07:57,544 --> 00:07:59,747
to the stars, the other
pinpricks of light

160
00:07:59,780 --> 00:08:03,016
in the night, but think
about for how many thousands

161
00:08:03,049 --> 00:08:05,819
and thousands and
thousands of years,

162
00:08:05,852 --> 00:08:08,255
people looked up at Mars
and all the thoughts

163
00:08:08,288 --> 00:08:13,394
they had about it compared
to what we know now.

164
00:08:13,427 --> 00:08:17,231

And so moving from here, I'd
like to just take you back

165
00:08:17,264 --> 00:08:21,001
and just take a quick look
at how far we've come.

166
00:08:21,034 --> 00:08:23,270
So fast-forward now
several centuries

167
00:08:23,303 --> 00:08:26,774
to the earliest telescopes
and it got so much better.

168
00:08:26,807 --> 00:08:28,776
I mean, look at that.

169
00:08:28,809 --> 00:08:30,711
That's fantastic, isn't it?

170
00:08:30,744 --> 00:08:33,947
You start to see some,
a little bit of detail

171
00:08:33,980 --> 00:08:36,850
emerging from planet Mars,

172
00:08:36,883 --> 00:08:39,386
but not too much,
certainly nothing

173
00:08:39,419 --> 00:08:41,688
compared to what we know now.

174
00:08:41,721 --> 00:08:45,192
Fast-forward now
to 1886 and we have

175

00:08:45,225 --> 00:08:47,928
this map of Mars put together

176
00:08:47,961 --> 00:08:53,667
by the Italian astronomer
Giovanni Schiaparelli

177
00:08:53,700 --> 00:08:58,839
and so this is the product
of a very long time.

178
00:08:58,872 --> 00:09:01,909
I really don't know how
long but a long time.

179
00:09:01,942 --> 00:09:04,478
Imagine the night after
night after night,

180
00:09:04,511 --> 00:09:07,815
all the careful
painstaking observation

181
00:09:07,848 --> 00:09:11,785
through those early telescopes
that was done by Schiaparelli

182
00:09:11,818 --> 00:09:15,289
patiently observing
and sketching

183
00:09:15,322 --> 00:09:18,358
and checking to see
if he was correct

184
00:09:18,391 --> 00:09:21,829
night after night and
then adding names,

185
00:09:21,862 --> 00:09:24,565

building a geography
of another planet.

186
00:09:24,598 --> 00:09:28,735
Imagine how exciting
that must've been

187
00:09:28,768 --> 00:09:29,869
in those early days.

188
00:09:29,903 --> 00:09:33,106
And I'd just like to take
a moment to read something

189
00:09:33,139 --> 00:09:38,378
from Schiaparelli's book
[speaks in foreign language].

190
00:09:38,411 --> 00:09:41,415
Rather than true channels
in a form familiar to us,

191
00:09:41,448 --> 00:09:43,784
we must imagine
depressions in the soil

192
00:09:43,817 --> 00:09:45,953
that are not very deep,

193
00:09:45,986 --> 00:09:47,054
extended in a
straight direction

194
00:09:47,087 --> 00:09:49,056
for thousands of
miles over a width

195
00:09:49,089 --> 00:09:52,826
of 100, 200 kilometers
and maybe more.

196
00:09:52,859 --> 00:09:54,895
I've already pointed
out that in the absence

197
00:09:54,928 --> 00:09:57,898
of rain on Mars, these
channels are probably

198
00:09:57,931 --> 00:10:00,667
the main mechanism by which
the water and with it,

199
00:10:00,700 --> 00:10:05,506
organic life can spread on
the dry surface of the planet.

200
00:10:05,539 --> 00:10:08,342
Interesting, isn't it?

201
00:10:08,375 --> 00:10:11,645
How far we've come but
how little has changed

202
00:10:11,678 --> 00:10:14,147
[chuckles] so this
is very much,

203
00:10:14,180 --> 00:10:15,983
I can imagine
Schiaparelli

204
00:10:16,016 --> 00:10:19,786
standing up at a landing site
selection workshop almost

205
00:10:19,819 --> 00:10:22,256
and making this, you
know, stating this

206
00:10:22,289 --> 00:10:23,690
as the objectives
for the mission.

207
00:10:23,723 --> 00:10:25,592
This is Mars astrobiology
was happening

208
00:10:25,625 --> 00:10:28,862
all the way back in 1893.

209
00:10:28,895 --> 00:10:31,331
But then a couple
decades later,

210
00:10:31,364 --> 00:10:32,933
it was all figured out, right?

211
00:10:32,966 --> 00:10:35,869
This New York Times,
Percival Lowell,

212
00:10:35,902 --> 00:10:38,038
There is Life on
the Planet Mars

213
00:10:38,071 --> 00:10:41,141
and so Professor
Percival Lowell here

214
00:10:41,174 --> 00:10:45,546
observing above Arizona,

215
00:10:45,579 --> 00:10:47,281
looking in the
skies above Arizona,

216
00:10:47,314 --> 00:10:50,050
observing these channels,

217
00:10:50,083 --> 00:10:53,120
which he interpreted as
not only evidence of life

218
00:10:53,153 --> 00:10:56,790
on Mars, but evidence of
intelligent life on Mars,

219
00:10:56,823 --> 00:11:01,929
life so intelligent that
it could dig canals.

220
00:11:01,962 --> 00:11:05,832
But let's fast-forward again
to the first successful flyby

221
00:11:05,865 --> 00:11:09,169
of Mars, the first image ever
sent back from deep space.

222
00:11:09,202 --> 00:11:13,373
This is a Mariner 4 in
1965 and this is an image

223
00:11:13,406 --> 00:11:17,044
of the surface of
Mars and it struck

224
00:11:17,077 --> 00:11:19,746
the scientific community
at the time that Mars

225
00:11:19,779 --> 00:11:21,748
did not look like a
planet that was teeming

226
00:11:21,781 --> 00:11:23,884
with intelligent
life but instead,

227
00:11:23,917 --> 00:11:29,890
looked like a fairly desolate
gray cratered surface.

228
00:11:29,923 --> 00:11:34,027
Now, moving a little
bit forward to 1975

229
00:11:34,060 --> 00:11:37,798
and Venera 9, first image
sent back from the surface

230
00:11:37,831 --> 00:11:41,501
of another planet but
not Mars, anybody know

231
00:11:41,534 --> 00:11:43,203
what planet this is?

232
00:11:43,236 --> 00:11:45,772
- Venus.
- Venus, of course, yeah.

233
00:11:45,805 --> 00:11:49,343
So and not a JPL
mission, by the way,

234
00:11:49,376 --> 00:11:53,280
This is the Soviet
Union had this honor

235
00:11:53,313 --> 00:11:55,582
of sending back the first
images from the surface

236
00:11:55,615 --> 00:11:58,051
of another planet; it's
really an incredible technical

237
00:11:58,084 --> 00:12:02,489
achievement, ask any of the
engineers in the audience,

238
00:12:02,522 --> 00:12:04,625
to have a spacecraft
on the surface of Venus

239
00:12:04,658 --> 00:12:06,093
and have it survive long enough

240
00:12:06,126 --> 00:12:10,197
to transmit these images back.

241
00:12:10,230 --> 00:12:13,266
But the same year,
NASA was sending

242
00:12:13,299 --> 00:12:15,569
this spacecraft to Mars.

243
00:12:15,602 --> 00:12:19,006
This is, of course, Viking
and this is a two-part mission

244
00:12:19,039 --> 00:12:22,843
that was, well, in multiple
ways it's a two-part mission,

245
00:12:22,876 --> 00:12:25,112
Viking 1 and Viking
2, each of which

246
00:12:25,145 --> 00:12:30,817
had orbiters and landers.

247
00:12:30,850 --> 00:12:34,588
And here's an image
from a Viking orbiter.

248
00:12:34,621 --> 00:12:37,457
I meant to say say on the
last slide but this is fine.

249
00:12:37,490 --> 00:12:40,560
Actually, we'll go back
there, so 1975 happens

250
00:12:40,593 --> 00:12:44,264
to be the year I was born,
so if you wanna have a sense

251
00:12:44,297 --> 00:12:47,567
of how long we've been doing
this sending back pictures

252
00:12:47,600 --> 00:12:51,304
from the surface of the other
planets, this is it so I'm it.

253
00:12:51,337 --> 00:12:53,840
Maybe you think I'm old and
we've been doing it forever

254
00:12:53,873 --> 00:12:58,345
or maybe you think I'm young
and is a a brand-new thing

255
00:12:58,378 --> 00:13:01,048
but I don't know whether
I think I'm young

256
00:13:01,081 --> 00:13:05,485
or old, but sort of
in between, I hope.

257
00:13:05,518 --> 00:13:08,055
Anyway, Viking orbiter
so some great images

258
00:13:08,088 --> 00:13:11,158
sent back from
orbit around Mars.

259
00:13:11,191 --> 00:13:13,827
We start to see some real
beautiful detail emerging

260
00:13:13,860 --> 00:13:15,896
on the surface and, of course,

261
00:13:15,929 --> 00:13:19,099
clouds, fantastic
clouds on Mars.

262
00:13:19,132 --> 00:13:21,702
Now we get the Viking landers.

263
00:13:21,735 --> 00:13:24,204
This is the first image
sent back, as far as I know,

264
00:13:24,237 --> 00:13:27,607
from the surface of Mars
showing the foot of the lander

265
00:13:27,640 --> 00:13:30,510
there and some Martian
regolith and rocks

266
00:13:30,543 --> 00:13:34,347
in the field of
view, and Viking

267
00:13:34,380 --> 00:13:36,583
was very much an
astrobiology mission,

268

00:13:36,616 --> 00:13:39,786
so a key objective of Viking

269
00:13:39,819 --> 00:13:42,989
was to seek the signs
of life on Mars.

270
00:13:43,022 --> 00:13:46,293
This is distinct from the
objectives that 2020 has,

271
00:13:46,326 --> 00:13:48,762
which is also about seeking
the signs of life on Mars.

272
00:13:48,795 --> 00:13:51,598
Viking's objective was to
seek the signs of extant life

273
00:13:51,631 --> 00:13:54,067
on Mars, that is,
life that was alive

274
00:13:54,100 --> 00:13:56,737
at the time or
had recently died,

275
00:13:56,770 --> 00:14:00,540
and so the question was, is
there life on Mars currently?

276
00:14:00,573 --> 00:14:03,910
And to do this, in
part, Viking reached out

277
00:14:03,943 --> 00:14:06,680
and scooped some of the
soil at its landing site

278
00:14:06,713 --> 00:14:11,351

and brought it into a different
instruments within Lander

279
00:14:11,384 --> 00:14:14,221
and did some, a number
of biology experiments.

280
00:14:14,254 --> 00:14:17,424
So these results were
basically negative

281
00:14:17,457 --> 00:14:20,427
to inconclusive,
depending who you talk to.

282
00:14:20,460 --> 00:14:22,963
Most of the scientific
community agrees, I would say,

283
00:14:22,996 --> 00:14:26,266
that the Viking results of
the life detection experiments

284
00:14:26,299 --> 00:14:28,602
were negative, that
is, they did not show

285
00:14:28,635 --> 00:14:33,440
compelling evidence for life
on Mars, extant life on Mars.

286
00:14:33,473 --> 00:14:37,978
And so a couple decades went
of sort of a dark period

287
00:14:38,011 --> 00:14:41,114
for Martian astrobiology
and one of the things

288
00:14:41,147 --> 00:14:44,151

that turn that around
was this discovery,

289
00:14:44,184 --> 00:14:47,053
this sort of
sausagy shaped thing

290
00:14:47,086 --> 00:14:51,858
in this Martian meteorite,
the Allan Hills meteorite,

291
00:14:51,891 --> 00:14:55,295
ALH84001, so the first
meteorite collected

292
00:14:55,328 --> 00:14:57,931
from the Allen Hills
region of Antarctica

293
00:14:57,964 --> 00:15:01,067
in the '84, 1984
collection season

294
00:15:01,100 --> 00:15:04,137
and this is, we believe,
a Martian meteorite,

295
00:15:04,170 --> 00:15:06,940
so some big rock
impacted the planet Mars,

296
00:15:06,973 --> 00:15:10,410
threw material off
of the planet Mars,

297
00:15:10,443 --> 00:15:16,283
some of which eventually
made its way to Earth

298
00:15:16,316 --> 00:15:18,018

and made it into our
laboratories and some people

299
00:15:18,051 --> 00:15:22,289
in '96, Chris McKay and others

300
00:15:22,322 --> 00:15:29,796
published a paper
documenting these features,

301
00:15:29,829 --> 00:15:32,599
sorry, Dave McKay,
not Chris McKay,

302
00:15:32,632 --> 00:15:36,303
published a paper
documenting these features

303
00:15:36,336 --> 00:15:39,139
and presenting what they
felt was potential evidence

304
00:15:39,172 --> 00:15:42,075
for fossil life in
this Martian meteorite.

305
00:15:42,108 --> 00:15:43,844
It was very exciting
at the time.

306
00:15:43,877 --> 00:15:46,546
Bill Clinton gave a
press conference about it

307
00:15:46,579 --> 00:15:48,982
so it got the attention
of the whole nation

308
00:15:49,015 --> 00:15:52,452
and in a sense, it launched,

it helped very much

309
00:15:52,485 --> 00:15:56,923
to launch the field that I'm
now a member of: astrobiology.

310
00:15:56,956 --> 00:15:59,259
The NASA Astrobiology
Institute started

311
00:15:59,292 --> 00:16:01,695
soon after this; people
had been studying

312
00:16:01,728 --> 00:16:04,731
exobiology before that,
which is basically

313
00:16:04,764 --> 00:16:06,633
the same thing but we
renamed astrobiology

314
00:16:06,666 --> 00:16:10,403
and so it really
stirred the pot

315
00:16:10,436 --> 00:16:13,940
of the search for life,
extraterrestrial life,

316
00:16:13,973 --> 00:16:16,877
and particularly life
on Mars, but similar

317
00:16:16,910 --> 00:16:19,779
to the Viking experiments,
further work was done

318
00:16:19,812 --> 00:16:23,116
and most scientists, I

would say, do not believe

319
00:16:23,149 --> 00:16:25,118
that this represents
a good evidence

320
00:16:25,151 --> 00:16:28,655
of ancient life on Mars but
it certainly got us thinking.

321
00:16:28,688 --> 00:16:30,991
And help to set the
tone and it helped

322
00:16:31,024 --> 00:16:33,026
to set the strategy that we use

323
00:16:33,059 --> 00:16:35,061
for searching for life on Mars

324
00:16:35,094 --> 00:16:37,063
and we employ, on Mars
2020, we will employ

325
00:16:37,096 --> 00:16:39,766
a strategy that's very
similar to that used

326
00:16:39,799 --> 00:16:42,602
by the workers who investigated
the Allan Hills meteorite.

327
00:16:42,635 --> 00:16:46,973
So the year later, we
had the first Mars rover,

328
00:16:47,006 --> 00:16:49,242
the little, trusty
little sojourner,

329
00:16:49,275 --> 00:16:50,810
part of the Pathfinder mission.

330
00:16:50,843 --> 00:16:53,046
It originally had a
seven-day prime mission

331
00:16:53,079 --> 00:16:55,649
that was extended
to 30-day mission,

332
00:16:55,682 --> 00:16:59,352
ended surviving
for maybe 54 days,

333
00:16:59,385 --> 00:17:01,955
I think, something like that.

334
00:17:01,988 --> 00:17:04,457
Here it is investigating
target Yogi

335
00:17:04,490 --> 00:17:07,594
and interestingly, some
of the same features,

336
00:17:07,627 --> 00:17:09,896
some of the basic
mobility system there,

337
00:17:09,929 --> 00:17:12,499
the basic architecture
of the rover continues

338
00:17:12,532 --> 00:17:15,669
in our designs today,
then, of course,

339
00:17:15,702 --> 00:17:18,171

we got to Spirit
and Opportunity,

340
00:17:18,204 --> 00:17:20,807
a twin pair of rovers that
went to two different places

341
00:17:20,840 --> 00:17:26,579
on Mars and in 2004,

342
00:17:26,612 --> 00:17:28,481
made a bunch of
great discoveries,

343
00:17:28,514 --> 00:17:31,418
including very good
geochemical evidence

344
00:17:31,451 --> 00:17:33,820
from the surface of Mars
for the past presence

345
00:17:33,853 --> 00:17:37,657
of liquid water on
Mars and then followed

346
00:17:37,690 --> 00:17:41,227
up by a much larger, much
more complex rover, MSL's,

347
00:17:41,260 --> 00:17:43,897
Mars Science Laboratory's
Curiosity rover.

348
00:17:43,930 --> 00:17:45,765
Here it is next
to a drill site.

349
00:17:45,798 --> 00:17:48,902
You see a a drill

hole right there

350
00:17:48,935 --> 00:17:51,938
if you're close to the front
and then a mini drill hole

351
00:17:51,971 --> 00:17:53,940
that was rolled
first to sort of test

352
00:17:53,973 --> 00:17:55,675
and see if this
rock would be safe

353
00:17:55,708 --> 00:17:57,811
for a full drill,
but Curiosity made

354
00:17:57,844 --> 00:17:59,980
many, many important
discoveries

355
00:18:00,013 --> 00:18:03,383
and continues to make
important discoveries today.

356
00:18:03,416 --> 00:18:05,785
One of the most
important things it did

357
00:18:05,818 --> 00:18:08,722
was it investigated very
early in its mission

358
00:18:08,755 --> 00:18:11,925
an area called Yellowknife Bay

359
00:18:11,958 --> 00:18:13,994
and in Yellowknife
Bay, Curiosity

360
00:18:14,027 --> 00:18:17,263
and the science team
discovered some mudstones,

361
00:18:17,296 --> 00:18:19,966
so some some rocks that
originally would've been mud,

362
00:18:19,999 --> 00:18:22,569
probably deposited on the floor

363
00:18:22,602 --> 00:18:25,405
on the bed of a lake,
very ancient lake,

364
00:18:25,438 --> 00:18:27,640
more than three
billion years old,

365
00:18:27,673 --> 00:18:29,809
and that Lakewood
would've had water in it

366
00:18:29,842 --> 00:18:32,512
that was circumneutral
in its pH,

367
00:18:32,545 --> 00:18:35,715
that is, it's close in
its pH and its mixture

368
00:18:35,748 --> 00:18:39,786
of acid and base to the water
that comes out of your tap

369
00:18:39,819 --> 00:18:43,156
and Curiosity determine
that by investigating

370
00:18:43,189 --> 00:18:45,725
the minerals that were
found in that rock,

371
00:18:45,758 --> 00:18:48,061
preserved in that rock
that were produced

372
00:18:48,094 --> 00:18:49,996
in the presence of
that liquid water

373
00:18:50,029 --> 00:18:51,998
and then it made many
other measurements

374
00:18:52,031 --> 00:18:54,567
on the samples of that mudstone

375
00:18:54,600 --> 00:18:58,004
and detected organic
molecules in that rock,

376
00:18:58,037 --> 00:19:00,240
very, very little but
but they did detect

377
00:19:00,273 --> 00:19:02,709
organic molecules;
they measured

378
00:19:02,742 --> 00:19:07,247
the isotopic composition of
hydrogen that came out of,

379
00:19:07,280 --> 00:19:09,783
that originally was
associated with water,

380

00:19:09,816 --> 00:19:12,085
that we think, in the
environment of formation

381
00:19:12,118 --> 00:19:14,087
of the clay minerals
and that mudstone

382
00:19:14,120 --> 00:19:16,589
The isotopic composition
of that hydrogen

383
00:19:16,622 --> 00:19:19,426
told us that at the
time of deposition

384
00:19:19,459 --> 00:19:21,394
of that rock, the
atmosphere of Mars

385
00:19:21,427 --> 00:19:23,897
had not completely
escaped, so Mars today

386
00:19:23,930 --> 00:19:26,833
has a very, very thin
atmosphere compared to Earth.

387
00:19:26,866 --> 00:19:30,070
But in order to have a
lake on the surface of Mars

388
00:19:30,103 --> 00:19:31,905
and to deposit rocks like that,

389
00:19:31,938 --> 00:19:34,908
we believe that Mars must've
had a much thicker atmosphere

390
00:19:34,941 --> 00:19:40,447

over three billion years
ago with much more water.

391
00:19:40,480 --> 00:19:42,849
Okay.

392
00:19:42,882 --> 00:19:47,120
So this is a busy slide but
that's sort of the point.

393
00:19:47,153 --> 00:19:51,057
This shows you the missions
that are currently active

394
00:19:51,090 --> 00:19:53,660
on the surface of
Mars or planned

395
00:19:53,693 --> 00:19:57,464
for the near future or
sort of the farther future

396
00:19:57,497 --> 00:20:02,001
and so one thing to note
here is all of the orbiters

397
00:20:02,034 --> 00:20:06,106
that we have around Mars
and it's these orbiters

398
00:20:06,139 --> 00:20:08,842
that give us such great
scientific knowledge

399
00:20:08,875 --> 00:20:12,178
about the surface of Mars
and really are the key

400
00:20:12,211 --> 00:20:14,781
to us selecting

scientifically valuable

401
00:20:14,814 --> 00:20:17,417
and safe landing
sites for our rover

402
00:20:17,450 --> 00:20:20,320
so it's only because
of these orbiters

403
00:20:20,353 --> 00:20:22,922
and their ability to take very
high resolution photographs

404
00:20:22,955 --> 00:20:25,892
of the surface with
resolution high enough

405
00:20:25,925 --> 00:20:28,495
to see rocks that
are large enough

406
00:20:28,528 --> 00:20:32,165
that could tip over the rover
of the rover lands on it.

407
00:20:32,198 --> 00:20:34,200
That's what allows us
to land such a complex

408
00:20:34,233 --> 00:20:38,738
and capable rover such as
Curiosity or Mars 2020.

