1
00:00:03,350 --> 00:00:02,230
so in 2003 we launched a pair of twin

2
00:00:07,749 --> 00:00:03,360
rovers

3
00:00:11,509 --> 00:00:07,759
to get the mars program back to the

4
00:00:14,070 --> 00:00:11,519
surface we intended them to last 90 days

5
00:00:16,310 --> 00:00:14,080
today uh basically five and three

6
00:00:18,070 --> 00:00:16,320
quarters years later they're still going

7
00:00:21,029 --> 00:00:18,080
pretty good design by our engineers at

8
00:00:23,429 --> 00:00:21,039
jpl these rovers in moving at the pace

9
00:00:24,870 --> 00:00:23,439
of a giant tortoise about an hour a day

10
00:00:26,870 --> 00:00:24,880
that's their pace

11
00:00:29,029 --> 00:00:26,880
have uncovered things about mars that

12
00:00:30,630 --> 00:00:29,039
you can only see from the surface

13
00:00:32,630 --> 00:00:30,640

first thing they learned

14
00:00:35,190 --> 00:00:32,640
crawling along the edges of things like

15
00:00:37,190 --> 00:00:35,200
craters there's the opportunity rover

16
00:00:39,510 --> 00:00:37,200
is that there is a history of water on

17
00:00:41,990 --> 00:00:39,520
mars in all of the rocks

18
00:00:43,830 --> 00:00:42,000
while it looks as dry as a bone actually

19
00:00:46,310 --> 00:00:43,840
if you look closer this is the victoria

20
00:00:47,750 --> 00:00:46,320
crater that we spent a year at um as

21
00:00:49,670 --> 00:00:47,760
seen as we started to drive around and

22
00:00:51,270 --> 00:00:49,680
went into the crater we realized in the

23
00:00:52,950 --> 00:00:51,280
layers exposed in this crater and in

24
00:00:54,709 --> 00:00:52,960
some of these rocks our history of

25
00:00:56,389 --> 00:00:54,719
minerals that can only be made in the

26
00:00:58,389 --> 00:00:56,399
presence of water

27
00:01:00,229 --> 00:00:58,399
we have no physical way good old

28
00:01:01,830 --> 00:01:00,239
chemistry doesn't lie to make them so

29
00:01:03,189 --> 00:01:01,840
while mars may looked as parched as

30
00:01:05,270 --> 00:01:03,199
anything we'd ever want to think about

31
00:01:07,350 --> 00:01:05,280
today the history of water is there in

32
00:01:08,950 --> 00:01:07,360
the rocks and if we could go to places

33
00:01:10,870 --> 00:01:08,960
more interesting than these flat parking

34
00:01:12,230 --> 00:01:10,880
lots with a few craters we could get to

35
00:01:14,149 --> 00:01:12,240
places where the history of water in the

36
00:01:15,990 --> 00:01:14,159
rocks could lead to preservational

37
00:01:18,710 --> 00:01:16,000
environments the kind of which on earth

38
00:01:19,830 --> 00:01:18,720

preserve evidence of life so our next

39
00:01:22,550 --> 00:01:19,840
mission to mars i'll show you in a

40
00:01:24,390 --> 00:01:22,560
second is actually after that can we go

41
00:01:25,429 --> 00:01:24,400
to places better than this that expose

42
00:01:30,469 --> 00:01:25,439
mars

43
00:01:32,069 --> 00:01:30,479
and if it was what are the signatures

44
00:01:34,789 --> 00:01:32,079
i mean imagine that

45
00:01:36,550 --> 00:01:34,799
are we alone no there were the martians

46
00:01:38,149 --> 00:01:36,560
whatever the martians look like so here

47
00:01:40,230 --> 00:01:38,159
you see odyssey crawling down into

48
00:01:41,510 --> 00:01:40,240
victoria crater today it's heading far

49
00:01:43,350 --> 00:01:41,520
south um

50
