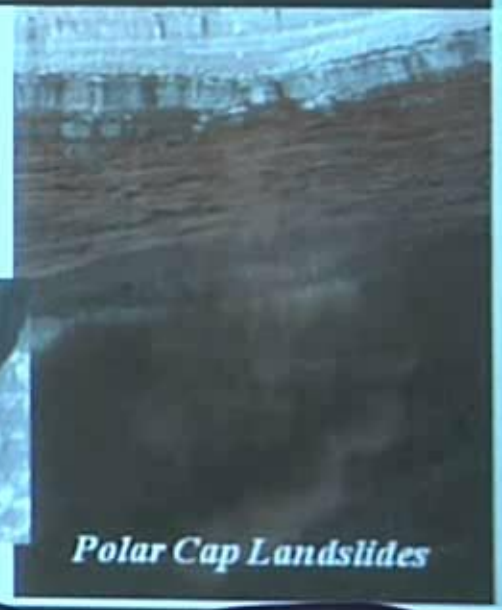

Possible Brine Flows?


Global Dust Storm
June 26, 2001
September 4, 2001


Polar Cap Extent
March 1999
January 2001


Sand Dunes


Polar Cap Landslides

1
00:00:00,799 --> 00:00:05,510
all right settle down and get your seats

2
00:00:08,950 --> 00:00:07,110
so my name is janet for tessium at

3
00:00:11,030 --> 00:00:08,960
princeton university i'm delighted to

4
00:00:12,470 --> 00:00:11,040
welcome you today to the panel on mars

5
00:00:14,310 --> 00:00:12,480
exploration

6
00:00:15,829 --> 00:00:14,320
um the planet mars has fascinated

7
00:00:18,150 --> 00:00:15,839
astronomers and space scientists for

8
00:00:20,710 --> 00:00:18,160
generations to say nothing of historians

9
00:00:22,390 --> 00:00:20,720
and this particular sociologist as well

10
00:00:24,150 --> 00:00:22,400
and the papers in this session are

11
00:00:25,830 --> 00:00:24,160
focusing on the red planet but they each

12
00:00:28,070 --> 00:00:25,840
display very different approaches to the

13
00:00:29,429 --> 00:00:28,080

history of mars exploration and each of

14
00:00:31,269 --> 00:00:29,439
these approaches reveal some of the

15
00:00:33,270 --> 00:00:31,279
contingencies and temporalities of this

16
00:00:34,790 --> 00:00:33,280
exploration work

17
00:00:36,549 --> 00:00:34,800
we'll hear first from richard zurich

18
00:00:39,110 --> 00:00:36,559
who's the chief scientist for the mars

19
00:00:40,150 --> 00:00:39,120
program at jpl focusing on the missions

20
00:00:42,069 --> 00:00:40,160
zurich will take us through the

21
00:00:44,229 --> 00:00:42,079
trajectory of mars exploration and its

22
00:00:46,709 --> 00:00:44,239
understanding from percival lowell to

23
00:00:48,549 --> 00:00:46,719
curiosity such an approach will show us

24
00:00:50,549 --> 00:00:48,559
how each successive mission builds upon

25
00:00:52,069 --> 00:00:50,559
the successes and critical questions of

26
00:00:54,549 --> 00:00:52,079
the prior mission and how our knowledge

27
00:00:56,150 --> 00:00:54,559
of mars is built up over time

28
00:00:58,229 --> 00:00:56,160
next we'll hear from david grinspoon

29
00:01:00,630 --> 00:00:58,239
curator of astrobiology at the denver

30
00:01:01,910 --> 00:01:00,640
museum for nature and science david will

31
00:01:03,990 --> 00:01:01,920
take the science point of view

32
00:01:05,910 --> 00:01:04,000
specifically looking at the growth and

33
00:01:07,830 --> 00:01:05,920
change of the astrobiology community and

34
00:01:09,910 --> 00:01:07,840
its questions throughout this period of

35
00:01:11,429 --> 00:01:09,920
mars exploration and this kind of

36
00:01:14,230 --> 00:01:11,439
approach can tell us more about the

37
00:01:16,149 --> 00:01:14,240
concept of habitability habitability how

38
00:01:17,590 --> 00:01:16,159

it has been historically understood and

39
00:01:19,749 --> 00:01:17,600
with what kinds of implications for the

40
00:01:22,070 --> 00:01:19,759
kind of science that is done

41
00:01:23,910 --> 00:01:22,080
jpl historian eric conway focuses more

42
00:01:25,670 --> 00:01:23,920
on the engineering side specifically

43
00:01:27,749 --> 00:01:25,680
engineering for a single mission the

44
00:01:29,429 --> 00:01:27,759
much belabored mars sample return and

45
00:01:30,710 --> 00:01:29,439
those of you at the meeting in germany

46
00:01:33,270 --> 00:01:30,720
earlier this year will know that that is

47
00:01:35,030 --> 00:01:33,280
a topic very dear to my heart as well

48
00:01:37,670 --> 00:01:35,040
in this way eric conway will definitely

49
00:01:39,350 --> 00:01:37,680
show us how a group of engineers at jpl

50
00:01:41,270 --> 00:01:39,360
were on the front lines of trying to

51
00:01:43,270 --> 00:01:41,280
implement shifting declarations from

52
00:01:45,510 --> 00:01:43,280
complex from the space science board and

53
00:01:47,109 --> 00:01:45,520
even the president himself which reveals

54
00:01:49,350 --> 00:01:47,119
the complexities on the ground of being

55
00:01:51,270 --> 00:01:49,360
caught in the middle of 30 years of nasa

56
00:01:53,109 --> 00:01:51,280
crossfire

57
00:01:54,630 --> 00:01:53,119
finally henry lambreit professor of

58
00:01:55,990 --> 00:01:54,640
public administration and international

59
00:01:57,830 --> 00:01:56,000
affairs and political science at the

60
00:02:00,149 --> 00:01:57,840
university of syracuse will take an

61
00:02:01,749 --> 00:02:00,159
individual approach focusing on the role

62
00:02:03,830 --> 00:02:01,759
and contributions of different nasa

63
00:02:05,749 --> 00:02:03,840

administrators lambert reveals the

64
00:02:07,830 --> 00:02:05,759
importance of leadership complexities of

65
00:02:09,669 --> 00:02:07,840
decision-making and the critical role of

66
00:02:11,830 --> 00:02:09,679
individuals in pushing forward the

67
00:02:13,750 --> 00:02:11,840
vision of mars exploration

68
00:02:15,589 --> 00:02:13,760
as a final note before we begin as an

69
00:02:17,670 --> 00:02:15,599
ethnographer working with contemporary

70
00:02:19,350 --> 00:02:17,680
planetary exploration missions

71
00:02:21,110 --> 00:02:19,360
these four histories continue to

72
00:02:23,510 --> 00:02:21,120
resonate throughout space exploration

73
00:02:25,030 --> 00:02:23,520
today and the past is very much with us

74
00:02:28,309 --> 00:02:25,040
in the present this is not just as a

75
00:02:30,630 --> 00:02:28,319
form of curiosity no pun intended

76
00:02:32,710 --> 00:02:30,640
but as the past moments of budget crises

77
00:02:34,229 --> 00:02:32,720
and bold visions show us the concerns of

78
00:02:36,229 --> 00:02:34,239
our predecessors are very much our

79
00:02:37,910 --> 00:02:36,239
concerns today and there are lessons

80
00:02:39,350 --> 00:02:37,920
here for how they chose to resolve those

81
00:02:40,790 --> 00:02:39,360
questions that can help us to address

82
00:02:43,350 --> 00:02:40,800
our own historical moment and our

83
00:02:45,110 --> 00:02:43,360
challenges but perhaps more profoundly

84
00:02:47,350 --> 00:02:45,120
their choices shaped in a foundational

85
00:02:49,270 --> 00:02:47,360
way the kinds of spacecraft we fly and

86
00:02:50,790 --> 00:02:49,280
the kinds of science that we do today

87
00:02:52,790 --> 00:02:50,800
and that's one of the things that brings

88
00:02:54,949 --> 00:02:52,800

work on earth and work on mars ever

89
00:02:56,710 --> 00:02:54,959
closer together and continues to inspire

90
00:02:57,670 --> 00:02:56,720
our enthusiasm for mars exploration

91
00:02:59,110 --> 00:02:57,680
today

92
00:03:01,350 --> 00:02:59,120
so with that i'd like to start by

93
00:03:03,030 --> 00:03:01,360
welcoming richard zurek to the podium

94
00:03:04,949 --> 00:03:03,040
chief scientist for the mars program at

95
00:03:06,630 --> 00:03:04,959
the jet propulsion laboratory dr

96
00:03:07,990 --> 00:03:06,640
zurich's phd is in the atmospheric

97
00:03:10,390 --> 00:03:08,000
sciences he specializes in the

98
00:03:12,309 --> 00:03:10,400
atmospheres of earth and mars he served

99
00:03:14,390 --> 00:03:12,319
as project scientist for mars surveyor

100
00:03:16,309 --> 00:03:14,400
1998 missions mars climate orbiter and

101
00:03:18,630 --> 00:03:16,319
mars polar lander he's worked with data

102
00:03:20,390 --> 00:03:18,640
from mariner and from viking has led

103
00:03:21,990 --> 00:03:20,400
atmospheric advisory groups to support

104
00:03:23,910 --> 00:03:22,000
aerobraking engineering for our current

105
00:03:25,350 --> 00:03:23,920
generation of mars orbiters and is

106
00:03:26,710 --> 00:03:25,360
presently the project scientist for the

107
00:03:34,470 --> 00:03:26,720
extraordinary mars reconnaissance

108
00:03:38,070 --> 00:03:37,110
well what i hope to do today is to trace

109
00:03:40,710 --> 00:03:38,080
through

110
00:03:42,789 --> 00:03:40,720
space exploration but also before that

111
00:03:45,110 --> 00:03:42,799
the persistent themes that have made us

112
00:03:47,670 --> 00:03:45,120
interested in mars and to show you that

113
00:03:49,750 --> 00:03:47,680

in many ways those themes still drive us

114
00:03:50,949 --> 00:03:49,760
today as to what we want to do at the

115
00:03:52,070 --> 00:03:50,959
red planet

116
00:03:54,229 --> 00:03:52,080
however

117
00:03:55,429 --> 00:03:54,239
our concept of what mars is and what it

118
00:03:58,149 --> 00:03:55,439
may be

119
00:04:00,470 --> 00:03:58,159
has certainly changed over that time

120
00:04:03,750 --> 00:04:00,480
so just very briefly if i go to the

121
00:04:07,750 --> 00:04:05,429
here's what i'll try to talk about those

122
00:04:09,670 --> 00:04:07,760
persistent themes and i'll start going

123
00:04:12,390 --> 00:04:09,680
back to what i'll call the percival

124
00:04:14,390 --> 00:04:12,400
lowell view of mars and then we'll talk

125
00:04:15,910 --> 00:04:14,400
about the two waves mars exploration

126
00:04:16,949 --> 00:04:15,920
you've already heard about the lost

127
00:04:19,509 --> 00:04:16,959
decade

128
00:04:21,590 --> 00:04:19,519
which is what separates that first wave

129
00:04:23,749 --> 00:04:21,600
where we flew by we went into orbit and

130
00:04:25,270 --> 00:04:23,759
then with viking we landed

131
00:04:28,070 --> 00:04:25,280
and then in the second wave of

132
00:04:30,790 --> 00:04:28,080
exploration we've got more of an orbiter

133
00:04:32,390 --> 00:04:30,800
lander synergy and added a new element

134
00:04:34,790 --> 00:04:32,400
that you heard about earlier too which

135
00:04:36,950 --> 00:04:34,800
mobility on the surface and we'll talk

136
00:04:38,550 --> 00:04:36,960
about how that has helped advance what

137
00:04:40,629 --> 00:04:38,560
we do at the planet

138
00:04:43,670 --> 00:04:40,639

ending up with an idea about what mars

139
00:04:45,590 --> 00:04:43,680
is today but also i i need to caution

140
00:04:48,469 --> 00:04:45,600
you that that story is very much

141
00:04:50,469 --> 00:04:48,479
unfolding at this very moment we have

142
00:04:51,990 --> 00:04:50,479
two orbiters plus the mars express

143
00:04:54,230 --> 00:04:52,000
european orbiter

144
00:04:56,469 --> 00:04:54,240
active at the planet we still have the

145
00:04:58,469 --> 00:04:56,479
opportunity rover working on the surface

146
00:05:00,390 --> 00:04:58,479
and of course curiosity has now arrived

147
00:05:01,670 --> 00:05:00,400
to join them with its own expedition of

148
00:05:02,710 --> 00:05:01,680
things

149
00:05:04,070 --> 00:05:02,720
so

150
00:05:06,469 --> 00:05:04,080
to begin

151
00:05:08,070 --> 00:05:06,479
those dominant themes

152
00:05:10,230 --> 00:05:08,080
mars is a place that we think has

153
00:05:12,629 --> 00:05:10,240
changed enormously over time that it was

154
00:05:15,029 --> 00:05:12,639
very different in its early history

155
00:05:17,670 --> 00:05:15,039
and it is now a different planet than it

156
00:05:19,670 --> 00:05:17,680
was in that early time

157
00:05:22,550 --> 00:05:19,680
the geologic evolution of the planet has

158
00:05:24,390 --> 00:05:22,560
certainly changed over its history giant

159
00:05:26,150 --> 00:05:24,400
volcanoes are built up

160
00:05:28,790 --> 00:05:26,160
there are places in erosion on the

161
00:05:31,189 --> 00:05:28,800
planet in some places the wind is acted

162
00:05:33,350 --> 00:05:31,199
for a billion years in a way that we

163
00:05:35,670 --> 00:05:33,360

don't really have any terrestrial analog

164
00:05:37,189 --> 00:05:35,680
for so there are processes and this is

165
00:05:39,350 --> 00:05:37,199
what the planets give us are these

166
00:05:41,189 --> 00:05:39,360
natural laboratories to be able to

167
00:05:43,189 --> 00:05:41,199
understand processes

168
00:05:46,150 --> 00:05:43,199
but of course a key thing with mars has

169
00:05:48,629 --> 00:05:46,160
always been whether or not life is on

170
00:05:50,950 --> 00:05:48,639
the planet today or it had been in the

171
00:05:52,710 --> 00:05:50,960
past whether or not there is evidence of

172
00:05:54,550 --> 00:05:52,720
that past life that might be preserved

173
00:05:56,230 --> 00:05:54,560
today and that's certainly something

174
00:05:58,790 --> 00:05:56,240
that we've been looking for in our space

175
00:05:59,510 --> 00:05:58,800
exploration of mars

176
00:06:01,510 --> 00:05:59,520
so

177
00:06:03,270 --> 00:06:01,520
let's begin well not really from the

178
00:06:04,469 --> 00:06:03,280
beginning but at least let's go back a

179
00:06:05,909 --> 00:06:04,479
hundred years

180
00:06:08,790 --> 00:06:05,919
and let's talk about what the view of

181
00:06:11,590 --> 00:06:08,800
mars was then on those three themes

182
00:06:15,029 --> 00:06:11,600
percival thought that he had a simple

183
00:06:17,189 --> 00:06:15,039
explanation for what mars was it fed all

184
00:06:19,189 --> 00:06:17,199
of it fit all the observational data

185
00:06:21,510 --> 00:06:19,199
that he had at hand and he was

186
00:06:23,670 --> 00:06:21,520
responsible for accumulating more

187
00:06:26,230 --> 00:06:23,680
information about the red planet in a

188
00:06:28,550 --> 00:06:26,240

more systematic way in fact he coined

189
00:06:30,230 --> 00:06:28,560
the term planetology

190
00:06:32,150 --> 00:06:30,240
in a way that was actually a great

191
00:06:33,990 --> 00:06:32,160