409
00:20:38,771 --> 00:20:40,673
And then moving out
here, of course,

410
00:20:40,706 --> 00:20:42,609
we hope to get insight

on the surface.

411
00:20:42,642 --> 00:20:45,445
This will study the
subsurface of Mars,

412
00:20:45,478 --> 00:20:48,014
looking for Mars
quakes, et cetera.

413
00:20:48,047 --> 00:20:50,750
Other orbiters, the
United Arab Emirates

414
00:20:50,783 --> 00:20:54,721
is planning an orbiter
in the 2020 timeframe.

415
00:20:54,754 --> 00:20:58,024
India successfully made
it into Mars orbit.

416
00:20:58,057 --> 00:21:00,560
That's a fantastic
achievement there.

417
00:21:00,593 --> 00:21:03,830
China has several
Mars missions planned,

418
00:21:03,863 --> 00:21:07,767
including a concept
from Mars Sample Return

419
00:21:07,800 --> 00:21:10,403
so we'll see there;
note that you don't see

420
00:21:10,436 --> 00:21:15,441
a United States Sample

Return mission labeled there

421
00:21:15,474 --> 00:21:18,478
so we've only gone as far
as to say we're planning

422
00:21:18,511 --> 00:21:21,381
Mars 2020, of course,
based on our success

423
00:21:21,414 --> 00:21:25,218
and based on future
priorities, I certainly hope

424
00:21:25,251 --> 00:21:26,920
that we do something like this

425
00:21:26,953 --> 00:21:28,388
and work to get
our samples back

426
00:21:28,421 --> 00:21:30,857
but that's uncertain right now,

427
00:21:30,890 --> 00:21:33,526
and then ExoMars
so the Europeans,

428
00:21:33,559 --> 00:21:37,931
the European Space Agency
is planning a rover

429
00:21:37,964 --> 00:21:41,801
to launch also in 2020 and land

430
00:21:41,834 --> 00:21:44,003
at a different
place than Mars 2020

431

00:21:44,036 --> 00:21:50,076
and explore the surface for
signs of ancient life as well.

432
00:21:50,109 --> 00:21:53,580
Now moving to 2021, and I hope

433
00:21:53,613 --> 00:21:56,950
we see some images
like this in 2021.

434
00:21:56,983 --> 00:21:59,352
This is an artist concept.

435
00:21:59,385 --> 00:22:01,955
It's a pretty
detailed CAD drawing

436
00:22:01,988 --> 00:22:07,093
of our rover sitting in a
Martian environment there

437
00:22:07,126 --> 00:22:09,529
so just to give
you a sense of what

438
00:22:09,562 --> 00:22:12,198
we plan he rover to look like.

439
00:22:12,231 --> 00:22:14,767
It looks very
similar to Curiosity.

440
00:22:14,800 --> 00:22:18,171
Those of you familiar with
that rover will recognize this

441
00:22:18,204 --> 00:22:20,473
and a lot of the
features are the same.

442
00:22:20,506 --> 00:22:23,343
In fact, as much is possible,
we have kept the features

443
00:22:23,376 --> 00:22:26,246
of Mars 2020 the
same as Curiosity

444
00:22:26,279 --> 00:22:29,382
and we're taking what we
call a heritage approach,

445
00:22:29,415 --> 00:22:31,551
that is, we inherit
as much as possible

446
00:22:31,584 --> 00:22:35,188
the designs, all the hard work
that went into the designs

447
00:22:35,221 --> 00:22:38,858
of MSL that has been and
continues to be so successful

448
00:22:38,891 --> 00:22:41,027
so that we don't have
to reinvent the wheel

449
00:22:41,060 --> 00:22:44,097
so to speak, although we
are reinventing the wheels

450
00:22:44,130 --> 00:22:45,898
[audience chuckling]
because Curiosity

451
00:22:45,931 --> 00:22:47,634
had some problems
with its wheels.

452
00:22:47,667 --> 00:22:49,602
They're degrading
faster than expected.

453
00:22:49,635 --> 00:22:51,404
They're still doing
great and we think

454
00:22:51,437 --> 00:22:55,141
they'll last for quite a
while but they're degrading

455
00:22:55,174 --> 00:22:58,778
faster than expected so
we've redesigned the wheels.

456
00:22:58,811 --> 00:23:01,481
The wheels on 2020 look very
different than the wheels

457
00:23:01,514 --> 00:23:07,754
on MSL and we think we won't
have any of those issues.

458
00:23:07,787 --> 00:23:11,090
So we plan to launch in 2020.

459
00:23:11,123 --> 00:23:14,193
We are gonna keep the name
of the mission Mars 2020

460
00:23:14,226 --> 00:23:16,029
to make sure that
happens on time.

461
00:23:16,062 --> 00:23:17,730
We hope it looks
exactly like this.

462
00:23:17,763 --> 00:23:20,333
This is the MSL launch

463
00:23:20,366 --> 00:23:23,670
and we will ride
on a very similar,

464
00:23:23,703 --> 00:23:29,942
almost identical launch
vehicle, an Atlas 5 Rocket,

465
00:23:29,975 --> 00:23:32,145
then we move into the
next phase of the mission,

466
00:23:32,178 --> 00:23:34,147
which we call the cruise phase

467
00:23:34,180 --> 00:23:36,349
and so this is the
time that it takes us

468
00:23:36,382 --> 00:23:39,819
to get from outside
of Earth's orbit

469
00:23:39,852 --> 00:23:44,057
to all the way to the
upper atmosphere of Mars.

470
00:23:44,090 --> 00:23:46,492
That takes about seven
months and we will arrive,

471
00:23:46,525 --> 00:23:50,129
I believe, on
February 18th, 2021.

472
00:23:50,162 --> 00:23:52,231

We already know that,
which is incredible to me.

473
00:23:52,264 --> 00:23:53,866
the people who are able to sort

474
00:23:53,899 --> 00:23:57,070
this out and get it accurately,

475
00:23:57,103 --> 00:23:59,605
at which point, we
enter a very short

476
00:23:59,638 --> 00:24:01,708
but extremely exciting
phase of the mission

477
00:24:01,741 --> 00:24:04,977
called Entry Descent
and Landing, EDL,

478
00:24:05,010 --> 00:24:09,449
okay, and so if you haven't
seen a video on YouTube

479
00:24:09,482 --> 00:24:11,617
called Seven Minutes of Terror,

480
00:24:11,650 --> 00:24:15,154
please go google
that, don't do it now.

481
00:24:15,187 --> 00:24:18,524
Do it when you get home but
go check that video out.

482
00:24:18,557 --> 00:24:20,927
It's fantastic; it was produced

483

00:24:20,960 --> 00:24:23,363
for MSL to tell people

484
00:24:23,396 --> 00:24:27,600
about the fantastic new Entry
Descent and Landing System

485
00:24:27,633 --> 00:24:31,104
that that mission used and you
see the final part of it here

486
00:24:31,137 --> 00:24:33,940
called the Sky Crane
Maneuver, and so many people

487
00:24:33,973 --> 00:24:37,910
thought this was crazy
before it worked perfectly

488
00:24:37,943 --> 00:24:43,182
and interesting story, so
I received my job offer

489
00:24:43,215 --> 00:24:47,086
at JPL on a Thursday
and it was the Thursday

490
00:24:47,119 --> 00:24:50,957
before the Sunday on which
this was planned to happen

491
00:24:50,990 --> 00:24:53,626
for MSL and it was come to JPL

492
00:24:53,659 --> 00:24:56,429
and work on Mars Sample Return

493
00:24:56,462 --> 00:24:59,132
and so I thought about
it over the weekend

494
00:24:59,165 --> 00:25:02,468
and watched with
great trepidation

495
00:25:02,501 --> 00:25:07,940
and excitement as MSL just
nailed it in that landing

496
00:25:07,973 --> 00:25:11,611
and so there's this
descent stage here

497
00:25:11,644 --> 00:25:14,814
and the rover is lowered
down on a bridle there

498
00:25:14,847 --> 00:25:16,749
and just touches
down very softly.

499
00:25:16,782 --> 00:25:18,151
So this is totally
distinct

500
00:25:18,184 --> 00:25:19,585
from the previous
rover missions

501
00:25:19,618 --> 00:25:22,155
that used a giant bouncy ball,

502
00:25:22,188 --> 00:25:23,923
that comes down on a parachute

503
00:25:23,956 --> 00:25:26,459
and then in a big
bouncing ball that rolls

504

00:25:26,492 --> 00:25:28,961
to stop and opens
up like a flower

505
00:25:28,994 --> 00:25:31,330
and there's a little platform
and the rover comes off.

506
00:25:31,363 --> 00:25:34,967
That's how the
MER Rovers worked.

507
00:25:35,000 --> 00:25:37,503
But Curiosity and 2020
are much too large

508
00:25:37,536 --> 00:25:39,739
and much too complex
to bounce all around

509
00:25:39,772 --> 00:25:41,574
over the surface
of Mars and so we

510
00:25:41,607 --> 00:25:43,943
have to use this
different method.

511
00:25:43,976 --> 00:25:47,280
Now we can come all the
way down on retro rockets

512
00:25:47,313 --> 00:25:50,650
because that would pollute
the surface of the rover

513
00:25:50,683 --> 00:25:52,785
and pollute the immediate
landing environment

514

00:25:52,818 --> 00:25:55,221
and so we hover there
above the surface

515
00:25:55,254 --> 00:25:58,024
and lower down a bridle
and then the descent stage

516
00:25:58,057 --> 00:26:03,162
flies off and crashes somewhere
safe away from the rover,

517
00:26:03,195 --> 00:26:07,033
then we move into
the long sort of meat

518
00:26:07,066 --> 00:26:10,536
of the mission, the surface
mission, surface operations

519
00:26:10,569 --> 00:26:14,941
and this is what it will
look like basically,

520
00:26:14,974 --> 00:26:19,145
although these images
come from the MSL Hazcams,

521
00:26:19,178 --> 00:26:22,381
the hazard cameras
cameras that are down

522
00:26:22,414 --> 00:26:24,450
along the front
side of the rover.

523
00:26:24,483 --> 00:26:27,186
We will have those
engineering cameras as well

524

00:26:27,219 --> 00:26:29,121
but on 2020,
they'll be in color,

525
00:26:29,154 --> 00:26:31,324
so we'll be able to
put together a set

526
00:26:31,357 --> 00:26:34,293
of images like this in
color for our mission.

527
00:26:34,326 --> 00:26:37,396
We're planning for, building
for a 20-kilometer traverse

528
00:26:37,429 --> 00:26:41,133
capability and we're
qualifying our systems

529
00:26:41,166 --> 00:26:44,003
to 1-1/2 Mars years rather than

530
00:26:44,036 --> 00:26:47,206
the one Mars year
for which Curiosity

531
00:26:47,239 --> 00:26:50,042
was qualified and
the reason for that

532
00:26:50,075 --> 00:26:53,412
is we have an incredibly
ambitious set of objectives,

533
00:26:53,445 --> 00:26:56,816
which I'll go into
here that go beyond,

534
00:26:56,849 --> 00:27:00,086

it builds on what MSL did

535
00:27:00,119 --> 00:27:03,489
and the objectives that
MSL traveled to Mars with.

536
00:27:03,522 --> 00:27:06,259
So we start out just like MSL

537
00:27:06,292 --> 00:27:08,961
landing in a new landing site.

538
00:27:08,994 --> 00:27:11,497
It's new to us but it's
very, very old terrain,

539
00:27:11,530 --> 00:27:13,833
almost certainly older
than three billion years,

540
00:27:13,866 --> 00:27:16,769
3-1/2 billion years
probably, and just like

541
00:27:16,802 --> 00:27:19,572
any field geologist
arriving in a new place,

542
00:27:19,605 --> 00:27:22,408
our robotic field geologist
takes a look around.

543
00:27:22,441 --> 00:27:25,077
So we use our scientific
cameras to look around us,

544
00:27:25,110 --> 00:27:28,347
look at the rocks
and soil or regolith

545
00:27:28,380 --> 00:27:31,717
that we see around us
and try to understand

546
00:27:31,750 --> 00:27:34,520
what was the environment,
the past environment

547
00:27:34,553 --> 00:27:37,890
in which those rocks were
deposited or put into place.

548
00:27:37,923 --> 00:27:40,560
What were the processes
that led to the formation

549
00:27:40,593 --> 00:27:43,129
of those rocks that
we see around us?

550
00:27:43,162 --> 00:27:45,231
That's part one
of objective one.

551
00:27:45,264 --> 00:27:47,233
There's a critical second part.

552
00:27:47,266 --> 00:27:49,769
After those rocks
were deposited,

553
00:27:49,802 --> 00:27:51,938
maybe as sediments on
the bottom of a lake,

554
00:27:51,971 --> 00:27:54,640
maybe as volcanic
rocks put in place

555

00:27:54,673 --> 00:27:57,777
by volcanic eruption,
after they became rocks,

556
00:27:57,810 --> 00:28:00,746
they then had billions
of years to be altered

557
00:28:00,779 --> 00:28:03,015
from their original state,
and this is very important

558
00:28:03,048 --> 00:28:05,751
so we wanna understand
the processes of formation

559
00:28:05,784 --> 00:28:09,488
but also of alteration so
that's the first objective.

560
00:28:09,521 --> 00:28:12,592
Then we move into in
situ astrobiology,

561
00:28:12,625 --> 00:28:15,094
that is astrobiology that
is done on the surface

562
00:28:15,127 --> 00:28:18,030
of the planet Mars and
the first step here

563
00:28:18,063 --> 00:28:21,434
is to take what we are learning
as we go about the geology

564
00:28:21,467 --> 00:28:24,303
of our landing site about
that past environment

565

00:28:24,336 --> 00:28:26,639
and ask the question:
could this environment

566
00:28:26,672 --> 00:28:29,141
have supported life
in the distant past?

567
00:28:29,174 --> 00:28:32,278
That is, was it habitable,
could it have been inhabited?

568
00:28:32,311 --> 00:28:35,114
So we asked that
question and our approach

569
00:28:35,147 --> 00:28:38,484
to that, we basically,
we learn from MSL

570
00:28:38,517 --> 00:28:40,620
so, of course, it's
very important to look

571
00:28:40,653 --> 00:28:44,090
for evidence of liquid
water so liquid water

572
00:28:44,123 --> 00:28:47,426
is basically the one
thing that unites all life

573
00:28:47,459 --> 00:28:51,764
as we know it at some point in
every living organism's life.

574
00:28:51,797 --> 00:28:54,734
It requires liquid water
and so we look for evidence

575

00:28:54,767 --> 00:28:57,236
of liquid water but we
don't just stop there.

576
00:28:57,269 --> 00:29:00,606
We take the next step and
we ask, just like MSL did,

577
00:29:00,639 --> 00:29:02,575
what was the chemistry
of that water?

578
00:29:02,608 --> 00:29:04,910
How long did it
last on the surface?

579
00:29:04,943 --> 00:29:07,913
Was it just an ephemeral
little wispy pond

580
00:29:07,946 --> 00:29:10,282
or was it a deep
leak that lasted

581
00:29:10,315 --> 00:29:12,985
for many, many
thousands of years?

582
00:29:13,018 --> 00:29:15,054
So those sorts of
questions are important

583
00:29:15,087 --> 00:29:17,523
and then we wanna know
what types of things

584
00:29:17,556 --> 00:29:20,459
were dissolved in that
water and what type of rock

585

00:29:20,492 --> 00:29:22,928
was that water in contact with?

586
00:29:22,961 --> 00:29:25,197
What type of rocker that
water have dissolved?

587
00:29:25,230 --> 00:29:27,600
And what type of
elements and molecules

588
00:29:27,633 --> 00:29:29,535
and minerals could've
been re-mobilized

589
00:29:29,568 --> 00:29:31,671
by the water interacting
with the rock

590
00:29:31,704 --> 00:29:35,608
and providing the food and
the fuel for microorganisms?

591
00:29:35,641 --> 00:29:38,377
We're looking for evidence
of ancient life on Mars.

592
00:29:38,410 --> 00:29:40,813
We're not looking for
ancient polar bears

593
00:29:40,846 --> 00:29:43,849
and so forth, big complex life.

594
00:29:43,882 --> 00:29:48,387
We're looking for evidence
of ancient microbial life.

595
00:29:48,420 --> 00:29:50,723
For the vast majority

of Earth history,

596
00:29:50,756 --> 00:29:54,193
all life on Earth
was microbial.

597
00:29:54,226 --> 00:29:57,563
It wasn't until
oxygen first appeared

598
00:29:57,596 --> 00:30:00,566
in the atmosphere of the
Earth 2-1/2 billion years ago

599
00:30:00,599 --> 00:30:04,170
that the stage started to
be set for the emergence

600
00:30:04,203 --> 00:30:07,206
of complex life on Earth,
okay, there many, many ways

601
00:30:07,239 --> 00:30:09,842
to make your living as
an organism on Earth

602
00:30:09,875 --> 00:30:12,445
to metabolize, many
different chemical reactions.

603
00:30:12,478 --> 00:30:14,680
In fact, almost any
chemical reaction

604
00:30:14,713 --> 00:30:17,349
that you can imagine,
there's some organism

605
00:30:17,382 --> 00:30:20,019
making its living

off of that reaction.

606
00:30:20,052 --> 00:30:23,823
We make our living off
of one reaction only.

607
00:30:23,856 --> 00:30:27,526
We go and we seek out
complex organic matter.

608
00:30:27,559 --> 00:30:30,996
We stuff it in our face,
we breathe oxygen in.

609
00:30:31,029 --> 00:30:33,632
We combine that organic matter,
that complex organic matter

610
00:30:33,665 --> 00:30:37,603
with that oxygen and
we basically burn it.

611
00:30:37,636 --> 00:30:39,805
We burn our food,
right, you all know that

612
00:30:39,838 --> 00:30:43,109
and there's a lot of
energy released by that,

613
00:30:43,142 --> 00:30:45,277
so much energy that we
can build these big bodies

614
00:30:45,310 --> 00:30:47,513
and big brains and so forth.

615
00:30:47,546 --> 00:30:50,216
It turns out so
there are organisms

616
00:30:50,249 --> 00:30:52,451
that live on other
chemical reactions.

617
00:30:52,484 --> 00:30:56,155
Imagine rust, you know, rust
is a spontaneous reaction

618
00:30:56,188 --> 00:30:59,125
that occurs in your
environment where iron

619
00:30:59,158 --> 00:31:02,695
is combined with oxygen and
generates another form of iron

620
00:31:02,728 --> 00:31:05,464
so there's some
energy released there.

621
00:31:05,497 --> 00:31:08,334
Organisms can live
off of that energy

622
00:31:08,367 --> 00:31:11,370
but only very, very simple,
very, very small organisms,

623
00:31:11,403 --> 00:31:14,640
microbial orgasms, so we
don't believe that Mars

624
00:31:14,673 --> 00:31:17,910
had an appreciable
oxygen in its atmosphere

625
00:31:17,943 --> 00:31:19,945
for much of its
history like Earth has

626
00:31:19,978 --> 00:31:23,315
for the last 2-1/2 billion
years and for that reason

627
00:31:23,348 --> 00:31:27,720
and other reasons, we believe
Mars would've only had

628
00:31:27,753 --> 00:31:29,655
microbial life so
that's the kind of life

629
00:31:29,688 --> 00:31:31,724
we're looking for
and here's an example

630
00:31:31,757 --> 00:31:34,293
that you see there in that
image above astrobiology.

631
00:31:34,326 --> 00:31:36,762
We'll talk more about
what that is in a moment.

632
00:31:36,795 --> 00:31:39,165
So we rove around
assessing habitability

633
00:31:39,198 --> 00:31:42,101
and then we start to
look for actual evidence

634
00:31:42,134 --> 00:31:45,137
of ancient life, so this
is really where we step

635
00:31:45,170 --> 00:31:50,009
beyond what MSL is spending
most of their time doing.

636
00:31:50,042 --> 00:31:53,112
MSL has mostly been
concerned with assessing

637
00:31:53,145 --> 00:31:56,048
geology and habitability;
they certainly have

638
00:31:56,081 --> 00:31:58,684
the capabilities to look
for signs of ancient life.

639
00:31:58,717 --> 00:32:02,488
The focus of the mission
has been on habitability

640
00:32:02,521 --> 00:32:06,258
but we have as a core
objective to seek the signs

641
00:32:06,291 --> 00:32:10,396
of life on Mars and really it
has, it's been since Viking

642
00:32:10,429 --> 00:32:12,965
that a NASA mission
has done that.

643
00:32:12,998 --> 00:32:15,501
Again, Viking sought
evidence of extant life.

644
00:32:15,534 --> 00:32:17,570
We're seeking evidence
of ancient life

645
00:32:17,603 --> 00:32:20,773
so as we do that, maybe
we'll detect signs of life,

646
00:32:20,806 --> 00:32:24,510
maybe we won't but we will
select sampling locations

647
00:32:24,543 --> 00:32:27,213
at our landing site
that we believe

648
00:32:27,246 --> 00:32:29,849
have the highest potential
in that environment

649
00:32:29,882 --> 00:32:32,785
to preserve signs
of ancient life

650
00:32:32,818 --> 00:32:36,722
or separate from astrobiology,
signs of planetary evolution

651
00:32:36,755 --> 00:32:40,693
so records of the ancient
changing climate of Mars.

652
00:32:40,726 --> 00:32:42,862
That also is incredibly
interesting to us,

653
00:32:42,895 --> 00:32:44,697
whether or not Mars
was ever inhabited,

654
00:32:44,730 --> 00:32:48,234
we'd like to understand
how Mars became habitable

655
00:32:48,267 --> 00:32:50,269
and how that
habitability decreased

656
00:32:50,302 --> 00:32:54,106
as the atmosphere left
the planet, for example.

657
00:32:54,139 --> 00:32:56,308
So we will choose
those locations

658
00:32:56,341 --> 00:32:58,210
and then we will
take the next step.