00:01:45,030 --> 00:01:43,360
this is one of the great success stories

51
00:01:47,030 --> 00:01:45,040
of robotic exploration although it took

52
00:01:48,389 --> 00:01:47,040
five years to go as far as a couple of

53
00:01:49,350 --> 00:01:48,399
men and women could go in a couple of

54
00:01:51,590 --> 00:01:49,360
days

55
00:01:53,350 --> 00:01:51,600
we did it for the cost of a james

56
00:01:55,190 --> 00:01:53,360
cameron movie not for the cost of

57
00:01:57,190 --> 00:01:55,200
something bigger so robotic exploration

58
00:01:58,550 --> 00:01:57,200
is important now this funny view

59
00:02:01,109 --> 00:01:58,560
you might say is about as boring as you

60
00:02:04,069 --> 00:02:01,119
can see this is the real mars swales of

61
00:02:06,870 --> 00:02:04,079
dust like dunes and patches of we think

62
00:02:08,469 --> 00:02:06,880
sulfate-rich rocks covering about 10 or

63
00:02:10,790 --> 00:02:08,479

15 of the planet

64
00:02:12,390 --> 00:02:10,800
this is the real mars the mars the

65
00:02:14,390 --> 00:02:12,400
humans would interact with problem is

66
00:02:16,470 --> 00:02:14,400
these little dunes of fine talcum powder

67
00:02:19,270 --> 00:02:16,480
stuff aren't too good for driving robots

68
00:02:21,190 --> 00:02:19,280
in they can get stuck we got stuck for

69
00:02:23,430 --> 00:02:21,200
40 days in this stuff with opportunity

70
00:02:25,670 --> 00:02:23,440
we backed ourselves out and escaped but

71
00:02:27,830 --> 00:02:25,680
we have to build better mobility systems

72
00:02:29,190 --> 00:02:27,840
so we don't get stuck on the real mars

73
00:02:30,470 --> 00:02:29,200
now this funny picture is one of my

74
00:02:31,509 --> 00:02:30,480
favorites i thought i'd share with you

75
00:02:33,670 --> 00:02:31,519
for a minute

76
00:02:34,869 --> 00:02:33,680
after driving around mars in one place

77
00:02:36,630 --> 00:02:34,879
for a while

78
00:02:38,470 --> 00:02:36,640
spirit dug around its wheels they're

79
00:02:41,430 --> 00:02:38,480
about this big

80
00:02:44,390 --> 00:02:41,440
about a year ago and discovered lots of

81
00:02:48,150 --> 00:02:44,400
basically silica in the soil the white

82
00:02:50,869 --> 00:02:48,160
stuff is basically pure silica leached

83
00:02:52,710 --> 00:02:50,879
out of rocks by the action of water so

84
00:02:53,990 --> 00:02:52,720
in this dry place

85
00:02:55,750 --> 00:02:54,000
perhaps less interesting than where

86
00:02:57,110 --> 00:02:55,760
opportunity's been in meridiani we've

87
00:02:58,470 --> 00:02:57,120
uncovered the signature of water we

88
00:03:00,149 --> 00:02:58,480

found minerals like gertite for those

89
00:03:02,149 --> 00:03:00,159
either like minerals again made in the

90
00:03:05,350 --> 00:03:02,159
presence of water typically on earth we

91
00:03:07,910 --> 00:03:05,360
think on mars so the dry mars we see

92
00:03:09,670 --> 00:03:07,920
from remote sensing from orbit is

93
00:03:11,990 --> 00:03:09,680
actually telling us a history of water

94
00:03:13,830 --> 00:03:12,000
on a planet that i would call a water

95
00:03:16,470 --> 00:03:13,840
planet today the history of water on

96
00:03:18,070 --> 00:03:16,480
mars is masked by rocks like these that

97
00:03:20,710 --> 00:03:18,080
are typical volcanic rocks these are

98
00:03:22,470 --> 00:03:20,720
basaltic rocks we think um and so it's

