1
00:00:07,249 --> 00:00:03,050
NASA's Jet Propulsion Laboratory

2
00:00:09,680 --> 00:00:07,259
presents the von Karman lecture a series

3
00:00:12,049 --> 00:00:09,690
of talks by scientists and engineers who

4
00:00:14,720 --> 00:00:12,059
are exploring our planet our solar

5
00:00:30,990 --> 00:00:14,730
system and all that lies beyond

6
00:00:34,830 --> 00:00:33,690
well hello and welcome to NASA's Jet

7
00:00:37,260 --> 00:00:34,840
Propulsion Laboratory in Pasadena

8
00:00:39,810 --> 00:00:37,270
California on a very hot afternoon here

9
00:00:41,369 --> 00:00:39,820
in Pasadena for our monthly public

10
00:00:45,240 --> 00:00:41,379
lecture series called the von Karman

11
00:00:47,939 --> 00:00:45,250
series I'm Preston dykes well 50 years

12
00:00:49,920 --> 00:00:47,949
ago three human beings set out on a

13
00:00:52,619 --> 00:00:49,930

journey across a quarter of a million

14
00:00:54,780 --> 00:00:52,629
miles of space to the moon two of them

15
00:00:56,819 --> 00:00:54,790
set down in a fragile landing craft on

16
00:00:58,229 --> 00:00:56,829
the lunar surface and one of them

17
00:00:59,910 --> 00:00:58,239
stepped into history

18
00:01:02,850 --> 00:00:59,920
uttering a phrase that we all know by

19
00:01:04,619 --> 00:01:02,860
heart but for that one human being to

20
00:01:06,840 --> 00:01:04,629
make that one small step took the

21
00:01:08,789 --> 00:01:06,850
focused efforts of hundreds of thousands

22
00:01:11,550 --> 00:01:08,799
of people over the course of a decade in

23
00:01:14,250 --> 00:01:11,560
industry in universities and in

24
00:01:16,620 --> 00:01:14,260
government for their part JPL and

25
00:01:18,929 --> 00:01:16,630
Caltech which manages JPL for NASA

26
00:01:21,749 --> 00:01:18,939
didn't play the leading roles in the

27
00:01:24,990 --> 00:01:21,759
Apollo effort but for all who

28
00:01:26,789 --> 00:01:25,000
contributed to Apollo as for all of us

29
00:01:30,330 --> 00:01:26,799
who play even a small role in the space

30
00:01:31,980 --> 00:01:30,340
program today the true reward lay not in

31
00:01:33,330 --> 00:01:31,990
the glory of the moment but in

32
00:01:37,590 --> 00:01:33,340
contributing to something greater

33
00:01:40,440 --> 00:01:37,600
something that mattered JPL's primary

34
00:01:42,450 --> 00:01:40,450
role then and now is to help lead the

35
00:01:44,760 --> 00:01:42,460
robotic exploration of the solar system

36
00:01:46,410 --> 00:01:44,770
and that included developing guidance

37
00:01:48,380 --> 00:01:46,420
navigation and communication

38
00:01:50,969 --> 00:01:48,390

technologies that contributed to Apollo

39
00:01:53,190 --> 00:01:50,979
JPL also manages NASA's Deep Space

40
00:01:55,590 --> 00:01:53,200
Network used for communicating with all

41
00:01:57,570 --> 00:01:55,600
spacecraft that fly beyond the moon but

42
00:01:59,730 --> 00:01:57,580
during Apollo the Deep Space Network was

43
00:02:01,980 --> 00:01:59,740
used to receive the astronauts TV

44
00:02:04,230 --> 00:02:01,990
transmissions from the moon and it also

45
00:02:06,360 --> 00:02:04,240
was a vital communications backup during

46
00:02:09,419 --> 00:02:06,370
Apollo especially during the tense days

47
00:02:11,070 --> 00:02:09,429
of Apollo 13 Caltech

48
00:02:13,440 --> 00:02:11,080
long a world leader in the field of

49
00:02:15,119 --> 00:02:13,450
geology contributed both to the field

50
00:02:17,430 --> 00:02:15,129
training of the astronauts and as you'll

51
00:02:20,520 --> 00:02:17,440
hear tonight to the study of the samples

52
00:02:23,160 --> 00:02:20,530
they returned tonight we'll hear just

53
00:02:25,110 --> 00:02:23,170
part of the Apollo story the road to

54
00:02:27,210 --> 00:02:25,120
Apollo and how JPL figured into it and

55
00:02:29,280 --> 00:02:27,220
how scientists at Caltech and other

56
00:02:31,559 --> 00:02:29,290
institutions teased out some of the

57
00:02:32,789 --> 00:02:31,569
moon's greatest secrets we'll have two

58
00:02:33,869 --> 00:02:32,799
speakers tonight followed by some

59
00:02:35,759 --> 00:02:33,879
discussion and then we'll take your

60
00:02:37,770 --> 00:02:35,769
questions if you're watching our live

61
00:02:40,470 --> 00:02:37,780
webcast you can submit questions via the

62
00:02:44,440 --> 00:02:40,480
YouTube chat all right now for our first

63
00:02:46,199 --> 00:02:44,450

speaker JPL is fortunate to have an Emmy

64
00:02:49,210 --> 00:02:46,209
award-winning producer on its staff

65
00:02:52,300 --> 00:02:49,220
blame Baggett's first space production

66
00:02:54,160 --> 00:02:52,310
for PBS back in 1985 with spaceflight

67
00:02:56,890 --> 00:02:54,170
the first nationally broadcast

68
00:02:59,619 --> 00:02:56,900
television series ever made about the

69
00:03:02,589 --> 00:02:59,629
space race one of his key advisors on a

70
00:03:05,490 --> 00:03:02,599
was Apollo 11 astronaut Michael Collins

71
00:03:08,080 --> 00:03:05,500
who called Space Flight the real stuff

72
00:03:09,640 --> 00:03:08,090
Blane next turned to astronomy he was

73
00:03:12,420 --> 00:03:09,650
the executive producer of the

74
00:03:15,430 --> 00:03:12,430
astronomers also produced for PBS in

75
00:03:17,710 --> 00:03:15,440
1999 he joined JPL and is now a JPL

76
00:03:20,320 --> 00:03:17,720
fellow working full time on films about

77
00:03:22,960 --> 00:03:20,330
JPL historic role in the exploration of

78
00:03:24,490 --> 00:03:22,970
space among his many honors Blaine is

79
00:03:26,770 --> 00:03:24,500
the recipient of the highest honor NASA

80
00:03:29,440 --> 00:03:26,780
bestows on a civilian the Distinguished

81
00:03:32,050 --> 00:03:29,450
Service Medal and finally if all of that

82
00:03:35,770 --> 00:03:32,060
wasn't enough Blaine's birthday just

83
00:03:37,990 --> 00:03:35,780
happens to be July 20th which is the

84
00:03:40,270 --> 00:03:38,000
very day that Apollo 11 made the first

85
00:03:40,870 --> 00:03:40,280
human landing on the moon so please

86
00:03:48,220 --> 00:03:40,880
welcome

87
00:03:48,789 --> 00:03:48,230
Blaine Baggett thank you and good