659
00:32:58,243 --> 00:33:01,580
The third objective is to
sample, so to collect samples.

660
00:33:01,613 --> 00:33:04,316
You see a drill hole there

661
00:33:04,349 --> 00:33:07,152
drilled actually in
Western Australia

662
00:33:07,185 --> 00:33:09,822
but the drill holes
on Mars look like that

663
00:33:09,855 --> 00:33:14,326
so we will carry with us
about 40 sample tubes,

664
00:33:14,359 --> 00:33:17,463
titanium tubes,
and I'll talk more

665
00:33:17,496 --> 00:33:19,198
about how we'll use
them in a moment

666
00:33:19,231 --> 00:33:22,735
but we will use those
to drill into rock

667
00:33:22,768 --> 00:33:25,704
so MSL has a drill as
well but the MSL drill

668
00:33:25,737 --> 00:33:28,140
makes powder, turns
the rock into powder

669
00:33:28,173 --> 00:33:30,709
and brings that
powder up into using

670
00:33:30,742 --> 00:33:34,046
its sampling system called
chimera up into a system

671
00:33:34,079 --> 00:33:36,348
where it can dump little
little bits of powder

672
00:33:36,381 --> 00:33:38,550
into instruments that
have little doors

673
00:33:38,583 --> 00:33:41,453
on the top of the rover so
this is the SAM instrument

674
00:33:41,486 --> 00:33:43,355
and the CheMin instrument.

675
00:33:43,388 --> 00:33:45,557
The SAM instrument
is a very complex,

676

00:33:45,590 --> 00:33:48,093
basically geochemistry
lab in a box

677
00:33:48,126 --> 00:33:49,728
that has many
different capabilities,

678
00:33:49,761 --> 00:33:52,865
including to measure the
molecular composition

679
00:33:52,898 --> 00:33:56,001
of organic matter
and other things

680
00:33:56,034 --> 00:33:59,038
and then CheMin is an
X-ray refractometer

681
00:33:59,071 --> 00:34:01,073
so it measures the
crystalline chemistry,

682
00:34:01,106 --> 00:34:04,209
the mineral chemistry
of the rock samples.

683
00:34:04,242 --> 00:34:07,212
We're different so instead
of creating powder,

684
00:34:07,245 --> 00:34:09,581
we do create powder,
but that's our focus.

685
00:34:09,614 --> 00:34:12,418
Instead of just creating powder
and analyzing that powder,

686

00:34:12,451 --> 00:34:14,453
what we do is as
we drill a core,

687
00:34:14,486 --> 00:34:16,956
so we have a hollow drill
bit that makes a core

688
00:34:16,989 --> 00:34:18,991
that's about the size
of piece of chalk

689
00:34:19,024 --> 00:34:22,428
or your pinky finger
and we seal that core

690
00:34:22,461 --> 00:34:26,332
in a titanium tube and we
can do that about 40 times

691
00:34:26,365 --> 00:34:29,735
and will deposit those
samples on the surface of Mars

692
00:34:29,768 --> 00:34:32,371
and then I'll cross
our fingers and hope

693
00:34:32,404 --> 00:34:34,440
that NASA decides to
go back and get them

694
00:34:34,473 --> 00:34:36,942
and bring them back so
that we can look at them

695
00:34:36,975 --> 00:34:39,812
in labs like the one
I'm running here at JPL

696

00:34:39,845 --> 00:34:43,015
or many labs, many
people around the Earth

697
00:34:43,048 --> 00:34:45,351
and in the international
community would actually love

698
00:34:45,384 --> 00:34:48,587
to get their hands,
their doubly gloved,

699
00:34:48,620 --> 00:34:51,423
incredibly clean hands
[audience laughing]

700
00:34:51,456 --> 00:34:55,027
on tiny, tiny pieces of
Mars that we collect.

701
00:34:55,060 --> 00:34:56,795
Okay so that's the
sampling objective

702
00:34:56,828 --> 00:35:00,399
and the fourth objective,
also very, very important,

703
00:35:00,432 --> 00:35:03,635
it says prepare for
humans, so the actual text

704
00:35:03,668 --> 00:35:06,438
of the objective says
contribute to, of course,

705
00:35:06,471 --> 00:35:08,307
it's not just us
preparing for humans,

706

00:35:08,340 --> 00:35:10,776
contribute to the
preparation for human,

707
00:35:10,809 --> 00:35:13,479
for future human
exploration of Mars.

708
00:35:13,512 --> 00:35:17,016
Okay, so I'm a big supporter

709
00:35:17,049 --> 00:35:21,120
of the quest to get humans
on the surface of Mars.

710
00:35:21,153 --> 00:35:24,690
It sounds like we
may be redirecting

711
00:35:24,723 --> 00:35:27,526
our focus away from
what has been the focus

712
00:35:27,559 --> 00:35:30,429
is to get humans to
the surface of Mars,

713
00:35:30,462 --> 00:35:33,098
to potentially the idea
that we go to the moon

714
00:35:33,131 --> 00:35:35,834
as a stepping stone
and get to Mars.

715
00:35:35,867 --> 00:35:38,704
I'd like us just to go straight
the Mars but we'll see.

716
00:35:38,737 --> 00:35:42,341

Not my job to make that
decision, unfortunately.

717
00:35:42,374 --> 00:35:45,210
Anyway, getting humans
to the surface of Mars,

718
00:35:45,243 --> 00:35:48,013
I think we'd all love
to someday see pictures

719
00:35:48,046 --> 00:35:50,783
of human beings on
the surface of Mars

720
00:35:50,816 --> 00:35:53,185
and see pictures that they
take with their camera

721
00:35:53,218 --> 00:35:55,788
and to hear from them,
in their own words,

722
00:35:55,821 --> 00:35:58,157
what it's like to stand on
the surface of another planet.

723
00:35:58,190 --> 00:35:59,925
I mean imagine
how transformative

724
00:35:59,958 --> 00:36:03,228
that would be, I
think, for all humans

725
00:36:03,261 --> 00:36:06,698
and so we prepare
for that vision

726
00:36:06,731 --> 00:36:10,202

in a couple important
ways very directly.

727
00:36:10,235 --> 00:36:12,771
We measure the temperature,
humidity, wind,

728
00:36:12,804 --> 00:36:14,673
and dust environment,
all the things

729
00:36:14,706 --> 00:36:17,476
that NASA would like to know

730
00:36:17,509 --> 00:36:20,612
in order to just send
humans safely to Mars

731
00:36:20,645 --> 00:36:23,182
and have them survive there
on the surface of the planet

732
00:36:23,215 --> 00:36:26,919
and then we have one of our
instruments called MOXIE

733
00:36:26,952 --> 00:36:29,822
is a technology demonstration.

734
00:36:29,855 --> 00:36:34,126
It is a 1% scale model.

735
00:36:34,159 --> 00:36:36,462
The principal investigator
has described it

736
00:36:36,495 --> 00:36:39,832
is that a 1% scale model
of a chemical plant

737
00:36:39,865 --> 00:36:42,434
that could one day be
sent ahead of humans

738
00:36:42,467 --> 00:36:45,204
to sit there on the
surface of the planet

739
00:36:45,237 --> 00:36:48,774
and just chug away and
take carbon dioxide

740
00:36:48,807 --> 00:36:50,375
out of the Martian atmosphere.

741
00:36:50,408 --> 00:36:53,045
It's mostly carbon
dioxide and convert

742
00:36:53,078 --> 00:36:55,481
that chemically to oxygen.

743
00:36:55,514 --> 00:36:59,284
Oxygen would be important for
humans on the surface of Mars.

744
00:36:59,317 --> 00:37:01,720
They could breathe it,
of course, but it's also

745
00:37:01,753 --> 00:37:04,823
a fantastic component
and ingredient for fuel

746
00:37:04,856 --> 00:37:06,959
for their rocket
that would help them

747
00:37:06,992 --> 00:37:10,062

get back off the surface,
a very important component

748
00:37:10,095 --> 00:37:12,764
of a human mission, of
course, so we'll do that.

749
00:37:12,797 --> 00:37:14,833
Now, those of the ways
we're very directly

750
00:37:14,866 --> 00:37:18,504
helping prepare for for
human exploration of Mars,

751
00:37:18,537 --> 00:37:21,106
but in a sense,
everything we do

752
00:37:21,139 --> 00:37:23,208
prepares for humans at Mars.

753
00:37:23,241 --> 00:37:24,810
The more we know about
the surface of Mars,

754
00:37:24,843 --> 00:37:27,012
the better prepared we
are to send people there

755
00:37:27,045 --> 00:37:30,249
and get them home safely.

756
00:37:30,282 --> 00:37:34,786
So I mentioned objective, the
third objective, sampling,

757
00:37:34,819 --> 00:37:37,189
and I just wanted to
take a brief moment

758
00:37:37,222 --> 00:37:40,092
to share with you something
that was recently presented

759
00:37:40,125 --> 00:37:44,630
by Thomas Zurbuchen to
the Space Studies Board

760
00:37:44,663 --> 00:37:48,467
and we were all excited to see
an official NASA presentation

761
00:37:48,500 --> 00:37:52,938
on notional sample
return architectures.

762
00:37:52,971 --> 00:37:58,243
Naturally, NASA
can be very careful

763
00:37:58,276 --> 00:38:01,346
with the way it discusses
Mars Sample Return.

764
00:38:01,379 --> 00:38:08,120
It's a very complex, incredibly
difficult proposition

765
00:38:08,153 --> 00:38:10,622
that combines multiple
missions as you see here

766
00:38:10,655 --> 00:38:15,928
so our mission, 2020,
would collect the samples

767
00:38:15,961 --> 00:38:20,265
but then we would
send a another rover

768
00:38:20,298 --> 00:38:23,468
away from Earth to land
here on a platform.

769
00:38:23,501 --> 00:38:26,104
This thing you see is a rocket.

770
00:38:26,137 --> 00:38:28,273
We call that the MAV,
the Mars Assent Vehicle.

771
00:38:28,306 --> 00:38:29,841
If you watched the
movie The Martian,

772
00:38:29,874 --> 00:38:31,610
they talked a lot
about the MAV.

773
00:38:31,643 --> 00:38:34,079
That was a MAV that got
humans off the surface

774
00:38:34,112 --> 00:38:37,249
but in this case, it's a
much, much, much smaller

775
00:38:37,282 --> 00:38:39,117
and lighter man of
that would only launch

776
00:38:39,150 --> 00:38:41,086
our rock samples of
the surface,

777
00:38:41,119 --> 00:38:42,254
maybe as a
platform there

778
00:38:42,287 --> 00:38:45,190
with solar panels,
imagining a smaller rover

779
00:38:45,223 --> 00:38:48,060
goes out, picks up our
samples, brings them back

780
00:38:48,093 --> 00:38:51,129
to the landing
pad with the MAV,

781
00:38:51,162 --> 00:38:53,565
there's the MAV launching
into orbit there

782
00:38:53,598 --> 00:38:56,235
and then you see this
little bowling ball

783
00:38:56,268 --> 00:38:58,337
coming out of the
front of the rocket.

784
00:38:58,370 --> 00:39:01,039
We call that the
Orbiting Sample, the OS.

785
00:39:01,072 --> 00:39:04,543
The Orbiting Sample has our
little sample tubes inside

786
00:39:04,576 --> 00:39:09,615
and then that OS
rendezvous with an orbiter.

787
00:39:09,648 --> 00:39:13,218
This is another spacecraft
so count the spacecraft here

788
00:39:13,251 --> 00:39:15,520
but there are several.

789
00:39:15,553 --> 00:39:17,689
Another spacecraft
that would rendezvous

790
00:39:17,722 --> 00:39:20,325
with that Orbiting Sample
and some piece of it

791
00:39:20,358 --> 00:39:23,128
may be would detach
here and fly back,

792
00:39:23,161 --> 00:39:27,299
either to land directly on
Earth or in cis lunar space,

793
00:39:27,332 --> 00:39:28,934
so go into orbit
around the moon

794
00:39:28,967 --> 00:39:31,336
and then we maybe would
send astronauts out

795
00:39:31,369 --> 00:39:33,972
to retrieve those samples,
so that's the basic vision

796
00:39:34,005 --> 00:39:38,644
for how it it might
happen if it does happen.

797
00:39:38,677 --> 00:39:40,412
Why would we want to do that?

798
00:39:40,445 --> 00:39:43,215

Why would we want to
return samples from Mars

799
00:39:43,248 --> 00:39:45,951
if it's so complicated
and so difficult

800
00:39:45,984 --> 00:39:48,186
and take so much time?

801
00:39:48,219 --> 00:39:52,291
Well, here's one reason:
if we're interested

802
00:39:52,324 --> 00:39:57,229
in sending humans to Mars,
what more precious sample

803
00:39:57,262 --> 00:40:00,165
[chuckles] could we
possibly have to send

804
00:40:00,198 --> 00:40:02,234
to the surface of
Mars and return?

805
00:40:02,267 --> 00:40:04,670
So it it certainly seems
to me, and opinions vary

806
00:40:04,703 --> 00:40:08,006
widely on this, you'll find
many, many different opinions

807
00:40:08,039 --> 00:40:10,942
on us of how important
robotic sample return

808
00:40:10,975 --> 00:40:13,745
is to the prospect of

human exploration of Mars.

809
00:40:13,778 --> 00:40:16,181
Some people think it's
completely decoupled.

810
00:40:16,214 --> 00:40:18,550
I think it might be
very important,

811
00:40:18,583 --> 00:40:19,451
if for no
other reason

812
00:40:19,484 --> 00:40:22,020
than just the
psychology of a nation

813
00:40:22,053 --> 00:40:25,123
or of an international
community and being willing

814
00:40:25,156 --> 00:40:27,726
to take that big risk
to send humans there

815
00:40:27,759 --> 00:40:29,695
and hope to get
them back safely,

816
00:40:29,728 --> 00:40:32,364
I think we would want
to first demonstrate

817
00:40:32,397 --> 00:40:36,101
the capability to get
some rocks back safely.

818
00:40:36,134 --> 00:40:38,603
[audience chuckling]

819
00:40:38,636 --> 00:40:41,673
Here's another reason; this
is the big scientific reason

820
00:40:41,706 --> 00:40:44,943
and so this is an image,
it's hard to make out maybe

821
00:40:44,976 --> 00:40:46,912
but what's happening
here is this is

822
00:40:46,945 --> 00:40:49,481
on my microscope in the
lab and we're looking

823
00:40:49,514 --> 00:40:52,684
at a 3-1/2
billion-year-old rock there

824
00:40:52,717 --> 00:40:54,586
called the Strelley
Pool Formation

825
00:40:54,619 --> 00:40:55,721
and all the
dark stuff

826
00:40:55,754 --> 00:40:57,723
that you see as organic matter,

827
00:40:57,756 --> 00:40:59,224
so you see a bunch
of different shapes.

828
00:40:59,257 --> 00:41:02,227
Take a look up here,
these little spheres,

829
00:41:02,260 --> 00:41:04,529
maybe you have to trust me
or maybe can see for yourself

830
00:41:04,562 --> 00:41:09,101
but it's one, two, three,
four, maybe five little spheres

831
00:41:09,134 --> 00:41:12,104
made of organic
carbon and then these

832
00:41:12,137 --> 00:41:16,742
lens-shaped features,
complex morphology.

833
00:41:16,775 --> 00:41:19,044
You have a big sphere down here

834
00:41:19,077 --> 00:41:21,012
with some surface ornamentation

835
00:41:21,045 --> 00:41:23,048
that you can see when
it comes into focus.

836
00:41:23,081 --> 00:41:24,750
The microscope is just
focusing up and down

837
00:41:24,783 --> 00:41:26,852
over and over through
these things he can see

838
00:41:26,885 --> 00:41:29,121
a little bit of their
three-dimensional structure

839
00:41:29,154 --> 00:41:32,290

but these are complex
organic shapes.

840
00:41:32,323 --> 00:41:34,926
The scale bar here
is 10 micrometers

841
00:41:34,959 --> 00:41:37,763
so the width of this
image is about the width

842
00:41:37,796 --> 00:41:40,599
of your hair to give you a
sense of the scale of these.

843
00:41:40,632 --> 00:41:44,736
They are quite small but these
we would call micro fossils

844
00:41:44,769 --> 00:41:48,573
so this is clear
evidence of life

845
00:41:48,606 --> 00:41:50,575
3-1/2 billion years ago,

846
00:41:50,608 --> 00:41:54,946
so it's very difficult
to see these things.

847
00:41:54,979 --> 00:41:57,282
You can't just go and pick
up a rock in the field

848
00:41:57,315 --> 00:41:59,451
and take a look at it
and see things like this.

849
00:41:59,484 --> 00:42:02,220
You have to bring it home,

slice it up very thin,

850
00:42:02,253 --> 00:42:04,389
so thin that you can
shine a light through it

851
00:42:04,422 --> 00:42:06,758
and then polish it to
a very fine polish,

852
00:42:06,791 --> 00:42:09,127
then put on a microscope,
shine light through it

853
00:42:09,160 --> 00:42:12,230
and you can start
to see these shapes.

854
00:42:12,263 --> 00:42:15,133
Okay, and so we can't
do that yet with a rover

855
00:42:15,166 --> 00:42:18,637
so we'd like to bring samples
back and look for things

856
00:42:18,670 --> 00:42:23,475
like these or other signs of
ancient life in those samples.

857
00:42:23,508 --> 00:42:26,044
So here's a quick video.

858
00:42:26,077 --> 00:42:28,580
This is me in
Western Australia,

859
00:42:28,613 --> 00:42:31,983
a place called Pilbara
region, Northwest Australia,

860
00:42:32,016 --> 00:42:35,320
and this area has the
best oldest record

861
00:42:35,353 --> 00:42:39,157
of life on the planet; notice
I say the best oldest record

862
00:42:39,190 --> 00:42:41,126
of life on the planet,
it's not necessarily

863
00:42:41,159 --> 00:42:43,462
the oldest record of
life on the planet.

864
00:42:43,495 --> 00:42:47,265
That might be in Greenland,
depending who you talk to

865
00:42:47,298 --> 00:42:49,968
or believe, it
might be in Canada,

866
00:42:50,001 --> 00:42:52,370
depending who you
talk to or believe

867
00:42:52,403 --> 00:42:54,439
but pretty much any
scientist who does

868
00:42:54,472 --> 00:42:57,409
this kind of work
believes that these rocks,

869
00:42:57,442 --> 00:43:00,512
which are up to 3.5
billion years old

870
00:43:00,545 --> 00:43:03,815
do contain very good
evidence of life,

871
00:43:03,848 --> 00:43:06,117
so another way to put it is
the oldest widely accepted

872
00:43:06,150 --> 00:43:08,987
evidence for life on Earth
comes from these rocks

873
00:43:09,020 --> 00:43:11,523
in the Pilbara region
of Western Australia.

874
00:43:11,556 --> 00:43:14,493
And so few years
ago, I asked the,

875
00:43:14,526 --> 00:43:16,728
before I was involved
in the mission actually,

876
00:43:16,761 --> 00:43:20,365
asked one of the
sampling system team

877
00:43:20,398 --> 00:43:23,001
if they had an extra drill
bit that I could borrow

878
00:43:23,034 --> 00:43:25,837
and I bought this drill
I stuck the drill bit,

879
00:43:25,870 --> 00:43:28,874
a Mars 2020 prototype drill
bit on the end of that drill

880
00:43:28,907 --> 00:43:32,143
and took it Western
Australia and drilled

881
00:43:32,176 --> 00:43:35,580
into these very old rocks
that contain signs of life

882
00:43:35,613 --> 00:43:42,387
and here's what that looks
like, just to get a sense, oop.

883
00:43:42,420 --> 00:43:48,093
[drill rattling]

884
00:43:48,126 --> 00:43:51,162
So notice the sound,
that's percussion.

885
00:43:51,195 --> 00:43:54,666
It's a rotary percussive
drill or a RotoHammer,

886
00:43:54,699 --> 00:43:56,835
the same technology, the
same basic technology

887
00:43:56,868 --> 00:43:59,471
that we use use on
MSL and on 2020.

888
00:43:59,504 --> 00:44:01,573
It's the same technology
that climbers use

889
00:44:01,606 --> 00:44:03,608
when they wanna drill
a bolt into a rock.

890
00:44:03,641 --> 00:44:05,610
It's just a great way
of drilling into a rock

891
00:44:05,643 --> 00:44:07,479
if you can't bring
water along with you

892
00:44:07,512 --> 00:44:09,948
to cool the drill bit; you
need to percuss on the rock

893
00:44:09,981 --> 00:44:12,517
and break it into small
pieces at the interface

894
00:44:12,550 --> 00:44:18,723
of the drill bit so they can
cut without involving water.

895
00:44:18,756 --> 00:44:21,626
Okay, so that's what
this drill looks like,

896
00:44:21,659 --> 00:44:25,397
sort of a better picture,
and then we deploy

897
00:44:25,430 --> 00:44:27,599
the drill on this
thing and this thing

898
00:44:27,632 --> 00:44:30,602
and this thing is
called a stromatolite.

899
00:44:30,635 --> 00:44:34,873
I've got one right here,
so this stromatolite

900
00:44:34,906 --> 00:44:37,475
that you see here is
3-1/2 billion years old.

901
00:44:37,508 --> 00:44:41,179
This one is about not quite
a billion years younger,

902
00:44:41,212 --> 00:44:43,882
still very old 2.7
billion years old,

903
00:44:43,915 --> 00:44:49,120
the one you see there,
the one on the screen

904
00:44:49,153 --> 00:44:52,557
we affectionately refer
to as a Mickey Mouse ears

905
00:44:52,590 --> 00:44:55,560
stromatolite shape,
you can see why.