99
00:03:24,309 --> 00:03:22,480
it's it's beguiling as shakespeare once

100
00:03:25,589 --> 00:03:24,319
said so it's important to remember every

101
00:03:27,270 --> 00:03:25,599
time we've gone to mars we thought we

102
00:03:29,589 --> 00:03:27,280
got it yep viking going tomorrow's gonna

103
00:03:31,670 --> 00:03:29,599
find life nope not there

104
00:03:33,589 --> 00:03:31,680
go back to mars

105
00:03:34,869 --> 00:03:33,599
again with other missions and this is

106
00:03:35,910 --> 00:03:34,879
the launch of our mars reconnaissance

107
00:03:37,509 --> 00:03:35,920
orbiter and we thought we'd see

108
00:03:40,229 --> 00:03:37,519
something and we got something else so

109
00:03:41,430 --> 00:03:40,239
in 2005 we launched the mro the mars

110
00:03:43,670 --> 00:03:41,440
reconnaissance orbiter and this was one

111
00:03:46,149 --> 00:03:43,680
of my dreams to go to mars with the kind

112
00:03:47,589 --> 00:03:46,159
of eyes and spectrometers that could see

113
00:03:48,550 --> 00:03:47,599

mars as if we were walking on the

114
00:03:50,710 --> 00:03:48,560
surface

115
00:03:52,630 --> 00:03:50,720
an mro got to mars it has a big 65

116
00:03:53,990 --> 00:03:52,640
centimeter optic flying right down it

117
00:03:55,589 --> 00:03:54,000
there

118
00:03:57,429 --> 00:03:55,599
and it arrived at mars and it changed

119
00:04:00,710 --> 00:03:57,439
the way we see the planet typically we

120
00:04:02,149 --> 00:04:00,720
see mars at this scale craters then

121
00:04:04,470 --> 00:04:02,159
thanks to the mars global surveyor we

122
00:04:06,550 --> 00:04:04,480
saw mars at this scale

123
00:04:10,470 --> 00:04:06,560
now we see mars if you look in at the

124
00:04:12,149 --> 00:04:10,480
next frame at for now 20 000 places not

125
00:04:14,070 --> 00:04:12,159
at this scale this is the typical scale

126
00:04:16,390 --> 00:04:14,080
that we get from them from the mro but

127
00:04:18,550 --> 00:04:16,400
at that scale we can now fly over the

128
00:04:20,550 --> 00:04:18,560
surface of mars for tens of thousands of

129
00:04:23,110 --> 00:04:20,560
places as if you were in a helicopter

130
00:04:24,469 --> 00:04:23,120
zipping over at that scale geology can

131
00:04:26,390 --> 00:04:24,479
become definitive and this happens to be

132
00:04:27,510 --> 00:04:26,400
a gully site where these gullies once

133
00:04:29,830 --> 00:04:27,520
erupted

134
00:04:32,230 --> 00:04:29,840
fluids newtonian fluids probably water

135
00:04:33,350 --> 00:04:32,240
we don't absolutely know they're stained

136
00:04:35,030 --> 00:04:33,360
by dust

137
00:04:36,390 --> 00:04:35,040
but we've discovered more than six

138
00:04:38,070 --> 00:04:36,400

thousand of these kinds of gullies some

139
00:04:39,990 --> 00:04:38,080
of which have changed in the course of

140
00:04:41,350 --> 00:04:40,000
the last couple years this is the polar

141
00:04:42,870 --> 00:04:41,360
ice cap of marsh showing the chocolate

142
00:04:44,310 --> 00:04:42,880
block terrain and this white thing you

143
00:04:47,670 --> 00:04:44,320
see here is a little patch of ice

144
00:04:49,590 --> 00:04:47,680
exposed we do this routinely so mro has

145
00:04:51,510 --> 00:04:49,600
changed the way we see the planet the

146
00:04:53,430 --> 00:04:51,520
other thing we've done with mro is used

