1
00:00:04,430 --> 00:00:02,240
so I show you all this stuff about Venus

2
00:00:06,530 --> 00:00:04,440
because it's really really an important

3
00:00:08,930 --> 00:00:06,540
end member for how big rocky planets

4
00:00:10,910 --> 00:00:08,940
work and some scientists at one point

5
00:00:12,620 --> 00:00:10,920
thought that all these mountains areas

6
00:00:14,539 --> 00:00:12,630
on Venus were like the mountain ridges

7
00:00:17,510 --> 00:00:14,549
of the ocean floor and Venus is ripping

8
00:00:20,269 --> 00:00:17,520
itself apart and exuding energy through

9
00:00:22,010 --> 00:00:20,279
these caz madhai these canyons or chasms

10
00:00:24,259 --> 00:00:22,020
the way the mid-ocean ridges do on earth

11
00:00:25,820 --> 00:00:24,269
now maybe some of you thought about

12
00:00:27,890 --> 00:00:25,830
mid-ocean ridges I think it's important

13
00:00:29,960 --> 00:00:27,900

to say that our planet regulates its

14
00:00:32,060 --> 00:00:29,970
internal heat balance by a system of

15
00:00:34,700 --> 00:00:32,070
forty-five thousand kilometers of

16
00:00:36,500 --> 00:00:34,710
mid-ocean ridges which come on land in

17
00:00:38,299 --> 00:00:36,510
Iceland a little bit in Africa and we

18
00:00:40,130 --> 00:00:38,309
see the hotspot traces of them in Hawaii

19
00:00:42,080 --> 00:00:40,140
in other places we did not have that

20
00:00:44,330 --> 00:00:42,090
system our planet would be a lot hotter

21
00:00:45,740 --> 00:00:44,340
the crust would have to conduct more of

22
00:00:48,139 --> 00:00:45,750
the energy of this big hot interior

23
00:00:50,420 --> 00:00:48,149
that's not good would not be as good a

24
00:00:51,650 --> 00:00:50,430
place to live well here we have an area

25
00:00:53,270 --> 00:00:51,660
the United States would fit right here

26
00:00:55,400 --> 00:00:53,280
here we have an area called of the regio

27
00:00:57,560 --> 00:00:55,410
part of aphrodite on venus connected by

28
00:00:59,779 --> 00:00:57,570
all these deep deep canyon systems

29
00:01:01,729 --> 00:00:59,789
perhaps like mid-ocean ridges or I'm

30
00:01:03,799 --> 00:01:01,739
sorry mid-ocean trenches but again we

31
00:01:05,929 --> 00:01:03,809
don't know because the scales we see are

32
00:01:07,570 --> 00:01:05,939
inadequate to resolve that there are

33
00:01:10,039 --> 00:01:07,580
measurements of the Venus atmosphere

34
00:01:12,380 --> 00:01:10,049
measuring the isotopes of hydrogen that

35
00:01:13,460 --> 00:01:12,390
suggest Venus once had global oceans

36
00:01:17,120 --> 00:01:13,470
that would have filled all these low

37
00:01:19,670 --> 00:01:17,130
blue areas oceans of water that's a

38
00:01:22,160 --> 00:01:19,680

possibility if it did Venus may have

39
00:01:24,050 --> 00:01:22,170
been a habitable planet in fact early in

40
00:01:25,820 --> 00:01:24,060
the history of our Sun some scientists

41
00:01:27,770 --> 00:01:25,830
think the Sun was less luminous a little

42
00:01:30,140 --> 00:01:27,780
less hot it's sort of flairs for a while

43
00:01:32,749 --> 00:01:30,150
cools down and then it well eventually

44
00:01:34,789 --> 00:01:32,759
guys that Venus would have been right in

45
00:01:36,679 --> 00:01:34,799
the habitable zone imagine that two big

46
00:01:39,200 --> 00:01:36,689
rocky planets with oceans in the

47
00:01:41,149 --> 00:01:39,210
habitable zone one went one way the

48
00:01:42,260 --> 00:01:41,159
other one the other so as we look at the

49
00:01:45,350 --> 00:01:42,270
Venus atmosphere in the Earth's

50
00:01:48,109 --> 00:01:45,360
atmosphere we're reminded that there's a

51
00:01:50,660 --> 00:01:48,119