906
00:44:55,593 --> 00:44:58,930
You can see there's the
millimeter scale bar there

907
00:44:58,963 --> 00:45:02,300
so this has
submillimeter layering,

908
00:45:02,333 --> 00:45:03,301
a submillimeter texture

909
00:45:03,334 --> 00:45:06,271
so when geologists talk
about shapes and rocks,

910

00:45:06,304 --> 00:45:08,673
they call them textures,
not like a texture you feel

911
00:45:08,706 --> 00:45:12,310
but just the shape within
the rock or morphologies.

912
00:45:12,343 --> 00:45:15,880
We often use that word
so the morphology there

913
00:45:15,913 --> 00:45:20,986
is suggestive of biologic
activity, why is that?

914
00:45:21,019 --> 00:45:24,522
It has these very fine wrinkly
layers that you can see

915
00:45:24,555 --> 00:45:26,558
all the way down there on
the bottom of the image

916
00:45:26,591 --> 00:45:29,327
and then culminating
there in the dome shape

917
00:45:29,360 --> 00:45:32,197
up at the top and the
dome itself is divided

918
00:45:32,230 --> 00:45:34,966
into two parts, okay,
so that's what makes it

919
00:45:34,999 --> 00:45:36,635
super compelling,
and these are some

920

00:45:36,668 --> 00:45:38,503
of the most beautiful
stromatolite.

921
00:45:38,536 --> 00:45:40,005
They're in the
tum-bi-ana formation

922
00:45:40,038 --> 00:45:43,942
in Western Australia,
2.7 billion years old.

923
00:45:43,975 --> 00:45:45,944
Let's just get a
little closer look

924
00:45:45,977 --> 00:45:48,046
and I'm just gonna put
this one down here.

925
00:45:48,079 --> 00:45:51,416
This, again, is older; this
is 3.5 billion years old.

926
00:45:51,449 --> 00:45:53,551
This is some of
the oldest evidence

927
00:45:53,584 --> 00:45:55,887
for life on Earth: it's a
piece of a stromatolite.

928
00:45:55,920 --> 00:45:59,190
I'm gonna hand it
someone down here

929
00:45:59,223 --> 00:46:01,993
and I'd like you to
pass that around.

930

00:46:02,026 --> 00:46:03,862
Don't worry about breaking
it and don't worry

931
00:46:03,895 --> 00:46:06,865
about touching it,
smell it if you want

932
00:46:06,898 --> 00:46:09,734
and just take a close look.

933
00:46:09,767 --> 00:46:11,403
You'll see the layers in there.

934
00:46:11,436 --> 00:46:12,971
You'll see a dome shaped
near the top of it.

935
00:46:13,004 --> 00:46:15,940
See if you can tell
which way is up there

936
00:46:15,973 --> 00:46:20,378
and that is a bona fide 3.5
billion-year-old stromatolite

937
00:46:20,411 --> 00:46:22,847
but here, you get a
little bit closer look

938
00:46:22,880 --> 00:46:25,016
on this fine scale layering.

939
00:46:25,049 --> 00:46:27,719
The one you have in your
hand is made of quartz.

940
00:46:27,752 --> 00:46:33,158
This one is made of
a carbonate mineral

941
00:46:33,191 --> 00:46:35,527
and we believe
these stromatolites

942
00:46:35,560 --> 00:46:38,563
were originally
made of carbonate,

943
00:46:38,596 --> 00:46:42,067
calcium magnesium carbonate
the same calcium carbonate

944
00:46:42,100 --> 00:46:43,668
as what seashells are made of,

945
00:46:43,701 --> 00:46:46,271
so it's a very important
biologic mineral, in that case,

946
00:46:46,304 --> 00:46:50,208
it's dolomite but it has been
converted over geologic time.

947
00:46:50,241 --> 00:46:52,243
Remember I talked about
trying to understand

948
00:46:52,276 --> 00:46:55,647
the processes of alteration
of rocks being very important?

949
00:46:55,680 --> 00:46:58,750
These rocks were
altered to quartz

950
00:46:58,783 --> 00:47:00,919
and in that process,
they may lose some

951
00:47:00,952 --> 00:47:04,022
of their original properties,
some of their original pieces

952
00:47:04,055 --> 00:47:06,858
of evidence, so we'd
like to find rocks

953
00:47:06,891 --> 00:47:09,227
that are as primary
as possible, that is,

954
00:47:09,260 --> 00:47:11,229
that are in the shape,
as much as possible,

955
00:47:11,262 --> 00:47:13,431
the original shape in
which they were formed.

956
00:47:13,464 --> 00:47:15,133
These rocks fit that bill;

957
00:47:15,166 --> 00:47:17,702
they're still
original carbonate.

958
00:47:17,735 --> 00:47:21,740
So drilled that rock, you see
some powder generated here.

959
00:47:21,773 --> 00:47:23,441
This is that same
picture you saw before.

960
00:47:23,474 --> 00:47:25,643
This the top of the
Mickey Mouse stromatolite.

961

00:47:25,676 --> 00:47:28,580
Drilled a little bit behind it

962
00:47:28,613 --> 00:47:31,583
and then took the drill
bit off the drill.

963
00:47:31,616 --> 00:47:33,184
We just had a simple
brass tube inside

964
00:47:33,217 --> 00:47:35,320
the drill bit pull that
out and this is what

965
00:47:35,353 --> 00:47:37,655
the sample looked
like when it came out

966
00:47:37,688 --> 00:47:39,524
and we think our
samples as well.

967
00:47:39,557 --> 00:47:42,927
Some rocks that we drill
with Mars 2020 produce

968
00:47:42,960 --> 00:47:44,929
a beautiful core, like
a little golf pencil

969
00:47:44,962 --> 00:47:47,632
or a piece of chalk; it
holds together beautifully.

970
00:47:47,665 --> 00:47:49,634
Some rocks, especially
when they're layered

971
00:47:49,667 --> 00:47:52,103

with fine layers, it's
very hard to to drill them

972
00:47:52,136 --> 00:47:54,172
with that Rotary percussive
drill and have them

973
00:47:54,205 --> 00:47:56,374
hold together and
they form small pieces

974
00:47:56,407 --> 00:47:58,676
but if you're very careful
when you handle them,

975
00:47:58,709 --> 00:48:01,679
as the workers of the
future certainly would be,

976
00:48:01,712 --> 00:48:04,048
working with rocks from
the surface of Mars,

977
00:48:04,081 --> 00:48:07,752
you can put them back together
in as close as possible

978
00:48:07,785 --> 00:48:10,388
to their original orientation,
so that's what we did.

979
00:48:10,421 --> 00:48:12,624
This is out in the
field, we did this,

980
00:48:12,657 --> 00:48:14,526
wrapped them in foil
brought them back

981
00:48:14,559 --> 00:48:16,394

to the lab and then
we did something

982
00:48:16,427 --> 00:48:19,731
that I doubt they
will do much of

983
00:48:19,764 --> 00:48:21,299
if sample never
come back from Mars:

984
00:48:21,332 --> 00:48:25,036
we poured epoxy right
down in this crack

985
00:48:25,069 --> 00:48:26,905
and that was to get them
all to hold together

986
00:48:26,938 --> 00:48:29,340
so we commonly do that
with geologic samples

987
00:48:29,373 --> 00:48:32,377
if they're friable or they
they like to break into pieces

988
00:48:32,410 --> 00:48:35,547
and fall apart, we'll
impregnate them with epoxy

989
00:48:35,580 --> 00:48:37,549
so we'll sometimes
put them in a vacuum

990
00:48:37,582 --> 00:48:39,217
so that lots of
bubbles don't form,

991
00:48:39,250 --> 00:48:41,820

but we fill them with epoxy
that cures and hardens,

992
00:48:41,853 --> 00:48:45,623
then we can slice them
in half and we can pull

993
00:48:45,656 --> 00:48:47,959
a little thin slice off,
mount it to a glass slide,

994
00:48:47,992 --> 00:48:49,961
like I said, and polish
it, grind it down

995
00:48:49,994 --> 00:48:51,729
so it's thinner than
a sheet of paper.

996
00:48:51,762 --> 00:48:55,567
You can shine through it
and that's what we have here

997
00:48:55,600 --> 00:49:00,238
so this is that same sample
that I just showed you,

998
00:49:00,271 --> 00:49:02,874
epoxy impregnated, cut in half,

999
00:49:02,907 --> 00:49:05,009
mounted to a slide, cut off,

1000
00:49:05,042 --> 00:49:07,712
polish, polish, polish,
thinner than a sheet of paper,

1001
00:49:07,745 --> 00:49:10,148
shining light through
it on a microscope

1002
00:49:10,181 --> 00:49:12,283
in my lab where we
can make mosaics.

1003
00:49:12,316 --> 00:49:15,186
Remember that Viking mosaic
is made up of bunches

1004
00:49:15,219 --> 00:49:17,222
of images of Mars all
stitched together.

1005
00:49:17,255 --> 00:49:19,757
Same thing here; this
is thousands of images,

1006
00:49:19,790 --> 00:49:22,260
so we're using that
the 20 times objective,

1007
00:49:22,293 --> 00:49:24,395
the 20X objective
on the microscope

1008
00:49:24,428 --> 00:49:27,899
taking thousands of
images and you can't tell

1009
00:49:27,932 --> 00:49:30,435
from that, but I'm gonna
show you a little video here

1010
00:49:30,468 --> 00:49:31,970
and we're just gonna zoom in.

1011
00:49:32,003 --> 00:49:34,305
So remember that that Mickey
Mouse ears stromatolite.

1012
00:49:34,338 --> 00:49:35,540
Look at the stromatolite
you've got in your hand

1013
00:49:35,573 --> 00:49:38,476
if you have it and
then see if we can see

1014
00:49:38,509 --> 00:49:41,679
any features at a smaller scale

1015
00:49:41,712 --> 00:49:45,049
that indicate past
biologic activity.

1016
00:49:45,082 --> 00:49:48,186
Uh-oh, here we go.

1017
00:49:48,219 --> 00:49:51,322
Okay, so we're zooming in,

1018
00:49:51,355 --> 00:49:54,492
start to see that dome
shape structure there.

1019
00:49:54,525 --> 00:49:58,596
Okay, so in stromatolites,
they're fractal in some sense,

1020
00:49:58,629 --> 00:50:03,701
that is they exhibit patterns
across a multitude of scale

1021
00:50:03,734 --> 00:50:06,504
so at centimeter
scale, some of them,

1022
00:50:06,537 --> 00:50:08,907
the largest stromatolites I've

seen are as big as a person.

1023
00:50:08,940 --> 00:50:12,243
They're six feet
tall, huge domes.

1024
00:50:12,276 --> 00:50:14,746
These ones are smaller,
domes about that big,

1025
00:50:14,779 --> 00:50:17,081
that Mickey Mouse
stromatolite that you saw

1026
00:50:17,114 --> 00:50:20,084
was all about fist sized
but then it has layers

1027
00:50:20,117 --> 00:50:22,153
all within it and those
layers themselves are layered

1028
00:50:22,186 --> 00:50:24,589
and have little domes and
so you see a dome here.

1029
00:50:24,622 --> 00:50:28,126
You see some carbonate
minerals in the gray material

1030
00:50:28,159 --> 00:50:30,328
on either side of
that dome shape

1031
00:50:30,361 --> 00:50:32,897
and then the dark cloudy
dark stuff you see

1032
00:50:32,930 --> 00:50:34,299
is organic matter,

1033
00:50:34,332 --> 00:50:36,434
2.7 billion-year-old
organic matter,

1034
00:50:36,467 --> 00:50:39,003
so that gets us very excited,

1035
00:50:39,036 --> 00:50:42,340
so let's look closer.

1036
00:50:42,373 --> 00:50:45,476
I said let's look
closer, he said.

1037
00:50:45,509 --> 00:50:47,812
Uh-oh, we're gonna have
to do the movie again.

1038
00:50:47,845 --> 00:50:53,718
Here we go, okay, so we're
zooming in on the dome.

1039
00:50:53,751 --> 00:50:55,620
I won't stop it this time.

1040
00:50:55,653 --> 00:50:57,755
We'll zoom in a little
closer and we say,

1041
00:50:57,788 --> 00:51:00,224
what's that thing and
we zoom in closer again

1042
00:51:00,257 --> 00:51:03,661
and this little shape, this
little squiggly shape there.

1043
00:51:03,694 --> 00:51:06,798

That gets us very,
very interested

1044
00:51:06,831 --> 00:51:10,301
so that may be a
fossil bacterium,

1045
00:51:10,334 --> 00:51:16,607
2.7-year-old bacterial
cell, filamentous cell.

1046
00:51:16,640 --> 00:51:19,143
So that's the kind of
thing we'd like to look for

1047
00:51:19,176 --> 00:51:21,379
in samples returned from Mars.

1048
00:51:21,412 --> 00:51:23,982
We can't do that sort of
thing on a rover currently.

1049
00:51:24,015 --> 00:51:26,417
We're quite a ways from
having the capabilities

1050
00:51:26,450 --> 00:51:28,486
physically to prepare
the sample like that

1051
00:51:28,519 --> 00:51:30,688
and take those sort
of microscopic images.

1052
00:51:30,721 --> 00:51:32,757
We would need to
get the samples back

1053
00:51:32,790 --> 00:51:35,259
to be able to see

something like,

1054
00:51:35,292 --> 00:51:37,795
then we can take the next
step in our labs on Earth

1055
00:51:37,828 --> 00:51:41,065
and here's an image
not of the same rock

1056
00:51:41,098 --> 00:51:43,868
but of a filamentous
micro fossil,

1057
00:51:43,901 --> 00:51:46,404
2.4 billion years
old in this case.

1058
00:51:46,437 --> 00:51:50,241
In the top left image
marked A, you can really see

1059
00:51:50,274 --> 00:51:52,744
that it's a hollow
filament, I hope.

1060
00:51:52,777 --> 00:51:55,380
The little box shown
there is enlarged

1061
00:51:55,413 --> 00:51:59,450
on an electron microscope
in the two bottom panels.

1062
00:51:59,483 --> 00:52:01,652
The dark material you
see at bottom right

1063
00:52:01,685 --> 00:52:03,721
that's sort of in an

oval an ellipse shape,

1064
00:52:03,754 --> 00:52:06,090
that's the organic carbon
there that's exposed

1065
00:52:06,123 --> 00:52:08,326
at the surface of the
sample from that filament,

1066
00:52:08,359 --> 00:52:10,194
so you can see it's
a hollow filament.

1067
00:52:10,227 --> 00:52:14,465
It has a a cell wall
that is nanometers thick,

1068
00:52:14,498 --> 00:52:18,870
itself is no several
micrometers in diameter

1069
00:52:18,903 --> 00:52:21,339
and then in the panel
at the top right you see

1070
00:52:21,372 --> 00:52:25,243
we've shot a hole
in the filament

1071
00:52:25,276 --> 00:52:28,379
and we shot that hole so
that we could sputter away

1072
00:52:28,412 --> 00:52:31,416
the organic matter and pull
into a mass spectrometer

1073
00:52:31,449 --> 00:52:33,818
and measure the

ratio of carbon 13

1074
00:52:33,851 --> 00:52:35,920
to carbon 12, why
is that important?

1075
00:52:35,953 --> 00:52:40,258
We get this number
here, minus 33.2,

1076
00:52:40,291 --> 00:52:43,528
so the ocean has a
carbon isotope ratio,

1077
00:52:43,561 --> 00:52:47,632
the ratio of carbon 13 to
carbon 12 of about zero, okay,

1078
00:52:47,665 --> 00:52:50,368
sort of nonliving
carbon, the source

1079
00:52:50,401 --> 00:52:52,303
of carbon for living organisms.

1080
00:52:52,336 --> 00:52:55,239
When organisms take
carbon into their bodies,

1081
00:52:55,272 --> 00:52:59,043
either as CO2 or is
dissolved carbonate ions

1082
00:52:59,076 --> 00:53:02,113
in seawater, they
preferentially take up

1083
00:53:02,146 --> 00:53:06,150
the lighter isotope of carbon,
carbon 12 versus carbon 13

1084
00:53:06,183 --> 00:53:07,919
and they do what's
called fractionation.

1085
00:53:07,952 --> 00:53:11,823
They change the mixture
of carbon in their bodies

1086
00:53:11,856 --> 00:53:14,559
and they produce numbers
that are far away

1087
00:53:14,592 --> 00:53:17,929
from zero like minus 33, you'll
just have to trust me there

1088
00:53:17,962 --> 00:53:20,498
but that is a
strong sign of life

1089
00:53:20,531 --> 00:53:23,801
for those of us who
do this kind of work,

1090
00:53:23,834 --> 00:53:25,770
so how do we get that
strong sign of life?

1091
00:53:25,803 --> 00:53:27,472
Besides all the stuff
I told you about,

1092
00:53:27,505 --> 00:53:29,674
sample preparation, we use
an instrument like this.

1093
00:53:29,707 --> 00:53:32,743
This is called a secondary
ion mass spectrometer.

1094
00:53:32,776 --> 00:53:34,946
It's in a lab at
Wisconsin where I worked

1095
00:53:34,979 --> 00:53:37,281
before I came to JPL,
you can see it takes up

1096
00:53:37,314 --> 00:53:40,818
most of a very large room
and it has a three-ton magnet

1097
00:53:40,851 --> 00:53:43,087
there so where we're a
long way from being able

1098
00:53:43,120 --> 00:53:47,391
to fly a three-ton magnet
but here are some of things

1099
00:53:47,424 --> 00:53:51,829
we do fly, so this is what
we call our family picture.

1100
00:53:51,862 --> 00:53:55,833
These are the instruments
distributed about the rover.

1101
00:53:55,866 --> 00:53:58,002
We'll start appear with MEDA.

1102
00:53:58,035 --> 00:54:00,538
MEDA is contributed from Spain

1103
00:54:00,571 --> 00:54:04,575
and it is our weather station,
it's like the REMS instrument

1104

00:54:04,608 --> 00:54:07,411
on an MSL, we measure
wind speed, temperature,

1105
00:54:07,444 --> 00:54:10,448
humidity, pressure,
other things

1106
00:54:10,481 --> 00:54:14,118
and then we move over
here to SuperCam.

1107
00:54:14,151 --> 00:54:16,454
This is, it's a
little hard to see,

1108
00:54:16,487 --> 00:54:19,257
but this is the mast, we
call the remote-sensing mast,

1109
00:54:19,290 --> 00:54:21,259
so we have the body of
the rover with its wheels.

1110
00:54:21,292 --> 00:54:23,060
It then has a mast
with some instruments

1111
00:54:23,093 --> 00:54:24,428
at the top of the mast.

1112
00:54:24,461 --> 00:54:27,098
One of them is SuperCam,
looks like a big eye

1113
00:54:27,131 --> 00:54:31,469
on the top of the rover,
that eye is a telescope

1114
00:54:31,502 --> 00:54:33,571

that has a laser in
the middle of it,

1115
00:54:33,604 --> 00:54:38,242
so we fire the laser down at
a rock several meters away.

1116
00:54:38,275 --> 00:54:40,178
I'll just it point
here at SuperCam.

1117
00:54:40,211 --> 00:54:42,747
We fire that laser like that

1118
00:54:42,780 --> 00:54:45,683
and but is a much higher
energy laser than this one

1119
00:54:45,716 --> 00:54:48,886
and we create a
plasma in the rock

1120
00:54:48,919 --> 00:54:50,888
and we do it's
called laser-induced

1121
00:54:50,921 --> 00:54:52,089
breakdown spectroscopy

1122
00:54:52,122 --> 00:54:54,759
and by doing that, we can
measure the elemental chemistry

1123
00:54:54,792 --> 00:54:56,594
of the rock that we've shot.

1124
00:54:56,627 --> 00:55:00,331
Now, ChemCam on MSL, an
instrument just like SuperCam,

1125
00:55:00,364 --> 00:55:03,668
much like SuperCam on the
Curiosity rover could do that

1126
00:55:03,701 --> 00:55:05,469
but that's about
where it stopped.

1127
00:55:05,502 --> 00:55:08,105
SuperCam has those
capabilities and builds on that

1128
00:55:08,138 --> 00:55:11,075
with additional
spectroscopic capabilities.

1129
00:55:11,108 --> 00:55:13,110
One of them is called
Raman spectroscopy

1130
00:55:13,143 --> 00:55:15,546
that allows us to measure
the molecular composition

1131
00:55:15,579 --> 00:55:18,049
of the rock, including
its mineral composition,

1132
00:55:18,082 --> 00:55:19,951
potentially its
organic composition.

1133
00:55:19,984 --> 00:55:22,486
That's a partnership between
France and the United States

1134
00:55:22,519 --> 00:55:26,724
in Los Alamos National Lab,
then we have Mastcam-Z.

1135
00:55:26,757 --> 00:55:29,227
These are two
identical zoom lenses.

1136
00:55:29,260 --> 00:55:32,096
This is similar to the
Mastcam instrument on MSL.

1137
00:55:32,129 --> 00:55:35,166
The Mastcam instrument
had a wide-angle camera

1138
00:55:35,199 --> 00:55:39,637
and a zoom telephoto camera,
neither lens was a zoom lens.

1139
00:55:39,670 --> 00:55:42,240
They were both fixed
focal length lenses,

1140
00:55:42,273 --> 00:55:46,010
35 to 100 millimeter-ish.

1141
00:55:46,043 --> 00:55:48,379
Mastcam-Z has two zoom lenses

1142
00:55:48,412 --> 00:55:51,148
that encompass that full range

1143
00:55:51,181 --> 00:55:53,117
and so it gives us
much more flexibility

1144
00:55:53,150 --> 00:55:57,221
with our stereoscopic
imaging for science,

1145
00:55:57,254 --> 00:56:00,958
then we move down here,

let's skip around here

1146
00:56:00,991 --> 00:56:03,527
to MOXIE we already
talked about.

1147
00:56:03,560 --> 00:56:05,196
That's the instrument
that generates oxygen

1148
00:56:05,229 --> 00:56:08,599
from carbon dioxide to
test that technology

1149
00:56:08,632 --> 00:56:11,168
then we have this instrument
here called RIMFAX.