147
00:04:55,110 --> 00:04:53,440
a radar sounding method to slice right

148
00:04:57,590 --> 00:04:55,120
through the polar ice caps what do they

149
00:04:59,990 --> 00:04:57,600
look like and so using 20 megahertz

150
00:05:02,150 --> 00:05:00,000
wavelength radar built in this case for

151
00:05:03,590 --> 00:05:02,160
us by the by our friends in italy we've

152
00:05:06,150 --> 00:05:03,600
been able to slice through sort of the

153
00:05:08,230 --> 00:05:06,160
way mris do our body and see the

154
00:05:10,150 --> 00:05:08,240
layering structure of the polar ice caps

155
00:05:11,749 --> 00:05:10,160
of mars they're about three kilometers

156
00:05:14,310 --> 00:05:11,759
thick they have layers hundreds of

157
00:05:16,070 --> 00:05:14,320
meters thick they run a scale the length

158
00:05:17,909 --> 00:05:16,080
of half the united states

159
00:05:19,749 --> 00:05:17,919
this shows what we thought was happening

160
00:05:21,670 --> 00:05:19,759
that in fact these these ice caps are

161
00:05:22,390 --> 00:05:21,680
built up episodically

162
00:05:25,110 --> 00:05:22,400
and

163
00:05:27,430 --> 00:05:25,120

um that's a really important discovery

164
00:05:29,749 --> 00:05:27,440
within these layers could be lenses of

165
00:05:31,110 --> 00:05:29,759
preserved liquid water

166
00:05:33,830 --> 00:05:31,120
those could be the places where you'd

167
00:05:35,909 --> 00:05:33,840
want to go to seek signs of active life

168
00:05:38,230 --> 00:05:35,919
finally we've also found in equatorial

169
00:05:40,150 --> 00:05:38,240
areas near the equator of mars with

170
00:05:42,550 --> 00:05:40,160
imaging and radar that under the dust

171
00:05:44,150 --> 00:05:42,560
cover there are buried glaciers

172
00:05:45,749 --> 00:05:44,160
tropical mountain glaciers near the

173
00:05:46,469 --> 00:05:45,759
equator on mars

174
00:05:49,110 --> 00:05:46,479
so

175
00:05:50,870 --> 00:05:49,120
mro the mars express the mars

176
00:05:53,350 --> 00:05:50,880
exploration rovers the mars global

177
00:05:54,870 --> 00:05:53,360
surveyor they have changed how we see

178
00:05:56,150 --> 00:05:54,880
the planet we would now describe mars as

179
00:05:58,390 --> 00:05:56,160
a water planet

180
00:06:00,870 --> 00:05:58,400
a water plant that could have preserved

181
00:06:01,990 --> 00:06:00,880
the biological signatures in rocks of

182
00:06:05,830 --> 00:06:02,000
life

183
00:06:07,830 --> 00:06:05,840
let me turn to phoenix in 2003 nasa said

184
00:06:08,870 --> 00:06:07,840
okay world community all of you could

185
00:06:10,150 --> 00:06:08,880
have bid we're going to have a

186
00:06:12,629 --> 00:06:10,160
competition like the olympics to pick

187
00:06:14,550 --> 00:06:12,639
the next mission to mars mars scout and

188
00:06:17,270 --> 00:06:14,560

after a year and a half of competition a

189
00:06:18,870 --> 00:06:17,280
landed spacecraft developed at at

190
00:06:21,510 --> 00:06:18,880
lockheed martin and jet propulsion lab

191
00:06:23,029 --> 00:06:21,520
in arizona went to mars to ask what is

192
00:06:24,230 --> 00:06:23,039
the ice really like up near the north

193
00:06:26,230 --> 00:06:24,240
polar cap

194
00:06:28,870 --> 00:06:26,240
why would we care about it so it landed

195
00:06:31,270 --> 00:06:28,880
it popped up its uh cameras and it

196