88
00:03:51,220 --> 00:03:48,799

evening

89
00:03:53,229 --> 00:03:51,230
Wow it's fantastic to see you all here

90
00:03:55,809 --> 00:03:53,239
thank you so much for coming out I'm

91
00:03:58,990 --> 00:03:55,819
just delighted to see so many of you and

92
00:04:01,059 --> 00:03:59,000
by the way my also I served my birthday

93
00:04:05,410 --> 00:04:01,069
it also serves as the day that we first

94
00:04:13,990 --> 00:04:05,420
landed on Mars with Viking so something

95
00:04:17,050 --> 00:04:14,000
was meant to be I think okay maybe I

96
00:04:20,529 --> 00:04:17,060
better stop her on the head the more

97
00:04:23,260 --> 00:04:20,539
that I have come to understand the moons

98
00:04:25,450 --> 00:04:23,270
of the solar system the more I

99
00:04:28,390 --> 00:04:25,460
appreciate them for their incredible

100
00:04:31,420 --> 00:04:28,400
diversity I would start with in the

101
00:04:35,800 --> 00:04:31,430
outer solar system at the with these

102
00:04:41,589 --> 00:04:35,810
moons Hyperion looks to me like a

103
00:04:45,430 --> 00:04:41,599
seashell pan looks to me like a UFO and

104
00:04:48,520 --> 00:04:45,440
if we have any star war fans out there

105
00:04:51,400 --> 00:04:48,530
oh I don't have to make the reference

106
00:04:53,469 --> 00:04:51,410
but there's the darks Dark Star but

107
00:04:56,860 --> 00:04:53,479
there's more to the moons than just

108
00:04:58,330 --> 00:04:56,870
unusual shapes moons in our solar system

109
00:05:01,600 --> 00:04:58,340
are now the prime

110
00:05:04,540 --> 00:05:01,610
targets for the search for life Saturn's

111
00:05:07,290 --> 00:05:04,550
moon Enceladus is a beautiful icy world

112
00:05:10,930 --> 00:05:07,300
where geysers are constantly erupting

113
00:05:14,620 --> 00:05:10,940

spring out into space water ice Titan

114
00:05:17,590 --> 00:05:14,630
which also orbits Saturn has rivers and

115
00:05:21,159 --> 00:05:17,600
lakes but they're made of liquid ethane

116
00:05:23,830 --> 00:05:21,169
and methane and NASA's just announced an

117
00:05:26,560 --> 00:05:23,840
exciting mission called dragonfly that's

118
00:05:30,159 --> 00:05:26,570
going to explore Titan and on the right

119
00:05:33,730 --> 00:05:30,169
is Jupiter's moon Europa beneath it's

120
00:05:37,480 --> 00:05:33,740
icy crust is a Waterworld thought to

121
00:05:41,770 --> 00:05:37,490
contain more h2o than in all the oceans

122
00:05:43,629 --> 00:05:41,780
on earth combined and here at JPL we're

123
00:05:46,390 --> 00:05:43,639
hard at work on a mission right now

124
00:05:47,400 --> 00:05:46,400
called Europa clipper to be launched to

125
00:05:52,210 --> 00:05:47,410
this world

126
00:05:54,930 --> 00:05:52,220
now these moons and many others there

127
00:05:58,390 --> 00:05:54,940
are almost 200 moons in the solar system

128
00:06:00,879 --> 00:05:58,400
those moons and many others exist in the

129
00:06:02,980 --> 00:06:00,889
outer solar system if we move inward

130
00:06:03,370 --> 00:06:02,990
towards the Sun we find a different

131
00:06:06,879 --> 00:06:03,380
story

132
00:06:09,129 --> 00:06:06,889
Mars has two very small moons Venus and

133
00:06:14,770 --> 00:06:09,139
Mercury have none only the earth has a

134
00:06:17,680 --> 00:06:14,780
sizable moon and a beautiful moon why

135
00:06:20,920 --> 00:06:17,690
that is that we really have the

136
00:06:23,140 --> 00:06:20,930
terrestrial planets we were all all we

137
00:06:25,750 --> 00:06:23,150
have one large moon is a great mystery

138
00:06:27,640 --> 00:06:25,760

but I will leave the science of the moon

139
00:06:30,370 --> 00:06:27,650
and the engineering it took to get us

140
00:06:32,260 --> 00:06:30,380
there to two great pioneers who are with

141
00:06:34,150 --> 00:06:32,270
us tonight that I it's a great honor and

142
00:06:38,560 --> 00:06:34,160
privilege for me to share the stage with

143
00:06:41,350 --> 00:06:38,570
them now as for the present we are in

144
00:06:45,040 --> 00:06:41,360
the news not only because of the Apollo

145
00:06:48,129 --> 00:06:45,050
11 anniversary we are in the news about

146
00:06:52,120 --> 00:06:48,139
the moon because nASA has declared we

147
00:06:56,350 --> 00:06:52,130
are going forward to the moon - it's the

148
00:06:59,080 --> 00:06:56,360
next step and on our way to Mars now to

149
00:07:02,050 --> 00:06:59,090
me time will tell whether this is the

150
00:07:05,529 --> 00:07:02,060
latest case of us becoming moonstruck

151
00:07:08,170 --> 00:07:05,539
and whether being moonstruck is going to

152
00:07:10,330 --> 00:07:08,180
actually stick again the biggest

153
00:07:11,800 --> 00:07:10,340
question I think is whether we will have

154
00:07:15,879 --> 00:07:11,810
the will which

155
00:07:17,980 --> 00:07:15,889
translates into the funding to go those

156
00:07:20,379 --> 00:07:17,990
in favor of going to the moon have their

157
00:07:22,720 --> 00:07:20,389
arguments first of all the technologies

158
00:07:25,060 --> 00:07:22,730
have come a long long way in the last 50

159
00:07:27,430 --> 00:07:25,070
years and what we've learned about the

160
00:07:29,370 --> 00:07:27,440
moon in these last 50 years helps to

161
00:07:31,659 --> 00:07:29,380
make the case for going again for

162
00:07:34,780 --> 00:07:31,669
instance once it was thought that the

163
00:07:38,680 --> 00:07:34,790

moon's bone-dry that's turned out not to

164
00:07:41,590 --> 00:07:38,690
be the case missions by NASA and by the

165
00:07:44,710 --> 00:07:41,600
Indian Space Agency have found evidence

166
00:07:47,680 --> 00:07:44,720
of water in the polar regions of the

167
00:07:49,659 --> 00:07:47,690
moon and craters where sunlight in the

168
00:07:52,930 --> 00:07:49,669
shadow of craters where sunlight doesn't

169
00:07:54,850 --> 00:07:52,940
reach these areas our prime real estate

170
00:07:58,560 --> 00:07:54,860
for future exploration and settlement

171
00:08:01,990 --> 00:07:58,570
there you see some examples of the water

172
00:08:04,810 --> 00:08:02,000
because if you wish to live off the land

173