1150
00:56:11,201 --> 00:56:12,937
This comes to us from Norway.

1151
00:56:12,970 --> 00:56:16,040
It's a contributed instrument,
it's really an antenna there

1152
00:56:16,073 --> 00:56:19,076
that sits underneath
the rover and this is,

1153
00:56:19,109 --> 00:56:20,978
for the first time on
the surface of Mars,

1154
00:56:21,011 --> 00:56:24,115
a ground-penetrating
radar so as we look around

1155
00:56:24,148 --> 00:56:25,816
and see structures
in our environment,

1156
00:56:25,849 --> 00:56:27,885
see how the rocks
in our environment

1157
00:56:27,918 --> 00:56:29,487
are stacked together

1158
00:56:29,520 --> 00:56:33,291
and penetrate from the
surface with Mastcam-Z

1159
00:56:33,324 --> 00:56:35,426
and our other cameras,
RIMFAX will allow us

1160
00:56:35,459 --> 00:56:37,728
to look into the
subsurface and see

1161
00:56:37,761 --> 00:56:41,165
how those structural relations
continue into the subsurface

1162
00:56:41,198 --> 00:56:43,234
so that's a fantastic
new capability.

1163
00:56:43,267 --> 00:56:45,136
We have some
calibration targets

1164
00:56:45,169 --> 00:56:47,805
but then let's blast
back over here.

1165
00:56:47,838 --> 00:56:49,740
This is the robotic
arm; you can't tell that

1166
00:56:49,773 --> 00:56:51,942
from this image but
it's in stowed position

1167
00:56:51,975 --> 00:56:54,512
and out on the end of
the arm is the turret

1168
00:56:54,545 --> 00:56:57,214
and the turret has the
drill, but also has

1169
00:56:57,247 --> 00:57:00,418
these two instruments:
PIXL and SHERLOC.

1170
00:57:00,451 --> 00:57:04,689
PIXL is a microfocus X-ray
fluorescence instrument

1171
00:57:04,722 --> 00:57:08,459
so it's similar in a sense in
terms of its scientific niche

1172
00:57:08,492 --> 00:57:10,728
to the APXS instrument on MSL

1173
00:57:10,761 --> 00:57:12,697
that measure the elemental
chemistry of rocks

1174
00:57:12,730 --> 00:57:16,901
by placing the instrument
down on the surface of a rock.

1175
00:57:16,934 --> 00:57:20,137
PIXL, instead of measuring
the bulk, average chemistry

1176

00:57:20,170 --> 00:57:24,275
of the rock, it shoots,
it fires an X-ray beam,

1177
00:57:24,308 --> 00:57:27,111
shines an X-ray beams, sort
of is more appropriate,

1178
00:57:27,144 --> 00:57:29,513
down on the surface of
the rock and the diameter

1179
00:57:29,546 --> 00:57:32,216
of that beam is about the
diameter of your hair,

1180
00:57:32,249 --> 00:57:35,086
about 100 micrometers,
and it scans that beam.

1181
00:57:35,119 --> 00:57:37,321
It rasters that beam over
an area about the size

1182
00:57:37,354 --> 00:57:40,057
of a postage stamp, and
instead of measuring

1183
00:57:40,090 --> 00:57:43,294
just a bulk elemental
composition, it makes maps

1184
00:57:43,327 --> 00:57:46,497
of the elemental
composition so imagine a map

1185
00:57:46,530 --> 00:57:48,666
of the silicon
concentration in a rock.

1186

00:57:48,699 --> 00:57:51,969
Imagine a map over that's
stromatolite that you saw

1187
00:57:52,002 --> 00:57:54,038
and I'll show you something
like that in a moment.

1188
00:57:54,071 --> 00:57:57,641
SHERLOC is a
laser-based instrument.

1189
00:57:57,674 --> 00:58:01,178
It fires an ultraviolet
laser, similar diameter,

1190
00:58:01,211 --> 00:58:03,981
beam diameter to PIXL,
about 100 microns

1191
00:58:04,014 --> 00:58:07,118
and it rasters that over
a small area as well

1192
00:58:07,151 --> 00:58:10,254
and instead of measuring
the elemental composition,

1193
00:58:10,287 --> 00:58:12,490
now it's measuring the
molecular composition

1194
00:58:12,523 --> 00:58:14,425
through a combination
of fluorescence

1195
00:58:14,458 --> 00:58:17,261
and Raman spectroscopy,
okay, so we're measuring

1196

00:58:17,294 --> 00:58:20,331
the molecular composition,
we can detect,

1197
00:58:20,364 --> 00:58:23,801
we can map the concentration
of minerals that we know

1198
00:58:23,834 --> 00:58:26,470
are important to life,
like the carbonates

1199
00:58:26,503 --> 00:58:28,873
I told you about
earlier, but also,

1200
00:58:28,906 --> 00:58:32,610
of organic matter, if
there is any there.

1201
00:58:32,643 --> 00:58:35,479
Okay, so just briefly, we land

1202
00:58:35,512 --> 00:58:38,215
in a fresh new landing site,

1203
00:58:38,248 --> 00:58:40,317
take a look around
with Mastcam-Z,

1204
00:58:40,350 --> 00:58:42,553
start to look at the
textures and structures

1205
00:58:42,586 --> 00:58:46,023
and colors in the environment,
start to understand

1206
00:58:46,056 --> 00:58:47,958
how the rocks there

relate to each other.

1207
00:58:47,991 --> 00:58:50,394
We peer into the
subsurface with RIMFAX,

1208
00:58:50,427 --> 00:58:52,263
with our
ground-penetrating radar,

1209
00:58:52,296 --> 00:58:53,697
take data that look like this.

1210
00:58:53,730 --> 00:58:56,734
This is data from Svalbard
testing the RIMFAX instrument

1211
00:58:56,767 --> 00:58:59,270
on a glacier that
sits on top of rocks.

1212
00:58:59,303 --> 00:59:01,739
That gives you a sense of
what the data might look like.

1213
00:59:01,772 --> 00:59:03,974
All the time, we're
measuring the weather

1214
00:59:04,007 --> 00:59:07,745
with our MEDA instrument, here
it is looking at a dust devil

1215
00:59:07,778 --> 00:59:11,081
on Mars, and then
as we look around

1216
00:59:11,114 --> 00:59:14,518
with Mastcam-Z, we
find rocks that look

1217
00:59:14,551 --> 00:59:17,354
particularly interesting
and we shoot them

1218
00:59:17,387 --> 00:59:20,424
with our laser, with
SuperCam, and we look at them

1219
00:59:20,457 --> 00:59:22,326
with the telescope in SuperCam

1220
00:59:22,359 --> 00:59:24,628
and we measure their
chemistry from afar,

1221
00:59:24,661 --> 00:59:28,566
so about as far as I am
to the people over there,

1222
00:59:28,599 --> 00:59:32,169
so several meters away,
several yards away,

1223
00:59:32,202 --> 00:59:34,772
we can measure the
chemistry of a rock remotely

1224
00:59:34,805 --> 00:59:37,942
and decide do we want to rove
up to and actually deploy

1225
00:59:37,975 --> 00:59:40,177
our arm and do
some more science?

1226
00:59:40,210 --> 00:59:42,112
If we do decide that,
we park up close

1227
00:59:42,145 --> 00:59:44,548
to something and
we deploy our arm

1228
00:59:44,581 --> 00:59:46,050
and out at the
end of the turret,

1229
00:59:46,083 --> 00:59:48,219
as I said, we have
PIXL and SHERLOC.

1230
00:59:48,252 --> 00:59:53,424
SHERLOC has a subsystem that
we call WATSON, funnily enough.

1231
00:59:53,457 --> 00:59:56,093
Watson is a camera
that's very similar,

1232
00:59:56,126 --> 00:59:58,362
identical really, to
the MAHLI instrument,

1233
00:59:58,395 --> 01:00:02,066
the Mars Hand Lens Imager
on the Curiosity rover.

1234
01:00:02,099 --> 01:00:05,035
So Watson is our close-up
scientific imager,

1235
01:00:05,068 --> 01:00:08,205
like a macro lens that we take
images from centimeters away

1236
01:00:08,238 --> 01:00:10,774
from the target and
once we find something

1237
01:00:10,807 --> 01:00:13,611
very interesting, we
deploy a tool we call

1238
01:00:13,644 --> 01:00:16,146
our abrading bit so we
switch our drill bits.

1239
01:00:16,179 --> 01:00:18,816
We take the coring bit
off and we put on a bit

1240
01:00:18,849 --> 01:00:22,553
that's designed to
abrade to flatten

1241
01:00:22,586 --> 01:00:29,460
a circular area in the rock
of about four, 45 centimeters,

1242
01:00:29,493 --> 01:00:32,763
sorry, four
centimeters in diameter

1243
01:00:32,796 --> 01:00:36,367
and then we have what we
call a Gas Dust Removal Tool

1244
01:00:36,400 --> 01:00:39,236
so we have this just
fantastic device

1245
01:00:39,269 --> 01:00:41,238
that's full of
very pure nitrogen

1246
01:00:41,271 --> 01:00:44,475
and after we've abraded
our little circular spot

1247
01:00:44,508 --> 01:00:46,877
that we'll later analyze,
we need to get the dust

1248
01:00:46,910 --> 01:00:49,647
that we've generated
off of that area

1249
01:00:49,680 --> 01:00:52,816
and so we puff it with
a Gas Dust Removal Tool,

1250
01:00:52,849 --> 01:00:57,955
the GDIRT, so the G-D-R-T or
the GDIRT cleans it off for us,

1251
01:00:57,988 --> 01:01:00,691
then we switch to
PIXL and we make a map

1252
01:01:00,724 --> 01:01:02,293
of the elemental composition.

1253
01:01:02,326 --> 01:01:04,094
We switch back to
SHERLOC make a map

1254
01:01:04,127 --> 01:01:06,730
of the molecular composition
and if we like what we find,

1255
01:01:06,763 --> 01:01:09,033
we deploy the drill
and we drill a hole.

1256
01:01:09,066 --> 01:01:11,869
So on Mars 2020, we have
a distinct investigation

1257

01:01:11,902 --> 01:01:14,438
that's not associated
with any one instrument

1258
01:01:14,471 --> 01:01:17,474
on the rover, but it's meant
to represent the interests

1259
01:01:17,507 --> 01:01:19,843
of those scientists who
would work on the samples

1260
01:01:19,876 --> 01:01:22,880
if we're able to get
them home one day

1261
01:01:22,913 --> 01:01:25,215
and that's called Return
Sample Science or RSS.

1262
01:01:25,248 --> 01:01:27,518
We can also use
SuperCam and SHERLOC

1263
01:01:27,551 --> 01:01:29,920
to make some measurements
inside the borehole

1264
01:01:29,953 --> 01:01:31,789
to get some sense
of the chemistry

1265
01:01:31,822 --> 01:01:34,892
of that sample that
we've just chosen to put

1266
01:01:34,925 --> 01:01:37,828
in the rover, so how
do we do this part?

1267

01:01:37,861 --> 01:01:39,763
How do we seek the
signs of ancient life?

1268
01:01:39,796 --> 01:01:41,699
I just want to show
you an example here

1269
01:01:41,732 --> 01:01:43,667
of how we do it on
Earth using some

1270
01:01:43,700 --> 01:01:45,970
of the Mars 2020
instruments, so this

1271
01:01:46,003 --> 01:01:48,072
is a 3.4 billion-year-old
stromatolite.

1272
01:01:48,105 --> 01:01:50,641
This is from the same rock
unit as the stromatolite

1273
01:01:50,674 --> 01:01:53,677
that I've passed around to you,
the Strelley Pull Formation.

1274
01:01:53,710 --> 01:01:55,813
Some of the oldest
evidence for life on Earth.

1275
01:01:55,846 --> 01:01:58,248
It's a fossil microbial
mat, as we talked about.

1276
01:01:58,281 --> 01:02:00,751
You can see the textures,
the morphologies,

1277

01:02:00,784 --> 01:02:03,921
the shapes in the rock,
these layers, these fine dark

1278
01:02:03,954 --> 01:02:06,724
and light layers that are
wrinkly and if you study

1279
01:02:06,757 --> 01:02:09,860
these things all the
time, this looks very much

1280
01:02:09,893 --> 01:02:12,162
to you like evidence
of ancient life

1281
01:02:12,195 --> 01:02:15,265
of fossil microbial
mat, if you don't,

1282
01:02:15,298 --> 01:02:17,534
I don't know it looks
maybe like a mess,

1283
01:02:17,567 --> 01:02:20,070
[woman chuckles]
but get used to it.

1284
01:02:20,103 --> 01:02:22,206
Get used to talking
about stromatolites

1285
01:02:22,239 --> 01:02:24,108
'cause we're looking for them.

1286
01:02:24,141 --> 01:02:26,243
In any case, Mars
2020 can recognize

1287
01:02:26,276 --> 01:02:28,412

potential biosignatures,
potential signs

1288
01:02:28,445 --> 01:02:30,981
of ancient life as
lifelike patterns

1289
01:02:31,014 --> 01:02:33,317
in the exploration environments
so that's pretty simple.

1290
01:02:33,350 --> 01:02:36,387
We're looking for patterns in
our exploration environment

1291
01:02:36,420 --> 01:02:38,622
that are life-like, well,
what does that mean?

1292
01:02:38,655 --> 01:02:40,591
A little bit more technically,

1293
01:02:40,624 --> 01:02:43,127
first of all, they
could be concentrations

1294
01:02:43,160 --> 01:02:47,231
of biologically important
elements, what are those?

1295
01:02:47,264 --> 01:02:50,134
Sometimes we call
them CHONs or CHNOPS.

1296
01:02:50,167 --> 01:02:53,470
C-H-O-N-P-S,

1297
01:02:53,503 --> 01:02:57,174
carbon, hydrogen, nitrogen,
oxygen, phosphorus, sulfur.

1298
01:02:57,207 --> 01:02:59,443
There are many others,
iron is important for life

1299
01:02:59,476 --> 01:03:01,945
but these are critical
for life as we know it.

1300
01:03:01,978 --> 01:03:04,748
We're looking for
those elements.

1301
01:03:04,781 --> 01:03:06,116
Minerals, what
are the minerals?

1302
01:03:06,149 --> 01:03:08,118
We've already talked about
some carbonate minerals

1303
01:03:08,151 --> 01:03:09,653
that are important
for life and sulfates

1304
01:03:09,686 --> 01:03:12,122
and other types of
minerals or molecules,

1305
01:03:12,155 --> 01:03:14,124
organic matter, okay,

1306
01:03:14,157 --> 01:03:15,358
so concentrations
of organic matter

1307
01:03:15,392 --> 01:03:19,463
in a rock, particularly when
they are spatially associated

1308
01:03:19,496 --> 01:03:22,900
with biologically
suggestive morphology.

1309
01:03:22,933 --> 01:03:25,836
Okay, so it's especially
exciting to us

1310
01:03:25,869 --> 01:03:29,039
if we see those concentrations
and they are aligned,

1311
01:03:29,072 --> 01:03:31,575
they show variability
or heterogeneity

1312
01:03:31,608 --> 01:03:34,545
that is itself associated
in space with a shape

1313
01:03:34,578 --> 01:03:37,848
that looks like something that
biology could've produced,

1314
01:03:37,881 --> 01:03:39,583
so what does that look like?

1315
01:03:39,616 --> 01:03:42,319
So we mapped this part
of the stromatolite

1316
01:03:42,352 --> 01:03:45,189
with the PIXL instrument, the
laboratory version of PIXL

1317
01:03:45,222 --> 01:03:48,058
and we see the layered
shapes now showing up,

1318

01:03:48,091 --> 01:03:50,994
not an invisible image
but in elemental maps,

1319
01:03:51,027 --> 01:03:54,865
so green is showing silicon,
that is where quartz

1320
01:03:54,898 --> 01:03:57,367
has replaced the
original carbonate.

1321
01:03:57,400 --> 01:04:01,472
Carbonate is shown
in blue with calcium,

1322
01:04:01,505 --> 01:04:04,108
so it's calcium magnesium
carbonate I told you

1323
01:04:04,141 --> 01:04:07,010
and the carbonate has variable
iron concentration in it,

1324
01:04:07,043 --> 01:04:09,279
so that's where you
start to get the pink.

1325
01:04:09,312 --> 01:04:13,183
And Abby Allwood who's a
JPL stromatolite expert,

1326
01:04:13,216 --> 01:04:15,285
an expert in other
things as well,

1327
01:04:15,318 --> 01:04:18,322
but especially
Precambrian geology,

1328

01:04:18,355 --> 01:04:21,258
she is the principal
investigator of PIXL

1329
01:04:21,291 --> 01:04:24,628
and she published a study
a number of years ago

1330
01:04:24,661 --> 01:04:28,799
using a benchtop
instrument to study

1331
01:04:28,832 --> 01:04:31,802
the stromatolite and see this
variable iron concentration

1332
01:04:31,835 --> 01:04:33,637
as an additional
piece of evidence

1333
01:04:33,670 --> 01:04:36,106
that these stromatolites
were biological

1334
01:04:36,139 --> 01:04:38,308
and it was that that
sparked the idea

1335
01:04:38,341 --> 01:04:42,813
that now became PIXL so
next, we map the same area

1336
01:04:42,846 --> 01:04:46,450
with the SHERLOC instrument,
and SHERLOC tells us

1337
01:04:46,483 --> 01:04:50,220
about minerals and organic
matter that's in the rock

1338

01:04:50,253 --> 01:04:53,157
and so you see quartz
where there's silicon,

1339
01:04:53,190 --> 01:04:56,894
so that's good news, quartz
is silicon and oxygen.

1340
01:04:56,927 --> 01:04:59,997
Quartz interspersed
with dolomite, so that's

1341
01:05:00,030 --> 01:05:02,366
the calcium magnesium
carbonate I told you about

1342
01:05:02,399 --> 01:05:05,302
and then green, we're
very excited about green

1343
01:05:05,335 --> 01:05:08,305
is organic carbon or a
substance called kerogen

1344
01:05:08,338 --> 01:05:11,942
and this is complex
macromolecular organic matter.

1345
01:05:11,975 --> 01:05:15,612
It's not the same
chemistry as the original

1346
01:05:15,645 --> 01:05:18,916
organic matter that
the microbes made,

1347
01:05:18,949 --> 01:05:21,552
but the organics that
the microbes made,

1348

01:05:21,585 --> 01:05:24,321
subject to billions of
years of geologic time

1349
01:05:24,354 --> 01:05:26,456
kind of smooshes
together and combines

1350
01:05:26,489 --> 01:05:29,393
into this complex substance
called kerogen that itself

1351
01:05:29,426 --> 01:05:32,296
can be preserved on
billion-year timescales

1352
01:05:32,329 --> 01:05:35,465
so that is a kind of thing
we'd be looking for on Mars

1353
01:05:35,498 --> 01:05:38,869
is kerogen concentrated
into shapes like this,

1354
01:05:38,902 --> 01:05:42,139
so this was very exciting,
an early demonstration

1355
01:05:42,172 --> 01:05:46,176
of the power of using these
two JPL instruments together

1356
01:05:46,209 --> 01:05:49,913
as part of the Mars 2020
payload, PIXL and SHERLOC.

1357
01:05:49,946 --> 01:05:52,950
Okay, just a few quick
words on the sample

1358

01:05:52,983 --> 01:05:56,119
and caching subsystem,
so in what we call

1359
01:05:56,152 --> 01:05:59,523
the flight system, that is all
the parts of the spacecraft

1360
01:05:59,556 --> 01:06:01,491
that are not the payload,
all the science instruments

1361
01:06:01,524 --> 01:06:05,162
we call the payload, the
flight system is the big robot,

1362
01:06:05,195 --> 01:06:07,898
the rover, the big
new development

1363
01:06:07,931 --> 01:06:08,799
in the flight
system

1364
01:06:08,832 --> 01:06:10,834
is the sampling and
caching subsystem

1365
01:06:10,867 --> 01:06:14,037
so it's actually
several robots in one,

1366
01:06:14,070 --> 01:06:16,373
so we have the rover
is a big robot.

1367
01:06:16,406 --> 01:06:18,809
We have a robotic arm
that has the turret

1368

01:06:18,842 --> 01:06:21,378
with some scientific
instruments but also the drill,

1369
01:06:21,411 --> 01:06:24,514
the coring drill
so that's a robot

1370
01:06:24,547 --> 01:06:28,318
and then we have
the bit carousel.

1371
01:06:28,351 --> 01:06:30,153
So the way this
works is at the end

1372
01:06:30,186 --> 01:06:32,022
of the robotic
arm is the drill.

1373
01:06:32,055 --> 01:06:35,192
When it comes time to drill,
let's say we've just abraded

1374
01:06:35,225 --> 01:06:37,461
a patch and we've
deployed the GDIRT,

1375
01:06:37,494 --> 01:06:41,331
and we've blown the GDIRT
off of the little area

1376
01:06:41,364 --> 01:06:44,401
that we've abraded and
it's time now to sample,

1377
01:06:44,434 --> 01:06:46,803
so we have our abrading bit
on the end of the drill.

1378

01:06:46,836 --> 01:06:49,740
We need to bring the robotic
arm back to the bit carousel

1379
01:06:49,773 --> 01:06:52,342
that you see there,
that little circle

1380
01:06:52,375 --> 01:06:54,544
on the front of it with
a smaller purple circle

1381
01:06:54,577 --> 01:06:56,780
in the middle, we dock
the end of the robotic arm

1382
01:06:56,813 --> 01:07:01,418
to that bit carousel
and we sit there

1383
01:07:01,451 --> 01:07:03,820
for a moment and
there's some action

1384
01:07:03,853 --> 01:07:05,822
happening now in
the other robot,

1385
01:07:05,855 --> 01:07:07,357
the adaptive caching assembly.