debate at the time because he was

192
00:06:36,230 --> 00:06:34,000
accused of being very selective about

193
00:06:38,469 --> 00:06:36,240
what things he took from geological

194
00:06:40,629 --> 00:06:38,479
studies of the earth about

195
00:06:42,790 --> 00:06:40,639
how the earth had evolved and such and

196
00:06:45,189 --> 00:06:42,800
that's because his simple idea was is

197
00:06:47,189 --> 00:06:45,199
that mars was just an older version of

198
00:06:48,469 --> 00:06:47,199
the earth mars and earth have many

199
00:06:50,629 --> 00:06:48,479
similarities

200
00:06:51,990 --> 00:06:50,639
they rotate about the same period so

201
00:06:53,749 --> 00:06:52,000
their days are about the same the

202
00:06:56,469 --> 00:06:53,759
temperature contrasts between night and

203
00:06:58,629 --> 00:06:56,479
day are moderated because of that

204
00:07:01,029 --> 00:06:58,639
rotation axis of both planets are tipped

205
00:07:04,309 --> 00:07:01,039
over about 25 degrees that means there

206
00:07:07,990 --> 00:07:04,319
are seasons it's a warm summer pole and

207
00:07:10,150 --> 00:07:08,000
a cold winter pole on the planet there

208
00:07:12,309 --> 00:07:10,160
so those similarities plus the fact that

209
00:07:15,110 --> 00:07:12,319
mars was all land in effect about the

210
00:07:17,909 --> 00:07:15,120
same land area as the land area of the

211
00:07:20,150 --> 00:07:17,919
earth and the fact that both had

212
00:07:22,309 --> 00:07:20,160
atmospheres in which the sunlight went

213
00:07:24,150 --> 00:07:22,319

to the surface and could power not only

214
00:07:26,230 --> 00:07:24,160
the atmospheric circulation but would be

215
00:07:27,430 --> 00:07:26,240
available as energy to life forms on the

216
00:07:28,870 --> 00:07:27,440
surface

217
00:07:30,550 --> 00:07:28,880
now there was something exceptional

218
00:07:33,830 --> 00:07:30,560
about mars and lowell's view and that

219
00:07:35,510 --> 00:07:33,840
was the canals he and other observers

220
00:07:37,189 --> 00:07:35,520
saw the canals

221
00:07:39,430 --> 00:07:37,199
they saw them in different forms some

222
00:07:41,909 --> 00:07:39,440
were rarely large and fuzzy markings on

223
00:07:43,830 --> 00:07:41,919
the planet that they drew others where

224
00:07:46,629 --> 00:07:43,840
as lowell drew them were very straight

225
00:07:48,390 --> 00:07:46,639
and geometric that were indicating that

226
00:07:50,150 --> 00:07:48,400
hey there's more than just life on the

227
00:07:52,469 --> 00:07:50,160
planet there's actually intelligent life

228
00:07:56,230 --> 00:07:52,479
on the planet we've come a long way from

229
00:07:57,749 --> 00:07:56,240
that time but even if you go to the

230
00:08:00,150 --> 00:07:57,759
mid-century here

231
00:08:01,589 --> 00:08:00,160
that is into the 60s when mariner 4 was

232
00:08:04,070 --> 00:08:01,599
being launched and we were about to

233
00:08:05,430 --> 00:08:04,080
embark upon our space exploration

234
00:08:07,990 --> 00:08:05,440
it is amazing

235
00:08:09,589 --> 00:08:08,000
how strong those ideas were and how we

236
00:08:11,990 --> 00:08:09,599
continued to debate him

237
00:08:15,110 --> 00:08:12,000
in fact there was a mars handbook that

238
00:08:17,589 --> 00:08:15,120

was published by nasa in the late 60s 70

239
00:08:19,270 --> 00:08:17,599
cents by the way a real bargain for a

240
00:08:21,830 --> 00:08:19,280
student at the time

241
00:08:23,990 --> 00:08:21,840
that handbook still wouldn't dismiss the

242
00:08:25,990 --> 00:08:24,000
possibility of canals even though

243
00:08:27,670 --> 00:08:26,000
mariner 4 had already taken its pictures

244
00:08:29,510 --> 00:08:27,680
and they were still being analyzed the

245
00:08:31,430 --> 00:08:29,520
resolution of those pictures

246
00:08:33,509 --> 00:08:31,440
was not quite adequate to completely

247
00:08:36,790 --> 00:08:33,519
rule out what might still be on the

248
00:08:38,790 --> 00:08:36,800
surface of mars and in fact our space

249
00:08:41,110 --> 00:08:38,800
exploration can be thought of as a

250
00:08:43,990 --> 00:08:41,120
desire to go to ever higher spatial

251
00:08:46,310 --> 00:08:44,000
resolutions to be able to see

252
00:08:49,829 --> 00:08:46,320
the fine detail that could actually help

253
00:08:52,230 --> 00:08:49,839
us test key theories about the planet

254
00:08:53,430 --> 00:08:52,240
so this was percival lowell's view of

255
00:08:54,790 --> 00:08:53,440
the planet

256
00:08:57,110 --> 00:08:54,800
and

257
00:08:59,670 --> 00:08:57,120
it had polar caps mars had polar caps it

258
00:09:02,710 --> 00:08:59,680
had dark areas one argument that the

259
00:09:05,110 --> 00:09:02,720
dark areas were could only be explained

260
00:09:07,990 --> 00:09:05,120
by life was the fact that they changed

261
00:09:10,630 --> 00:09:08,000
color with the seasons and in fact they

262
00:09:13,190 --> 00:09:10,640
even reappeared after dust storms had

263
00:09:15,750 --> 00:09:13,200

brightened those areas and the areas got

264
00:09:18,310 --> 00:09:15,760
dark again and what else except

265
00:09:19,670 --> 00:09:18,320
vegetation would be able to do that so

266
00:09:22,070 --> 00:09:19,680
trying to understand those kinds of

267
00:09:23,430 --> 00:09:22,080
mysteries has also been about what we're

268
00:09:24,470 --> 00:09:23,440
about

269
00:09:26,870 --> 00:09:24,480
now

270
00:09:28,710 --> 00:09:26,880
by the 60s the earth-based measurements

271
00:09:31,350 --> 00:09:28,720
were also getting better and there were

272
00:09:32,389 --> 00:09:31,360
some signs that mars wasn't nearly

273
00:09:33,590 --> 00:09:32,399
as

274
00:09:36,470 --> 00:09:33,600
hospitable

275
00:09:38,710 --> 00:09:36,480
an environment for life as percival

276
00:09:41,269 --> 00:09:38,720
thought many decades earlier the

277
00:09:43,990 --> 00:09:41,279
atmosphere was getting thinner well our

278
00:09:45,670 --> 00:09:44,000
idea of the atmosphere was that it was

279
00:09:46,630 --> 00:09:45,680
not nearly as thick as we had thought it

280
00:09:48,790 --> 00:09:46,640
had been

281
00:09:52,150 --> 00:09:48,800
and there were also better techniques

282
00:09:53,509 --> 00:09:52,160
than the imagery and the photographic

283
00:09:55,750 --> 00:09:53,519
photographs that were taken through

284
00:09:57,670 --> 00:09:55,760
telescopes and such that called into

285
00:09:59,829 --> 00:09:57,680
question the very idea that the canals

286
00:10:02,470 --> 00:09:59,839
existed

287
00:10:04,630 --> 00:10:02,480
mariner 4 successfully launches i might

288
00:10:07,509 --> 00:10:04,640

remind you that mariner 3 was the first

289
00:10:09,750 --> 00:10:07,519
attempt in the same launch opportunity

290
00:10:11,670 --> 00:10:09,760
uh the shroud didn't separate it went

291
00:10:14,069 --> 00:10:11,680
into the ocean they figured out the

292
00:10:16,150 --> 00:10:14,079
problem they diagnosed it they fixed it

293
00:10:18,310 --> 00:10:16,160
mariner 4 was launched in the same

294
00:10:20,550 --> 00:10:18,320
launch opportunity we're talking about a

295
00:10:22,069 --> 00:10:20,560
period of several weeks here i doubt we

296
00:10:24,870 --> 00:10:22,079
could get the failure review board

297
00:10:27,430 --> 00:10:24,880
together in these days to respond in

298
00:10:29,350 --> 00:10:27,440
such a way and that was a sign of the

299
00:10:31,430 --> 00:10:29,360
experimentation of the times the risk

300
00:10:32,389 --> 00:10:31,440
they were willing to take and just the

301
00:10:35,430 --> 00:10:32,399
excitement

302
00:10:37,910 --> 00:10:35,440
and the drive of getting things done

303
00:10:40,710 --> 00:10:37,920
okay so that first wave of space

304
00:10:43,110 --> 00:10:40,720
exploration mariner 4 mariner 6 and 7

305
00:10:45,670 --> 00:10:43,120
flybys we're just seeing bits of the

306
00:10:47,910 --> 00:10:45,680
planet mariner 4 the images went across

307
00:10:49,509 --> 00:10:47,920
one percent of the planet at fairly

308
00:10:51,590 --> 00:10:49,519
coarse resolution

309
00:10:52,550 --> 00:10:51,600
over 100 kilometers per pixel in most

310
00:10:55,350 --> 00:10:52,560
cases

311
00:10:57,910 --> 00:10:55,360
mariner 9 first spacecraft from earth to

312
00:10:59,990 --> 00:10:57,920
go into orbit around another planet

313
00:11:02,150 --> 00:11:00,000

and that showed us a very different kind

314
00:11:04,389 --> 00:11:02,160
of mars and i'll come back to that

315
00:11:06,150 --> 00:11:04,399
and then it succeeded by the viking

316
00:11:08,550 --> 00:11:06,160
experiment very ambitious as you heard

317
00:11:10,630 --> 00:11:08,560
this morning in which we were saying

318
00:11:13,190 --> 00:11:10,640
there's a paradigm that if life can

319
00:11:15,509 --> 00:11:13,200
exist anywhere on the planet it exists

320
00:11:17,990 --> 00:11:15,519
everywhere on the planet so that i can

321
00:11:19,750 --> 00:11:18,000
land i can scoop up some soil i don't

322
00:11:21,750 --> 00:11:19,760
need to be very particular about where i

323
00:11:23,829 --> 00:11:21,760
land and i should be able to find out

324
00:11:25,829 --> 00:11:23,839
whether or not the planet has life

325
00:11:28,630 --> 00:11:25,839
what did we find

326
00:11:31,269 --> 00:11:28,640
well mariner 4 showed us this a very

327
00:11:32,630 --> 00:11:31,279
moonlike landscape on the planet we

328
00:11:34,150 --> 00:11:32,640
shouldn't have been too surprised in

329
00:11:35,910 --> 00:11:34,160
fact papers had been written that we

330
00:11:37,670 --> 00:11:35,920
should expect

331
00:11:39,990 --> 00:11:37,680
craters on mars it was closer to the

332
00:11:42,069 --> 00:11:40,000
asteroid belt after all the impact rate

333
00:11:43,910 --> 00:11:42,079
should be higher than for the moon but

334
00:11:46,069 --> 00:11:43,920
we still had this mind of a thicker

335
00:11:48,550 --> 00:11:46,079
atmosphere that was screening out some

336
00:11:50,710 --> 00:11:48,560
of those impacts making it less so

337
00:11:52,230 --> 00:11:50,720
it was certainly a rugged planet

338
00:11:54,710 --> 00:11:52,240

and as

339
00:11:57,110 --> 00:11:54,720
we got more examples of what it looked

340
00:11:59,509 --> 00:11:57,120
like we still could see things that were

341
00:12:01,910 --> 00:11:59,519
saying yes it's not just a dead world

342
00:12:03,670 --> 00:12:01,920
there are polar caps for instance and

343
00:12:06,790 --> 00:12:03,680
there are things like you see this ring

344
00:12:09,110 --> 00:12:06,800
feature in the middle of the lower right

345
00:12:11,430 --> 00:12:09,120
thing there which those are clouds and

346
00:12:13,910 --> 00:12:11,440
they could be orographically derived

347
00:12:15,509 --> 00:12:13,920
percival hadn't seen any mountains

348
00:12:17,509 --> 00:12:15,519
either at the terminators or when they

349
00:12:19,430 --> 00:12:17,519
were seen on edge and mountains would

350
00:12:20,710 --> 00:12:19,440
have been a bad thing for his canals

351
00:12:22,710 --> 00:12:20,720
because canals would have to go up and

352
00:12:25,670 --> 00:12:22,720
over such things and they didn't seem to

353
00:12:27,990 --> 00:12:25,680
do that in any particular way but in

354
00:12:30,310 --> 00:12:28,000
reality of course there were some rather

355
00:12:31,910 --> 00:12:30,320
tall mountains on mars the great

356
00:12:33,750 --> 00:12:31,920
volcanoes

357
00:12:35,670 --> 00:12:33,760
that we've seen that's the viking image

358
00:12:37,750 --> 00:12:35,680
over there that shows you what we were

359
00:12:39,750 --> 00:12:37,760
indeed looking at when we saw

360
00:12:42,470 --> 00:12:39,760
these clouds around the rings

361
00:12:44,389 --> 00:12:42,480
we didn't appreciate just how high these

362
00:12:46,389 --> 00:12:44,399
mountains might be in fact there were

363
00:12:48,389 --> 00:12:46,399

several people bruce murray actually in

364
00:12:50,150 --> 00:12:48,399
a debate prior to mariner 9 going into

365
00:12:52,230 --> 00:12:50,160
orbit said there are no mountains on

366
00:12:54,230 --> 00:12:52,240
mars geologically it doesn't seem to be

367
00:12:56,310 --> 00:12:54,240
a very active planet and of course

368
00:12:58,790 --> 00:12:56,320
mariner 9 disproved that

369
00:13:00,870 --> 00:12:58,800
in a big way but first there was a

370
00:13:02,949 --> 00:13:00,880
global dust storm similar to this one

371
00:13:04,870 --> 00:13:02,959
that was shown later in these hubble

372
00:13:05,670 --> 00:13:04,880
images of the planet

373
00:13:09,750 --> 00:13:05,680
and

374
00:13:12,150 --> 00:13:09,760
couldn't see most of the surface except

375
00:13:14,069 --> 00:13:12,160
for four prominent dark spots which

376
00:13:17,990 --> 00:13:14,079
turned out to be the summits of these

377
00:13:19,670 --> 00:13:18,000
very tall volcanoes rising uh high into

378
00:13:22,150 --> 00:13:19,680
the atmosphere

379
00:13:24,069 --> 00:13:22,160
well mariner 9 showed us not only had

380
00:13:25,990 --> 00:13:24,079
there been water active on the planet

381
00:13:28,550 --> 00:13:26,000
but there must have been episodes of

382
00:13:30,150 --> 00:13:28,560
massive water activity streamlined

383
00:13:31,590 --> 00:13:30,160
islands and some of the big channels

384
00:13:33,509 --> 00:13:31,600
massive

385
00:13:35,590 --> 00:13:33,519