lot of the story at scales that we saw

52
00:01:53,060 --> 00:01:50,670
that we people need to get our grips on

53
00:01:55,460 --> 00:01:53,070
so this is an artist rendering as we

54
00:01:57,230 --> 00:01:55,470
don't have any data of what the hilly

55
00:01:58,520 --> 00:01:57,240
Ridge Plains of Venus these areas we

56
00:02:00,319 --> 00:01:58,530
called tesslar might look like there's

57
00:02:02,359 --> 00:02:00,329
even new data suggests Venus may be

58
00:02:04,249 --> 00:02:02,369
erupting today like the volcanoes on

59
00:02:06,469 --> 00:02:04,259
Earth like the ones that I effectively

60
00:02:09,260 --> 00:02:06,479
opened in Iceland or other places this

61
00:02:11,029 --> 00:02:09,270
is a possibility again without without

62
00:02:12,320 --> 00:02:11,039
robotic remote sensing understanding

63
00:02:13,460 --> 00:02:12,330

what these weird landscapes here's a

64
00:02:15,940 --> 00:02:13,470
giant impact crater

65
00:02:17,990 --> 00:02:15,950
on Venus this is the spiderweb terrain

66
00:02:20,630 --> 00:02:18,000
understanding all this stuff is hard I

67
00:02:22,520 --> 00:02:20,640
mean if I showed you those maps and

68
00:02:24,200 --> 00:02:22,530
pictures made by Landers that look like

69
00:02:26,840 --> 00:02:24,210
this you can recognize the Russian

70
00:02:28,490 --> 00:02:26,850
writing on the those Landers you'd

71
00:02:31,160 --> 00:02:28,500
wonder in fact the longest surface

72
00:02:32,540 --> 00:02:31,170
operation on the planet Venus in the

73
00:02:36,290 --> 00:02:32,550
history of humans that made this image

74
00:02:38,060 --> 00:02:36,300
was for roughly two hours so imagine

75
00:02:40,070 --> 00:02:38,070
having to do all your work whatever

76
00:02:42,500 --> 00:02:40,080
you're doing in two hours it's kind of

77
00:02:45,040 --> 00:02:42,510
like a sprint here you see the lander

78
00:02:48,380 --> 00:02:45,050
view from the Soviet missions in 1982

79
00:02:50,930 --> 00:02:48,390
CCCP USSR lens cap of course it fell off

80
00:02:53,690 --> 00:02:50,940
good thing and the view from the other

81
00:02:56,270 --> 00:02:53,700
one so this is our complete data set

82
00:02:58,160 --> 00:02:56,280
you've just seen it in ten seconds of

83
00:03:00,380 --> 00:02:58,170
the surface imaging of the planet Venus

84
00:03:02,240 --> 00:03:00,390
in contrast for Mars we have a terabit

85
00:03:04,850 --> 00:03:02,250
of images from the Rovers and other

86
00:03:07,820 --> 00:03:04,860
things so let me stop for a minute just

87
00:03:09,590 --> 00:03:07,830
put in perspective biggest other planet

88
00:03:12,080 --> 00:03:09,600

in our solar system that's rocky Venus

89
00:03:15,070 --> 00:03:12,090
Jupiter is a gas giant of course Saturn

90
00:03:17,449 --> 00:03:15,080
and others we know less than we did in

91
00:03:20,600 --> 00:03:17,459
perspective about Venus than we did

92
00:03:23,420 --> 00:03:20,610
about the earth probably in the 1940s so

93
00:03:25,310 --> 00:03:23,430
in the Space Age of the last 51 years we

94
00:03:27,800 --> 00:03:25,320
haven't filled in the textbooks on Venus

95
00:03:29,210 --> 00:03:27,810
who knows what it might tell us about

96
00:03:31,340 --> 00:03:29,220
how our own climate system works so

97
00:03:32,960 --> 00:03:31,350
here's earth large climate system

98
00:03:35,180 --> 00:03:32,970
recording in the atmosphere this is from

99
00:03:36,710 --> 00:03:35,190
a shuttle flight and you can see our

100
00:03:38,900 --> 00:03:36,720
moan now one of the things interesting

101
00:03:42,050 --> 00:03:38,910
about the earth is we have a very large

102
00:03:44,330 --> 00:03:42,060