1386
01:07:07,390 --> 01:07:09,393
Inside the adaptive
caching assembly,

1387
01:07:09,426 --> 01:07:12,296
you can see an
inset here,

1388
01:07:12,329 --> 01:07:14,731

there's another
small helper arm.

1389
01:07:14,764 --> 01:07:17,501
We call this the Sample
Handling Arm, the SHA.

1390
01:07:17,534 --> 01:07:21,471
That little arm goes
over and picks up

1391
01:07:21,504 --> 01:07:24,141
a sample tube, a
titanium sample tube,

1392
01:07:24,174 --> 01:07:26,276
out of tube storage
you see here.

1393
01:07:26,309 --> 01:07:28,779
We've got 42 there,
pulls out a sample tube

1394
01:07:28,812 --> 01:07:31,181
and brings it over
and it sticks into it,

1395
01:07:31,214 --> 01:07:33,483
sticks it inside a drill
bit that is sitting

1396
01:07:33,516 --> 01:07:37,654
in the bit carousel, then
the bit carousel rotates

1397
01:07:37,687 --> 01:07:40,657
into position, we
pull the abrading bit

1398
01:07:40,690 --> 01:07:43,160

off of the end of the
drill and we swap it out

1399
01:07:43,193 --> 01:07:45,696
for the coring that
that has a sample tube

1400
01:07:45,729 --> 01:07:48,598
installed within it,
now we're ready to drill

1401
01:07:48,631 --> 01:07:50,801
and we move the arm
back over the target.

1402
01:07:50,834 --> 01:07:53,704
We drill into the target,
fill up that sample tube

1403
01:07:53,737 --> 01:07:56,773
with rock or regolith,
we have a special bit

1404
01:07:56,806 --> 01:07:59,676
for collecting loose
unconsolidated material

1405
01:07:59,709 --> 01:08:04,247
like soil, either a rock
core or a regolith sample.

1406
01:08:04,280 --> 01:08:07,084
We move back over the
bit carousel and we put

1407
01:08:07,117 --> 01:08:10,620
that filled sample,
the drill bit

1408
01:08:10,653 --> 01:08:13,423

with the filled sample
tube now, rotate it back

1409
01:08:13,456 --> 01:08:15,692
into the adaptive
caching assembly,

1410
01:08:15,725 --> 01:08:18,895
this little SHA sample handling
arm, grabs that sample tube,

1411
01:08:18,928 --> 01:08:20,897
and pulls it out
and moves it through

1412
01:08:20,930 --> 01:08:22,866
a number of
stations, so we have

1413
01:08:22,899 --> 01:08:25,135
a little camera inside
there, we can take a picture

1414
01:08:25,168 --> 01:08:28,438
of the very top of the
sample and then we move it

1415
01:08:28,471 --> 01:08:30,841
to a sealing station,
so we hermetically seal,

1416
01:08:30,874 --> 01:08:33,443
we put a little sealing
plug into the top

1417
01:08:33,476 --> 01:08:35,779
of that sample and
push it down tight

1418
01:08:35,812 --> 01:08:38,915

so that we won't lose
the volatile materials

1419
01:08:38,948 --> 01:08:41,618
that are so precious
inside that sample.

1420
01:08:41,651 --> 01:08:44,154
We'll seal it up tight,
we'll stick it back

1421
01:08:44,187 --> 01:08:46,890
into tube storage
and it will sit there

1422
01:08:46,923 --> 01:08:50,560
until it comes time for us to
drop it on the surface of Mars

1423
01:08:50,593 --> 01:08:53,897
and just briefly, well,
I'll quickly show you

1424
01:08:53,930 --> 01:08:57,134
these sample tubes but and
so here's the coring bit.

1425
01:08:57,167 --> 01:08:59,136
Here's what the sample
tube looks like.

1426
01:08:59,169 --> 01:09:01,538
These are not to scale,
so the sample tube

1427
01:09:01,571 --> 01:09:03,507
is obviously smaller
than the drill bit

1428
01:09:03,540 --> 01:09:06,209

but that sits up in
there, here's a cutaway

1429
01:09:06,242 --> 01:09:10,280
of a sample tube with a
sample shown inside it

1430
01:09:10,313 --> 01:09:13,984
with the seal, the gold
seal that's inside there.

1431
01:09:14,017 --> 01:09:17,054
So sometimes we're
collecting samples

1432
01:09:17,087 --> 01:09:18,955
but something that's very
important for us to do,

1433
01:09:18,988 --> 01:09:20,690
in addition addition
to collecting samples,

1434
01:09:20,723 --> 01:09:23,493
is to collect what we
sometimes call blanks

1435
01:09:23,526 --> 01:09:26,430
or witnesses and
this is important

1436
01:09:26,463 --> 01:09:30,267
because we are working
so hard on this mission

1437
01:09:30,300 --> 01:09:33,570
to meet requirements that
are really unprecedented

1438
01:09:33,603 --> 01:09:37,140

with regard to our need to
keep these samples clean.

1439
01:09:37,173 --> 01:09:39,576
They're so precious that
we have to keep them

1440
01:09:39,609 --> 01:09:44,481
incredibly clean, that
said, we can't keep them,

1441
01:09:44,514 --> 01:09:46,416
it's impossible to do
this sort of mission

1442
01:09:46,449 --> 01:09:48,852
and keep them perfectly clean,

1443
01:09:48,885 --> 01:09:51,888
so there will almost inevitably
be some small trace amount

1444
01:09:51,921 --> 01:09:55,358
of contamination, it's
impossible to avoid really

1445
01:09:55,391 --> 01:09:57,928
and we're gonna keep
that as low as possible

1446
01:09:57,961 --> 01:10:01,298
but what we really want
to understand: what is it?

1447
01:10:01,331 --> 01:10:03,700
And so one of the things we
do, we have some special tubes

1448
01:10:03,733 --> 01:10:06,403
called witness tubes

and now we go over,

1449
01:10:06,436 --> 01:10:08,905
grab that witness tube
out, put in a drill bit,

1450
01:10:08,938 --> 01:10:11,475
put it in the drill, wave
it around, maybe percuss it

1451
01:10:11,508 --> 01:10:14,678
around in free space,
treat it in every way

1452
01:10:14,711 --> 01:10:17,848
exactly the same as we do
a sample with the exception

1453
01:10:17,881 --> 01:10:19,783
of actually drilling
into rock, otherwise,

1454
01:10:19,816 --> 01:10:22,986
it's exactly the same
and then we put it back.

1455
01:10:23,019 --> 01:10:25,489
We seal it up and
we lock it away.

1456
01:10:25,522 --> 01:10:28,892
Inside that tube is this
fancy thing you see here

1457
01:10:28,925 --> 01:10:32,629
and we're getting to the
end of our design of this,

1458
01:10:32,662 --> 01:10:34,464
but it's pretty complex,

but there's many

1459
01:10:34,497 --> 01:10:36,867
different substances
inside meant to monitor

1460
01:10:36,900 --> 01:10:38,835
all different types
of contamination

1461
01:10:38,868 --> 01:10:41,872
that we think we might find
and some that we have no idea

1462
01:10:41,905 --> 01:10:45,008
that we we might find
and so we'll monitor that

1463
01:10:45,041 --> 01:10:47,043
with these witnesses
and seal them up

1464
01:10:47,076 --> 01:10:49,446
and we can bring those
back along with the samples

1465
01:10:49,479 --> 01:10:53,049
and analyze those and
anything we detect in these

1466
01:10:53,082 --> 01:10:55,952
would be suspect if we detect
it in our sample, right?

1467
01:10:55,985 --> 01:10:59,589
So if we found some
organic compound in here

1468
01:10:59,622 --> 01:11:02,259
that suggested the

presence of biology,

1469
01:11:02,292 --> 01:11:05,228
if we found it in this and
found it in our Mars sample,

1470
01:11:05,261 --> 01:11:07,097
it'd be really hard for
us to interpret that

1471
01:11:07,130 --> 01:11:10,100
in a Mars sample as evidence
for life, you get the picture.

1472
01:11:10,133 --> 01:11:13,003
Okay, so that is
coring and sampling.

1473
01:11:13,036 --> 01:11:15,038
Before we go to landing
sites, actually,

1474
01:11:15,071 --> 01:11:18,808
just briefly wanna tell you
that the way we're doing this,

1475
01:11:18,841 --> 01:11:22,846
so we drop individual sample
tubes out on the surface

1476
01:11:22,879 --> 01:11:25,415
one at a time and so
is our basic model

1477
01:11:25,448 --> 01:11:28,585
for exploration during
our prime mission,

1478
01:11:28,618 --> 01:11:30,921
which will be a

couple Earth years,

1479
01:11:30,954 --> 01:11:36,826
maybe up to three Earth
years in our primary mission,

1480
01:11:36,859 --> 01:11:40,096
we'll rove around, we wanna
explore two diverse regions

1481
01:11:40,129 --> 01:11:43,967
of interest, okay, so
two areas that are about

1482
01:11:44,000 --> 01:11:48,605
one kilometer on a side,
imagine about that big

1483
01:11:48,638 --> 01:11:51,107
so if you're familiar
with MSL, the whole area

1484
01:11:51,140 --> 01:11:53,643
of Yellowknife Bay,
that whole, all the work

1485
01:11:53,676 --> 01:11:55,579
that we did there,
that is similar

1486
01:11:55,612 --> 01:11:58,648
to a region of
interest but explore

1487
01:11:58,681 --> 01:12:00,550
one part of our landing site.

1488
01:12:00,583 --> 01:12:03,153
It's not possible to
explore exhaustively

1489
01:12:03,186 --> 01:12:06,122
our entire landing
ellipse, so we divide that

1490
01:12:06,155 --> 01:12:08,959
into two very diverse
regions of interest

1491
01:12:08,992 --> 01:12:11,695
and we'll commit kind of half,
about half of our mission

1492
01:12:11,728 --> 01:12:14,264
roughly to each one,
maybe collect half

1493
01:12:14,297 --> 01:12:17,601
of our samples in each
one but we'll rove out

1494
01:12:17,634 --> 01:12:19,769
and explore region
of interest one,

1495
01:12:19,802 --> 01:12:22,706
take a lot of measurements
with our onboard instruments,

1496
01:12:22,739 --> 01:12:24,975
collect samples, maybe
about 10 samples,

1497
01:12:25,008 --> 01:12:26,943
and then we'll keep
those in storage

1498
01:12:26,976 --> 01:12:29,679
and we'll drive away to
region of interest two,

1499
01:12:29,712 --> 01:12:32,549
right on the border of
region of interest two,

1500
01:12:32,582 --> 01:12:34,251
we'll start to
drop our samples.

1501
01:12:34,284 --> 01:12:36,920
We'll find a safe spot
where those samples

1502
01:12:36,953 --> 01:12:40,790
can sit for 10 years or
so if it takes that long

1503
01:12:40,823 --> 01:12:43,893
and we'll drop them one
at a time in a collection

1504
01:12:43,926 --> 01:12:46,930
that we call a depot,
then we'll leave that spot

1505
01:12:46,963 --> 01:12:49,566
and we'll go and explore
region of interest two

1506
01:12:49,599 --> 01:12:51,668
and make a bunch more
measurements of hopefully,

1507
01:12:51,701 --> 01:12:53,670
different more interesting
kinds of rocks.

1508
01:12:53,703 --> 01:12:55,872
We'll collect maybe
10 more samples.

1509
01:12:55,905 --> 01:12:58,975
We'll come back to that depot
and we'll drop our samples

1510
01:12:59,008 --> 01:13:00,844
and the reason we wanna
do that is as soon

1511
01:13:00,877 --> 01:13:04,247
as we can offload
those 10 samples or so,

1512
01:13:04,280 --> 01:13:08,084
we've offloaded a
huge amount of risk.

1513
01:13:08,117 --> 01:13:10,654
We now have a collection
of samples on the surface

1514
01:13:10,687 --> 01:13:13,757
that the follow-on mission
could come and return

1515
01:13:13,790 --> 01:13:16,126
should something
happen to our rover

1516
01:13:16,159 --> 01:13:18,194
while exploring region
of interest two,

1517
01:13:18,227 --> 01:13:20,263
then we bring the samples
region of interest two

1518
01:13:20,296 --> 01:13:21,865
back to the same
place and drop those.

1519
01:13:21,898 --> 01:13:25,068
Now we've offloaded more
risk again and we can start

1520
01:13:25,101 --> 01:13:27,337
to go into, we hope
if we're lucky enough,

1521
01:13:27,370 --> 01:13:30,507
extended missions where we
can maybe take a bit more risk

1522
01:13:30,540 --> 01:13:33,343
and go up that higher
hill or over the horizon

1523
01:13:33,376 --> 01:13:36,279
and do some more
collecting there.

1524
01:13:36,312 --> 01:13:38,915
Okay, so where we're
thinking about going

1525
01:13:38,948 --> 01:13:42,352
and we have, over the
last several years,

1526
01:13:42,385 --> 01:13:44,554
we've whittled down her
list of landing sites

1527
01:13:44,587 --> 01:13:49,626
from, oh, 30ish or so

1528
01:13:49,659 --> 01:13:52,962
down to three, only three,

1529

01:13:52,995 --> 01:13:55,265
in a series of landing site
workshops, these are open

1530
01:13:55,298 --> 01:13:58,268
to the public, the
next what is happening,

1531
01:13:58,301 --> 01:14:01,304
it's generally scientists
who come to these things,

1532
01:14:01,337 --> 01:14:04,708
but we have 100,
200 even scientists

1533
01:14:04,741 --> 01:14:06,676
who come from all
over the world,

1534
01:14:06,709 --> 01:14:11,715
in some cases, to help
decide where we should send

1535
01:14:11,748 --> 01:14:14,951
this precious
asset of Mars 2020.

1536
01:14:14,984 --> 01:14:17,721
Sometimes we vote at
the end of these things

1537
01:14:17,754 --> 01:14:20,156
and it's sort of like the
basketball tournament.

1538
01:14:20,189 --> 01:14:22,926
We whittle it down
to a top eight

1539

01:14:22,959 --> 01:14:26,162
and then down to a final
four, but in this case,

1540
01:14:26,195 --> 01:14:28,198
we're able to actually
whittle it to three

1541
01:14:28,231 --> 01:14:31,501
at the last landing site
workshop and, interestingly,

1542
01:14:31,534 --> 01:14:35,038
coincidentally, we selected
three different landing sites

1543
01:14:35,071 --> 01:14:37,707
that represent
three very different

1544
01:14:37,740 --> 01:14:39,976
ancient habitable environments.

1545
01:14:40,009 --> 01:14:43,680
The first one is Jezero
crater, so Jezero

1546
01:14:43,713 --> 01:14:47,317
and the second one, Northeast
Syrtis are close to each other

1547
01:14:47,350 --> 01:14:49,786
on Mars in the Isidis
region of Mars.

1548
01:14:49,819 --> 01:14:53,390
They're on the edge of one
of the largest impact craters

1549
01:14:53,423 --> 01:14:56,559

in the solar system
so a very large impact

1550
01:14:56,592 --> 01:14:59,796
produced at a time
when very large rocks

1551
01:14:59,829 --> 01:15:01,498
were floating around
the solar system.

1552
01:15:01,531 --> 01:15:04,501
This was very early in
planetary formation.

1553
01:15:04,534 --> 01:15:07,670
That impact occurred, but
then these environments

1554
01:15:07,703 --> 01:15:10,440
formed out on the edge of
that feature and Jezero

1555
01:15:10,473 --> 01:15:13,510
is in a smaller, younger
slightly younger crater

1556
01:15:13,543 --> 01:15:16,646
and you see it's a little
bit maybe hard to see

1557
01:15:16,679 --> 01:15:19,916
in this image but here
is the rim of the crater.

1558
01:15:19,949 --> 01:15:22,986
There's a river that flows
into the crater there

1559
01:15:23,019 --> 01:15:26,756

and out at the end of
that river is a delta.

1560
01:15:26,789 --> 01:15:30,326
A delta is a fantastic
thing for planetary science

1561
01:15:30,359 --> 01:15:33,563
because it's a feature that
can be observed from orbit,

1562
01:15:33,596 --> 01:15:36,065
which tells us there was
a body of standing water

1563
01:15:36,098 --> 01:15:40,503
into which another
body of water flowed

1564
01:15:40,536 --> 01:15:43,506
and dumped its sediment, okay,
that's how a delta is formed

1565
01:15:43,539 --> 01:15:46,276
so this river here that
flowed into Jezero crater

1566
01:15:46,309 --> 01:15:50,947
dumped sediment there and
so bodies of standing water

1567
01:15:50,980 --> 01:15:53,483
clearly are great places
to go look for evidence

1568
01:15:53,516 --> 01:15:56,085
of ancient life, in fact,
almost everything we know

1569
01:15:56,118 --> 01:15:58,221

about the history
of life on Earth

1570
01:15:58,254 --> 01:16:01,224
comes from shallow
water environments,

1571
01:16:01,257 --> 01:16:03,793
rocks deposited in
shallow water environments

1572
01:16:03,826 --> 01:16:06,696
and so we know well how
to search for evidence

1573
01:16:06,729 --> 01:16:09,399
of ancient life here, there's
a great mineral diversity

1574
01:16:09,432 --> 01:16:14,103
here, we have clays,
some igneous minerals

1575
01:16:14,136 --> 01:16:17,874
might be particularly ancient
and then carbonate minerals

1576
01:16:17,907 --> 01:16:20,510
here, throughout
the landing site.

1577
01:16:20,543 --> 01:16:22,579
But, these are particularly
interesting to me

1578
01:16:22,612 --> 01:16:24,080
these are
carbonate minerals

1579
01:16:24,113 --> 01:16:27,016

up along the shore of what
would've been an ancient lake.

1580
01:16:27,049 --> 01:16:29,586
This is the type of environment
where stromatolites form

1581
01:16:29,619 --> 01:16:33,256
so very exciting place
to go explore at Jezero.

1582
01:16:33,289 --> 01:16:35,425
Northeastern Syrtis now
is a very different type

1583
01:16:35,458 --> 01:16:39,529
of environment, more
mysterious in a sense, older.

1584
01:16:39,562 --> 01:16:42,932
It may be the oldest, certainly
some of the oldest crust

1585
01:16:42,965 --> 01:16:45,134
exposed at Mars, some
of the oldest rocks

1586
01:16:45,167 --> 01:16:47,937
we could possibly
go explore on Mars

1587
01:16:47,970 --> 01:16:51,508
but these are not, we
think, sedimentary rocks

1588
01:16:51,541 --> 01:16:53,409
like these rocks
here at Jezero.

1589
01:16:53,442 --> 01:16:57,881

These are ancient igneous
rocks and the igneous rocks

1590
01:16:57,914 --> 01:17:01,518
may have formed from
volcanism, may have formed

1591
01:17:01,551 --> 01:17:04,654
from impacts, so maybe
earlier rocks that were melted

1592
01:17:04,687 --> 01:17:07,991
by giant impacts occurring very
early in the history of Mars

1593
01:17:08,024 --> 01:17:11,227
but then we have mineralogic
evidence from orbit

1594
01:17:11,260 --> 01:17:14,998
of the interaction of these
igneous rocks with water

1595
01:17:15,031 --> 01:17:18,301
a very, very long time
ago and so ancient water

1596
01:17:18,334 --> 01:17:20,870
would've flowed through
these rocks, through cracks

1597
01:17:20,903 --> 01:17:24,340
in these rocks, dissolved
bits of those rocks

1598
01:17:24,373 --> 01:17:26,910
and provided food
for microorganisms

1599
01:17:26,943 --> 01:17:27,911

that could've lived

1600
01:17:27,944 --> 01:17:30,446
in those little fracture
networks, potentially

1601
01:17:30,479 --> 01:17:33,349
in hydrothermal systems that
were generated by all that,

1602
01:17:33,382 --> 01:17:35,818
the energy of those
ancient impacts crashing

1603
01:17:35,851 --> 01:17:38,821
into the rocks there, so
that's Northeast Syrtis,

1604
01:17:38,854 --> 01:17:41,824
and then Columbia Hills
is in Gusev crater

1605
01:17:41,857 --> 01:17:44,961
so this is where Spirit
went and the Spirit rover

1606
01:17:44,994 --> 01:17:49,799
found these high silicon rocks
there the home plate area

1607
01:17:49,832 --> 01:17:53,870
of the Columbia Hills and
in these high silicon rocks

1608
01:17:53,903 --> 01:17:59,442
were observed these digitate
or finger-like morphologies.

1609
01:17:59,475 --> 01:18:02,078
This is from a MER,

a Spirit image,

1610
01:18:02,111 --> 01:18:05,648
and these finger-like
morphologies formed

1611
01:18:05,681 --> 01:18:09,786
in a high silicon rock
suggests to some scientists

1612
01:18:09,819 --> 01:18:13,156
that these rocks formed in a
siliceous sinter environment,

1613
01:18:13,189 --> 01:18:14,891
something like the
environments you see

1614
01:18:14,924 --> 01:18:17,327
in Yellowstone, so imagine
a bubbling hot spring

1615
01:18:17,360 --> 01:18:20,663
on the surface with
water flowing out

1616
01:18:20,696 --> 01:18:23,032
and bubbling through the rocks,
hot water maybe dissolving

1617
01:18:23,065 --> 01:18:27,403
things, re-precipitating things
so that sort of environment.

1618
01:18:27,436 --> 01:18:29,572
There are some people
who believe

1619
01:18:29,605 --> 01:18:31,107
that these rocks

preserve

1620
01:18:31,140 --> 01:18:34,377
in an environment like
that and some people

1621
01:18:34,410 --> 01:18:37,246
take an alternative view
and so it's controversial

1622
01:18:37,279 --> 01:18:40,917
but we're now working
out, working through a lot

1623
01:18:40,950 --> 01:18:43,720
of the controversy by
studying these sites

1624
01:18:43,753 --> 01:18:46,222
in greater detail than
they've yet been studied.

1625
01:18:46,255 --> 01:18:49,058
We have our science team
working hard day after day.