canyons that were cut and there are

386
00:13:37,590 --> 00:13:35,600
stream beds inside the canyons that have

387
00:13:39,269 --> 00:13:37,600
shown the changing positions

388
00:13:41,430 --> 00:13:39,279

furthermore it showed that for instance

389
00:13:44,389 --> 00:13:41,440
in the polar caps the polar caps were

390
00:13:46,310 --> 00:13:44,399
layered in a way the suggested ice ages

391
00:13:48,710 --> 00:13:46,320
and the progressive build up and maybe

392
00:13:51,030 --> 00:13:48,720
tear down of these things

393
00:13:52,550 --> 00:13:51,040
and that of course excited us about what

394
00:13:54,550 --> 00:13:52,560
the planet might have done in recent

395
00:13:56,230 --> 00:13:54,560
geologic time

396
00:13:58,150 --> 00:13:56,240
if you needed more evidence that water

397
00:13:59,670 --> 00:13:58,160
had flowed on the surface there were

398
00:14:01,670 --> 00:13:59,680
these valley networks however they

399
00:14:04,230 --> 00:14:01,680
weren't everywhere and it suggested that

400
00:14:06,790 --> 00:14:04,240
there was a kind of episodic nature to

401
00:14:08,710 --> 00:14:06,800
the climate change on mars

402
00:14:11,430 --> 00:14:08,720
well all of that was good the fact there

403
00:14:13,430 --> 00:14:11,440
was water it was still on the planet it

404
00:14:15,269 --> 00:14:13,440
hadn't completely desiccated even though

405
00:14:16,710 --> 00:14:15,279
it might be much drier today than it had

406
00:14:18,310 --> 00:14:16,720
been in the past

407
00:14:20,389 --> 00:14:18,320
when viking went and landed on the

408
00:14:22,949 --> 00:14:20,399
surface though we were disappointed

409
00:14:25,110 --> 00:14:22,959
disappointed in that when we scooped up

410
00:14:27,670 --> 00:14:25,120
pieces of the soil put it into the

411
00:14:30,150 --> 00:14:27,680
astrobiological instruments that were on

412
00:14:32,790 --> 00:14:30,160
viking we didn't get definitive evidence

413
00:14:35,350 --> 00:14:32,800

that there were any life forms in fact

414
00:14:36,790 --> 00:14:35,360
we couldn't find carbon in the material

415
00:14:38,389 --> 00:14:36,800
which was strange in itself because

416
00:14:40,310 --> 00:14:38,399
there should have been inorganic carbon

417
00:14:41,590 --> 00:14:40,320
just from the end fall of meteorites on

418
00:14:43,750 --> 00:14:41,600
the planet

419
00:14:44,389 --> 00:14:43,760
so that suggested that the surface in

420
00:14:46,790 --> 00:14:44,399
fact

421
00:14:48,710 --> 00:14:46,800
could be a very hostile there could be

422
00:14:50,870 --> 00:14:48,720
oxidizing agents that would break down

423
00:14:53,189 --> 00:14:50,880
the very compounds that were important

424
00:14:55,269 --> 00:14:53,199
to life as we knew it

425
00:14:57,430 --> 00:14:55,279
that gave us pause

426
00:14:59,590 --> 00:14:57,440
a bigger pause was the fact that we

427
00:15:00,949 --> 00:14:59,600
changed the launch system for the human

428
00:15:03,269 --> 00:15:00,959
program again

429
00:15:04,550 --> 00:15:03,279
and so we had our last decade and then

430
00:15:06,949 --> 00:15:04,560
we got back

431
00:15:10,150 --> 00:15:06,959
to exploration and mars there were some

432
00:15:12,389 --> 00:15:10,160
stumbles in doing that but once we did

433
00:15:14,870 --> 00:15:12,399
what we found we got

434
00:15:17,269 --> 00:15:14,880
maps of the surface at resolutions that

435
00:15:18,470 --> 00:15:17,279
were unprecedented to all of planetary

436
00:15:20,389 --> 00:15:18,480
exploration

437
00:15:22,629 --> 00:15:20,399
we also were able to do things like

438
00:15:25,110 --> 00:15:22,639

actually measure the topography just how

439
00:15:28,230 --> 00:15:25,120
high was everything did those channels

440
00:15:30,389 --> 00:15:28,240
actually flow downstream downhill

441
00:15:32,790 --> 00:15:30,399
and we were able to do that for a time

442
00:15:35,269 --> 00:15:32,800
we actually had a better global

443
00:15:37,910 --> 00:15:35,279
topography map of mars than we did for

444
00:15:39,670 --> 00:15:37,920
some regions of the earth

445
00:15:42,949 --> 00:15:39,680
other things that we were finding was

446
00:15:45,030 --> 00:15:42,959
the presence of ice in the mid-latitudes

447
00:15:46,870 --> 00:15:45,040
close to the surface so one of the

448
00:15:49,829 --> 00:15:46,880
questions is if mars had all this water

449
00:15:51,509 --> 00:15:49,839
early where did it go today one thought

450
00:15:53,670 --> 00:15:51,519
was it had been lost to space in fact

451
00:15:55,990 --> 00:15:53,680
that was percival lowell's idea about

452
00:15:58,310 --> 00:15:56,000
planets just gradually lost water over

453
00:16:01,189 --> 00:15:58,320
time the earth would do that too it was

454
00:16:03,910 --> 00:16:01,199
just behind mars in that planetary

455
00:16:06,389 --> 00:16:03,920
evolution because mars being smaller was

456
00:16:08,470 --> 00:16:06,399
an older planet in his scheme

457
00:16:10,870 --> 00:16:08,480
what we know now is that the other place

458
00:16:13,350 --> 00:16:10,880
that water can go and still be there to

459
00:16:15,670 --> 00:16:13,360
interact with the surface is in the near

460
00:16:17,990 --> 00:16:15,680
surface areas and stuff

461
00:16:20,230 --> 00:16:18,000
so evidence for past water activity on

462
00:16:21,990 --> 00:16:20,240
the ground and in the near surface

463
00:16:24,310 --> 00:16:22,000

phoenix dug down through a few

464
00:16:26,629 --> 00:16:24,320
centimeters of soil exposed the ice we

465
00:16:28,389 --> 00:16:26,639
know it is there it's physically present

466
00:16:30,550 --> 00:16:28,399
and we also found other things in the

467
00:16:33,110 --> 00:16:30,560
minerals that suggested there were

468
00:16:34,550 --> 00:16:33,120
reactions in chemistry that could go on

469
00:16:38,150 --> 00:16:34,560
that might explain some of those

470
00:16:39,749 --> 00:16:38,160
puzzling viking results uh two decades

471
00:16:40,949 --> 00:16:39,759
earlier

472
00:16:43,990 --> 00:16:40,959
so

473
00:16:46,790 --> 00:16:44,000
here's the litany of these spacecraft

474
00:16:48,790 --> 00:16:46,800
and i'll point out again this idea about

475
00:16:50,949 --> 00:16:48,800
in this case there was a synergy between

476
00:16:53,350 --> 00:16:50,959
orbiters and landers viking actually

477
00:16:55,350 --> 00:16:53,360
pioneered it the orbiters carried the

478
00:16:57,350 --> 00:16:55,360
landers into orbit

479
00:16:58,790 --> 00:16:57,360
tried to find and scout out the landing

480
00:17:00,870 --> 00:16:58,800
sites for them they didn't have much

481
00:17:03,110 --> 00:17:00,880
time to do that and then the landers

482
00:17:05,110 --> 00:17:03,120
were released went down to the surface

483
00:17:07,270 --> 00:17:05,120
well now we do it by separate missions

484
00:17:09,350 --> 00:17:07,280
for the landers and for the orbiters but

485
00:17:11,669 --> 00:17:09,360
they're still doing the same roles find

486
00:17:14,069 --> 00:17:11,679
the landing sites find the interesting

487
00:17:16,549 --> 00:17:14,079
places on the planet so that when we do

488
00:17:18,309 --> 00:17:16,559

land we invest our time and effort in

489
00:17:21,270 --> 00:17:18,319
the right places the places with the

490
00:17:23,669 --> 00:17:21,280
highest scientific potential

491
00:17:25,590 --> 00:17:23,679
we also use the orbiters as relay

492
00:17:27,750 --> 00:17:25,600
communication satellites which

493
00:17:30,070 --> 00:17:27,760
enormously increases the amount of data

494
00:17:31,750 --> 00:17:30,080
that we can return from the landers

495
00:17:33,830 --> 00:17:31,760
and we're doing that at unprecedented

496
00:17:35,350 --> 00:17:33,840
levels today with curiosity and that's

497
00:17:37,990 --> 00:17:35,360
good because if you count the number of

498
00:17:40,390 --> 00:17:38,000
cameras that mission has they're quite a

499
00:17:43,350 --> 00:17:41,350
so

500
00:17:45,669 --> 00:17:43,360
back to mars we started and we

501
00:17:47,669 --> 00:17:45,679
introduced a new element which was

502
00:17:48,630 --> 00:17:47,679
rovers and the ability to move about the

503
00:17:51,110 --> 00:17:48,640
surface

504
00:17:53,350 --> 00:17:51,120
that's important for two reasons

505
00:17:55,190 --> 00:17:53,360
the biggest one is is that you don't

506
00:17:57,270 --> 00:17:55,200
want to have the frustration

507
00:17:59,510 --> 00:17:57,280
of seeing something interesting that's

508
00:18:01,110 --> 00:17:59,520
just beyond the reach of your robotic

509
00:18:02,789 --> 00:18:01,120
arm or whatever device you have that

510
00:18:04,950 --> 00:18:02,799
gets your instruments onto the surface

511
00:18:06,470 --> 00:18:04,960
or picks up soil samples from the

512
00:18:09,110 --> 00:18:06,480
surface to ingest

513
00:18:11,350 --> 00:18:09,120

on into onboard laboratories

514
00:18:13,029 --> 00:18:11,360
so that mobility was very important i

515
00:18:15,510 --> 00:18:13,039
think opportunity landing an eagle

516
00:18:17,510 --> 00:18:15,520
crater that was very pronounced because

517
00:18:19,830 --> 00:18:17,520
there it was the exposed bedrock right

518
00:18:21,510 --> 00:18:19,840
there in that small crater wall and if

519
00:18:23,029 --> 00:18:21,520
it had been a fixed lander it would

520
00:18:23,830 --> 00:18:23,039
never have been able to sample any of

521
00:18:29,190 --> 00:18:23,840
that

522
00:18:30,470 --> 00:18:29,200
and let me jump ahead here and one of

523
00:18:32,390 --> 00:18:30,480
the things that saw were these

524
00:18:35,270 --> 00:18:32,400
blueberries that you heard about

525
00:18:37,430 --> 00:18:35,280
which were hematite concretions hematite

526
00:18:40,150 --> 00:18:37,440
is something is a mineral that requires

527
00:18:42,230 --> 00:18:40,160
the presence of water to form this was

528
00:18:45,270 --> 00:18:42,240
the first of several lines of evidence

529
00:18:47,750 --> 00:18:45,280
that said this area had seen the

530
00:18:50,470 --> 00:18:47,760
activity and presence of water in fact

531
00:18:53,430 --> 00:18:50,480
in repeated episodes as well still early

532
00:18:55,990 --> 00:18:53,440
in the planet's history and how early

533
00:18:58,390 --> 00:18:56,000
was hard to determine from these alone

534
00:19:00,070 --> 00:18:58,400
let me back up for just a moment here to

535
00:19:03,270 --> 00:19:00,080
remind you about these

536
00:19:05,990 --> 00:19:03,280
global topography sets not only did we

537
00:19:08,470 --> 00:19:06,000
map out the topography of the planet but

538
00:19:10,470 --> 00:19:08,480

the magnetic fields mars lost its

539
00:19:11,830 --> 00:19:10,480
magnetic field very early but the fact

540
00:19:14,390 --> 00:19:11,840
that there are areas that are

541
00:19:16,230 --> 00:19:14,400
permanently magnetized even today says

542
00:19:18,230 --> 00:19:16,240
it must have been a very strong field

543
00:19:20,630 --> 00:19:18,240
and the loss of that may be very much

544
00:19:23,590 --> 00:19:20,640
connected to the loss of some of that

545
00:19:25,510 --> 00:19:23,600
atmosphere that was there in early times

546
00:19:27,430 --> 00:19:25,520
we also see evidence geologically

547
00:19:29,190 --> 00:19:27,440
whenever you see layers ah that's a

548
00:19:31,430 --> 00:19:29,200
geologist's dream because that's telling

549
00:19:32,470 --> 00:19:31,440
you here's a rock record of history that

550
00:19:34,789 --> 00:19:32,480
i can read

551
00:19:36,630 --> 00:19:34,799
we also saw things like these gullies on

552
00:19:38,310 --> 00:19:36,640
the walls of craters and canyons and

553
00:19:40,470 --> 00:19:38,320
that suggests that maybe the planet is

554
00:19:41,990 --> 00:19:40,480
still active even today

555
00:19:44,310 --> 00:19:42,000
we answered one of those old mysteries

556
00:19:46,630 --> 00:19:44,320
about how things darken

557
00:19:49,350 --> 00:19:46,640
because on mars it's the wind that does

558
00:19:51,430 --> 00:19:49,360
it and but just not any wind sometimes

559
00:19:54,230 --> 00:19:51,440
there are the dust devils

560
00:19:56,710 --> 00:19:54,240
and you think dust devils a track or two

561
00:19:59,029 --> 00:19:56,720
across here well in some cases you get

562
00:20:01,590 --> 00:19:59,039
thousands of dust devils creating a

563
00:20:03,669 --> 00:20:01,600

cross and then from space or from the

564
00:20:06,230 --> 00:20:03,679
earth what you're seeing is the gradual

565
00:20:09,270 --> 00:20:06,240
darkening of this vast region all due to

566
00:20:11,350 --> 00:20:09,280
the action at a very local scale

567
00:20:13,029 --> 00:20:11,360
seasonally dependent you bet you don't

568
00:20:14,950 --> 00:20:13,039
get those kinds of things until the

569
00:20:17,110 --> 00:20:14,960
surface is hot enough to get that

570
00:20:19,750 --> 00:20:17,120
vertical motion in the spinning action

571
00:20:21,350 --> 00:20:19,760
of the dust devil

572
00:20:23,350 --> 00:20:21,360
opportunity is still looking

573
00:20:25,270 --> 00:20:23,360
ground-truthing things today

574
00:20:26,870 --> 00:20:25,280
we see some more spherules here but

575
00:20:29,029 --> 00:20:26,880
these aren't hematite these are

576
00:20:31,350 --> 00:20:29,039
something different which just goes to

577
00:20:33,750 --> 00:20:31,360