00:08:07,770 --> 00:08:04,820
as nASA says it wants to do with a

174
00:08:11,200 --> 00:08:07,780
permanent presence you need water

175
00:08:15,100 --> 00:08:11,210
by the way India it's scheduled for a

176
00:08:18,279 --> 00:08:15,110
new mission to the moon next week it's a

177
00:08:21,010 --> 00:08:18,289
combination of an orbiter a lander and a

178
00:08:22,690 --> 00:08:21,020
rover and what is its purpose

179
00:08:26,500 --> 00:08:22,700
it's going to go prospecting for

180
00:08:29,140 --> 00:08:26,510
resources including water and then

181
00:08:31,719 --> 00:08:29,150
there's China its program its space

182
00:08:34,990 --> 00:08:31,729
program is growing by leaps and bounds

183
00:08:36,880 --> 00:08:35,000
and China has made no secret of its

184
00:08:40,029 --> 00:08:36,890
interest in exploiting the resources of

185
00:08:42,820 --> 00:08:40,039
the moon a Chinese rover launched in

186
00:08:45,760 --> 00:08:42,830
just January this year is now roving on

187
00:08:48,220 --> 00:08:45,770
the moon and on the far side of the moon

188
00:08:50,530 --> 00:08:48,230

for direct communication isn't possible

189
00:08:54,730 --> 00:08:50,540
it's an impressive technological

190
00:08:57,610 --> 00:08:54,740
achievement and by the way I don't know

191
00:08:59,740 --> 00:08:57,620
if you know where the rover landed on

192
00:09:04,430 --> 00:08:59,750
the far side of the moon but it's in a

193
00:09:07,460 --> 00:09:04,440
crater named after Theodore von Karman

194
00:09:09,769 --> 00:09:07,470
I hope that name sounds familiar

195
00:09:13,280 --> 00:09:09,779
it's none other than the first director

196
00:09:17,389 --> 00:09:13,290
of JPL and for whom this auditorium and

197
00:09:19,610 --> 00:09:17,399
this lecture series is named after and I

198
00:09:21,800 --> 00:09:19,620
can't help but wonder whether the

199
00:09:26,329 --> 00:09:21,810
selection of a crater named after von

200
00:09:28,670 --> 00:09:26,339
Karman is somehow intentional in terms

201
00:09:32,679 --> 00:09:28,680
of where the Chinese landed but I'm not

202
00:09:38,240 --> 00:09:35,269
the larger point I'm trying to make is

203
00:09:41,360 --> 00:09:38,250
that we may be at the beginning of a new

204
00:09:44,780 --> 00:09:41,370
space race a space race this time that

205
00:09:46,730 --> 00:09:44,790
is a multinational one a moon rush where

206
00:09:50,889 --> 00:09:46,740
the prize is to stake out regions

207
00:09:55,309 --> 00:09:50,899
suitable for establishing human presence

208
00:09:58,189 --> 00:09:55,319
so speaking of space races let's now go

209
00:10:01,670 --> 00:09:58,199
back to the first one to understand how

210
00:10:04,249 --> 00:10:01,680
Apollo came to be that means we have to

211
00:10:06,650 --> 00:10:04,259
go back to 1957 and the launch of

212
00:10:08,300 --> 00:10:06,660
Sputnik and to help us we're going to

213
00:10:10,069 --> 00:10:08,310

watch a video clip from one of my

214
00:10:13,009 --> 00:10:10,079
documentaries called destination moon

215
00:10:16,300 --> 00:10:13,019
which I had butchered myself to cut it

216
00:10:18,559 --> 00:10:16,310
down in order to show it in a short clip

217
00:10:22,550 --> 00:10:18,569
hard to do but better for me to do it

218
00:10:30,679 --> 00:10:22,560
than anyone else so if we could Jon can

219
00:10:34,009 --> 00:10:30,689
we roll the first clip Thanks in October

220
00:10:35,840 --> 00:10:34,019
of 1957 the Soviet Union shocked the

221
00:10:40,100 --> 00:10:35,850
world with the launch of the first Earth

222
00:10:43,460 --> 00:10:40,110
orbiting satellite Sputnik America's

223
00:10:54,110 --> 00:10:43,470
response a satellite called Vanguard was

224
00:10:58,850 --> 00:10:56,450
Vanguard would the only one in a long

225
00:11:03,079 --> 00:10:58,860
string of setbacks for the United States

226
00:11:06,019 --> 00:11:03,089
space program on a visit to the u.s. in

227
00:11:08,960 --> 00:11:06,029
1959 Soviet premier Nikita Khrushchev

228
00:11:16,070 --> 00:11:08,970
made sure to underscore the disparity

229
00:11:18,079 --> 00:11:16,080
between the two nations a scientific

230
00:11:26,660 --> 00:11:18,089
feat heavily capitalized on by red

231
00:11:28,670 --> 00:11:26,670
propaganda America's hopes for competing

232
00:11:31,010 --> 00:11:28,680
in the race for the heavens rested with

233
00:11:32,570 --> 00:11:31,020
its newly formed space agency the

234
00:11:36,920 --> 00:11:32,580
National Aeronautics and Space

235
00:11:38,600 --> 00:11:36,930
Administration NASA was given an

236
00:11:40,910 --> 00:11:38,610
assortment of technical facilities

237
00:11:42,980 --> 00:11:40,920
scattered across the country one of them

238
00:11:46,760 --> 00:11:42,990

was the Jet Propulsion Laboratory in

239
00:11:50,570 --> 00:11:46,770
Pasadena California of all the groups

240
00:11:52,660 --> 00:11:50,580
NASA inherited JPL was a part this

241
00:11:55,400 --> 00:11:52,670
research center was then like today

242
00:11:57,380 --> 00:11:55,410
managed and staffed by employees of one

243
00:12:00,920 --> 00:11:57,390
of the world's most renowned engineering

244
00:12:03,100 --> 00:12:00,930
universities the California Institute of

245
00:12:10,220 --> 00:12:05,720
JPL errs were accustomed to a tradition

246
00:12:13,910 --> 00:12:10,230
of independence from JPL's perspective

247
00:12:17,570 --> 00:12:13,920
NASA was a newcomer with no portfolio in

248
00:12:20,449 --> 00:12:17,580
contrast JPL had built missiles and the

249
00:12:26,480 --> 00:12:20,459
first successful u.s. satellite Explorer

250
00:12:28,760 --> 00:12:26,490
1 JPL was led by William Pickering when

251
00:12:31,220 --> 00:12:28,770
NASA asked Pickering his ideas for the

252
00:12:33,230 --> 00:12:31,230
nation's robotic space program he

253
00:12:35,390 --> 00:12:33,240
responded with an ambitious plan that

254
00:12:38,000 --> 00:12:35,400
called for JPL flying an armada of

255
00:12:39,050 --> 00:12:38,010
spacecraft to the moon and nearby

256
00:12:42,190 --> 00:12:39,060
planets

257
00:12:44,120 --> 00:12:42,200
[Music]