1626
01:18:49,091 --> 01:18:51,894
We just had a teleconference
today about Northeast Syrtis

1627
01:18:51,927 --> 01:18:54,330
wrapping up months
of hard work done

1628
01:18:54,363 --> 01:18:58,067
by our science team on this
site, all leading towards

1629
01:18:58,100 --> 01:19:01,170
the next landing site workshop,

which we expect will happen

1630
01:19:01,203 --> 01:19:05,775
sometime this
summer and it's in

1631
01:19:05,808 --> 01:19:08,211
the days, weeks, and months
after that landing site

1632
01:19:08,244 --> 01:19:11,614
that we hope that landing
site selection workshop,

1633
01:19:11,647 --> 01:19:14,083
that we hope to whittle
this down to a top site

1634
01:19:14,116 --> 01:19:16,653
and a backup site so
the decision is not ours

1635
01:19:16,686 --> 01:19:18,855
to make, we'll make
a recommendation.

1636
01:19:18,888 --> 01:19:20,990
The Mars 2020 Mission
will make a recommendation

1637
01:19:21,023 --> 01:19:24,227
to the Mars Exploration
Program, who will, in turn,

1638
01:19:24,260 --> 01:19:26,429
make a recommendation
to someone called

1639
01:19:26,462 --> 01:19:28,998
the associate administrator

of the Science Mission

1640
01:19:29,031 --> 01:19:31,734
Directorate, okay, this is
sort of a one level down

1641
01:19:31,767 --> 01:19:35,038
from the NASA administrator,
the different directorates

1642
01:19:35,071 --> 01:19:37,206
at NASA, the science
mission directorate

1643
01:19:37,239 --> 01:19:40,543
is largely in charge
of missions like ours.

1644
01:19:40,576 --> 01:19:42,545
It's the associate
administrator of that group

1645
01:19:42,578 --> 01:19:44,947
who is the true decider
there but we'll make

1646
01:19:44,980 --> 01:19:47,517
a strong recommendation
there of a top site

1647
01:19:47,550 --> 01:19:49,719
and a backup and we
hope to have that site

1648
01:19:49,752 --> 01:19:53,122
selected by late next
summer or early in the fall.

1649
01:19:53,155 --> 01:19:55,324
That would be two

years prior to launch

1650
01:19:55,357 --> 01:19:58,061
so that gives us a big chunk
of time to really focus

1651
01:19:58,094 --> 01:20:02,198
on a single environment and
go to analog environments

1652
01:20:02,231 --> 01:20:05,334
that are like that on Earth and
really study those in detail

1653
01:20:05,367 --> 01:20:09,305
and really develop in great
detail our exploration strategy

1654
01:20:09,338 --> 01:20:13,509
that we will deploy when
we finally do get to Mars.

1655
01:20:13,542 --> 01:20:16,345
And so that is all
I have for you today

1656
01:20:16,378 --> 01:20:20,583
except to show you this
great sunset image.

1657
01:20:20,616 --> 01:20:26,389
That's the sun setting
Mars, blue Sun in a red sky

1658
01:20:26,422 --> 01:20:29,058
and then of course
a URL, stay tuned.

1659
01:20:29,091 --> 01:20:32,095
Thanks are coming, and

I'd love to take questions

1660
01:20:32,128 --> 01:20:45,208
that you have, thanks.
[audience applauding]

1661
01:20:45,241 --> 01:20:48,711
Thanks a lot, yeah, and
please do come to the mic

1662
01:20:48,744 --> 01:20:51,080
so we've got someone
there the mic, go ahead.

1663
01:20:51,113 --> 01:20:55,384
- I haven't seen
any solar panels.

1664
01:20:55,417 --> 01:20:58,287
Can you talk about
the energy source here

1665
01:20:58,320 --> 01:21:01,858
and also about the
communication capabilities?

1666
01:21:01,891 --> 01:21:04,961
- Yeah, so you did notice
there were no solar panels

1667
01:21:04,994 --> 01:21:08,397
on the rover, so we have,
just like the Curiosity rover

1668
01:21:08,430 --> 01:21:11,033
for MSL, we have what's
called the MMRTG,

1669
01:21:11,066 --> 01:21:14,537
the Multi-Mission Radioisotope

Thermoelectric Generator

1670
01:21:14,570 --> 01:21:17,540
and so it's a
nuclear power source.

1671
01:21:17,573 --> 01:21:21,010
It generates heat, which is
converted into electricity

1672
01:21:21,043 --> 01:21:25,047
that runs our rover, so
that's our power source

1673
01:21:25,080 --> 01:21:27,550
and then you asked about
communication capabilities.

1674
01:21:27,583 --> 01:21:31,053
We have also, like MSL, we
have a direct-to-Earth antenna,

1675
01:21:31,086 --> 01:21:34,724
so we can communicate,
it's quite low bandwidth.

1676
01:21:34,757 --> 01:21:37,293
We can communicate direct
from the surface of Mars

1677
01:21:37,326 --> 01:21:39,362
to Earth and another
antenna that allows us

1678
01:21:39,395 --> 01:21:41,964
to communicate with our
orbiters that are flying

1679
01:21:41,997 --> 01:21:45,301
around Mars, orbiting

around Mars that then relay

1680
01:21:45,334 --> 01:21:48,638
the data from the
rover back to the Earth

1681
01:21:48,671 --> 01:21:50,640
through the Deep Space Network

1682
01:21:50,673 --> 01:21:52,975
and that's a much higher
bandwidth way to communicate

1683
01:21:53,008 --> 01:21:55,211
so that's how we get our
plans up to the rover

1684
01:21:55,244 --> 01:21:59,749
and the data back down from
the rover, other questions?

1685
01:21:59,782 --> 01:22:02,251
Yeah, if you could
use the mic, thanks.

1686
01:22:02,284 --> 01:22:04,587
That way the people
on the video can hear.

1687
01:22:04,620 --> 01:22:07,957
- Okay, you mentioned a
safe place you're gonna put

1688
01:22:07,990 --> 01:22:11,694
the samples, however,
there are dust storms,

1689
01:22:11,727 --> 01:22:14,530
10 years' worth of dust
storms could cover that up.

1690
01:22:14,563 --> 01:22:16,999
Is there gonna be some
kind of beacon to,

1691
01:22:17,032 --> 01:22:23,573
like a GPS beacon or something
to tell you where they are?

1692
01:22:23,606 --> 01:22:25,575
- Yeah, it's a good
thought, it is something

1693
01:22:25,608 --> 01:22:28,177
we're thinking
about definitely.

1694
01:22:28,210 --> 01:22:32,915
There will be no beacon, there
will be no active signaling

1695
01:22:32,948 --> 01:22:36,786
done by the samples, they
will have etched onto them

1696
01:22:36,819 --> 01:22:39,655
unique identifiers that
are machine readable

1697
01:22:39,688 --> 01:22:42,458
so we hope a robot
could read those labels

1698
01:22:42,491 --> 01:22:44,493
so we know which sample
is which but we won't have

1699
01:22:44,526 --> 01:22:47,396
any kind of a homing beacon
or anything like that

1700
01:22:47,429 --> 01:22:51,400
but trust me, the site where
those samples are dropped

1701
01:22:51,433 --> 01:22:55,404
will be among the most
exhaustively documented

1702
01:22:55,437 --> 01:22:58,474
and the best-known places
in the known universe.

1703
01:22:58,507 --> 01:23:00,042
[audience laughing]
So we will take many,

1704
01:23:00,075 --> 01:23:03,746
many images, both from the
ground, from that area,

1705
01:23:03,779 --> 01:23:07,416
360 panoramas and so forth;
we don't have a GPS network

1706
01:23:07,449 --> 01:23:10,586
around Mars yet but we
do have these orbiters

1707
01:23:10,619 --> 01:23:14,590
so we can take images of
and we can see the rovers

1708
01:23:14,623 --> 01:23:17,460
from our orbiters and
so we'll take images

1709
01:23:17,493 --> 01:23:21,597
like that if we still
have those orbiters then

1710
01:23:21,630 --> 01:23:25,334
and so we'll use that
strategy in order to get back

1711
01:23:25,367 --> 01:23:28,137
and maybe we'll still have
wheel tracks leading up to it

1712
01:23:28,170 --> 01:23:30,172
but you're right, there
is weather on Mars.

1713
01:23:30,205 --> 01:23:33,976
There are dust storms and
but we did we do understand

1714
01:23:34,009 --> 01:23:36,979
those phenomena to some
degree, not completely

1715
01:23:37,012 --> 01:23:39,582
but we'll choose our
location very carefully

1716
01:23:39,615 --> 01:23:43,352
with all that in
mind, other questions?

1717
01:23:43,385 --> 01:23:45,454
Yes, please.

1718
01:23:45,487 --> 01:23:49,025
- Okay, with all these new
sensors and new cameras,

1719
01:23:49,058 --> 01:23:52,595
we're gonna gather a lot of
data, how have we evolved

1720
01:23:52,628 --> 01:23:55,231
our data transmission
techniques?

1721
01:23:55,264 --> 01:23:59,335
Are we planning on sending
a special antenna/satellite

1722
01:23:59,368 --> 01:24:02,204
something to have a
better communication

1723
01:24:02,237 --> 01:24:04,774
and avoid the delay
issues we had,

1724
01:24:04,807 --> 01:24:09,578
like the delay timed
between the rover itself

1725
01:24:09,611 --> 01:24:12,214
and the mission control panel?

1726
01:24:12,247 --> 01:24:14,583
So what are your
thoughts on that?

1727
01:24:14,616 --> 01:24:16,652
- That's a great question,
I mean that's one

1728
01:24:16,685 --> 01:24:19,522
of our key concerns at
this stage of development.

1729
01:24:19,555 --> 01:24:23,392
We have this incredibly psychic
capable scientific payload

1730

01:24:23,425 --> 01:24:26,262
capable of generating
maps so we can generate

1731
01:24:26,295 --> 01:24:31,300
gobs of data, we can generate
more data than than MSL really

1732
01:24:31,333 --> 01:24:34,136
was generating, we have
more cameras that are,

1733
01:24:34,169 --> 01:24:36,706
some of them are color now
instead of black and white

1734
01:24:36,739 --> 01:24:39,408
so we have higher
data requirements

1735
01:24:39,441 --> 01:24:40,676
to get our
science done.

1736
01:24:40,709 --> 01:24:44,213
At the same time, the
orbiters around Mars

1737
01:24:44,246 --> 01:24:49,652
are aging and NASA does
not have a plan yet

1738
01:24:49,685 --> 01:24:55,024
official to send another
orbiter to back up those

1739
01:24:55,057 --> 01:24:59,228
but we do have multiple
orbiters around Mars currently.

1740

01:24:59,261 --> 01:25:02,932
We have MRO, we
have Mars Odyssey.

1741
01:25:02,965 --> 01:25:05,401
I won't list them so
I don't forget any

1742
01:25:05,434 --> 01:25:08,471
but anyway, we have
Maven newly in orbit

1743
01:25:08,504 --> 01:25:11,307
but we're in conversation
with all those teams

1744
01:25:11,340 --> 01:25:14,710
and with the Mars expiration
program to figure out

1745
01:25:14,743 --> 01:25:16,479
the best way to
get the bandwidth

1746
01:25:16,512 --> 01:25:18,481
we need to get the data down.

1747
01:25:18,514 --> 01:25:21,617
There's no way, unfortunately,
really that we know of yet

1748
01:25:21,650 --> 01:25:24,153
to minimize that
time of communication

1749
01:25:24,186 --> 01:25:26,088
that gets down to
the speed of light

1750
01:25:26,121 --> 01:25:29,592

but it's getting the data
rate, getting the bandwidth

1751
01:25:29,625 --> 01:25:31,660
that we can across
the DSN is one

1752
01:25:31,693 --> 01:25:36,032
of our key concerns
and so it may indeed

1753
01:25:36,065 --> 01:25:39,035
partly be international
partnership.

1754
01:25:39,068 --> 01:25:42,204
The Europeans have orbiters
in place and we'll partner

1755
01:25:42,237 --> 01:25:45,174
with them as well
as using NASA assets

1756
01:25:45,207 --> 01:25:49,645
so we hope to do all that,
thanks, other questions?

1757
01:25:49,678 --> 01:25:51,380
Yep.

1758
01:25:51,413 --> 01:25:54,183
Oh, let's take yours

1759
01:25:54,216 --> 01:25:55,951
and then make sure
I don't forget.

1760
01:25:55,984 --> 01:25:57,286
Let's get one from
online; we have

1761
01:25:57,319 --> 01:25:59,455
some people online
but you go ahead.

1762
01:25:59,488 --> 01:26:01,991
- Hi, could you talk a
little bit about the process?

1763
01:26:02,024 --> 01:26:05,194
You talked about the different
instruments that tested

1764
01:26:05,227 --> 01:26:08,064
an area before he
decided to dig.

1765
01:26:08,097 --> 01:26:10,633
What's the time lapse
between the scientist

1766
01:26:10,666 --> 01:26:13,302
being able to evaluate
each of those stages

1767
01:26:13,335 --> 01:26:18,007
and when it actually,
many decisions there.

1768
01:26:18,040 --> 01:26:20,209
- Yeah, another
fantastic question,

1769
01:26:20,242 --> 01:26:23,512
so these are really
hitting on the key issues

1770
01:26:23,545 --> 01:26:25,815
that we spend so much
time talking about.

1771
01:26:25,848 --> 01:26:29,318
She's asking about the time
between when the scientist

1772
01:26:29,351 --> 01:26:32,455
get the data or we run
the experiments on Mars,

1773
01:26:32,488 --> 01:26:35,291
the time between that point and
when we collect the samples.

1774
01:26:35,324 --> 01:26:37,726
Obviously, it takes time
to get the data down

1775
01:26:37,759 --> 01:26:40,029
as we were last talking about,
to get the data from Mars

1776
01:26:40,062 --> 01:26:43,699
to Earth, sometimes it's
not just the latency

1777
01:26:43,732 --> 01:26:46,268
between Mars and Earth,
it actually takes days

1778
01:26:46,301 --> 01:26:48,938
or in some cases, weeks
to get all the data down

1779
01:26:48,971 --> 01:26:52,007
because we have critical
engineering data

1780
01:26:52,040 --> 01:26:54,210
that we need to after
day to assess the safety

1781
01:26:54,243 --> 01:26:56,579
of the rover that's
very high priority

1782
01:26:56,612 --> 01:26:58,114
and then in
some cases,

1783
01:26:58,147 --> 01:26:59,615
for these large
science experiments,

1784
01:26:59,648 --> 01:27:03,018
we slowly get the data
and assemble these maps,

1785
01:27:03,051 --> 01:27:06,856
those elemental maps and
molecular maps I showed you

1786
01:27:06,889 --> 01:27:09,725
may take a while, may
take days to get down

1787
01:27:09,758 --> 01:27:12,495
and then the data are
down, they're in a raw form

1788
01:27:12,528 --> 01:27:14,530
and the scientist
have to process them

1789
01:27:14,563 --> 01:27:17,900
and crunch them in
and then put together

1790
01:27:17,933 --> 01:27:21,704
those beautiful maps that
you see and then, only then,

1791
01:27:21,737 --> 01:27:23,739
can they start to
make sense of it

1792
01:27:23,772 --> 01:27:25,674
and that doesn't
happen instantly

1793
01:27:25,707 --> 01:27:28,310
and that can certainly
take days or weeks

1794
01:27:28,343 --> 01:27:31,380
and so partly for that reason,
partly for some other reason,

1795
01:27:31,413 --> 01:27:35,184
we're employing a strategy
we call the walkabout, okay,

1796
01:27:35,217 --> 01:27:38,587
and this is as distinct from
maybe a linear strategy.

1797
01:27:38,620 --> 01:27:42,925
So imagine we're roving along
and let's take the example

1798
01:27:42,958 --> 01:27:46,061
of MSL roving from
its landing site close

1799
01:27:46,094 --> 01:27:47,830
to Yellowknife Bay
to Mount Sharp.

1800
01:27:47,863 --> 01:27:51,333
You can imagine the linear
approach roving from this place

1801
01:27:51,366 --> 01:27:55,137
to that place along the
way, taking scientific data,

1802
01:27:55,170 --> 01:27:58,874
collecting samples,
processing them in the rover

1803
01:27:58,907 --> 01:28:01,010
moving onto the next place.

1804
01:28:01,043 --> 01:28:04,413
Now imagine six months
after you were back

1805
01:28:04,446 --> 01:28:06,982
at some interesting place,
you find something new

1806
01:28:07,015 --> 01:28:09,652
in the data, you say, oh,
wow, that's incredible.

1807
01:28:09,685 --> 01:28:12,855
We need to go back, that's a
very hard decision to make,

1808
01:28:12,888 --> 01:28:14,990
to turn around that rover
and drive all the way

1809
01:28:15,023 --> 01:28:18,327
back to that place in and
look at that place again

1810
01:28:18,360 --> 01:28:21,564
and so we are organizing
ourself based on some things

1811
01:28:21,597 --> 01:28:26,001
that MSL has developed
at a place called Pahrump

1812
01:28:26,034 --> 01:28:28,671
where the Pahrump Hills,
this was a place right

1813
01:28:28,704 --> 01:28:30,472
at the base of Mount
Sharp, near the end

1814
01:28:30,505 --> 01:28:34,610
of MSL's primary mission for
their first extended mission

1815
01:28:34,643 --> 01:28:38,480
where they drove in loops,
okay, so we organized

1816
01:28:38,513 --> 01:28:43,719
our exploration of this
environment into three loops.

1817
01:28:43,752 --> 01:28:46,021
It could be two loops,
it's could be four loops

1818
01:28:46,054 --> 01:28:48,624
but let's say three and
imagine the first loop

1819
01:28:48,657 --> 01:28:52,228
so you get to your
campaign location.

1820
01:28:52,261 --> 01:28:55,064
We call this thing a campaign,
a walkabout campaign.

1821
01:28:55,097 --> 01:28:57,433
We get to the edge of
that campaign area,

1822
01:28:57,466 --> 01:29:00,703
maybe we find a local
topographic high

1823
01:29:00,736 --> 01:29:02,838
from which we can get
a nice expansive view

1824
01:29:02,871 --> 01:29:05,474
of our whole campaign
area, we take those images

1825
01:29:05,507 --> 01:29:07,610
then we roving
the campaign area

1826
01:29:07,643 --> 01:29:11,213
and we decide where in
that area we wanna stop

1827
01:29:11,246 --> 01:29:13,215
based on that
first imaging stop,

1828
01:29:13,248 --> 01:29:16,051
some interesting spots,
we stop at each of those

1829
01:29:16,084 --> 01:29:18,354
and we deploy our remote
instruments Mastcam-Z

1830
01:29:18,387 --> 01:29:21,090
and SuperCam to take
some remote science data

1831
01:29:21,123 --> 01:29:23,826
but we just we have the
discipline to move on

1832
01:29:23,859 --> 01:29:27,263
to the next stop, we don't
dally at these stops.

1833
01:29:27,296 --> 01:29:29,898
we get that first loop
done and get back to close

1834
01:29:29,931 --> 01:29:32,901
to the starting point, just
roving from stop to stop

1835
01:29:32,934 --> 01:29:35,671
to stop, collecting a bunch
of data along the way.

1836
01:29:35,704 --> 01:29:38,607
Now once we're back,
we have a lot more data

1837
01:29:38,640 --> 01:29:41,910
about that campaign location
and we understand it better,

1838
01:29:41,943 --> 01:29:43,812
certainly not completely
but we understand

1839
01:29:43,845 --> 01:29:45,948
it better than we
did when we arrived.

1840
01:29:45,981 --> 01:29:50,119
Based on that information, we
decide which of those stops

1841
01:29:50,152 --> 01:29:52,755
or maybe some different
stops to take to deploy

1842
01:29:52,788 --> 01:29:55,190
our more complex instruments
out the end of the arm

1843
01:29:55,223 --> 01:29:57,793
so we do what we call a
proximity science loop.

1844
01:29:57,826 --> 01:29:59,628
The first one was a
remote science loop.

1845
01:29:59,661 --> 01:30:01,630
The next was a
proximity science loop.

1846
01:30:01,663 --> 01:30:05,100
We drive around
roughly the same route,

1847
01:30:05,133 --> 01:30:07,836
stopping at certain places,
probably fewer places

1848
01:30:07,869 --> 01:30:09,938
because the proximity
experiments take

1849
01:30:09,971 --> 01:30:12,441
more time and energy
and complexity

1850
01:30:12,474 --> 01:30:15,678
than the remote science
experiments generally do.

1851
01:30:15,711 --> 01:30:20,649
We deploy our robotic arm,
abrade, GDIRT, PIXL, SHERLOC

1852
01:30:20,682 --> 01:30:23,585
and so forth but again,
we maintain the discipline

1853
01:30:23,618 --> 01:30:27,222
not to dally and and to
move on to the next spot

1854
01:30:27,255 --> 01:30:30,559
and get ourselves back
roughly to our starting place

1855
01:30:30,592 --> 01:30:33,729
and it's in all that time
that we hope the data

1856
01:30:33,762 --> 01:30:37,566
are pouring in and the
interpretations are happening,

1857
01:30:37,599 --> 01:30:40,369
the scientists are working
as officially as possible

1858
01:30:40,402 --> 01:30:43,038
to make some sense of all the
data as they're coming down

1859
01:30:43,071 --> 01:30:45,808
and then we can decide
which of those places

1860
01:30:45,841 --> 01:30:49,011
is most interesting and
should we go sample.

1861
01:30:49,044 --> 01:30:51,880
At that point, we can go
back and take a sample,

1862
01:30:51,913 --> 01:30:54,583
process the data, continue
to process the data

1863
01:30:54,616 --> 01:30:56,719
from these later stops
and decide which of those

1864
01:30:56,752 --> 01:30:59,355
we wanna sample and so
forth, so that third loop

1865
01:30:59,388 --> 01:31:01,857
might be a sampling
loop, so that's basically

1866
01:31:01,890 --> 01:31:05,894
our walkabout strategy
that we're gonna use.