natural satellite now a generation ago

103
00:03:46,820 --> 00:03:44,340
when I was younger than you guys we

104
00:03:48,320 --> 00:03:46,830
actually sent multiple human voyages to

105
00:03:52,310 --> 00:03:48,330
the moon and you might say why didn't we

106
00:03:54,110 --> 00:03:52,320
do that it was brash brave bold we went

107
00:03:56,390 --> 00:03:54,120
to the moon because in fact it was

108
00:03:58,490 --> 00:03:56,400
better for us developed the systems for

109
00:04:00,380 --> 00:03:58,500
people to go fly to the moon in command

110
00:04:03,650 --> 00:04:00,390
service modules with capsules then

111
00:04:05,300 --> 00:04:03,660
robotically we actually those Bay's did

112
00:04:06,920 --> 00:04:05,310
not have the robotic capabilities to do

113
00:04:09,440 --> 00:04:06,930

what we do today you guys have grown up

114
00:04:11,570 --> 00:04:09,450
in a generation of robotic IT

115
00:04:13,280 --> 00:04:11,580
infrastructure when we went to the moon

116
00:04:16,010 --> 00:04:13,290
and saw landscapes like this from the

117
00:04:17,780 --> 00:04:16,020
field of view you can see flying over we

118
00:04:19,370 --> 00:04:17,790
went with human eyes the first time in

119
00:04:21,260 --> 00:04:19,380
December 1968

120
00:04:23,300 --> 00:04:21,270
so the Apollo program took us to the

121
00:04:25,520 --> 00:04:23,310
moon and you might say well you know

122
00:04:27,020 --> 00:04:25,530
what did that do for me well aside from

123
00:04:29,900 --> 00:04:27,030
tangy and Teflon

124
00:04:32,060 --> 00:04:29,910
what it did do for the United States was

125
00:04:34,700 --> 00:04:32,070
develop not only precision navigation

126
00:04:36,290 --> 00:04:34,710
which we use now been mapped into GPS

127
00:04:38,150 --> 00:04:36,300
but it also developed the first

128
00:04:39,170 --> 00:04:38,160
large-scale integrated circuits which we

129
00:04:42,170 --> 00:04:39,180
needed to go to the moon

130
00:04:44,990 --> 00:04:42,180
here you see Buzz Aldrin coming off the

131
00:04:46,040 --> 00:04:45,000
the the lander on the first visit to the

132
00:04:48,260 --> 00:04:46,050
moon on Apollo 11

133
00:04:50,270 --> 00:04:48,270
we of course erected aluminum guy-wire

134
00:04:52,040 --> 00:04:50,280
flags it was a big engineering challenge

135
00:04:54,200 --> 00:04:52,050
to do that by the way we developed the

136
00:04:57,440 --> 00:04:54,210
highest land speed cars on another

137
00:04:58,640 --> 00:04:57,450
surface the lunar roving vehicle and we

138
00:05:00,880 --> 00:04:58,650

went to the moon and brought back a

139
00:05:03,980 --> 00:05:00,890
legacy of a history of another world in

140
00:05:05,630 --> 00:05:03,990
890 pounds of rocks we actually set

141
00:05:08,000 --> 00:05:05,640
amazing speed records with these things

142
00:05:09,500 --> 00:05:08,010
they drove we left our name tags on

143
00:05:12,230 --> 00:05:09,510
there there's John Youngs Apollo 16

144
00:05:13,910 --> 00:05:12,240
mission this is the legacy of human

145
00:05:15,800 --> 00:05:13,920
exploration in the first decade of NASA

146
00:05:17,750 --> 00:05:15,810
we not only built weather satellites

147
00:05:19,640 --> 00:05:17,760
started missions to explore the outer

148
00:05:21,530 --> 00:05:19,650
solar system but we sent people to

149
00:05:23,870 --> 00:05:21,540
another planet now how many of you

150
00:05:26,780 --> 00:05:23,880
realize the last time any women or men

151
00:05:29,150 --> 00:05:26,790
ever left the protective magneto sheath

152
00:05:31,430 --> 00:05:29,160
of our planet was 1972 when these

153
00:05:35,360 --> 00:05:31,440