258
00:12:47,690 --> 00:12:44,130
Sputnik has been called America's

259
00:12:49,930 --> 00:12:47,700
technological pearl harbor it was a

260
00:12:52,310 --> 00:12:49,940
shock to the American psyche and the

261
00:12:54,530 --> 00:12:52,320
reactions ranged from the reasonable

262
00:12:56,600 --> 00:12:54,540
like placing greater emphasis on science

263
00:13:02,060 --> 00:12:56,610

and math in the classrooms for which I

264
00:13:04,250 --> 00:13:02,070
suffered to the extreme the ideal of

265
00:13:06,889 --> 00:13:04,260
setting off a nuclear bomb on the moon

266
00:13:10,250 --> 00:13:06,899
to demonstrate America's technological

267
00:13:11,810 --> 00:13:10,260
capability a number of well positioned

268
00:13:14,960 --> 00:13:11,820
people in the United States toyed with

269
00:13:17,000 --> 00:13:14,970
this idea they included the scientist

270
00:13:19,430 --> 00:13:17,010
Edward Teller known as the father of the

271
00:13:22,160 --> 00:13:19,440
hydrogen bomb and JPL's director at the

272
00:13:26,050 --> 00:13:22,170
time William Pickering now what you see

273
00:13:28,400 --> 00:13:26,060
here is an Air Force report because they

274
00:13:30,769 --> 00:13:28,410
explored this ideal to great depth

275
00:13:34,460 --> 00:13:30,779
creating this report that went on for

276
00:13:36,530 --> 00:13:34,470
about 250 pages one aspect of the report

277
00:13:38,900 --> 00:13:36,540
was to consider what sites might be

278
00:13:40,490 --> 00:13:38,910
derived from measuring the lunar debris

279
00:13:44,389 --> 00:13:40,500
that would be scattered by a nuclear

280
00:13:46,610 --> 00:13:44,399
explosion one of the research credited

281
00:13:50,180 --> 00:13:46,620
researchers on the project was a college

282
00:13:53,269 --> 00:13:50,190
student by the name of C E Sagan that's

283
00:13:55,639 --> 00:13:53,279
right that's the late Carl Sagan who

284
00:13:58,670 --> 00:13:55,649
would go on to become one of the world's

285
00:14:04,060 --> 00:13:58,680
best-known scientist and an outspoken

286
00:14:06,949 --> 00:14:04,070
critic the nuclear arms race meanwhile

287
00:14:10,130 --> 00:14:06,959
the Soviet Union continued to surprise

288
00:14:11,960 --> 00:14:10,140

and confound for instance when Nikita

289
00:14:13,460 --> 00:14:11,970
Khrushchev made the first visit of a

290
00:14:13,880 --> 00:14:13,470
Soviet head of state to the United

291
00:14:16,850 --> 00:14:13,890
States

292
00:14:19,370 --> 00:14:16,860
the Soviets timed the trip to coincide

293
00:14:23,240 --> 00:14:19,380
with the first mission to reach the moon

294
00:14:25,790 --> 00:14:23,250
Luna 2 to like just kind of rubbing our

295
00:14:28,910 --> 00:14:25,800
nose in it in just two weeks after that

296
00:14:31,370 --> 00:14:28,920
they launched Luna 3 they took this

297
00:14:33,560 --> 00:14:31,380
image to the far side of the Moon it's

298
00:14:37,030 --> 00:14:33,570
not much by today's standards but at the

299
00:14:40,810 --> 00:14:37,040
time it was a technological triumph an

300
00:14:44,060 --> 00:14:40,820
Eisenhower could only grin and bear it

301
00:14:47,389 --> 00:14:44,070
now ten weeks after John F Kennedy took

302
00:14:51,439 --> 00:14:47,399
office the Soviet Union struck again

303
00:14:54,940 --> 00:14:51,449
watching the first human into space now

304
00:14:57,040 --> 00:14:54,950
in Kennedy's inaugural dress he suggests

305
00:14:58,900 --> 00:14:57,050
it allowed in his speech that the

306
00:15:02,050 --> 00:14:58,910
Soviets and the Americans should explore

307
00:15:04,300 --> 00:15:02,060
space together but the launch of Gagarin

308
00:15:08,500 --> 00:15:04,310
changed that thinking at least for a

309
00:15:12,280 --> 00:15:08,510
time and a frustrated Kennedy wrote this

310
00:15:14,560 --> 00:15:12,290
memo directing Vice President Lyndon

311
00:15:17,440 --> 00:15:14,570
Johnson to conduct a survey to find a

312
00:15:20,290 --> 00:15:17,450
way any way to beat the Soviet Union in

313
00:15:22,720 --> 00:15:20,300

the space race what would it take

314
00:15:25,180 --> 00:15:22,730
Kennedy wanted to know putting up a

315
00:15:27,160 --> 00:15:25,190
Space Lab a trip around the moon landing

316
00:15:30,580 --> 00:15:27,170
a rocket on the moon landing a man on

317
00:15:33,010 --> 00:15:30,590
the moon or any other idea and no

318
00:15:34,540 --> 00:15:33,020
Kennedy's impatience he wanted to know

319
00:15:39,190 --> 00:15:34,550
are the people involved in the space

320
00:15:44,470 --> 00:15:39,200
program working 24 hours a day and if

321
00:15:47,650 --> 00:15:44,480
not John why not to get the answers to

322
00:15:53,100 --> 00:15:47,660
Kennedy's questions Johnson turned to

323
00:15:58,930 --> 00:15:53,110
NASA Administrator James Webb and

324
00:16:01,720 --> 00:15:58,940
Secretary's offense John McNamara Webb

325
00:16:03,700 --> 00:16:01,730
believed the only real hope to have the

326
00:16:06,730 --> 00:16:03,710
first first in space was landing an

327
00:16:08,350 --> 00:16:06,740
astronaut on the moon McNamara didn't

328
00:16:11,440 --> 00:16:08,360
think even that would be enough and

329
00:16:12,810 --> 00:16:11,450
argued for a mission to Mars a human

330
00:16:16,720 --> 00:16:12,820
mission to Mars

331
00:16:19,210 --> 00:16:16,730
well Webb's more practical proposal one

332
00:16:21,370 --> 00:16:19,220
out and Kennedy took it to Congress and

333
00:16:23,350 --> 00:16:21,380
now made his very famous speech

334
00:16:25,570 --> 00:16:23,360
proposing to land a man on the moon and

335
00:16:28,750 --> 00:16:25,580
returning him safely to earth before

336
00:16:31,570 --> 00:16:28,760
this decade is out what's not well-known

337
00:16:35,350 --> 00:16:31,580
is the phrase before the story of the

338
00:16:38,800 --> 00:16:35,360

phrase before this decade is out it was

339
00:16:41,230 --> 00:16:38,810
a last-minute compromise James Webb was

340
00:16:43,570 --> 00:16:41,240
given an advance copy at the last minute

341
00:16:46,540 --> 00:16:43,580
of what Kennedy was going to say and to

342
00:16:49,380 --> 00:16:46,550
his shock the script the address

343
00:16:52,930 --> 00:16:49,390
mentioned that there was a deadline of

344
00:16:54,880 --> 00:16:52,940
1967 Webb convinced the White House to

345
00:16:59,110 --> 00:16:54,890
take out the year and stay and say

346
00:17:01,210 --> 00:16:59,120
instead the decade is out hit 1967 state

347
00:17:05,290 --> 00:17:01,220
in we would not be saying today that

348
00:17:07,720 --> 00:17:05,300
NASA met Kennedy's goal

349
00:17:10,570 --> 00:17:07,730
but now let's turn to JPS role in

350
00:17:13,360 --> 00:17:10,580
getting footprints on the moon even

351
00:17:16,120 --> 00:17:13,370
before Kennedy's speech jpo is working

352
00:17:18,430 --> 00:17:16,130
on two moon projects the first was

353
00:17:20,079 --> 00:17:18,440
called Ranger it was designed to be a

354
00:17:22,360 --> 00:17:20,089
series of spacecraft that would take

355
00:17:25,690 --> 00:17:22,370
close-up images of the moon before crash

356
00:17:27,310 --> 00:17:25,700
landing but even crash landing on the

357
00:17:30,850 --> 00:17:27,320
moon turned out to be a lot harder than

358
00:17:34,660 --> 00:17:30,860
expected I will be asking John khazzani

359
00:17:37,210 --> 00:17:34,670
to relive his pain for us live about

360
00:17:41,410 --> 00:17:37,220
those days but for right now let me

361
00:17:41,940 --> 00:17:41,420
summarize what happened Ranger 1 didn't

362
00:17:57,100 --> 00:17:41,950
work

363
00:18:00,600 --> 00:17:57,110