00:06:33,270 --> 00:06:31,280
observed mars for a period of 150 days

197
00:06:34,790 --> 00:06:33,280
from the edge of the north polar ice cap

198
00:06:36,710 --> 00:06:34,800
and during descent

199
00:06:38,550 --> 00:06:36,720
we watched the descent through the eyes

200
00:06:40,950 --> 00:06:38,560
of mro and there's the there is the

201
00:06:43,510 --> 00:06:40,960
parachute with the lander seen from

202
00:06:45,590 --> 00:06:43,520
another spacecraft as it descended the

203
00:06:47,270 --> 00:06:45,600
geometry of that was rather challenging

204
00:06:49,589 --> 00:06:47,280
but we actually managed to pull it off

205
00:06:51,990 --> 00:06:49,599
we landed this is the foot pad and right

206
00:06:53,749 --> 00:06:52,000
underneath the lander after the landing

207
00:06:55,189 --> 00:06:53,759
rockets settled we found a patch of ice

208
00:06:57,029 --> 00:06:55,199
now this is what the north polar region

209
00:06:59,510 --> 00:06:57,039
of mars looks like in the far distance

210
00:07:02,790 --> 00:06:59,520
you can see the sun setting during 150

211
00:07:04,790 --> 00:07:02,800
days as we went from summer to to fall

212
00:07:06,790 --> 00:07:04,800
we watched the wind blow we tracked the

213
00:07:10,550 --> 00:07:06,800

star with lasers i mean the stars the

214
00:07:13,350 --> 00:07:10,560
sky with lasers um and we saw patches of

215
00:07:15,749 --> 00:07:13,360
ice exposed and evaporate as part of our

216
00:07:17,909 --> 00:07:15,759
measurements we ingested materials and

217
00:07:19,749 --> 00:07:17,919
detected for the first time definitively

218
00:07:21,029 --> 00:07:19,759
the molecule water on mars with a

219
00:07:23,589 --> 00:07:21,039
chemistry lab

220
00:07:25,270 --> 00:07:23,599
there's a patch of ice under the lander

221
00:07:27,670 --> 00:07:25,280
so mars where we thought there would be

222
00:07:29,029 --> 00:07:27,680
ice we've validated it's there if you

223
00:07:31,029 --> 00:07:29,039
start to look at the little white tinge

224
00:07:33,430 --> 00:07:31,039
here that's frost forming on the surface

225
00:07:35,430 --> 00:07:33,440
as we come out of mars northern summer

226
00:07:37,670 --> 00:07:35,440
so the winter sun set it got cold the

227
00:07:39,589 --> 00:07:37,680
solar panels got no light the batteries

228
00:07:42,070 --> 00:07:39,599
died and the mission essentially froze

229
00:07:45,189 --> 00:07:42,080
but we generated 100 gigabytes of data

230
00:07:47,430 --> 00:07:45,199
in 150 day mission for the price of a

231
00:07:49,430 --> 00:07:47,440
small blockbuster movie there's the

232
00:07:51,909 --> 00:07:49,440
wally like camera eyes saying goodbye to

233
00:07:54,070 --> 00:07:51,919
you from mars our next mission to mars

234
00:07:55,909 --> 00:07:54,080
is the one i'm most excited about and i

235
00:07:56,950 --> 00:07:55,919
get excited pretty easily as you can

236
00:07:58,790 --> 00:07:56,960
probably tell

237
00:08:00,469 --> 00:07:58,800
we've been dreaming of this since 2000

238
00:08:02,550 --> 00:08:00,479

when we broke the program for mars we

239
00:08:04,710 --> 00:08:02,560
dreamt of sending an astrobiological

240
00:08:08,070 --> 00:08:04,720
rover to mars in this case that we will

241
00:08:09,990 --> 00:08:08,080
land in the summer of 2012 with a

242
00:08:11,510 --> 00:08:10,000