show that everything is not the same

578
00:20:35,909 --> 00:20:33,760
everywhere on this planet we thought

579
00:20:37,190 --> 00:20:35,919
that for a time that it would be very

580
00:20:39,110 --> 00:20:37,200
homogenous

581
00:20:41,510 --> 00:20:39,120
the wind sort of carries everything

582
00:20:43,669 --> 00:20:41,520
around but it's a very thin veneer that

583
00:20:45,510 --> 00:20:43,679
the wind is distributing over the planet

584
00:20:47,750 --> 00:20:45,520
and getting beneath that and seeing what

585
00:20:50,070 --> 00:20:47,760
the planet is made of is what has helped

586
00:20:52,070 --> 00:20:50,080
us understand its history

587
00:20:54,230 --> 00:20:52,080
polygonal ground you bet there was ice

588
00:20:56,070 --> 00:20:54,240

in this ground at one time maybe it's

589
00:20:58,149 --> 00:20:56,080
still there maybe it's not maybe this is

590
00:21:01,270 --> 00:20:58,159
now desiccated but look at the scale of

591
00:21:03,669 --> 00:21:01,280
this it's very fractal you go from the a

592
00:21:06,310 --> 00:21:03,679
to the b you go down to something that's

593
00:21:08,630 --> 00:21:06,320
a football sized field and we actually

594
00:21:10,870 --> 00:21:08,640
see that there's even pattern grounds

595
00:21:11,750 --> 00:21:10,880
within that at the resolution of a few

596
00:21:15,430 --> 00:21:11,760
meters

597
00:21:17,909 --> 00:21:15,440
that's what resolution can do for you

598
00:21:20,070 --> 00:21:17,919
well we're in a new site now gale crater

599
00:21:21,909 --> 00:21:20,080
that was picked on the basis of this

600
00:21:24,149 --> 00:21:21,919
reconnaissance of the whole planet

601
00:21:25,909 --> 00:21:24,159
finding the right sites to try to go to

602
00:21:28,230 --> 00:21:25,919
look for some place that could have been

603
00:21:30,549 --> 00:21:28,240
habitable that is the conditions could

604
00:21:32,070 --> 00:21:30,559
have been conducive to life now whether

605
00:21:34,470 --> 00:21:32,080
or not they were that's what we're

606
00:21:36,470 --> 00:21:34,480
trying to get to down on the ground

607
00:21:37,990 --> 00:21:36,480
and trying to understand whether or not

608
00:21:39,909 --> 00:21:38,000
the role of water that we think we

609
00:21:41,830 --> 00:21:39,919
interpret from space is actually one

610
00:21:44,230 --> 00:21:41,840
that occurred but there are indeed

611
00:21:45,990 --> 00:21:44,240
layers and they are exposed here and

612
00:21:48,310 --> 00:21:46,000
they're not just it isn't just the

613
00:21:49,830 --> 00:21:48,320

morphology of these it's also the

614
00:21:51,990 --> 00:21:49,840
chemistry of these some of these are

615
00:21:54,710 --> 00:21:52,000
sulfates some of these are clays they're

616
00:21:57,110 --> 00:21:54,720
stratified they're separated in time

617
00:21:59,110 --> 00:21:57,120
suggesting that mars history has had

618
00:22:01,510 --> 00:21:59,120
different water environments over that

619
00:22:03,669 --> 00:22:01,520
time and our question is how global how

620
00:22:05,830 --> 00:22:03,679
regional was that

621
00:22:07,990 --> 00:22:05,840
so what are the lessons to take away

622
00:22:09,909 --> 00:22:08,000
mars is a complex planet it has many

623
00:22:12,630 --> 00:22:09,919
different kinds of land forms as

624
00:22:16,390 --> 00:22:12,640
cryosphere as the land has the surface

625
00:22:17,510 --> 00:22:16,400
layers it has an active atmosphere

626
00:22:20,710 --> 00:22:17,520
it also

627
00:22:23,750 --> 00:22:20,720
is a planet that is changing today

628
00:22:25,510 --> 00:22:23,760
these are called regional slope lineae

629
00:22:28,310 --> 00:22:25,520
which is our way of trying not to say we

630
00:22:30,470 --> 00:22:28,320
think they're brine flows on the planet

631
00:22:33,190 --> 00:22:30,480
because what you see is these darkening

632
00:22:35,190 --> 00:22:33,200
things occur only during certain seasons

633
00:22:37,590 --> 00:22:35,200
in fact when the ground is the warmest

634
00:22:40,390 --> 00:22:37,600
and a brine flow might be liquidized at

635
00:22:42,710 --> 00:22:40,400
that time and affecting on the plates

636
00:22:45,669 --> 00:22:42,720
polar caps they still change in fact we

637
00:22:47,830 --> 00:22:45,679
see a trend in which the south pole cap

638
00:22:49,750 --> 00:22:47,840

may actually completely lose its co2

639
00:22:52,149 --> 00:22:49,760
cover in 100 years if that's not

640
00:22:54,310 --> 00:22:52,159
reversed by the natural processes

641
00:22:56,230 --> 00:22:54,320
sand dunes sand dunes we've now got our

642
00:22:58,630 --> 00:22:56,240
record long enough and with resolution

643
00:23:00,630 --> 00:22:58,640
key enough that we are able to see it

644
00:23:02,310 --> 00:23:00,640
actually moves and of course the big

645
00:23:05,110 --> 00:23:02,320
dust storms

646
00:23:07,669 --> 00:23:05,120
now this i want to uh just take a moment

647
00:23:09,750 --> 00:23:07,679
to address this question of novelty that

648
00:23:11,270 --> 00:23:09,760
was brought up you know major

649
00:23:13,510 --> 00:23:11,280
discoveries right

650
00:23:15,110 --> 00:23:13,520
is there water in the atmosphere or not

651
00:23:17,190 --> 00:23:15,120
that's kind of the stage we're at in

652
00:23:19,990 --> 00:23:17,200
many cases certainly with exoplanets you

653
00:23:21,990 --> 00:23:20,000
know water in those atmospheres today

654
00:23:23,590 --> 00:23:22,000
when you go to the next step it isn't

655
00:23:25,430 --> 00:23:23,600
that you lose interest the nature of the

656
00:23:27,830 --> 00:23:25,440
question changes but it can be just as

657
00:23:29,669 --> 00:23:27,840
important take earth as an example we

658
00:23:31,909 --> 00:23:29,679
know there's ozone in the atmosphere we

659
00:23:34,470 --> 00:23:31,919
know it changes but we want to know why

660
00:23:35,590 --> 00:23:34,480
it changes and because it's the earth we

661
00:23:37,350 --> 00:23:35,600
want to know whether or not we've got

662
00:23:39,909 --> 00:23:37,360
some part in that

663
00:23:41,909 --> 00:23:39,919

the level of question gets more detailed

664
00:23:44,310 --> 00:23:41,919
but the importance of the question is

665
00:23:46,549 --> 00:23:44,320
just as great as before and in fact

666
00:23:48,230 --> 00:23:46,559
we're still trying to get to that point

667
00:23:50,470 --> 00:23:48,240
of understanding whether there's life on

668
00:23:51,750 --> 00:23:50,480
the planet

669
00:23:53,990 --> 00:23:51,760
all right

670
00:23:56,149 --> 00:23:54,000
if i came back and wrote down as i did

671
00:23:57,669 --> 00:23:56,159
here why mars today

672
00:23:59,830 --> 00:23:57,679
many of those questions are very much

673
00:24:01,909 --> 00:23:59,840
the same as what we saw before

674
00:24:03,110 --> 00:24:01,919
no we're not expecting intelligent

675
00:24:05,110 --> 00:24:03,120
beings

676
00:24:06,870 --> 00:24:05,120
we're not expecting engineers to greet

677
00:24:08,950 --> 00:24:06,880
us the engineers that built the canal

678
00:24:11,909 --> 00:24:08,960
system because it's not there

679
00:24:13,990 --> 00:24:11,919
but there is life and there was a point

680
00:24:17,190 --> 00:24:14,000
made earlier about yes but if it's not a

681
00:24:19,029 --> 00:24:17,200
skeleton if it's not people-like

682
00:24:20,870 --> 00:24:19,039
is the public going to still be engaged

683
00:24:22,470 --> 00:24:20,880
in that and i think

684
00:24:25,750 --> 00:24:22,480
what we've seen in the build up to

685
00:24:28,549 --> 00:24:25,760
curiosity says you bet they are because

686
00:24:32,149 --> 00:24:28,559
any kind of life form elsewhere anywhere

687
00:24:34,149 --> 00:24:32,159
else besides earth is important for them

688
00:24:36,390 --> 00:24:34,159

so the question that i'll leave you with

689
00:24:39,430 --> 00:24:36,400
is will there be a third wave of mars

690
00:24:41,029 --> 00:24:39,440
exploration involving humans and robots

691
00:24:43,430 --> 00:24:41,039
in different ways that we've done it

692
00:24:45,269 --> 00:24:43,440
before to this point the humans have all

693
00:24:47,510 --> 00:24:45,279
been back here on earth but still

694
00:24:49,750 --> 00:24:47,520
operating the vehicles far away

695
00:24:56,549 --> 00:24:49,760
that may change with this third wave

696
00:24:56,559 --> 00:25:20,390
15 minutes for questions

697
00:25:24,789 --> 00:25:22,070
there are sort of two things that

698
00:25:26,390 --> 00:25:24,799
characterize the dark areas one is they

699
00:25:28,870 --> 00:25:26,400
don't have dust

700
00:25:31,750 --> 00:25:28,880
because that's the bright areas and

701
00:25:32,710 --> 00:25:31,760
what makes a dark area dark and keep it

702
00:25:35,350 --> 00:25:32,720
dark

703
00:25:36,310 --> 00:25:35,360
it's tends to be a rougher surface

704
00:25:38,630 --> 00:25:36,320
and

705
00:25:40,230 --> 00:25:38,640
you can think of many reasons for that

706
00:25:41,750 --> 00:25:40,240
some of the darkest areas on the planet

707
00:25:43,669 --> 00:25:41,760
certain major which is the most

708
00:25:46,149 --> 00:25:43,679
prominent of those there's a huge

709
00:25:48,390 --> 00:25:46,159
volcanic complex and that may be younger

710
00:25:49,190 --> 00:25:48,400
geologically and that roughness is still

711
00:25:50,950 --> 00:25:49,200
there

712
00:25:53,269 --> 00:25:50,960
and it's the roughness that actually

713
00:25:55,029 --> 00:25:53,279

stirs up the wind which helps remove the

714
00:25:57,029 --> 00:25:55,039
dust after one of these global dust

715
00:26:00,870 --> 00:25:57,039
storms puts dust down and makes it

716
00:26:03,510 --> 00:26:00,880
brighter so it is a combination of slope

717
00:26:12,789 --> 00:26:03,520
roughness of the surface and composition

718
00:26:17,110 --> 00:26:15,590
uh jason callahan uh you mentioned uh

719
00:26:19,190 --> 00:26:17,120
that the magnetic

720
00:26:21,350 --> 00:26:19,200
uh the magnetosphere of mars had sort of

721
00:26:22,789 --> 00:26:21,360
had dissipated early in its life and

722
00:26:24,630 --> 00:26:22,799
that this might have resulted in the

723
00:26:27,110 --> 00:26:24,640
loss of the atmosphere or parts of the

724
00:26:29,190 --> 00:26:27,120
atmosphere anyhow

725
00:26:30,950 --> 00:26:29,200
what are the current theories on the

726
00:26:32,710 --> 00:26:30,960
cause of the dissipation of the

727
00:26:34,310 --> 00:26:32,720
magnetosphere

728
00:26:36,230 --> 00:26:34,320
that's a good question one of the areas

729
00:26:38,710 --> 00:26:36,240
that we don't know very well is the

730
00:26:40,310 --> 00:26:38,720
interior processes of mars

731
00:26:42,310 --> 00:26:40,320
fortunately the discovery program has

732
00:26:44,470 --> 00:26:42,320
just selected a mission that's going to

733
00:26:46,230 --> 00:26:44,480
put a seismometer down on the surface

734
00:26:47,190 --> 00:26:46,240
put a heat flow experiment into the

735
00:26:49,669 --> 00:26:47,200
crust

736
00:26:50,710 --> 00:26:49,679
which will help tell us about the models

737
00:26:52,310 --> 00:26:50,720
of that

738
00:26:54,870 --> 00:26:52,320

one of the things i also didn't mention

739
00:26:56,149 --> 00:26:54,880
here is mars has a dichotomy in its

740
00:26:57,990 --> 00:26:56,159
topography

741
00:27:00,870 --> 00:26:58,000
the southern highlands over which

742
00:27:03,350 --> 00:27:00,880
mariner 4 6 and 7 flew by got most of

743
00:27:06,310 --> 00:27:03,360
their photographs is a heavily created

744
00:27:08,470 --> 00:27:06,320
high altitude area the northern areas

745
00:27:10,870 --> 00:27:08,480
the northern plains are relatively low

746
00:27:12,870 --> 00:27:10,880
in elevation and relatively smooth

747
00:27:14,789 --> 00:27:12,880
looking like they've had a lot of debris

748
00:27:16,390 --> 00:27:14,799
that covers up that more cratered

749
00:27:17,909 --> 00:27:16,400
surface

750
00:27:19,669 --> 00:27:17,919
all of those things could be related to

751
00:27:20,389 --> 00:27:19,679
the internal processes

752
00:27:23,590 --> 00:27:20,399
of

753
00:27:25,350 --> 00:27:23,600
mental convection plumes hot spots and

754
00:27:27,430 --> 00:27:25,360
then we also have the whole issue of the

755
00:27:29,029 --> 00:27:27,440
farces volcanoes those three giant

756
00:27:31,830 --> 00:27:29,039
volcanoes on their ridge and olympus

757
00:27:33,750 --> 00:27:31,840
mons the solar system's biggest

758
00:27:35,990 --> 00:27:33,760
how that develops

759
00:27:37,909 --> 00:27:36,000
was there a persistent hot spot think of

760
00:27:39,750 --> 00:27:37,919
hawaii where the islands aren't strung

761
00:27:42,230 --> 00:27:39,760
out but they're all sitting in that

762
00:27:44,950 --> 00:27:42,240
plume is just not moving there's not

763
00:27:46,310 --> 00:27:44,960

much evidence of plate tectonics on mars

764
00:27:48,310 --> 00:27:46,320
and that seems to be one of the big

765
00:27:51,990 --> 00:27:48,320
differences and understanding its

766
00:27:54,870 --> 00:27:52,000
difference in the geological evolution

767
00:27:58,549 --> 00:27:54,880
yeah just a quick comment on the

768
00:28:00,630 --> 00:27:58,559
dust and darkening and changes of albedo

769
00:28:02,870 --> 00:28:00,640
in the telescopic days the wave of

770
00:28:03,990 --> 00:28:02,880
darkening was always one of the

771
00:28:05,510 --> 00:28:04,000