down and regrouped a year later they

364
00:18:03,460 --> 00:18:00,610
launched Ranger 6 it worked perfectly

365
00:18:07,130 --> 00:18:03,470
except in the last few minutes when its

366
00:18:11,470 --> 00:18:07,140
camera refused to turn on

367
00:18:16,090 --> 00:18:11,480
no pictures meant another failure

368
00:18:19,730 --> 00:18:16,100
January 30th 1964 was JPL's darkest day

369
00:18:21,860 --> 00:18:19,740
and in exactly this room crowded almost

370
00:18:23,810 --> 00:18:21,870
as well as probably as many people as

371
00:18:27,200 --> 00:18:23,820
you see right now in this room were

372
00:18:30,519 --> 00:18:27,210
people listening work to what was going

373
00:18:34,370 --> 00:18:30,529
on live and imagine what they felt like

374
00:18:37,820 --> 00:18:34,380
well let's see if I had better luck with

375
00:18:39,740 --> 00:18:37,830
Ranger seven and as you watch be aware

376
00:18:42,289 --> 00:18:39,750
that you're sitting in the same room as

377
00:18:43,850 --> 00:18:42,299
to some of the people some of the

378
00:18:55,759 --> 00:18:43,860
footage you're about to see of some of

379
00:18:59,810 --> 00:18:55,769
the people in there okay you have six

380
00:19:02,360 --> 00:18:59,820
Rangers which fail with each failure the

381
00:19:05,389 --> 00:19:02,370
pressure on JPL became more intense and

382
00:19:10,850 --> 00:19:05,399
after number six this was really really

383
00:19:12,950 --> 00:19:10,860
a catastrophe I had no fear that the lab

384
00:19:15,580 --> 00:19:12,960
was gonna fall apart it was quite the

385
00:19:21,980 --> 00:19:15,590
opposite everybody pulled together

386
00:19:24,310 --> 00:19:21,990
basically and what can I do to help six

387
00:19:29,000 --> 00:19:24,320
months after the debacle of Rangers six

388
00:19:30,789 --> 00:19:29,010

JPL was ready to try once more it had

389
00:19:37,610 --> 00:19:30,799
required working three shifts a day

390
00:19:41,120 --> 00:19:37,620
seven days a week the next one seven was

391
00:19:44,470 --> 00:19:41,130
a severe strain on everybody because it

392
00:19:47,419 --> 00:19:44,480
had to work and if it hadn't worked

393
00:19:49,399 --> 00:19:47,429
there's no telling what JPL would have

394
00:19:56,750 --> 00:19:49,409
been life or what would have happened to

395
00:19:57,890 --> 00:19:56,760
JPL it was a sobering experience

396
00:20:00,840 --> 00:19:57,900
[Music]

397
00:20:06,380 --> 00:20:00,850
launched through the 66 our cruise was a

398
00:20:09,270 --> 00:20:06,390
textbook flight three days after liftoff

399
00:20:14,970 --> 00:20:09,280
JPL's auditorium was once again filled

400
00:20:14,980 --> 00:20:20,700
[Music]

401
00:20:25,860 --> 00:20:23,460
at both pioneer and echo sites we are

402
00:20:28,160 --> 00:20:25,870
anticipating turn on momentarily we are

403
00:20:31,510 --> 00:20:28,170
five seconds from full power

404
00:20:34,370 --> 00:20:31,520
we have full power on channel

405
00:20:39,890 --> 00:20:34,380
[Applause]

406
00:20:48,250 --> 00:20:42,990
video is very strong

407
00:20:48,260 --> 00:20:52,000
three

408
00:20:56,210 --> 00:20:54,850
[Applause]

409
00:20:58,130 --> 00:20:56,220
[Music]

410
00:21:05,160 --> 00:20:58,140
[Applause]

411
00:21:13,630 --> 00:21:08,530
when impact occurred the auditorium

412
00:21:16,320 --> 00:21:13,640
erupted in a great cheer people shook

413
00:21:19,210 --> 00:21:16,330

hands and hugged one another some wept

414
00:21:24,550 --> 00:21:19,220
one hard-nosed engineer likened the

415
00:21:26,530 --> 00:21:24,560
event to a spiritual experience some

416
00:21:30,130 --> 00:21:26,540
people had smuggled in some champagne

417
00:21:35,050 --> 00:21:30,140
and champagne bottles were opened it was

418
00:21:48,730 --> 00:21:40,880
[Music]

419
00:21:52,150 --> 00:21:48,740
finally the now humbled JPL workforce

420
00:21:54,430 --> 00:21:52,160
has succeeded at the moon the television

421
00:21:57,130 --> 00:21:54,440
camera recorded some four thousand

422
00:22:00,130 --> 00:21:57,140
images that aren't much to behold today

423
00:22:01,750 --> 00:22:00,140
but at the time they were as a scientist

424
00:22:04,240 --> 00:22:01,760
in this room declared at the time a

425
00:22:10,270 --> 00:22:04,250
thousand times better than any image of

426
00:22:12,370 --> 00:22:10,280
the moon from Earth now the Rangers by

427
00:22:16,360 --> 00:22:12,380
the way here's some some headlines just

428
00:22:19,120 --> 00:22:16,370
to give you some sense of I think it it

429
00:22:21,460 --> 00:22:19,130
reveals the sense of anxiety that was

430
00:22:25,330 --> 00:22:21,470
relief you know the relief of we had

431
00:22:27,190 --> 00:22:25,340
finally succeeded I'm interested in the

432
00:22:30,770 --> 00:22:27,200
to hurt in the minor riot and going to a

433
00:22:40,130 --> 00:22:35,060
I don't know the story about that I'll

434
00:22:42,320 --> 00:22:40,140
have to look that up any rate so after

435
00:22:45,740 --> 00:22:42,330
Ranger came surveyor and surveyor was a

436
00:22:47,720 --> 00:22:45,750
far far more complicated mission this

437
00:22:50,299 --> 00:22:47,730
was about soft landing on the moon and

438
00:22:54,289 --> 00:22:50,309

staying alive on the moon for some time

439
00:22:56,029 --> 00:22:54,299
and I said well let's just watch the

440
00:22:57,830 --> 00:22:56,039
video I think that will that will tell

441
00:23:09,590 --> 00:22:57,840
more than I can so John if we can roll

442
00:23:12,350 --> 00:23:09,600
that please of all the questions NASA

443
00:23:13,970 --> 00:23:12,360
wanted answered the most important was

444
00:23:18,049 --> 00:23:13,980
knowing what the surface would be like

445
00:23:20,390 --> 00:23:18,059
for Apollo astronauts was it solid or

446
00:23:27,560 --> 00:23:20,400
would layers of dust act like lunar

447
00:23:29,360 --> 00:23:27,570
quicksand and swallow them whole NASA

448
00:23:32,750 --> 00:23:29,370
had hoped the answers would come from

449
00:23:35,330 --> 00:23:32,760
surveyor this was JPL's first experience

450
00:23:37,669 --> 00:23:35,340
in overseeing on behalf of NASA the work

451
00:23:40,070 --> 00:23:37,679
of an aerospace company but the

452
00:23:43,549 --> 00:23:40,080
contractor Hughes aerospace was

453
00:23:45,590 --> 00:23:43,559
struggling for good reasons surveyor was

454
00:23:48,500 --> 00:23:45,600
far more technically challenging than

455
00:23:51,649 --> 00:23:48,510
the Rangers this spacecraft not only had

456
00:23:55,430 --> 00:23:51,659
to soft land on the moon it had to do so

457
00:23:57,620 --> 00:23:55,440
autonomously it was also expected to

458
00:24:00,710 --> 00:23:57,630
send back images and science data from

459
00:24:04,549 --> 00:24:00,720
the lunar surface not for a day but for

460
00:24:07,340 --> 00:24:04,559
weeks that was a difficult trying period

461
00:24:11,299 --> 00:24:07,350
because we were growing up at the same

462
00:24:16,710 --> 00:24:11,309
time that Hughes was growing up and we

463
00:24:31,229 --> 00:24:16,720

didn't always mesh a trying time

464
00:24:38,710 --> 00:24:34,060
aerodynamic shroud is often grand bahama

465
00:24:41,169 --> 00:24:38,720
is tracking as shown by the animated

466
00:24:46,960 --> 00:24:41,179
diagrams and the monitor the Atlas sent

467
00:24:52,360 --> 00:24:50,050
sixty three hours after launch surveyor

468
00:24:53,320 --> 00:24:52,370
one was only one thousand miles away

469
00:24:55,660 --> 00:24:53,330
from the moon

470
00:25:00,730 --> 00:24:55,670
with the speed increasing as the moon's

471
00:25:00,740 --> 00:25:07,240
[Music]