1867
01:31:05,927 --> 01:31:09,465
Hopefully that
answers the question.

1868
01:31:09,498 --> 01:31:11,734
Oh, yeah, online.

1869
01:31:11,767 --> 01:31:13,469
- I see a couple.
- Okay, a couple online

1870
01:31:13,502 --> 01:31:17,840
questions, Shannon
asks, were there changes

1871

01:31:17,873 --> 01:31:21,577
mechanically and/or
to software on 2020

1872
01:31:21,610 --> 01:31:23,879
based on what we
learned from Curiosity

1873
01:31:23,912 --> 01:31:26,648
and other previous missions?

1874
01:31:26,681 --> 01:31:29,318
Absolutely, so
there were changes.

1875
01:31:29,351 --> 01:31:32,454
As I said earlier, we
take a heritage approach,

1876
01:31:32,487 --> 01:31:34,156
so as much as possible
we do what we call

1877
01:31:34,189 --> 01:31:36,525
build the print so
we take advantage

1878
01:31:36,558 --> 01:31:37,459
of those
great designs

1879
01:31:37,493 --> 01:31:41,230
from MSL and build
the rover as similarly

1880
01:31:41,263 --> 01:31:43,232
as possible but we do
change some things.

1881
01:31:43,265 --> 01:31:46,068

I mentioned the wheels
and, of course, software.

1882
01:31:46,101 --> 01:31:50,072
Some cases, it's easier to
change software than hardware

1883
01:31:50,105 --> 01:31:53,509
and we are doing a lot of
new things with software

1884
01:31:53,542 --> 01:31:56,145
so a big focus on autonomy.

1885
01:31:56,178 --> 01:31:59,848
This is obviously a wave
of the future in our homes

1886
01:31:59,881 --> 01:32:03,519
and on Mars; I have a a
robotic vacuum I just bought

1887
01:32:03,552 --> 01:32:06,822
that autonomously
vacuums my house

1888
01:32:06,855 --> 01:32:09,057
so we use very
similar technology,

1889
01:32:09,090 --> 01:32:11,326
I'm sure to what
that vacuum uses,

1890
01:32:11,359 --> 01:32:14,396
to drive the rover around
and avoid obstacles

1891
01:32:14,429 --> 01:32:18,567
on its own but also,

amazingly, to many people,

1892
01:32:18,600 --> 01:32:22,337
to me included, autonomously
to select targets

1893
01:32:22,370 --> 01:32:25,541
with very high accuracy so we
can program some parameters

1894
01:32:25,574 --> 01:32:28,610
into the robot and say,
we are really interested

1895
01:32:28,643 --> 01:32:30,279
in these rocks we've
been seeing

1896
01:32:30,312 --> 01:32:32,047
that have a
brightness,

1897
01:32:32,080 --> 01:32:35,751
an albedo between X and Y,

1898
01:32:35,784 --> 01:32:38,353
so we like rocks that
have about this color

1899
01:32:38,386 --> 01:32:40,622
or this brightness that
tend to be flat along

1900
01:32:40,655 --> 01:32:43,025
our route so if you
see rocks like that,

1901
01:32:43,058 --> 01:32:45,594
take pictures, robot,
along the drive.

1902
01:32:45,627 --> 01:32:49,298
as you see rocks like that,
shoot them with SuperCam.

1903
01:32:49,331 --> 01:32:51,333
MSL has started doing this.

1904
01:32:51,366 --> 01:32:54,303
It's a piece of
software called Aegis

1905
01:32:54,336 --> 01:32:58,040
and it has something
that over 90% accuracy

1906
01:32:58,073 --> 01:33:00,309
with its target, so when you
show up at the end of the drive

1907
01:33:00,342 --> 01:33:02,077
and you look back at the
pictures that it took

1908
01:33:02,110 --> 01:33:05,080
and the things that it
shot, over 90% of the time,

1909
01:33:05,113 --> 01:33:07,049
I think it's well
over 90% of the time,

1910
01:33:07,082 --> 01:33:09,785
it shoots just the kind of
stuff that we are looking for,

1911
01:33:09,818 --> 01:33:12,254
so this is fantastic
in many ways.

1912
01:33:12,287 --> 01:33:15,524
It's just fun and
interesting that the robot

1913
01:33:15,557 --> 01:33:18,460
is shooting targets that it
chooses itself, in a sense,

1914
01:33:18,493 --> 01:33:20,796
but also, it allows
us to offload some

1915
01:33:20,829 --> 01:33:23,832
of the more systematic
measurements that we wanna make

1916
01:33:23,865 --> 01:33:26,735
as we're roving across
some new terrain,

1917
01:33:26,768 --> 01:33:29,071
one of the things we
wanna do is just take

1918
01:33:29,104 --> 01:33:31,907
some basic measurements
every so often

1919
01:33:31,940 --> 01:33:35,210
and understand basically
how the chemistry

1920
01:33:35,243 --> 01:33:37,880
or morphology of those
rocks are changing

1921
01:33:37,913 --> 01:33:40,582
as we drove across
the territory.

1922
01:33:40,615 --> 01:33:42,751
When we show up
at a parking spot,

1923
01:33:42,784 --> 01:33:44,887
if we don't have
something like Aegis,

1924
01:33:44,920 --> 01:33:47,789
we would have to spend our
scientific planning time

1925
01:33:47,822 --> 01:33:49,958
to say, okay, first,
we have to take those

1926
01:33:49,991 --> 01:33:52,427
systematic measurements
before we can shoot

1927
01:33:52,460 --> 01:33:54,897
that interesting shiny
thing over there.

1928
01:33:54,930 --> 01:33:57,032
But with Aegis, you've
already got those in the bag

1929
01:33:57,065 --> 01:34:00,002
and you can focus
on the shiny thing

1930
01:34:00,035 --> 01:34:01,603
so we make some
really interesting

1931
01:34:01,636 --> 01:34:02,804
discoveries that way.

1932

01:34:02,837 --> 01:34:06,808
Yeah?

1933
01:34:06,841 --> 01:34:09,811
- Two things, one, how exactly
do you ensure that the rover

1934
01:34:09,844 --> 01:34:12,447
and all the component
parts and instruments

1935
01:34:12,480 --> 01:34:15,217
of all the little pieces
of them, the sky crane,

1936
01:34:15,250 --> 01:34:16,919
all the things would
be in contact with it,

1937
01:34:16,952 --> 01:34:19,888
that they are not
contaminated by Earth microbes

1938
01:34:19,921 --> 01:34:22,558
that could potentially
complicate your results?

1939
01:34:22,591 --> 01:34:24,059
And the second thing is

1940
01:34:24,092 --> 01:34:25,594
you mentioned
about software updates

1941
01:34:25,627 --> 01:34:28,430
so on Earth, I know
like, for example,

1942
01:34:28,463 --> 01:34:31,366
Tesla, the car manufacturer

can beam software updates

1943
01:34:31,399 --> 01:34:34,269
to cars that without
the owner of the car

1944
01:34:34,302 --> 01:34:36,305
have to bring it in
somewhere to get it updated.

1945
01:34:36,338 --> 01:34:39,608
Can you do that from
35 million miles away?

1946
01:34:39,641 --> 01:34:41,777
- Yes.
[audience laughing]

1947
01:34:41,810 --> 01:34:44,079
But we're very, very
careful when we do that

1948
01:34:44,112 --> 01:34:46,415
and when we try to
minimize the times

1949
01:34:46,448 --> 01:34:51,219
that we do those software
updates but it is possible.

1950
01:34:51,252 --> 01:34:53,722
So that's the second question.

1951
01:34:53,755 --> 01:34:57,859
We can do that and I'll just
read the next online question

1952
01:34:57,892 --> 01:34:59,127
before I answer
your first onr

1953
01:34:59,160 --> 01:35:01,563
because they're
sort of similar.

1954
01:35:01,596 --> 01:35:04,499
The online question
doesn't say from whom

1955
01:35:04,532 --> 01:35:07,769
but has there been more
discussion of exploring

1956
01:35:07,802 --> 01:35:10,038
Mars's recurring slope
linea, dark streaks

1957
01:35:10,071 --> 01:35:12,307
without risk of contamination?

1958
01:35:12,340 --> 01:35:14,576
So this gets to to
your point, I think,

1959
01:35:14,609 --> 01:35:17,245
which was how do we ensure
that all those pieces

1960
01:35:17,278 --> 01:35:19,715
and parts are contaminated
by Earth microbes?

1961
01:35:19,748 --> 01:35:21,783
I see some folks
in audience here

1962
01:35:21,816 --> 01:35:23,919
from our Planetary
Protection Group.

1963
01:35:23,952 --> 01:35:24,886
Yeah, raise your hands

1964
01:35:24,919 --> 01:35:26,521
if you're from
Planetary Protection.

1965
01:35:26,554 --> 01:35:27,322
- Woo!
Yeah!

1966
01:35:27,355 --> 01:35:28,724
[audience clapping]
- Hey!

1967
01:35:28,757 --> 01:35:30,459
That's right, they
deserve applause.

1968
01:35:30,492 --> 01:35:32,794
These are protectors
of the planet.

1969
01:35:32,827 --> 01:35:34,763
[audience chuckling]
Protectors of the planet Mars,

1970
01:35:34,796 --> 01:35:37,666
also protectors of the planet
Earth so planetary protection

1971
01:35:37,699 --> 01:35:41,036
works in two directions,
at least two directions,

1972
01:35:41,069 --> 01:35:43,739
sometimes it feels like it's
coming from every direction

1973

01:35:43,772 --> 01:35:46,908
but we do what we call forward.

1974
01:35:46,941 --> 01:35:50,145
We protect against what we
call forward contamination,

1975
01:35:50,178 --> 01:35:53,815
that is, we work to
minimize the extent

1976
01:35:53,848 --> 01:35:57,252
to which we deliver
Earth microbes to Mars.

1977
01:35:57,285 --> 01:36:01,523
It is impossible, as far
as [chuckles] we know,

1978
01:36:01,556 --> 01:36:04,526
to build a robot anywhere
close to this complex

1979
01:36:04,559 --> 01:36:07,596
and have it be
completely 100% sterile

1980
01:36:07,629 --> 01:36:12,000
or free from Earth microbes,
by completely sterilizing

1981
01:36:12,033 --> 01:36:15,937
like that, you destroy a lot
of the modern technologies

1982
01:36:15,970 --> 01:36:19,274
that we employ on this
rover, the computers,

1983
01:36:19,307 --> 01:36:22,911

the power source, the MMRTG,

1984
01:36:22,944 --> 01:36:25,547
they can be cleaned
very, very well

1985
01:36:25,580 --> 01:36:28,383
and they are cleaned
very, very well

1986
01:36:28,416 --> 01:36:31,987
but they can't be
completely 100% sterilized

1987
01:36:32,020 --> 01:36:36,058
and so we monitor that, these
folks who raised their hands

1988
01:36:36,091 --> 01:36:38,527
are the ones who monitor
that day after day.

1989
01:36:38,560 --> 01:36:41,563
They monitor spacecraft
surfaces, all the labs

1990
01:36:41,596 --> 01:36:45,534
where the clean rooms where
the rover is being assembled.

1991
01:36:45,567 --> 01:36:47,369
They're collecting
little witness plates.

1992
01:36:47,402 --> 01:36:49,071
I showed you the witness tubes.

1993
01:36:49,104 --> 01:36:50,872
They have their own
version, little coupons,

1994
01:36:50,905 --> 01:36:53,241
witness plates that sit
out in the clean room

1995
01:36:53,274 --> 01:36:56,378
and just have things fall on
them, bacteria and so forth,

1996
01:36:56,411 --> 01:37:00,549
and as they do these
swabs and analyze

1997
01:37:00,582 --> 01:37:03,418
the microbes that
are on the rover,

1998
01:37:03,451 --> 01:37:05,187
we call that the bio burden.

1999
01:37:05,220 --> 01:37:07,255
We try to knock down
that bio burden as low

2000
01:37:07,288 --> 01:37:08,557
as we possibly can,

2001
01:37:08,590 --> 01:37:10,492
we have some very
stringent requirements

2002
01:37:10,525 --> 01:37:15,030
from NASA on how
low that must be.

2003
01:37:15,063 --> 01:37:19,701
MSL met those requirements
very well with margin

2004

01:37:19,734 --> 01:37:22,838
and so we're using the same
techniques that MSL used

2005
01:37:22,871 --> 01:37:25,707
to keep that bio
burden low and minimize

2006
01:37:25,740 --> 01:37:28,043
forward contamination,
now that's one side

2007
01:37:28,076 --> 01:37:31,079
of planetary protection and
it's particularly relevant

2008
01:37:31,112 --> 01:37:33,648
to this question about
recurring slope lineae,

2009
01:37:33,681 --> 01:37:35,717
so these are these
dark streaks that form,

2010
01:37:35,750 --> 01:37:38,120
sometimes on the edges
the walls of craters

2011
01:37:38,153 --> 01:37:40,522
where you see they appear as
dark and then they go away.

2012
01:37:40,555 --> 01:37:42,691
They fade away,
potentially, it's evidence

2013
01:37:42,724 --> 01:37:47,996
for seeping water, maybe
very salty water on Mars.

2014

01:37:48,029 --> 01:37:51,800
These would be prime targets
if you're going to investigate

2015
01:37:51,833 --> 01:37:54,402
potential extant life on
Mars because it's a place

2016
01:37:54,435 --> 01:37:58,206
where liquid water might
currently exist at the surface.

2017
01:37:58,239 --> 01:38:00,642
We can't get anywhere
near those things

2018
01:38:00,675 --> 01:38:03,245
because we're not a mission
that's designed to do that.

2019
01:38:03,278 --> 01:38:05,580
We're a mission that's designed
to go look for evidence

2020
01:38:05,613 --> 01:38:09,050
of ancient life and we get
as clean as we need to be

2021
01:38:09,083 --> 01:38:12,220
to do that, you'd have
to be even cleaner

2022
01:38:12,253 --> 01:38:14,222
to go look at those
recurring slope lineae

2023
01:38:14,255 --> 01:38:16,992
we have no plans to do that,
maybe a future mission,

2024

01:38:17,025 --> 01:38:19,461
hopefully a future
mission, we'll go do that.

2025
01:38:19,494 --> 01:38:22,631
That's not our job but we are,

2026
01:38:22,664 --> 01:38:25,300
because we are the
outbound leg of a possible

2027
01:38:25,333 --> 01:38:27,936
Mars Sample Return Mission,
we are now concerned

2028
01:38:27,969 --> 01:38:31,373
with backward
contamination, that is,

2029
01:38:31,406 --> 01:38:34,109
potentially, if we
take a rock sample

2030
01:38:34,142 --> 01:38:39,147
that contains viable Martian
microbe that is harmful

2031
01:38:39,180 --> 01:38:42,717
to Earth life, we
good bring that back

2032
01:38:42,750 --> 01:38:45,854
and if that were
allowed to be opened

2033
01:38:45,887 --> 01:38:48,690
and have access to
the Earth environment

2034
01:38:48,723 --> 01:38:51,827

and escape from some
containment facility

2035
01:38:51,860 --> 01:38:53,195
it could be bad.

2036
01:38:53,228 --> 01:38:56,865
Now we take that possibility
extremely seriously

2037
01:38:56,898 --> 01:39:00,335
and we work very hard
to do everything we can

2038
01:39:00,368 --> 01:39:02,470
to not have
that happen,

2039
01:39:02,503 --> 01:39:03,705
including, we have
a requirement

2040
01:39:03,738 --> 01:39:07,342
that in every sample we
collect, it be completely free

2041
01:39:07,375 --> 01:39:11,213
from Earth organisms,
okay, so we are so clean

2042
01:39:11,246 --> 01:39:13,715
that we need to show
before we can launch

2043
01:39:13,748 --> 01:39:17,953
that every sample we take
will be completely sterile,

2044
01:39:17,986 --> 01:39:21,022
not the whole rover itself,

but the sample itself

2045
01:39:21,055 --> 01:39:23,825
will be sterile so
that, number one,

2046
01:39:23,858 --> 01:39:27,963
we give the scientist the best
chance to find any evidence

2047
01:39:27,996 --> 01:39:31,199
of life that's in those
samples and number two,

2048
01:39:31,232 --> 01:39:33,869
we don't get confused
between Earth life

2049
01:39:33,902 --> 01:39:36,738
and potential Mars life,
now, I think it would be

2050
01:39:36,771 --> 01:39:39,774
very difficult for us to
be confused for reasons

2051
01:39:39,807 --> 01:39:43,144
I won't go into 'cause
we're over time already

2052
01:39:43,177 --> 01:39:47,649
but it's also something
that is unlikely.

2053
01:39:47,682 --> 01:39:50,785
So pieces of Mars
do exist on Earth.

2054
01:39:50,818 --> 01:39:52,821
In a sense, we do

have samples from Mars

2055
01:39:52,854 --> 01:39:55,390
and these are the
meteorites, so Earth and Mars

2056
01:39:55,423 --> 01:39:58,393
have been exchanging
material for eons, okay,

2057
01:39:58,426 --> 01:40:00,695
so it's not as if the
samples we bring back

2058
01:40:00,728 --> 01:40:03,365
are the first pieces of
Mars ever to come to Earth.

2059
01:40:03,398 --> 01:40:05,901
Now that said, if
they come back,

2060
01:40:05,934 --> 01:40:10,005
they will be delivered
very carefully

2061
01:40:10,038 --> 01:40:11,606
to some facility,

2062
01:40:11,639 --> 01:40:13,441
some receiving facility
that that may have

2063
01:40:13,474 --> 01:40:15,443
a higher level of bio security

2064
01:40:15,476 --> 01:40:17,145
than any that currently
exists, this is

2065
01:40:17,178 --> 01:40:22,150
sort of the CDC-type,
think CDC Biosafety Level 5

2066
01:40:22,183 --> 01:40:25,453
or whatever you call
it, very, very secure

2067
01:40:25,486 --> 01:40:27,656
and they will not be
released probably until

2068
01:40:27,689 --> 01:40:29,791
they're sterilized or somehow,

2069
01:40:29,824 --> 01:40:31,760
we are totally confident
that they're free

2070
01:40:31,793 --> 01:40:42,604
from anything dangerous,
another question?

2071
01:40:42,637 --> 01:40:47,642
Okay, it looks like this'll
be the last question.

2072
01:40:47,675 --> 01:40:50,045
- Can you tell us a bit
more about how the machine

2073
01:40:50,078 --> 01:40:52,747
that converts carbon
dioxide to oxygen works

2074
01:40:52,780 --> 01:40:56,084
and if you have
any plans for it?

2075

01:40:56,117 --> 01:40:59,621
- Well, I can't tell
you too much about it,

2076
01:40:59,654 --> 01:41:02,824
not because of the big secret,
but because it's a kind

2077
01:41:02,857 --> 01:41:06,027
of physics and chemistry
that's not really my key area

2078
01:41:06,060 --> 01:41:08,063
but it's called, we
call the technique

2079
01:41:08,096 --> 01:41:13,668
solid oxide electrolysis,
okay, and so we take CO2 in

2080
01:41:13,701 --> 01:41:17,806
and then we react that in
what we call the SOXE stack,

2081
01:41:17,839 --> 01:41:21,543
the solid oxide
electrolysis stack

2082
01:41:21,576 --> 01:41:25,880
and we basically, pull the
oxygen off of that CO2 molecule

2083
01:41:25,913 --> 01:41:31,252
and generate CO and 0 and
0 combines to 02 as oxygen.

2084
01:41:31,285 --> 01:41:32,988
Is that what you're looking for

2085
01:41:33,021 --> 01:41:35,123

or something even
more technical?

2086
01:41:35,156 --> 01:41:37,659
I can definitely What
you to more details

2087
01:41:37,692 --> 01:41:41,162
that you can read
but plans for it,

2088
01:41:41,195 --> 01:41:43,531
it's to use it and test it out

2089
01:41:43,564 --> 01:41:47,035
and put it through its paces.

2090
01:41:47,068 --> 01:41:49,004
We're particularly
interested to understand

2091
01:41:49,037 --> 01:41:51,339
how does it work in the
dust environment of Mars?

2092
01:41:51,372 --> 01:41:53,675
So there's a little
filter out on the inlet

2093
01:41:53,708 --> 01:41:56,444
where the CO2 comes in; over
the course of our mission,

2094
01:41:56,477 --> 01:42:00,782
that will collect dust so what
is the pace at which MOXIE

2095
01:42:00,815 --> 01:42:03,852
becomes less and less
effective as dust builds up?

2096
01:42:03,885 --> 01:42:05,987
That's one good one
example of a question

2097
01:42:06,020 --> 01:42:08,123
that would clearly be very
important to understand

2098
01:42:08,156 --> 01:42:10,191
if you're gonna send
one of these things

2099
01:42:10,224 --> 01:42:12,594
that's 100 times larger
and more expensive

2100
01:42:12,627 --> 01:42:15,296
to the surface of Mars
we really want to push it

2101
01:42:15,329 --> 01:42:18,767
over the course of our
mission potentially to failure

2102
01:42:18,800 --> 01:42:22,704
and understand how and
why and when does it break

2103
01:42:22,737 --> 01:42:25,774
after getting a lot of great
data out of it, hopefully.

2104
01:42:25,807 --> 01:42:28,543
Okay, so that's all,
I'm still around.

2105
01:42:28,576 --> 01:42:31,846
I'm happy to have you
grab me, don't grab me,

2106
01:42:31,879 --> 01:42:33,915
but find me
[audience chuckling]

2107
01:42:33,948 --> 01:42:37,285
and I can answer questions or
if you've got a burning ones

2108
01:42:37,318 --> 01:42:39,921
that thanks again
so much for coming

2109
01:42:39,954 --> 01:42:49,964
and for putting this together.
[audience applauding]