stronger

772
00:28:07,669 --> 00:28:05,520
pieces of

773
00:28:09,990 --> 00:28:07,679
observational evidence it did occur that

774
00:28:11,110 --> 00:28:10,000
might have been related to biological

775
00:28:12,710 --> 00:28:11,120
activity

776
00:28:15,110 --> 00:28:12,720
and i've always found it interesting

777
00:28:18,710 --> 00:28:15,120
historically that carl sagan was one of

778
00:28:23,350 --> 00:28:18,720
the lead scientists in in debunking the

779
00:28:25,590 --> 00:28:23,360
the organic or or plant life

780
00:28:27,590 --> 00:28:25,600
model for that in favor of moving dust

781
00:28:28,630 --> 00:28:27,600
around he really followed the scientific

782
00:28:31,190 --> 00:28:28,640
method

783
00:28:33,510 --> 00:28:31,200
exactly the wave of darkening was the

784
00:28:36,789 --> 00:28:33,520
observation that there seemed to be

785
00:28:39,029 --> 00:28:36,799
this darkening of these features that

786
00:28:40,789 --> 00:28:39,039
occurred each spring and it started this

787
00:28:43,029 --> 00:28:40,799
wave of darkening started in the polar

788
00:28:45,190 --> 00:28:43,039

regions and seemed to sweep down

789
00:28:47,510 --> 00:28:45,200
into the lower latitudes

790
00:28:49,190 --> 00:28:47,520
so you know vegetation wouldn't it be

791
00:28:50,310 --> 00:28:49,200
responding to spring just like it does

792
00:28:52,789 --> 00:28:50,320
on the earth

793
00:28:55,029 --> 00:28:52,799
and jim pollock and carl sagan

794
00:28:57,190 --> 00:28:55,039
picked up an idea that had actually been

795
00:28:59,029 --> 00:28:57,200
promulgated to say well the dark areas

796
00:29:00,789 --> 00:28:59,039
are really volcanic dust and that's

797
00:29:02,630 --> 00:29:00,799
what's blowing around and changing with

798
00:29:04,950 --> 00:29:02,640
time but they took it and showed that

799
00:29:06,389 --> 00:29:04,960
you didn't need a volcano to do that and

800
00:29:08,789 --> 00:29:06,399
also you could

801
00:29:11,430 --> 00:29:08,799
match the timing the circulation would

802
00:29:13,190 --> 00:29:11,440
be that way to make it look like you

803
00:29:18,230 --> 00:29:13,200
were spreading the wave of the darkening

804
00:29:22,630 --> 00:29:20,070
i apologize for very provocative

805
00:29:23,669 --> 00:29:22,640
question but i'm still asking you well

806
00:29:26,870 --> 00:29:23,679
we have

807
00:29:29,909 --> 00:29:26,880
snc meteorites on the earth just studied

808
00:29:33,510 --> 00:29:29,919
in detail in the labs which are going to

809
00:29:36,149 --> 00:29:33,520
be confidently coming from ours

810
00:29:38,389 --> 00:29:36,159
then why we need to undertake sample

811
00:29:41,110 --> 00:29:38,399
return mission do you think we will take

812
00:29:44,070 --> 00:29:41,120
something new

813
00:29:46,870 --> 00:29:44,080

the meteorites are an interesting set of

814
00:29:49,510 --> 00:29:46,880
samples and the problem is we don't know

815
00:29:51,590 --> 00:29:49,520
their origins from the places on mars

816
00:29:54,310 --> 00:29:51,600
where did that material come from in

817
00:29:56,710 --> 00:29:54,320
fact there's a whole cluster of many of

818
00:29:58,950 --> 00:29:56,720
them that are of similar age so we're

819
00:30:01,029 --> 00:29:58,960
not getting a representative sample of

820
00:30:03,590 --> 00:30:01,039
all of the surface of mars

821
00:30:05,669 --> 00:30:03,600
so by knowing where we're going and

822
00:30:07,669 --> 00:30:05,679
taking those samples in the geologic

823
00:30:08,789 --> 00:30:07,679
context that we will observe when we

824
00:30:11,590 --> 00:30:08,799
collect them

825
00:30:14,070 --> 00:30:11,600
within these global data sets that's the

826
00:30:15,909 --> 00:30:14,080
big difference and that's the reason

827
00:30:18,310 --> 00:30:15,919
people have also suggested that we might

828
00:30:19,909 --> 00:30:18,320
just go to the moons of mars and pick up

829
00:30:22,070 --> 00:30:19,919
material that has been blasted off of

830
00:30:24,310 --> 00:30:22,080
the surface but that has the same

831
00:30:30,470 --> 00:30:24,320
problem we don't know the province of

832
00:30:33,990 --> 00:30:32,470
our next speaker is david grimstone who

833
00:30:36,389 --> 00:30:34,000
studies planetary evolution with a

834
00:30:38,630 --> 00:30:36,399
planet with a focus on habitability

835
00:30:40,470 --> 00:30:38,640
david was previously

836
00:30:42,230 --> 00:30:40,480
the denver museum of nature and science

837
00:30:44,710 --> 00:30:42,240
until yesterday when he moved to

838
00:30:46,549 --> 00:30:44,720

washington dc to take up the first ever

839
00:30:48,389 --> 00:30:46,559
chairship of astrobiology at the library

840
00:30:50,789 --> 00:30:48,399
of congress he's also the author of the

841
00:31:02,230 --> 00:30:50,799
award-winning book lonely planets the

842
00:31:07,430 --> 00:31:04,950
all right thanks a lot janet and

843
00:31:09,350 --> 00:31:07,440
thank you so much to the organizers uh

844
00:31:12,310 --> 00:31:09,360
for the ability to participate in this

845
00:31:13,190 --> 00:31:12,320
exciting anniversary party

846
00:31:16,070 --> 00:31:13,200
uh

847
00:31:18,230 --> 00:31:16,080
i don't have slides as janet mentioned i

848
00:31:19,990 --> 00:31:18,240
just yesterday finished driving across

849
00:31:22,470 --> 00:31:20,000
the country and i don't know where any

850
00:31:24,070 --> 00:31:22,480
of my stuff or any of my materials are

851
00:31:25,350 --> 00:31:24,080
but fortunate

852
00:31:27,350 --> 00:31:25,360
fortunately this is a topic i've been

853
00:31:29,990 --> 00:31:27,360
thinking about for uh for most of my

854
00:31:32,870 --> 00:31:30,000
life so hopefully it's in here and i do

855
00:31:34,389 --> 00:31:32,880
have some some crib notes here so the

856
00:31:36,710 --> 00:31:34,399
topic is the evolving concepts of

857
00:31:39,269 --> 00:31:36,720
planetary habitability in the age of

858
00:31:42,549 --> 00:31:39,279
planetary exploration and when i wrote

859
00:31:44,950 --> 00:31:42,559
the abstract it i it wasn't actually uh

860
00:31:46,470 --> 00:31:44,960
specifically about mars but i've been

861
00:31:48,630 --> 00:31:46,480
shoehorned into a mars session here

862
00:31:49,830 --> 00:31:48,640
which is fine i'm a big fan of mars and

863
00:31:53,190 --> 00:31:49,840

so i don't know if that means i should

864
00:31:55,190 --> 00:31:53,200
speak more about mars or or more about

865
00:31:56,630 --> 00:31:55,200
or less about mars because what a little

866
00:31:58,470 --> 00:31:56,640
bit of what i want to do is put mars in

867
00:32:00,470 --> 00:31:58,480
the in the larger context of our

868
00:32:02,389 --> 00:32:00,480
thoughts about habitability

869
00:32:05,750 --> 00:32:02,399
at any rate

870
00:32:10,070 --> 00:32:05,760
the story begins i think between 4.5 and

871
00:32:12,310 --> 00:32:10,080
4.6 billion years ago when uh the earth

872
00:32:14,149 --> 00:32:12,320
and its uh brethren and sister and

873
00:32:18,070 --> 00:32:14,159
accreted through a series of

874
00:32:20,549 --> 00:32:18,080
increasingly violent collisions um

875
00:32:22,230 --> 00:32:20,559
uh perhaps uh culminating with the the

876
00:32:23,909 --> 00:32:22,240
moon forming collision on the earth and

877
00:32:26,230 --> 00:32:23,919
then there were

878
00:32:28,870 --> 00:32:26,240
a smattering of of waves of accretion

879
00:32:31,430 --> 00:32:28,880
that had uh quickly uh settled down and

880
00:32:33,669 --> 00:32:31,440
were we're pretty much all over by four

881
00:32:34,789 --> 00:32:33,679
billion years ago setting the stage and

882
00:32:37,269 --> 00:32:34,799
then

883
00:32:40,149 --> 00:32:37,279
things sort of bubbled and percolated

884
00:32:43,350 --> 00:32:40,159
and evolved along

885
00:32:45,909 --> 00:32:43,360
after that accretion and then

886
00:32:47,909 --> 00:32:45,919
perhaps somewhat mysteriously

887
00:32:50,549 --> 00:32:47,919
about 50 years ago something very

888
00:32:51,269 --> 00:32:50,559

strange strange start started happening

889
00:33:03,990 --> 00:32:51,279
a

890
00:33:06,310 --> 00:33:04,000
event of uh

891
00:33:08,470 --> 00:33:06,320
an action of curiosity bits of the earth

892
00:33:10,389 --> 00:33:08,480
started flinging back into the solar

893
00:33:12,230 --> 00:33:10,399
system from whence they had come

894
00:33:15,509 --> 00:33:12,240
small metallic

895
00:33:17,430 --> 00:33:15,519
objects filled with instruments uh

896
00:33:21,110 --> 00:33:17,440
orbiting back out into the solar system

897
00:33:23,509 --> 00:33:22,149
now

898
00:33:26,070 --> 00:33:23,519
from the beginning

899
00:33:28,070 --> 00:33:26,080
one of the uh the motivating forces of

900
00:33:28,950 --> 00:33:28,080
this anti-accretion

901
00:33:30,789 --> 00:33:28,960
um

902
00:33:32,789 --> 00:33:30,799
this this returning of some some of the

903
00:33:35,990 --> 00:33:32,799
earth back out into the solar system uh

904
00:33:37,990 --> 00:33:36,000
has been the question of life elsewhere

905
00:33:39,909 --> 00:33:38,000
uh as as living beings and as a

906
00:33:41,590 --> 00:33:39,919
biosphere

907
00:33:43,990 --> 00:33:41,600
we want to know are we singular in some

908
00:33:46,789 --> 00:33:44,000
way or or are we commonplace

909
00:33:50,389 --> 00:33:46,799
and even um in a sense we are we are

910
00:33:52,950 --> 00:33:50,399
curious about curiosity itself is um

911
00:33:54,230 --> 00:33:52,960
is is our quest our our ability to

912
00:33:55,909 --> 00:33:54,240
wonder about the rest of the universe

913
00:33:58,710 --> 00:33:55,919

extraordinary or or is it somehow

914
00:34:01,110 --> 00:33:58,720
inevitable or both

915
00:34:03,190 --> 00:34:01,120
now uh right now i'm

916
00:34:04,149 --> 00:34:03,200
personally i'm hurtling through my 53rd

917
00:34:06,470 --> 00:34:04,159
orbit

918
00:34:09,109 --> 00:34:06,480
um so i'm just slightly older than

919
00:34:10,950 --> 00:34:09,119
planetary exploration uh i have to

920
00:34:13,109 --> 00:34:10,960
confess i don't have direct memories of

921
00:34:16,470 --> 00:34:13,119
mariner 2 from when i was three years

922
00:34:18,790 --> 00:34:16,480
old but i do actually think i remember

923
00:34:21,270 --> 00:34:18,800
the mariner 4 results being talked about

924
00:34:22,950 --> 00:34:21,280
in 1965 i definitely remember being

925
00:34:27,990 --> 00:34:22,960
excited about the appearance of the new

926
00:34:30,950 --> 00:34:28,000
beatles record beetle 65 in 1965

927
00:34:33,109 --> 00:34:30,960
and certainly like all space scientists

928
00:34:35,909 --> 00:34:33,119
of my generation

929
00:34:37,750 --> 00:34:35,919
the apollo project um launched me

930
00:34:39,589 --> 00:34:37,760
personally into space and and set me on

931
00:34:42,230 --> 00:34:39,599
my current course uh

932
00:34:45,190 --> 00:34:42,240
i like many of you i was also a science

933
00:34:47,190 --> 00:34:45,200
fiction freak from an early age and um

934
00:34:49,270 --> 00:34:47,200
as we gained the ability to send real

935
00:34:50,869 --> 00:34:49,280
machines into space

936
00:34:52,950 --> 00:34:50,879
the excitement of participating in that

937
00:34:54,710 --> 00:34:52,960
enterprise eclipsed even the excitement

938
00:34:56,470 --> 00:34:54,720

of the the fantasy space travels of

939
00:34:57,829 --> 00:34:56,480
isaac asimov and arthur c clarke

940
00:35:00,710 --> 00:34:57,839
although they all sort of merged

941
00:35:02,870 --> 00:35:00,720
together in my young imagination at any

942
00:35:04,870 --> 00:35:02,880
rate this golden anniversary that we're

943
00:35:06,550 --> 00:35:04,880
celebrating now provides an interesting

944
00:35:08,870 --> 00:35:06,560
opportunity to look

945
00:35:10,230 --> 00:35:08,880
back at our changing ideas about the

946
00:35:12,069 --> 00:35:10,240
limits of life and about the

947
00:35:14,069 --> 00:35:12,079
environments and natural history of

948
00:35:16,710 --> 00:35:14,079
planets and how they've changed uh

949
00:35:20,550 --> 00:35:16,720
throughout as a direct result of and

950
00:35:23,349 --> 00:35:20,560
during the time of planetary exploration

951
00:35:26,150 --> 00:35:23,359
planetary science as a field was born in

952
00:35:29,510 --> 00:35:26,160
response to planetary exploration and

953
00:35:31,750 --> 00:35:29,520
then the need to forge a new

954
00:35:33,190 --> 00:35:31,760
multi-disciplinary

955
00:35:35,670 --> 00:35:33,200
discipline

956
00:35:37,430 --> 00:35:35,680
that could handle this new data about

957
00:35:39,030 --> 00:35:37,440
the planets it wasn't really a question

958
00:35:41,750 --> 00:35:39,040
about astronomy

959
00:35:42,950 --> 00:35:41,760
as traditionally practiced

960
00:35:48,230 --> 00:35:42,960
and

961
00:35:50,470 --> 00:35:48,240
of the earth sciences so planetary

962
00:35:52,950 --> 00:35:50,480
science in a sense was born of a

963
00:35:56,470 --> 00:35:52,960

marriage between astronomy

964
00:35:58,310 --> 00:35:56,480
and earth sciences that was needed

965
00:36:00,790 --> 00:35:58,320
to scientifically respond to the

966
00:36:03,670 --> 00:36:00,800
opportunity to do planetary exploration

967
00:36:05,990 --> 00:36:03,680
and just as a another sort of personal

968
00:36:09,510 --> 00:36:06,000
observation in regards to that