472
00:25:26,170 --> 00:25:11,390
oddly the vehicle was supposed to enter

473
00:25:31,310 --> 00:25:28,520
certain distance above the surface the

474
00:25:33,250 --> 00:25:31,320
engines are all supposed to shut off and

475
00:25:41,890 --> 00:25:33,260
it is supposed to drop to the surface

476
00:25:41,900 --> 00:25:47,160
and you could hear a pin drop

477
00:25:54,600 --> 00:25:51,090
it worked we were down it's still

478
00:25:56,730 --> 00:25:54,610
transmitting for the first time an

479
00:26:02,180 --> 00:25:56,740
American spacecraft had achieved a soft

480
00:26:07,770 --> 00:26:05,670
surveyor 1 operated for six weeks in all

481
00:26:10,080 --> 00:26:07,780
the sturdy Landers sent back more than

482
00:26:13,770 --> 00:26:10,090
11,000 images before its batteries

483
00:26:17,370 --> 00:26:13,780
ceased to work and NASA had the answer

484
00:26:20,400 --> 00:26:17,380
to its question the lunar surface was

485
00:26:35,460 --> 00:26:20,410
solid and suitable for landing by the

486
00:26:38,460 --> 00:26:35,470
Apollo astronauts this is actually my

487
00:26:41,460 --> 00:26:38,470
favorite surveyor image because every

488
00:26:44,610 --> 00:26:41,470

single time I look at it what I see in

489
00:26:48,780 --> 00:26:44,620
it is almost Neil Armstrong stepping off

490
00:26:53,540 --> 00:26:48,790
the lunar module but it's not it's the

491
00:26:56,730 --> 00:26:53,550
shadow of surveyor 1 on the moon

492
00:26:59,150 --> 00:26:56,740
now I do not want this evening to be

493
00:27:01,170 --> 00:26:59,160
guilty of committing the sin of omission

494
00:27:03,500 --> 00:27:01,180
so I want to acknowledge that the

495
00:27:08,010 --> 00:27:03,510
Soviets were the first to another moon

496
00:27:12,420 --> 00:27:08,020
with Luna 9 it used airbags which we've

497
00:27:14,340 --> 00:27:12,430
adopted to go to Mars so it can be

498
00:27:17,760 --> 00:27:14,350
argued that this wasn't actually a soft

499
00:27:19,350 --> 00:27:17,770
landing and at the time it wasn't large

500
00:27:22,740 --> 00:27:19,360
enough to erase doubts about whether the

501
00:27:25,520 --> 00:27:22,750
lunar surface would would able to bear

502
00:27:29,580 --> 00:27:25,530
up for the weight of an Apollo Lander

503
00:27:33,060 --> 00:27:29,590
but it's interesting to make a

504
00:27:36,960 --> 00:27:33,070
comparison between the Luna 9 image of

505
00:27:39,900 --> 00:27:36,970
the moon and a surveyor image of the

506
00:27:43,200 --> 00:27:39,910
moon and we'd begin to understand that

507
00:27:45,840 --> 00:27:43,210
being first doesn't always mean being

508
00:27:49,110 --> 00:27:45,850
the best because what happened to the

509
00:27:53,370 --> 00:27:49,120
Soviet Union program in part was the

510
00:27:57,000 --> 00:27:53,380
concentration on first actually hindered

511
00:27:59,040 --> 00:27:57,010
their technological development and for

512
00:28:00,630 --> 00:27:59,050
completeness I have to mention one more

513
00:28:04,620 --> 00:28:00,640

first by the Soviets

514
00:28:06,750 --> 00:28:04,630
the few people know or remember would

515
00:28:08,880 --> 00:28:06,760
you believe me if I told you that the

516
00:28:11,190 --> 00:28:08,890
Apollo 8 astronauts were not the first

517
00:28:16,260 --> 00:28:11,200
Earthlings to fly to the moon and return

518
00:28:20,070 --> 00:28:16,270
to Earth that's true that's a fact these

519
00:28:25,620 --> 00:28:20,080
were the first Earthlings to accomplish

520
00:28:30,270 --> 00:28:25,630
them on zon 5 now it's easy to make a

521
00:28:32,010 --> 00:28:30,280
joke of this but Zhong 5 was serious

522
00:28:34,440 --> 00:28:32,020
business because it demonstrated the

523
00:28:37,470 --> 00:28:34,450
Soviets were very serious still about

524
00:28:39,980 --> 00:28:37,480
sending cosmonauts to the moon but their

525
00:28:44,610 --> 00:28:39,990
version of the Saturn 5 that the n1

526
00:28:48,240 --> 00:28:44,620
never worked now I'd like to make one

527
00:28:53,070 --> 00:28:48,250
more connection between JPL and Apollo

528
00:28:54,659 --> 00:28:53,080
and it has to do with Apollo 12 as you

529
00:28:56,220 --> 00:28:54,669
probably if you've been watching any of

530
00:28:59,010 --> 00:28:56,230
the great documentaries that are airing

531
00:29:01,200 --> 00:28:59,020
this week and on the news you probably

532
00:29:05,220 --> 00:29:01,210
know now it wasn't well known when I did

533
00:29:07,650 --> 00:29:05,230
Space Flight in 1985 but that Apollo 11

534
00:29:09,960 --> 00:29:07,660
landed with only 20 seconds of fuel left

535
00:29:12,810 --> 00:29:09,970
something like that and that was because

536
00:29:14,820 --> 00:29:12,820
the computer overshot where there was

537
00:29:16,110 --> 00:29:14,830
where they were supposed to land and

538
00:29:17,850 --> 00:29:16,120

they were headed towards a field of

539
00:29:19,980 --> 00:29:17,860
boulders so Neil Armstrong had to take

540
00:29:22,350 --> 00:29:19,990
control and find a safe place to win

541
00:29:23,430 --> 00:29:22,360
well the mission planners weren't going

542
00:29:25,500 --> 00:29:23,440
to let that happen again

543
00:29:27,960 --> 00:29:25,510
they wanted a pinpoint landing for

544
00:29:29,760 --> 00:29:27,970
Apollo 12 and they wanted to make sure

545
00:29:32,520 --> 00:29:29,770
that they had a landmark to know where

546
00:29:34,590 --> 00:29:32,530
they landed so they chose that on the

547
00:29:36,360 --> 00:29:34,600
moon everything was kind of the same so

548
00:29:39,299 --> 00:29:36,370
they decided to land next to another

549
00:29:41,370 --> 00:29:39,309
surveyor surveyor 3 and that's it that

550
00:29:44,820 --> 00:29:41,380
you see right here in front of you with

551
00:29:47,190 --> 00:29:44,830
Pete Conrad and my favorite all-time an

552
00:29:49,740 --> 00:29:47,200
astronaut and behind you can on the

553
00:29:55,140 --> 00:29:49,750
horizon you can see the lunar module

554
00:29:58,310 --> 00:29:55,150
that they landed in and Clete used sort

555
00:30:01,980 --> 00:29:58,320
of a hacksaw to take off the camera of

556
00:30:04,470 --> 00:30:01,990
the surveyor three and a piece of the

557
00:30:08,760 --> 00:30:04,480
scoop and brought it back there was a

558
00:30:10,919 --> 00:30:08,770
sense some scientists thought when they

559
00:30:12,840 --> 00:30:10,929
took it to the lab that there they found

560
00:30:15,629 --> 00:30:12,850
microbial life

561
00:30:19,919 --> 00:30:15,639
the camera that had come from earth

562
00:30:21,330 --> 00:30:19,929
somebody sneezed on it on earth if we

563
00:30:23,190 --> 00:30:21,340

went to the moon survived for three

564
00:30:24,749 --> 00:30:23,200
years and went back that's been pretty

565
00:30:29,480 --> 00:30:24,759
much discredited now they now think

566
00:30:34,799 --> 00:30:33,060
but but but what's important about it is

567
00:30:36,210 --> 00:30:34,809
this is exactly the same time we were

568
00:30:38,940 --> 00:30:36,220
beginning scientists were beginning to

569
00:30:40,980 --> 00:30:38,950
understand that life is far more Hardy