missions now let me stop here this is a

154
00:05:36,770 --> 00:05:35,370
famous picture in November of 1969 the

155
00:05:39,440 --> 00:05:36,780
second of the Apollo service missions

156
00:05:42,800 --> 00:05:39,450
Apollo 12 commander Alan bean went and

157
00:05:44,900 --> 00:05:42,810
sampled the lens of a robot we had sent

158
00:05:47,240 --> 00:05:44,910
to the moon three years before you might

159
00:05:49,400 --> 00:05:47,250
say okay sounds pretty cool he actually

160
00:05:52,130 --> 00:05:49,410
landed about 180 meters from with his

161
00:05:55,159 --> 00:05:52,140
Lander craft the lamb as it was called

162
00:05:58,220 --> 00:05:55,169
180 meters from that across a distance

163
00:06:00,470 --> 00:05:58,230

in space of 400,000 kilometers now do a

164
00:06:03,350 --> 00:06:00,480
little math pretty good navigation to go

165
00:06:06,470 --> 00:06:03,360
that far in deep space and land that far

166
00:06:08,690 --> 00:06:06,480
we were then in a missile race hmm apply

167
00:06:11,540 --> 00:06:08,700
that to the missile race of the late 60s

168
00:06:13,040 --> 00:06:11,550
I think you can all do the math this was

169
00:06:14,960 --> 00:06:13,050
one of the greatest technology feats in

170
00:06:16,790 --> 00:06:14,970
the history of the 20th century

171
00:06:18,650 --> 00:06:16,800
precision navigation on another planet

172
00:06:20,480 --> 00:06:18,660
across the abyss of deep space we

173
00:06:22,820 --> 00:06:20,490
actually discovered that the lens of

174
00:06:25,760 --> 00:06:22,830
that vehicle had been contaminated with

175
00:06:28,220 --> 00:06:25,770
a type of bacteria that survived three

176
00:06:30,710 --> 00:06:28,230
years in deep space no air water deep

177
00:06:32,409 --> 00:06:30,720
space radiation solar flares came back

178
00:06:35,810 --> 00:06:32,419
put in the petri dish culture that grew

179
00:06:37,190 --> 00:06:35,820
so life is tenacious and we worry about

180
00:06:40,040 --> 00:06:37,200
that as we explore planets where we're

181
00:06:40,820 --> 00:06:40,050
asking are they alive what if we bring

182
00:06:42,620 --> 00:06:40,830
ourselves to

183
00:06:44,150 --> 00:06:42,630
those planets and then we discovered

184
00:06:46,190 --> 00:06:44,160
that we're there okay that's a great

185
00:06:48,910 --> 00:06:46,200
result so as we think about astrobiology

186
00:06:51,560 --> 00:06:48,920
where life works even on the moon

187
00:06:53,690 --> 00:06:51,570
a-absolutely airless world throughout

188
00:06:55,940 --> 00:06:53,700

his history we brought life there not

189
00:06:58,130 --> 00:06:55,950
only us in commander bean but in others

190
00:07:00,140 --> 00:06:58,140
so this was a major thing this is my

191
00:07:02,170 --> 00:07:00,150
favorite picture of the moon this is six

192
00:07:04,520 --> 00:07:02,180
kilometers looking back at the the

193
00:07:06,430 --> 00:07:04,530
spacecraft that carried Apollo 17 to the

194
00:07:08,690 --> 00:07:06,440
moon across the hills of taurus-littrow

195
00:07:09,590 --> 00:07:08,700
that was the walk back distance if all

196
00:07:13,010 --> 00:07:09,600
had gone bad

197
00:07:13,580 --> 00:07:13,020
the guys had to walk back that far to

198
00:07:15,320 --> 00:07:13,590
get home

199
00:07:16,850 --> 00:07:15,330
of course we drove around we sampled

200
00:07:18,800 --> 00:07:16,860
rocks we did a lot of geology I'm a

201
00:07:20,300 --> 00:07:18,810
geologist this is really significant to

202
00:07:21,740 --> 00:07:20,310
me one thing we learned about the moon

203
00:07:25,040 --> 00:07:21,750
it's old

204
00:07:27,380 --> 00:07:25,050