969
00:36:11,109 --> 00:36:09,520
when i went to grad school in the 1980s

970
00:36:13,430 --> 00:36:11,119
at arizona

971
00:36:15,750 --> 00:36:13,440
in a department of planetary science

972
00:36:18,150 --> 00:36:15,760
none of my professors there had phds in

973
00:36:20,069 --> 00:36:18,160
planetary science because when they were

974
00:36:21,750 --> 00:36:20,079
in grad school there was no such thing

975
00:36:22,710 --> 00:36:21,760
now those same departments are filled

976
00:36:25,030 --> 00:36:22,720
with

977
00:36:27,510 --> 00:36:25,040
faculty that have degrees in planetary

978
00:36:31,510 --> 00:36:27,520
science similarly the birth of

979
00:36:32,870 --> 00:36:31,520
astrobiology in the late 90s

980
00:36:35,270 --> 00:36:32,880
was a

981
00:36:37,510 --> 00:36:35,280
sort of a marriage of convenience of

982
00:36:40,390 --> 00:36:37,520
planetary science with with astrophysics

983
00:36:41,589 --> 00:36:40,400
as well and and biology because we

984
00:36:43,270 --> 00:36:41,599
needed

985
00:36:47,430 --> 00:36:43,280
that approach that combination of

986
00:36:49,829 --> 00:36:47,440
disciplines to deal with our growing

987
00:36:53,270 --> 00:36:49,839
sense that we were on the trail of life

988
00:36:55,109 --> 00:36:53,280

and our growing conviction that not only

989
00:36:56,950 --> 00:36:55,119
was that the motivation for planetary

990
00:36:58,630 --> 00:36:56,960
exploration but we could now admit that

991
00:37:01,510 --> 00:36:58,640
it was the motivation for planetary

992
00:37:03,349 --> 00:37:01,520
exploration excel biology of course has

993
00:37:05,349 --> 00:37:03,359
existed since the beginning of planetary

994
00:37:07,109 --> 00:37:05,359
exploration but it was a little bit more

995
00:37:09,349 --> 00:37:07,119
fringy and

996
00:37:11,270 --> 00:37:09,359
nasa shied away from completely

997
00:37:15,030 --> 00:37:11,280
embracing it as the raise on debts of

998
00:37:15,910 --> 00:37:15,040
planetary exploration until the late 90s

999
00:37:18,310 --> 00:37:15,920
when

1000
00:37:20,150 --> 00:37:18,320
uh some scientific developments happened

1001
00:37:22,870 --> 00:37:20,160
which increased our confidence that this

1002
00:37:27,270 --> 00:37:22,880
was really a worthwhile and solid

1003
00:37:30,150 --> 00:37:27,280
endeavor and that the public excitement

1004
00:37:32,790 --> 00:37:30,160
about and the public support engendered

1005
00:37:35,349 --> 00:37:32,800
from embracing the search for life was

1006
00:37:37,750 --> 00:37:35,359
greater than the negative impact that

1007
00:37:39,589 --> 00:37:37,760
was felt previously of the sort of

1008
00:37:41,270 --> 00:37:39,599
ridicule factor that in some ways was

1009
00:37:43,270 --> 00:37:41,280
the legacy of uh

1010
00:37:46,230 --> 00:37:43,280
the the lowellian stain that took a

1011
00:37:48,390 --> 00:37:46,240
while to to erase and i think that um

1012
00:37:51,589 --> 00:37:48,400
the the birth of astrobiology was in

1013
00:37:54,630 --> 00:37:51,599

response can almost be boiled down

1014
00:37:56,630 --> 00:37:54,640
to a response to four developments

1015
00:37:57,670 --> 00:37:56,640
and in my notes the four developments

1016
00:38:00,470 --> 00:37:57,680
are simply

1017
00:38:02,230 --> 00:38:00,480
outlined as the mars rock

1018
00:38:05,109 --> 00:38:02,240
galileo europa

1019
00:38:07,349 --> 00:38:05,119
extremophiles and exoplanets

1020
00:38:08,710 --> 00:38:07,359
and i could ex explicate those further

1021
00:38:10,150 --> 00:38:08,720
but given that we don't have that much

1022
00:38:12,710 --> 00:38:10,160
time and that i think you all know what

1023
00:38:15,349 --> 00:38:12,720
i'm talking about perhaps i won't but at

1024
00:38:18,790 --> 00:38:15,359
least two of those developments the mars

1025
00:38:20,150 --> 00:38:18,800
rock of course alh 8401

1026
00:38:22,630 --> 00:38:20,160
and the

1027
00:38:26,230 --> 00:38:22,640
discovery of very good compelling

1028
00:38:28,390 --> 00:38:26,240
evidence for an ocean on europa a

1029
00:38:30,550 --> 00:38:28,400
likely or certainly potential perhaps

1030
00:38:32,950 --> 00:38:30,560
likely habitat on europa both of those

1031
00:38:36,790 --> 00:38:32,960
were direct results of planetary

1032
00:38:39,430 --> 00:38:36,800
exploration um and the the extremophiles

1033
00:38:41,190 --> 00:38:39,440
and the exoplanets are a little bit less

1034
00:38:42,870 --> 00:38:41,200
directly related to

1035
00:38:44,710 --> 00:38:42,880
planetary exploration per se but

1036
00:38:47,030 --> 00:38:44,720
certainly important in the founding of

1037
00:38:50,069 --> 00:38:47,040
astrobiology as a

1038
00:38:52,069 --> 00:38:50,079

field that's central to nasa's mission

1039
00:38:54,150 --> 00:38:52,079
astrobiology is

1040
00:38:56,710 --> 00:38:54,160
fundamentally about the relationship

1041
00:38:57,910 --> 00:38:56,720
between planets and life

1042
00:39:01,270 --> 00:38:57,920
and

1043
00:39:02,470 --> 00:39:01,280
so in thinking back over these 50 years

1044
00:39:04,390 --> 00:39:02,480
and wondering where we're going it's

1045
00:39:06,550 --> 00:39:04,400
interesting to note that i believe

1046
00:39:07,829 --> 00:39:06,560
actually in a certain sense our ideas

1047
00:39:10,630 --> 00:39:07,839
about life

1048
00:39:13,109 --> 00:39:10,640
have have actually changed very little

1049
00:39:15,349 --> 00:39:13,119
over these 50 years

1050
00:39:17,910 --> 00:39:15,359
and it's our knowledge of planets that

1051
00:39:19,589 --> 00:39:17,920
have that has changed a lot

1052
00:39:20,950 --> 00:39:19,599
and i'll um be a little bit more

1053
00:39:22,069 --> 00:39:20,960
specific what i mean about that in a

1054
00:39:23,829 --> 00:39:22,079
second

1055
00:39:25,109 --> 00:39:23,839
one of the things i love to do is read

1056
00:39:27,430 --> 00:39:25,119
outdated

1057
00:39:28,390 --> 00:39:27,440
books of popular science written by

1058
00:39:30,470 --> 00:39:28,400
scientists

1059
00:39:31,990 --> 00:39:30,480
and see what they they knew or what they

1060
00:39:35,190 --> 00:39:32,000
thought they knew and compare it to what

1061
00:39:37,270 --> 00:39:35,200
we know or what we think we know now

1062
00:39:39,990 --> 00:39:37,280
one of my favorite writers in this genre

1063
00:39:41,030 --> 00:39:40,000

is uh george gamoff

1064
00:39:44,069 --> 00:39:41,040
and

1065
00:39:46,310 --> 00:39:44,079
i i i have a copy of a book he wrote

1066
00:39:49,190 --> 00:39:46,320
called biography of the earth biography

1067
00:39:51,910 --> 00:39:49,200
of the earth that came out in 1947

1068
00:39:54,230 --> 00:39:51,920
and it's uh cover price is 35 cents

1069
00:39:56,390 --> 00:39:54,240
which gives you you know little context

1070
00:39:58,069 --> 00:39:56,400
on what else has changed in these uh in

1071
00:39:59,589 --> 00:39:58,079
these decades

1072
00:40:01,349 --> 00:39:59,599
and

1073
00:40:02,630 --> 00:40:01,359
it's stunning when you read that book

1074
00:40:03,910 --> 00:40:02,640
both what

1075
00:40:05,589 --> 00:40:03,920
they knew

1076
00:40:07,030 --> 00:40:05,599
and what they didn't know compared to

1077
00:40:08,470 --> 00:40:07,040
now

1078
00:40:10,550 --> 00:40:08,480
for instance

1079
00:40:12,230 --> 00:40:10,560
they had had the insight that the earth

1080
00:40:14,150 --> 00:40:12,240
is very old and that you could determine

1081
00:40:15,589 --> 00:40:14,160
that through radiometric dating however

1082
00:40:18,150 --> 00:40:15,599
the earth the age of the earth is

1083
00:40:20,150 --> 00:40:18,160
confidently given in gamav's book as 2

1084
00:40:21,910 --> 00:40:20,160
billion years old so they had the

1085
00:40:23,910 --> 00:40:21,920
principle right but but they didn't

1086
00:40:26,230 --> 00:40:23,920
quite have the decay constants and and

1087
00:40:27,990 --> 00:40:26,240
the math right um the origin of the moon

1088
00:40:30,630 --> 00:40:28,000

of course you know the moon had broken

1089
00:40:31,990 --> 00:40:30,640
off from the earth and the pacific ring

1090
00:40:34,390 --> 00:40:32,000
of fire and all that like we were taught

1091
00:40:36,710 --> 00:40:34,400
and taught in great school um and there

1092
00:40:39,349 --> 00:40:36,720
was no plate tectonics but there is a

1093
00:40:41,750 --> 00:40:39,359
section in that book about essentially

1094
00:40:43,910 --> 00:40:41,760
exobiology he he does speculate on

1095
00:40:45,990 --> 00:40:43,920
finding life on the other planets and

1096
00:40:47,510 --> 00:40:46,000
remember this is 1947 and what he says

1097
00:40:48,790 --> 00:40:47,520
is basically he doesn't use this exact

1098
00:40:50,230 --> 00:40:48,800
phrase but what he says is follow the

1099
00:40:54,550 --> 00:40:50,240
water

1100
00:40:57,589 --> 00:40:54,560
um and so in that sense um our basic

1101
00:41:01,589 --> 00:40:57,599
idea about how to look for life um

1102
00:41:03,750 --> 00:41:01,599
hasn't changed all that much well um

1103
00:41:07,829 --> 00:41:03,760
in 1953 the structure of dna was

1104
00:41:09,670 --> 00:41:07,839
deciphered and at that point

1105
00:41:11,349 --> 00:41:09,680
i will submit to you we knew as much

1106
00:41:12,790 --> 00:41:11,359
about life as we know

1107
00:41:14,470 --> 00:41:12,800
now

1108
00:41:15,829 --> 00:41:14,480
not really in the details if you're a

1109
00:41:17,910 --> 00:41:15,839
microbiologist you're sitting here

1110
00:41:20,230 --> 00:41:17,920
getting mad at me but what i mean is we

1111
00:41:22,470 --> 00:41:20,240
had the we had the fundamental knowledge

1112
00:41:24,470 --> 00:41:22,480
that we use now to look for life

1113
00:41:27,510 --> 00:41:24,480

elsewhere we knew that life was water in

1114
00:41:28,790 --> 00:41:27,520
organics and that's the sophistication

1115
00:41:31,030 --> 00:41:28,800
of

1116
00:41:33,589 --> 00:41:31,040
what we bring with us as we search for

1117
00:41:35,589 --> 00:41:33,599
habitable environments elsewhere

1118
00:41:37,750 --> 00:41:35,599
so um

1119
00:41:39,829 --> 00:41:37,760
the re what's really changed is what

1120
00:41:41,510 --> 00:41:39,839
we've learned about planets at the dawn

1121
00:41:43,750 --> 00:41:41,520
of the space age both venus and mars

1122
00:41:46,470 --> 00:41:43,760
were regarded by many scientists as

1123
00:41:47,990 --> 00:41:46,480
pretty good habitats for life as

1124
00:41:49,190 --> 00:41:48,000
rich zurek outlined there were there

1125
00:41:51,270 --> 00:41:49,200
were some doubts at the beginning of

1126
00:41:53,270 --> 00:41:51,280
mars exploration but the the idea that

1127
00:41:55,030 --> 00:41:53,280
there were could be plant life on mars

1128
00:41:57,589 --> 00:41:55,040
was still taken seriously and the idea

1129
00:41:59,910 --> 00:41:57,599
that venus might be a watery world there

1130
00:42:02,069 --> 00:41:59,920
were some cracks in that view because of

1131
00:42:04,309 --> 00:42:02,079
radio astronomy but but

1132
00:42:06,390 --> 00:42:04,319
when our first missions left for the

1133
00:42:07,270 --> 00:42:06,400
planets it was still

1134
00:42:09,030 --> 00:42:07,280
um

1135
00:42:11,109 --> 00:42:09,040
there was still a lot of optimism and in

1136
00:42:13,190 --> 00:42:11,119
fact in 1959

1137
00:42:15,109 --> 00:42:13,200
miller and yuri of the famous miller

1138
00:42:17,670 --> 00:42:15,119

yuri experiment wrote an article in

1139
00:42:19,349 --> 00:42:17,680
science magazine talking about um

1140
00:42:21,589 --> 00:42:19,359
that it's quite possible that we will

1141
00:42:24,630 --> 00:42:21,599
find dna based life on venus and mars

1142
00:42:25,990 --> 00:42:24,640
and what we could learn from that uh and

1143
00:42:28,790 --> 00:42:26,000
of course there's that famous paper in

1144
00:42:31,430 --> 00:42:28,800
61 that carl sagan wrote on the eve of

1145
00:42:33,190 --> 00:42:31,440
venus exploration talking about

1146
00:42:34,550 --> 00:42:33,200
summarizing current thought about venus

1147
00:42:36,230 --> 00:42:34,560
saying that uh

1148
00:42:38,550 --> 00:42:36,240
there may be it may be a carboniferous

1149
00:42:41,030 --> 00:42:38,560
swamped a windswept desert a planetary

1150
00:42:42,230 --> 00:42:41,040
oil field or a global global seltzer

1151
00:42:44,069 --> 00:42:42,240
ocean

1152
00:42:46,230 --> 00:42:44,079
and that's a classic paper if you

1153
00:42:48,309 --> 00:42:46,240
haven't read it science 1961 carl sagan

1154
00:42:50,309 --> 00:42:48,319
but certainly it wasn't outlandish there

1155
00:42:52,230 --> 00:42:50,319
could be life our kind of life on the

1156
00:42:53,589 --> 00:42:52,240
surface of either of those planets so

1157
00:42:55,190 --> 00:42:53,599
the early results of the first

1158
00:42:58,390 --> 00:42:55,200
interplanetary probes were very

1159
00:43:00,790 --> 00:42:58,400
disappointing in that regard our naive

1160
00:43:03,109 --> 00:43:00,800
optimism perhaps naive optimism

1161
00:43:05,030 --> 00:43:03,119
was dashed by those first results about

1162
00:43:06,069 --> 00:43:05,040
how learning how alien those planets

1163
00:43:08,150 --> 00:43:06,079

really were

1164
00:43:09,910 --> 00:43:08,160
new york times editorial in february

1165
00:43:12,150 --> 00:43:09,920
1963

1166
00:43:15,670 --> 00:43:12,160