570
00:30:43,019 --> 00:30:40,990
and far more tenacious than we ever

571
00:30:44,730 --> 00:30:43,029
expected and that there was more

572
00:30:46,789 --> 00:30:44,740
possibility for looking for the search

573
00:30:52,080 --> 00:30:46,799
for life elsewhere in the solar system

574
00:30:56,310 --> 00:30:52,090
so that to me is part of the legacy also

575
00:30:59,759 --> 00:30:56,320
of the moon landings is that I believe

576
00:31:01,619 --> 00:30:59,769
now that we are right now working hard

577
00:31:04,649 --> 00:31:01,629
to go through these other moons in the

578
00:31:06,600 --> 00:31:04,659
solar system to look for life it's

579
00:31:09,930 --> 00:31:06,610
really one of the great quests of all

580
00:31:14,279 --> 00:31:09,940
time so I want to leave you with this

581
00:31:17,369 --> 00:31:14,289
image of two footprints one robotic one

582
00:31:19,919 --> 00:31:17,379
human because to go the great quest that

583
00:31:34,430 --> 00:31:19,929
we want to go on it's going to take both

584
00:31:38,489 --> 00:31:36,539
outstanding flame that was excellent

585
00:31:40,589 --> 00:31:38,499
thank you so much well with that

586
00:31:42,450 --> 00:31:40,599
historical background in hand we'll

587
00:31:45,599 --> 00:31:42,460
change gears now to hear about some of

588
00:31:47,190 --> 00:31:45,609

the science of Apollo as you'll hear

589
00:31:48,869 --> 00:31:47,200
many of the elements in our

590
00:31:51,330 --> 00:31:48,879
understanding of the Moon that we take

591
00:31:55,229 --> 00:31:51,340
for granted today were actually huge

592
00:31:57,089 --> 00:31:55,239
mysteries in 1969 and those mysteries

593
00:31:58,889 --> 00:31:57,099
required that new techniques and new

594
00:32:01,649 --> 00:31:58,899
scientific instruments be developed

595
00:32:03,799 --> 00:32:01,659
after all no one had ever studied a

596
00:32:07,289 --> 00:32:03,809
pristine sample from Earth's moon before

597
00:32:09,330 --> 00:32:07,299
our next speaker is one of the people

598
00:32:11,310 --> 00:32:09,340
who helped develop those new ways of

599
00:32:14,249 --> 00:32:11,320
studying the lunar samples from Apollo

600
00:32:17,249 --> 00:32:14,259
11 what he and his colleagues learned

601
00:32:19,339 --> 00:32:17,259
helped to completely transform our

602
00:32:22,469 --> 00:32:19,349
understanding of the moon's history

603
00:32:24,690 --> 00:32:22,479
Arden Albee grew up in Michigan and

604
00:32:27,779 --> 00:32:24,700
studied at Harvard rifts receiving a PhD

605
00:32:29,999 --> 00:32:27,789
in geology he came to Caltech in 1959

606
00:32:31,979 --> 00:32:30,009
and retired after fifty years as a

607
00:32:34,619 --> 00:32:31,989
professor of geological and planetary

608
00:32:36,450 --> 00:32:34,629
sciences during that time in addition to

609
00:32:38,339 --> 00:32:36,460
teaching and research he served for six

610
00:32:41,789 --> 00:32:38,349
years as chief scientist right here at

611
00:32:43,799 --> 00:32:41,799
JPL and project scientist he served as

612
00:32:46,049 --> 00:32:43,809
project scientist for two years excuse

613
00:32:49,649 --> 00:32:46,059

me for two NASA missions to Mars stick

614
00:32:52,529 --> 00:32:49,659
to the script as well as serving on

615
00:32:55,200 --> 00:32:52,539
innumerable committees and boards for

616
00:32:56,999 --> 00:32:55,210
NASA and higher education so for a look

617
00:32:59,399 --> 00:32:57,009
at the science of the Apollo lunar

618
00:33:04,320 --> 00:32:59,409
samples please help me welcome dr. Arden

619
00:33:10,750 --> 00:33:07,090
thank you as you see I've been around

620
00:33:12,700 --> 00:33:10,760
here for a long time I wore this jacket

621
00:33:15,759 --> 00:33:12,710
because I found it in the back of the

622
00:33:20,320 --> 00:33:15,769
closet and there's a possibility I wore

623
00:33:22,269 --> 00:33:20,330
it 50 years ago to the first my

624
00:33:26,549 --> 00:33:22,279
daughter's would say no way back it's

625
00:33:30,880 --> 00:33:29,200
mine's gonna be a little bit more of I

626
00:33:33,700 --> 00:33:30,890
was there and I'm gonna tell you some

627
00:33:39,129 --> 00:33:33,710
funny things some difficult things some

628
00:33:41,950 --> 00:33:39,139
mysteries in 1610 Galileo used a very

629
00:33:45,549 --> 00:33:41,960
early telescope to provide our first

630
00:33:48,460 --> 00:33:45,559
real knowledge of the moon and in fact

631
00:33:51,549 --> 00:33:48,470
until the arrival of spacecraft other

632
00:33:55,060 --> 00:33:51,559
telescopic work did not add much more to

633
00:33:58,480 --> 00:33:55,070
that knowledge on this first slide we

634
00:34:01,990 --> 00:33:58,490
see the large smooth dark areas which

635
00:34:05,440 --> 00:34:02,000
Galileo called Marya or C's in Italian

636
00:34:07,450 --> 00:34:05,450
and the surrounding areas lighter in

637
00:34:09,970 --> 00:34:07,460
color which are pitted with craters

638
00:34:12,639 --> 00:34:09,980

which he caught which he called craters

639
00:34:15,790 --> 00:34:12,649
he did name them as craters these

640
00:34:19,619 --> 00:34:15,800
intensely cratered areas which appear

641
00:34:23,770 --> 00:34:19,629
white in contrast to the dark Mario

642
00:34:26,139 --> 00:34:23,780
became known as Tara or Highlands indeed

643
00:34:29,770 --> 00:34:26,149
they were higher than the dark color

644
00:34:32,109 --> 00:34:29,780
basins now many controversies about the

645
00:34:34,659 --> 00:34:32,119
moon as we heard a minute ago fermented

646
00:34:37,149 --> 00:34:34,669
for generations extreme positions were

647
00:34:42,190 --> 00:34:37,159
taken by gentlemen with great eloquence

648
00:34:44,770 --> 00:34:42,200
but few facts now almost forgotten now

649
00:34:47,200 --> 00:34:44,780
is the intense debate on such subjects

650
00:34:50,349 --> 00:34:47,210
as the depth to which a spacecraft might

651
00:34:52,720 --> 00:34:50,359
sink into the lunar dust the relative

652
00:34:57,550 --> 00:34:52,730
roles of all kanai's impaired and water

653
00:35:00,010 --> 00:34:57,560
in shaping the landscape and weather

654
00:35:01,839 --> 00:35:00,020
radiation could be accumulated in the

655
00:35:04,740 --> 00:35:01,849
dust from the radiation on the solar

656
00:35:07,440 --> 00:35:04,750
system and caused an explosion when the

657
00:35:12,490 --> 00:35:07,450
astronaut put his foot down in the soil

658
00:35:16,390 --> 00:35:12,500
and finally the presence of exotic

659
00:35:18,070 --> 00:35:16,400
organisms or water under the surface now

660
00:35:21,880 --> 00:35:18,080
many of these

661
00:35:24,390 --> 00:35:21,890
very passe to us now but we have to

662
00:35:28,270 --> 00:35:24,400
remember that such controversies

663
00:35:30,970 --> 00:35:28,280

consumed countless hours millions of

664
00:35:33,040 --> 00:35:30,980
dollars to settle and thousands of

665
00:35:36,310 --> 00:35:33,050
printed pages during the development of

666
00:35:38,800 --> 00:35:36,320
the Apollo the lunar Ranger the lunar

667
00:35:41,710 --> 00:35:38,810
surveyor project the JPL and the lunar

668