the first rocks told us famous picture

205
00:07:29,060 --> 00:07:27,390
that when we look at the moon we're

206
00:07:32,090 --> 00:07:29,070
looking at a surface that's frozen in

207
00:07:33,860 --> 00:07:32,100
time it's a fossil planet everything you

208
00:07:35,900 --> 00:07:33,870
see including the seismic network we

209
00:07:39,710 --> 00:07:35,910
stood up is recording a history of

210
00:07:41,000 --> 00:07:39,720
something like 3.7 3.8 billion years how

211
00:07:44,330 --> 00:07:41,010
many rocks have any of you seen that are

212
00:07:45,620 --> 00:07:44,340
that all none the first billion years of

213
00:07:48,320 --> 00:07:45,630

Earth history has been wiped

214
00:07:50,270 --> 00:07:48,330
so the Attic of the earth is recorded in

215
00:07:51,860 --> 00:07:50,280
the story on the moon and that told us a

216
00:07:53,480 --> 00:07:51,870
lot about ourselves here's the famous

217
00:07:55,640 --> 00:07:53,490
picture as we left the moon for the last

218
00:07:57,650 --> 00:07:55,650
time coming home to the earth so that's

219
00:07:58,150 --> 00:07:57,660
the last time people have gone into deep

220
00:08:00,530 --> 00:07:58,160
space

221
00:08:02,000 --> 00:08:00,540
that's a bold thing now this is what it

222
00:08:03,290 --> 00:08:02,010
looked like landing of course you've all

223
00:08:05,840 --> 00:08:03,300
heard the story of what Neil Armstrong

224
00:08:08,240 --> 00:08:05,850
had to do to free fly his vehicle I'd

225
00:08:10,100 --> 00:08:08,250
love to show the drive the land speed

226
00:08:13,040 --> 00:08:10,110
record here was about 16 kilometers an

227
00:08:15,260 --> 00:08:13,050
hour just for scale the the Mars

228
00:08:17,720 --> 00:08:15,270
exploration Rovers move about a 50th of

229
00:08:19,940 --> 00:08:17,730
that in their speed so these guys were

230
00:08:21,230 --> 00:08:19,950
trucking they actually had to build new

231
00:08:23,450 --> 00:08:21,240
hubcaps a couple of times because they

232
00:08:25,760 --> 00:08:23,460
went a little fast but again it was

233
00:08:27,260 --> 00:08:25,770
really a great way to explore in their

234
00:08:29,090 --> 00:08:27,270
trips and you see how rocky and bumpy it

235
00:08:31,970 --> 00:08:29,100
was going along the moon they actually

236
00:08:34,040 --> 00:08:31,980
covered on one mission and Apollo 17 27

237
00:08:37,730 --> 00:08:34,050
kilometers you know stopped here from it

238
00:08:41,150 --> 00:08:37,740

27 kilometres in one seven-hour extra

239
00:08:42,500 --> 00:08:41,160
vehicular activity event have we gone 27

240
00:08:46,100 --> 00:08:42,510
kilometers on Mars with the Mars

241
00:08:48,800 --> 00:08:46,110
exploration Rovers yet no and we've been

242
00:08:50,870 --> 00:08:48,810
driving for five and a half years so one

243
00:08:52,790 --> 00:08:50,880
day 27 kilometers out back collect the

244
00:08:54,290 --> 00:08:52,800
rocks come back we people like to

245
00:08:57,949 --> 00:08:54,300
explore fast

246
00:09:00,350 --> 00:08:57,959
in tough places this is the now why me

247
00:09:01,820 --> 00:09:00,360
generation that's important when you

248
00:09:03,949 --> 00:09:01,830
move things to the robotic time space

249
00:09:06,019 --> 00:09:03,959
you can freeze time you can move more

250
00:09:07,910 --> 00:09:06,029
slowly and so one of the things we do in

251
00:09:09,800 --> 00:09:07,920
exploring planets and the deep sea floor

252
00:09:11,000 --> 00:09:09,810
is we change the time scale so if it

253
00:09:13,250 --> 00:09:11,010
takes a week for a rover to go a hundred

254
00:09:15,560 --> 00:09:13,260
yards well too bad