um commenting on the results of mariner

1167
00:43:18,710 --> 00:43:15,680
2 that was entitled venus says no

1168
00:43:20,390 --> 00:43:18,720
and it talked about this marks the end

1169
00:43:23,589 --> 00:43:20,400
of the beginning of mankind's great

1170
00:43:25,670 --> 00:43:23,599
romantic dreams and said quote mars now

1171
00:43:27,910 --> 00:43:25,680
remains our only hope of turning this

1172
00:43:29,109 --> 00:43:27,920
universal dream into reality well two

1173
00:43:31,430 --> 00:43:29,119
and a half years later the new york

1174
00:43:33,430 --> 00:43:31,440
times had an editorial resulting uh

1175
00:43:36,069 --> 00:43:33,440
commenting on the mariner 4

1176
00:43:38,230 --> 00:43:36,079
results in in july 1965 and that

1177
00:43:39,670 --> 00:43:38,240
editorial was simply called the dead

1178
00:43:41,829 --> 00:43:39,680
planet so there's a lot of

1179
00:43:43,910 --> 00:43:41,839
disappointment at first uh

1180
00:43:46,230 --> 00:43:43,920
in response to perhaps our naive

1181
00:43:48,790 --> 00:43:46,240
optimism both neighboring planets turned

1182
00:43:50,230 --> 00:43:48,800
out to be a lot less earth-like uh in

1183
00:43:51,750 --> 00:43:50,240
terms of surface environments that had

1184
00:43:54,390 --> 00:43:51,760
been imagined by those planetary

1185
00:43:58,230 --> 00:43:54,400
astronomers who inferred oceans on venus

1186
00:44:00,550 --> 00:43:58,240
and seasonal plant life on mars

1187
00:44:03,510 --> 00:44:00,560
but optimism and wishful thinking

1188
00:44:06,470 --> 00:44:03,520

reigns supreme in this field

1189
00:44:08,710 --> 00:44:06,480
and they will not be dissuaded by data

1190
00:44:10,870 --> 00:44:08,720
life uh was pushed off the surface of

1191
00:44:13,349 --> 00:44:10,880
venus and mars and into the past of

1192
00:44:14,870 --> 00:44:13,359
venus and mars but in the subsurface of

1193
00:44:17,910 --> 00:44:14,880
mars and maybe even in the clouds of

1194
00:44:21,030 --> 00:44:17,920
venus and certainly in the glorious past

1195
00:44:22,950 --> 00:44:21,040
life still remains on those planets

1196
00:44:24,790 --> 00:44:22,960
for both venus and mars we actually have

1197
00:44:27,270 --> 00:44:24,800
reason to believe that each started out

1198
00:44:28,710 --> 00:44:27,280
much more earth-like and there was a

1199
00:44:30,309 --> 00:44:28,720
fall from grace at least this is the

1200
00:44:32,309 --> 00:44:30,319
story we tell ourselves and think we can

1201
00:44:36,390 --> 00:44:32,319
support with evidence so so i have a

1202
00:44:39,589 --> 00:44:36,400
list of six stages in our um views

1203
00:44:41,750 --> 00:44:39,599
of of uh habitability in the in in

1204
00:44:43,750 --> 00:44:41,760
in at least in in our solar system one

1205
00:44:46,230 --> 00:44:43,760
naive optimism two initial

1206
00:44:48,870 --> 00:44:46,240
disappointment three resurgent optimism

1207
00:44:51,270 --> 00:44:48,880
visions of past life resilient life

1208
00:44:54,069 --> 00:44:51,280
which is really what viking was based on

1209
00:44:56,870 --> 00:44:54,079
and non-surface life now viking was

1210
00:44:59,990 --> 00:44:56,880
motivated and by and perhaps helped to

1211
00:45:01,910 --> 00:45:00,000
quash this wave of resurgent optimism

1212
00:45:04,470 --> 00:45:01,920
but also we've had evolving ideas about

1213
00:45:06,790 --> 00:45:04,480

the habitable zone and the habitable

1214
00:45:08,870 --> 00:45:06,800
zone which was actually uh really first

1215
00:45:11,349 --> 00:45:08,880
discussed quantitatively by sushu huang

1216
00:45:13,190 --> 00:45:11,359
in the early 60s has become much more

1217
00:45:14,790 --> 00:45:13,200
sophisticated now and we realize it's

1218
00:45:16,069 --> 00:45:14,800
not just a function of stellar distance

1219
00:45:18,470 --> 00:45:16,079
it's also a function of planetary

1220
00:45:19,829 --> 00:45:18,480
evolution in size if you swapped mars

1221
00:45:21,910 --> 00:45:19,839
and venus

1222
00:45:23,589 --> 00:45:21,920
they might both be habitable mars

1223
00:45:25,750 --> 00:45:23,599
problem is not necessarily this too far

1224
00:45:28,790 --> 00:45:25,760
from the sun but it's too small it's

1225
00:45:30,550 --> 00:45:28,800
lost its its activity and its atmosphere

1226
00:45:32,470 --> 00:45:30,560
so if you swap mars and venus it might

1227
00:45:35,030 --> 00:45:32,480
we might have three habitable planets

1228
00:45:38,470 --> 00:45:35,040
so um and then finally of course beyond

1229
00:45:40,069 --> 00:45:38,480
the inner solar system right heidi we uh

1230
00:45:41,910 --> 00:45:40,079
we've learned a lot that's changed our

1231
00:45:45,829 --> 00:45:41,920
ideas about habitability and then

1232
00:45:46,790 --> 00:45:45,839
finally the exoplanet revolution um and

1233
00:45:48,550 --> 00:45:46,800
uh

1234
00:45:50,790 --> 00:45:48,560
let's see how much do i have okay five

1235
00:45:52,790 --> 00:45:50,800
minutes um so

1236
00:45:54,470 --> 00:45:52,800
during these same decades

1237
00:45:56,069 --> 00:45:54,480
our knowledge of earth

1238
00:45:58,309 --> 00:45:56,079

and the evolution and diversity of

1239
00:46:01,109 --> 00:45:58,319
terrestrial life was also rapidly

1240
00:46:03,030 --> 00:46:01,119
changing due to developments such as

1241
00:46:04,550 --> 00:46:03,040
plate tectonics

1242
00:46:06,950 --> 00:46:04,560
which was uh

1243
00:46:09,349 --> 00:46:06,960
in the early 60s still kind of a radical

1244
00:46:11,589 --> 00:46:09,359
idea by the end of the 60s widely

1245
00:46:14,790 --> 00:46:11,599
accepted as our unifying view of

1246
00:46:17,349 --> 00:46:14,800
terrestrial evolution and um

1247
00:46:19,829 --> 00:46:17,359
the plate tectonics led to the birth of

1248
00:46:21,510 --> 00:46:19,839
earth system science which i think now

1249
00:46:24,550 --> 00:46:21,520
we're trying to generalize to planetary

1250
00:46:25,829 --> 00:46:24,560
system science and um a couple ideas

1251
00:46:27,589 --> 00:46:25,839
that i think are worth mentioning the

1252
00:46:28,950 --> 00:46:27,599
formulation and debate of the gaia

1253
00:46:29,750 --> 00:46:28,960
hypothesis

1254
00:46:31,190 --> 00:46:29,760
as

1255
00:46:33,030 --> 00:46:31,200
checkered a

1256
00:46:35,910 --> 00:46:33,040
career of the guy as a guy hypothesis

1257
00:46:37,829 --> 00:46:35,920
has and as much abused as it has been i

1258
00:46:39,510 --> 00:46:37,839
think it also represents an essential

1259
00:46:41,270 --> 00:46:39,520
insight about life that's very important

1260
00:46:42,390 --> 00:46:41,280
as we think about the relationship

1261
00:46:44,950 --> 00:46:42,400
between life

1262
00:46:46,710 --> 00:46:44,960
and planets potentially elsewhere

1263
00:46:49,109 --> 00:46:46,720

that is the biosphere is an integral

1264
00:46:50,790 --> 00:46:49,119
part of the earth the inseparability of

1265
00:46:52,309 --> 00:46:50,800
the living and quote non-living parts of

1266
00:46:55,030 --> 00:46:52,319
the earth and life is something that in

1267
00:46:57,109 --> 00:46:55,040
a sense happens to a planet not just

1268
00:46:59,430 --> 00:46:57,119
something that happens on a planet and a

1269
00:47:00,870 --> 00:46:59,440
related idea that i have advanced that

1270
00:47:02,150 --> 00:47:00,880
i'll just plug here for a second is

1271
00:47:04,470 --> 00:47:02,160
something i call the living world

1272
00:47:06,950 --> 00:47:04,480
hypothesis which draws a function it

1273
00:47:09,030 --> 00:47:06,960
draws attention to the fact that life on

1274
00:47:11,109 --> 00:47:09,040
earth enjoys the benefits of residing at

1275
00:47:13,349 --> 00:47:11,119
the intersection of two great heat

1276
00:47:15,030 --> 00:47:13,359
engines the internal one and the

1277
00:47:15,990 --> 00:47:15,040
external one both of which are very

1278
00:47:18,230 --> 00:47:16,000
active

1279
00:47:20,069 --> 00:47:18,240
and um i have suggested that for the

1280
00:47:21,430 --> 00:47:20,079
long term existence of a biosphere this

1281
00:47:24,390 --> 00:47:21,440
may be as important as simply the

1282
00:47:26,150 --> 00:47:24,400
presence of liquid water and the only

1283
00:47:28,230 --> 00:47:26,160
other place we know in our solar system

1284
00:47:30,069 --> 00:47:28,240
that shares that attribute perhaps is

1285
00:47:31,990 --> 00:47:30,079
titan um

1286
00:47:34,150 --> 00:47:32,000
there's there was the um of course the

1287
00:47:35,670 --> 00:47:34,160
chicks lube impact

1288
00:47:37,510 --> 00:47:35,680

really brought home to us a relationship

1289
00:47:38,870 --> 00:47:37,520
between evolution of life on earth and

1290
00:47:42,630 --> 00:47:38,880
the rest of the solar system it wasn't

1291
00:47:44,230 --> 00:47:42,640
just an abstract concept the rare earth

1292
00:47:45,910 --> 00:47:44,240
hypothesis which i regard is

1293
00:47:47,349 --> 00:47:45,920
fundamentally wrong-headed i have a

1294
00:47:49,270 --> 00:47:47,359
paragraph here which i won't take the

1295
00:47:51,349 --> 00:47:49,280
time to read

1296
00:47:52,549 --> 00:47:51,359
why that is but if you want to ask me

1297
00:47:53,829 --> 00:47:52,559
you can

1298
00:47:55,670 --> 00:47:53,839
and the

1299
00:47:58,069 --> 00:47:55,680
of course the discovery of the numerous

1300
00:48:00,390 --> 00:47:58,079
extremophile metabolisms and habitats

1301
00:48:03,589 --> 00:48:00,400
which have greatly expanded the range of

1302
00:48:06,470 --> 00:48:03,599
watery physical conditions extremophiles

1303
00:48:09,349 --> 00:48:06,480
discoveries have taught us that water is

1304
00:48:12,630 --> 00:48:09,359
not only necessary but seemingly perhaps

1305
00:48:15,030 --> 00:48:12,640
sufficient for life at least on a planet

1306
00:48:16,549 --> 00:48:15,040
like ours that it's remarkably

1307
00:48:18,710 --> 00:48:16,559
coincident the range of life in the

1308
00:48:20,710 --> 00:48:18,720
range of liquid water

1309
00:48:22,950 --> 00:48:20,720
and um

1310
00:48:26,069 --> 00:48:22,960
finally uh almost finally i want to get

1311
00:48:28,069 --> 00:48:26,079
to the outer solar system the

1312
00:48:30,790 --> 00:48:28,079
the detailed reconnaissance of the outer

1313
00:48:33,430 --> 00:48:30,800

solar system beginning with voyager and

1314
00:48:35,030 --> 00:48:33,440
continuing with these later missions has

1315
00:48:36,950 --> 00:48:35,040
has really expanded our notions of

1316
00:48:38,630 --> 00:48:36,960
habitability because we've

1317
00:48:41,430 --> 00:48:38,640
learned about the existence of

1318
00:48:44,150 --> 00:48:41,440
gravitational habitable zones which uh

1319
00:48:47,190 --> 00:48:44,160
do not depend on proximity to any kind

1320
00:48:49,349 --> 00:48:47,200
of star and in fact who knows may define

1321
00:48:51,349 --> 00:48:49,359
the largest amount of real of habitable

1322
00:48:52,630 --> 00:48:51,359
real estate in

1323
00:48:54,790 --> 00:48:52,640
the um

1324
00:48:57,030 --> 00:48:54,800
in the universe finally more recently

1325
00:48:59,430 --> 00:48:57,040
the discovery of a complex complex

1326
00:49:02,069 --> 00:48:59,440
methane hydrosphere or methosphere on

1327
00:49:04,870 --> 00:49:02,079
titan and a likely subsurface aquifer on

1328
00:49:07,030 --> 00:49:04,880
on enceladus uh along with a rapidly

1329
00:49:09,190 --> 00:49:07,040
expanding catalog of exoplanets has

1330
00:49:11,190 --> 00:49:09,200
stimulated new ideas on the range and

1331
00:49:12,790 --> 00:49:11,200
detectability of have of planetary

1332
00:49:15,430 --> 00:49:12,800
habitability and we're even thinking a

1333
00:49:17,030 --> 00:49:15,440
little bit more about life beyond water

1334
00:49:19,910 --> 00:49:17,040
it's being taken a little more seriously

1335
00:49:22,470 --> 00:49:19,920
now because of the the methane liquid

1336
00:49:24,390 --> 00:49:22,480
methane cycle on titan

1337
00:49:26,790 --> 00:49:24,400
combined with the existence of complex

1338
00:49:29,109 --> 00:49:26,800

organics and copious energy sources

1339
00:49:31,910 --> 00:49:29,119
there are some very clever chemists that

1340
00:49:33,430 --> 00:49:31,920
are working on this problem and

1341
00:49:35,990 --> 00:49:33,440
sort of pushing us again to question

1342
00:49:38,069 --> 00:49:36,000
whether our water bias is uh

1343
00:49:40,150 --> 00:49:38,079
intellectually valid or just a

1344
00:49:43,430 --> 00:49:40,160
parochialism based on the

1345
00:49:45,270 --> 00:49:43,440
experience and environments of earth

1346
00:49:47,190 --> 00:49:45,280
i wanted to say i'm almost done i wanted

1347
00:49:49,349 --> 00:49:47,200
to say just

1348
00:49:50,950 --> 00:49:49,359
a couple things about venus because i

1349
00:49:53,349 --> 00:49:50,960
submitted an abstract that was just

1350
00:49:55,829 --> 00:49:53,359
about venus that was rejected from this

1351
00:49:57,589 --> 00:49:55,839
meeting which is fine but

1352
00:49:59,750 --> 00:49:57,599
especially having been shoehorned into a

1353
00:50:01,589 --> 00:49:59,760
mars session here i'm aware of what

1354
00:50:03,430 --> 00:50:01,599
might be caught a little bit of myopia

1355
00:50:05,270 --> 00:50:03,440
although it might be a useful myopia i

1356
00:50:07,589 --> 00:50:05,280
believe in exploring mars and i believe

1357
00:50:09,349 --> 00:50:07,599