rocket-powered helicopter system known

243
00:08:12,950 --> 00:08:11,520
as a skycrane developed at our jet

244
00:08:15,270 --> 00:08:12,960
propulsion lab

245
00:08:16,469 --> 00:08:15,280
this rover is as massive as a mini

246
00:08:19,670 --> 00:08:16,479
cooper car how many of you have ever

247
00:08:22,390 --> 00:08:19,680
been in a mini cooper no yes few hands

248
00:08:24,390 --> 00:08:22,400
okay they're not tiny right i mean

249
00:08:26,550 --> 00:08:24,400
football players might not prefer them

250
00:08:28,550 --> 00:08:26,560
but anyway we will not even land the

251
00:08:31,110 --> 00:08:28,560
spacecraft that gets us there we will

252
00:08:32,870 --> 00:08:31,120
drop the rover down on a on a winch and

253
00:08:34,870 --> 00:08:32,880
then we will measure rocks without even

254
00:08:36,709 --> 00:08:34,880
going to them by firing a laser beam and

255
00:08:38,310 --> 00:08:36,719
ionizing the surface of a rock we will

256
00:08:40,389 --> 00:08:38,320
measure what they're made of

257
00:08:42,790 --> 00:08:40,399
this is you know like star trek does

258
00:08:45,190 --> 00:08:42,800
mars um that will help us not have to

259
00:08:47,670 --> 00:08:45,200
drive everywhere we will drill up to

260
00:08:49,670 --> 00:08:47,680
this deep into rocks and then bring the

261
00:08:51,829 --> 00:08:49,680
samples sort of with this crazy looking

262
00:08:53,990 --> 00:08:51,839
extrusion process

263
00:08:57,030 --> 00:08:54,000

reminds me of my dog but anyway bring

264
00:08:58,630 --> 00:08:57,040
materials into the into the vehicle and

265
00:09:00,710 --> 00:08:58,640
inside the vehicle here at goddard we've

266
00:09:02,790 --> 00:09:00,720
built something called sam and everyone

267
00:09:03,910 --> 00:09:02,800
asked me why paul named it sam could

268
00:09:05,910 --> 00:09:03,920
have been sue

269
00:09:07,750 --> 00:09:05,920
could have been jim but sam is the

270
00:09:09,430 --> 00:09:07,760
service analysis of mars package that

271
00:09:10,550 --> 00:09:09,440
will allow us to measure

272
00:09:11,750 --> 00:09:10,560
chemically

273
00:09:13,430 --> 00:09:11,760
whether there are the biological

274
00:09:15,030 --> 00:09:13,440
building locks of life we can actually

275
00:09:17,269 --> 00:09:15,040
measure the carbon hydrogen oxygen

276
00:09:19,430 --> 00:09:17,279
nitrogen phosphorus and sulfur in soils

277
00:09:20,710 --> 00:09:19,440
and in the air at levels that are better

278
00:09:23,110 --> 00:09:20,720
than those we could measure in labs when

279
00:09:25,590 --> 00:09:23,120
i was in graduate school and now we have

280
00:09:27,110 --> 00:09:25,600
a robot lab we've developed right here

281
00:09:29,030 --> 00:09:27,120
that does all this stuff you see flying

282
00:09:31,750 --> 00:09:29,040
by this is the x-ray diffraction part of

283
00:09:33,910 --> 00:09:31,760
it that tells how rocks are put together

284
00:09:37,670 --> 00:09:33,920
this vehicle will launch next november

285
00:09:39,269 --> 00:09:37,680
it weighs about 700 kilograms 1400

286
00:09:41,030 --> 00:09:39,279
pounds we will land it with the most

287
00:09:42,710 --> 00:09:41,040
powerful system and the imaging system

288
00:09:45,990 --> 00:09:42,720

at the top i'll just point to it up

289
00:09:48,470 --> 00:09:46,000
there is inspired by james cameron 3d