they're good reasons to explore mars

1358
00:50:10,790 --> 00:50:09,359
first although partly we may be

1359
00:50:11,670 --> 00:50:10,800
searching under the

1360
00:50:13,349 --> 00:50:11,680
the

1361
00:50:15,270 --> 00:50:13,359
street lights for our keys because mars

1362
00:50:16,950 --> 00:50:15,280
is certainly much easier to explore but

1363
00:50:19,270 --> 00:50:16,960

uh just a couple quick points about

1364
00:50:21,109 --> 00:50:19,280
venus that that its close proximity to

1365
00:50:23,670 --> 00:50:21,119
earth and similarity in bulk properties

1366
00:50:25,109 --> 00:50:23,680
suggests an almost controlled experiment

1367
00:50:26,870 --> 00:50:25,119
with heliocentric distance in the

1368
00:50:28,710 --> 00:50:26,880
presence of life as the two main

1369
00:50:30,390 --> 00:50:28,720
variables

1370
00:50:32,150 --> 00:50:30,400
yet major differences in their

1371
00:50:33,910 --> 00:50:32,160
evolutionary paths have caused us to

1372
00:50:36,710 --> 00:50:33,920
re-evaluate our models of terrestrial

1373
00:50:39,109 --> 00:50:36,720
evolution certainly if we want to know

1374
00:50:41,430 --> 00:50:39,119
the limits of a habitable zone around

1375
00:50:42,710 --> 00:50:41,440
alpha centauri b which people want to

1376
00:50:44,710 --> 00:50:42,720
know now

1377
00:50:46,710 --> 00:50:44,720
the best way i would submit is to send

1378
00:50:48,230 --> 00:50:46,720
new missions to venus and certainly if

1379
00:50:50,230 --> 00:50:48,240
we want to know the future of life on

1380
00:50:52,150 --> 00:50:50,240
earth like planets around sun-like stars

1381
00:50:54,870 --> 00:50:52,160
we had better send new missions to venus

1382
00:50:56,309 --> 00:50:54,880
i was very encouraged by jim's chart

1383
00:50:58,390 --> 00:50:56,319
showing that there are some big venus

1384
00:51:01,109 --> 00:50:58,400
missions at least at least on the chart

1385
00:51:03,670 --> 00:51:01,119
if not uh nearing the launch pad right

1386
00:51:08,069 --> 00:51:03,680
now um

1387
00:51:09,829 --> 00:51:08,079
if curiosity finds signs of life on mars

1388
00:51:10,870 --> 00:51:09,839

in a strange way it will confirm our

1389
00:51:12,549 --> 00:51:10,880
views

1390
00:51:14,150 --> 00:51:12,559
of the origin of life

1391
00:51:16,309 --> 00:51:14,160
it doesn't really revolutionize

1392
00:51:19,349 --> 00:51:16,319
scientifically our view it confirms it

1393
00:51:21,910 --> 00:51:19,359
when we find those conglomerates

1394
00:51:23,349 --> 00:51:21,920
in gal crater we're confirming what we

1395
00:51:24,950 --> 00:51:23,359
thought that there was

1396
00:51:27,829 --> 00:51:24,960
rushing running water there it's very

1397
00:51:29,430 --> 00:51:27,839
exciting to find um but it's it's

1398
00:51:31,910 --> 00:51:29,440
interesting to me that in a certain

1399
00:51:34,150 --> 00:51:31,920
sense that if we make that tremendous

1400
00:51:36,069 --> 00:51:34,160
discovery it's more a confirmation than

1401
00:51:38,309 --> 00:51:36,079
a refutation of our current sort of

1402
00:51:40,710 --> 00:51:38,319
naturalistic worldview about life and

1403
00:51:43,109 --> 00:51:40,720
what it takes uh

1404
00:51:45,030 --> 00:51:43,119
in conclusion astrobiology is about the

1405
00:51:46,069 --> 00:51:45,040
relationship between planets and life

1406
00:51:49,750 --> 00:51:46,079
today

1407
00:51:51,750 --> 00:51:49,760
we are more sophisticated about planets

1408
00:51:52,950 --> 00:51:51,760
than we are about life

1409
00:51:55,190 --> 00:51:52,960
we are beginning to learn about the

1410
00:51:57,670 --> 00:51:55,200
diversity of planets we know nothing

1411
00:52:05,910 --> 00:51:57,680
about the diversity of life in another

1412
00:52:18,150 --> 00:52:07,910
thanks so much about five minutes for

1413
00:52:22,630 --> 00:52:20,069

uh that was that was really great

1414
00:52:24,470 --> 00:52:22,640
i wanted to poke at something that you

1415
00:52:26,549 --> 00:52:24,480
said earlier in your talk that would

1416
00:52:28,390 --> 00:52:26,559
appear to be a conflict with something

1417
00:52:29,910 --> 00:52:28,400
that you said later on you made the

1418
00:52:32,710 --> 00:52:29,920
observation about

1419
00:52:35,349 --> 00:52:32,720
life existing at the interface between

1420
00:52:37,270 --> 00:52:35,359
external and internal heat sources

1421
00:52:40,390 --> 00:52:37,280
and yet we think about europa doesn't

1422
00:52:42,710 --> 00:52:40,400
really have an external it's internal

1423
00:52:43,750 --> 00:52:42,720
and tightened almost the same way and

1424
00:52:45,829 --> 00:52:43,760
yet

1425
00:52:46,470 --> 00:52:45,839
your later statement was these may be

1426
00:52:52,470 --> 00:52:46,480
the

1427
00:52:54,790 --> 00:52:52,480
that and uh

1428
00:52:58,230 --> 00:52:54,800
yeah certainly very very very good point

1429
00:53:00,390 --> 00:52:58,240
uh you know i i think that um

1430
00:53:02,470 --> 00:53:00,400
when we

1431
00:53:03,510 --> 00:53:02,480
look around the universe and we try to

1432
00:53:07,670 --> 00:53:03,520
derive

1433
00:53:09,990 --> 00:53:07,680
criteria for what might make a habitable

1434
00:53:12,549 --> 00:53:10,000
environment we're um

1435
00:53:15,349 --> 00:53:12,559
very susceptible to the danger or we're

1436
00:53:17,030 --> 00:53:15,359
in danger of just looking for ourselves

1437
00:53:19,510 --> 00:53:17,040
out there and for reaching the

1438
00:53:21,030 --> 00:53:19,520

conclusion that you know the pain glossy

1439
00:53:22,950 --> 00:53:21,040
in conclusion this is the best of all

1440
00:53:25,430 --> 00:53:22,960
possible worlds we just have to look for

1441
00:53:27,349 --> 00:53:25,440
a place with conditions just like this

1442
00:53:29,990 --> 00:53:27,359
and it may be true but it may not be

1443
00:53:32,390 --> 00:53:30,000
true so it's interesting to say well

1444
00:53:34,630 --> 00:53:32,400
okay obviously earth has a climate

1445
00:53:37,190 --> 00:53:34,640
conducive to liquid water on the surface

1446
00:53:39,349 --> 00:53:37,200
and that's one set of criteria what else

1447
00:53:42,710 --> 00:53:39,359
is it about the earth that's

1448
00:53:44,710 --> 00:53:42,720
uh unusual that could also possibly

1449
00:53:46,549 --> 00:53:44,720
differentiate uh habitable planets from

1450
00:53:49,430 --> 00:53:46,559
non-habitable planets and and it is

1451
00:53:51,430 --> 00:53:49,440
striking the level of ongoing geological

1452
00:53:53,910 --> 00:53:51,440
and meteorological activity on earth and

1453
00:53:55,910 --> 00:53:53,920
and certainly life uh the more we learn

1454
00:53:57,670 --> 00:53:55,920
about life and or you know the way it

1455
00:53:59,910 --> 00:53:57,680
fits into earth system science it takes

1456
00:54:02,470 --> 00:53:59,920
advantage of that it's not just a

1457
00:54:04,549 --> 00:54:02,480
coincidence so that's really my point is

1458
00:54:06,549 --> 00:54:04,559
that um that's something unusual about

1459
00:54:10,549 --> 00:54:06,559
earth and for all we know it may be true

1460
00:54:12,470 --> 00:54:10,559
of all habitable planets um and and in

1461
00:54:14,630 --> 00:54:12,480
that sense i'm i'm intrigued by the fact

1462
00:54:17,109 --> 00:54:14,640
that titan shares that now europa is an

1463
00:54:19,510 --> 00:54:17,119

interesting case and maybe is it is a

1464
00:54:23,910 --> 00:54:19,520
test of this hypothesis uh if all you

1465
00:54:25,990 --> 00:54:23,920
need is liquid water and organics and uh

1466
00:54:28,150 --> 00:54:26,000
and energy sources europa ought to have

1467
00:54:30,309 --> 00:54:28,160
life but but in a certain sense uh you

1468
00:54:31,670 --> 00:54:30,319
know if if you sort of what i'm calling

1469
00:54:33,910 --> 00:54:31,680
the living world hypothesis if you

1470
00:54:36,390 --> 00:54:33,920
generalize it to you need ongoing

1471
00:54:39,190 --> 00:54:36,400
internally driven geologic activity that

1472
00:54:40,710 --> 00:54:39,200
is feeding this sort of cyclic um

1473
00:54:42,390 --> 00:54:40,720
exchange of matter and energy that life

1474
00:54:45,750 --> 00:54:42,400
feeds off of then you i think you could

1475
00:54:47,829 --> 00:54:45,760
argue that europa shares those although

1476
00:54:49,349 --> 00:54:47,839
maybe um that this inter intersection of

1477
00:54:51,990 --> 00:54:49,359
two heat engines is specifically

1478
00:54:53,510 --> 00:54:52,000
relevant for for surface life obviously

1479
00:54:55,349 --> 00:54:53,520
i'm still working on the idea maybe we

1480
00:54:56,870 --> 00:54:55,359
should have a beer later in the

1481
00:54:58,789 --> 00:54:56,880
and refine this yeah

1482
00:55:00,230 --> 00:54:58,799
oh this is a information you probably

1483
00:55:01,829 --> 00:55:00,240
know it well i've had a long

1484
00:55:03,270 --> 00:55:01,839
relationship with the museum of science

1485
00:55:06,789 --> 00:55:03,280
in baltimore i've lectured there many

1486
00:55:08,710 --> 00:55:06,799
times and they're opening a exobiology

1487
00:55:09,670 --> 00:55:08,720
exhibit sponsored by nasa i'm sure you

1488
00:55:11,829 --> 00:55:09,680

knew that

1489
00:55:13,829 --> 00:55:11,839
uh that'll be uh on the

1490
00:55:16,069 --> 00:55:13,839
first of november i've been invited as a

1491
00:55:19,030 --> 00:55:16,079
donor but you'll never guess what i

1492
00:55:22,230 --> 00:55:19,040
loaned them they wanted a pristine first

1493
00:55:25,030 --> 00:55:22,240
edition copy of the war of the worlds

1494
00:55:27,030 --> 00:55:25,040
that's good exobiology isn't it

1495
00:55:29,589 --> 00:55:27,040
excellent excellent well that i i i

1496
00:55:31,430 --> 00:55:29,599
think it's a great choice if if if for

1497
00:55:33,109 --> 00:55:31,440
for no other reason than that then the

1498
00:55:35,589 --> 00:55:33,119
first page of the war of the world is

1499
00:55:38,309 --> 00:55:35,599
one of the finest pieces of of western

1500
00:55:40,309 --> 00:55:38,319
literature uh that exists and even that

1501
00:55:43,270 --> 00:55:40,319
that that sort of crappy remake of that

1502
00:55:44,710 --> 00:55:43,280
movie um that with uh what's his name in

1503
00:55:51,510 --> 00:55:44,720
it

1504
00:55:53,270 --> 00:55:51,520
directly reading from that first page

1505
00:56:03,829 --> 00:55:53,280
which is you know it's worth just

1506
00:56:07,990 --> 00:56:05,829
i seem to remember

1507
00:56:10,309 --> 00:56:08,000
there was an instrument on curiosity

1508
00:56:11,670 --> 00:56:10,319
that would help characterize the source

1509
00:56:13,270 --> 00:56:11,680
of methane

1510
00:56:17,910 --> 00:56:13,280
that's been seen have we gotten any

1511
00:56:19,750 --> 00:56:17,920
recent news from that ah um

1512
00:56:21,670 --> 00:56:19,760
that's a great question um

1513
00:56:23,270 --> 00:56:21,680

curiosity should be able to resolve the

1514
00:56:25,349 --> 00:56:23,280
the methane issue and i i when i

1515
00:56:27,510 --> 00:56:25,359
mentioned the recurring

1516
00:56:28,549 --> 00:56:27,520
uh the recurring existence of wishful

1517
00:56:31,670 --> 00:56:28,559
thinking

1518
00:56:33,750 --> 00:56:31,680
in um in interpretations of data from

1519
00:56:36,470 --> 00:56:33,760
mars i was thinking for instance about

1520
00:56:38,150 --> 00:56:36,480
the publication in the 1960s of the re

1521
00:56:41,510 --> 00:56:38,160
in science magazine of the report the

1522
00:56:43,589 --> 00:56:41,520
spectral signature of chlorophyll

1523
00:56:46,309 --> 00:56:43,599
on mars which later turned out to be

1524
00:56:47,750 --> 00:56:46,319
deuterium and earth's atmosphere and it

1525
00:56:49,270 --> 00:56:47,760
may turn out that these methane

1526
00:56:51,430 --> 00:56:49,280
observations

1527
00:56:53,589 --> 00:56:51,440
historically fit into

1528
00:56:55,430 --> 00:56:53,599
that uh

1529
00:56:56,950 --> 00:56:55,440
that that pantheon of optimistic

1530
00:56:58,870 --> 00:56:56,960
interpretations we don't know yet

1531
00:57:00,470 --> 00:56:58,880
they're they're it's it's controversial

1532
00:57:01,910 --> 00:57:00,480
and there's some very smart people are

1533
00:57:03,589 --> 00:57:01,920
very critical of the methane

1534
00:57:05,990 --> 00:57:03,599
interpretation and some other very smart

1535
00:57:08,950 --> 00:57:06,000
people are uh are sure that it's true

1536
00:57:11,670 --> 00:57:08,960
and it's it's exciting that curiosity uh

1537
00:57:13,990 --> 00:57:11,680
has that ability in the sam instrument

1538
00:57:17,589 --> 00:57:14,000

to look for very minut quantities of

1539
00:57:22,789 --> 00:57:19,829
methane is a leaky substance and uh the

1540
00:57:24,150 --> 00:57:22,799
the uh the curiosity team is large and

1541
00:57:27,349 --> 00:57:24,160
there have been some

1542
00:57:29,829 --> 00:57:27,359
hints that maybe some people know the

1543
00:57:31,910 --> 00:57:29,839
answer to this question and i was i was

1544
00:57:33,990 --> 00:57:31,920
during jim green's talk i was trying to

1545
00:57:36,390 --> 00:57:34,000
read his lips very carefully but nothing

1546
00:57:38,309 --> 00:57:36,400
has been officially released but i

1547
00:57:39,670 --> 00:57:38,319
wouldn't be surprised if sometime this

1548
00:57:41,829 --> 00:57:39,680
year there was an announcement about

1549
00:57:49,829 --> 00:57:41,839
that