00:35:44,710 --> 00:35:41,720
orbiter project at Langley were all

669
00:35:48,010 --> 00:35:44,720
undertaken to resolve some of these and

670
00:35:51,070 --> 00:35:48,020
other questions that affected the safety

671
00:35:53,470 --> 00:35:51,080
of the astronauts for the mission now

672
00:35:56,650 --> 00:35:53,480
clearly we all know that Apollo did not

673
00:36:00,430 --> 00:35:56,660
sink out of sight and the dust and it

674
00:36:04,240 --> 00:36:00,440
didn't explode on landing but in fact

675
00:36:06,880 --> 00:36:04,250
the Apollo 11 spacecraft the samples and

676
00:36:10,630 --> 00:36:06,890
the crew were actually quarantined for

677
00:36:13,920 --> 00:36:10,640
21 days until testing showed that exotic

678
00:36:16,570 --> 00:36:13,930
organisms were not present

679
00:36:18,670 --> 00:36:16,580
now engineers and planners worked for a

680
00:36:20,400 --> 00:36:18,680
decade more than a decade to solve the

681
00:36:23,410 --> 00:36:20,410
problems of getting to the moon and back

682
00:36:25,900 --> 00:36:23,420
at the same time scientists were working

683
00:36:28,390 --> 00:36:25,910
on problems that would allow them to

684
00:36:30,280 --> 00:36:28,400
interpret the lunar samples they didn't

685
00:36:30,850 --> 00:36:30,290
know what time is that's what we they're

686
00:36:33,700 --> 00:36:30,860
doing

687
00:36:36,100 --> 00:36:33,710
in the late 40s scientists have been

688
00:36:38,140 --> 00:36:36,110

involved in the war effort took their

689
00:36:41,170 --> 00:36:38,150
new knowledge of isotopes and mass

690
00:36:44,170 --> 00:36:41,180
spectrometry and took them back to the

691
00:36:45,940 --> 00:36:44,180
universities a new generation of

692
00:36:49,000 --> 00:36:45,950
graduate students began to use these

693
00:36:52,180 --> 00:36:49,010
tools to attack problems in geology and

694
00:36:54,430 --> 00:36:52,190
other fields these included some of the

695
00:36:57,430 --> 00:36:54,440
ones that you probably know about the

696
00:37:00,520 --> 00:36:57,440
4.6 billion year old age of iron

697
00:37:03,100 --> 00:37:00,530
meteorites highlighting the health

698
00:37:06,700 --> 00:37:03,110
problems due to the lead additives in

699
00:37:09,580 --> 00:37:06,710
gasoline and detailed study of impact

700
00:37:11,800 --> 00:37:09,590
craters here on earth isotopic

701
00:37:14,620 --> 00:37:11,810
geochemistry was born at the University

702
00:37:17,310 --> 00:37:14,630
of Chicago under the leadership of Nobel

703
00:37:19,840 --> 00:37:17,320
Prize winner Harold Urey and others

704
00:37:21,850 --> 00:37:19,850
their students moved to Caltech and

705
00:37:24,280 --> 00:37:21,860
other universities around the country in

706
00:37:27,070 --> 00:37:24,290
the early 50s and continued these kinds

707
00:37:30,890 --> 00:37:27,080
of studies and were to become critical

708
00:37:33,330 --> 00:37:30,900
to understanding the return lunar

709
00:37:35,670 --> 00:37:33,340
well in the mid-sixties the Apollo

710
00:37:38,370 --> 00:37:35,680
program began to fund scientists to

711
00:37:41,820 --> 00:37:38,380
develop clean labs new instruments and

712
00:37:44,700 --> 00:37:41,830
new protocols and procedures to prepare

713
00:37:47,340 --> 00:37:44,710

for the return of the samples hundreds

714
00:37:50,270 --> 00:37:47,350
of teams from many countries were chosen

715
00:37:52,800 --> 00:37:50,280
to work on the Apollo 11 samples

716
00:37:55,500 --> 00:37:52,810
necessitating the development of new

717
00:37:58,920 --> 00:37:55,510
precision instruments and labs for the

718
00:38:01,310 --> 00:37:58,930
analysis of small samples a number of

719
00:38:03,900 --> 00:38:01,320
these teams were at Caltech and JPL

720
00:38:07,350 --> 00:38:03,910
chosen to work with different approaches

721
00:38:12,480 --> 00:38:07,360
I was part of a team at Caltech dubbed

722
00:38:16,020 --> 00:38:12,490
the lunatic asylum which included quite

723
00:38:17,880 --> 00:38:16,030
a variety of different approaches now

724
00:38:19,320 --> 00:38:17,890
during the quarantine period scientists

725
00:38:22,590 --> 00:38:19,330
and technicians in the Earth lunar

726
00:38:24,570 --> 00:38:22,600
receiving laboratory studies and

727
00:38:26,640 --> 00:38:24,580
preparing samples which had been

728
00:38:29,610 --> 00:38:26,650
selected for distribution to the various

729
00:38:33,510 --> 00:38:29,620
teams these samples were sent out under

730
00:38:37,230 --> 00:38:33,520
strict security we had to keep them in a

731
00:38:40,140 --> 00:38:37,240
safe etc and an embargo on releasing any

732
00:38:44,930 --> 00:38:40,150
results until the Apollo 11 lunar

733
00:38:48,030 --> 00:38:44,940
conference in January of 1970 in Houston

734
00:38:52,200 --> 00:38:48,040
each team was required to arrive at the

735
00:38:54,750 --> 00:38:52,210
conference turn in a written paper give

736
00:38:57,930 --> 00:38:54,760
that paper and then publish that paper

737
00:39:00,690 --> 00:38:57,940
without any changes so it was like this

738
00:39:03,450 --> 00:39:00,700

then amounted to a real blind test and

739
00:39:06,300 --> 00:39:03,460
in addition there was a fixed word limit

740
00:39:09,000 --> 00:39:06,310
and I could remember spending my

741
00:39:11,670 --> 00:39:09,010
Christmas vacation in part editing and

742
00:39:13,860 --> 00:39:11,680
re-adding our manuscript to see if we

743
00:39:16,260 --> 00:39:13,870
could just take out a few words here and

744
00:39:19,620 --> 00:39:16,270
get a few more words in there because

745
00:39:21,450 --> 00:39:19,630
that was one of the difficulties now the

746
00:39:23,820 --> 00:39:21,460
combination of these rules set up a

747
00:39:26,670 --> 00:39:23,830
giant blind test of all these new

748
00:39:28,560 --> 00:39:26,680
techniques and everybody headed to

749
00:39:30,630 --> 00:39:28,570
Houston tense with the excitement see

750
00:39:34,530 --> 00:39:30,640
what others had learned and to see if

751
00:39:36,000 --> 00:39:34,540
they'd gotten it right but the new

752
00:39:39,300 --> 00:39:36,010
instrumentation came through with flying

753
00:39:41,730 --> 00:39:39,310
colors a decade before we could not have

754
00:39:42,570 --> 00:39:41,740
gotten all the data that we got and if

755
00:39:43,770 --> 00:39:42,580
we had it we

756
00:39:46,170 --> 00:39:43,780
couldn't have interpreted it because we

757
00:39:47,390 --> 00:39:46,180
wouldn't know what to do with it well

758
00:39:50,160 --> 00:39:47,400
what were some of these measurements

759
00:39:52,530 --> 00:39:50,170
well studies of the mineralogy mineral

760
00:39:55,350 --> 00:39:52,540
chemistry texture and bulk composition

761
00:39:58,740 --> 00:39:55,360
of rocks are used to determine physical

762
00:40:00,750 --> 00:39:58,750
and chemical history trace element

763
00:40:03,330 --> 00:40:00,760

chemistry is used to determine

764
00:40:07,200 --> 00:40:03,340
signatures a very specific geochemical

765
00:40:10,220 --> 00:40:07,210
processes precise isotopic analyses are

766
00:40:16,280 --> 00:40:10,230
used to study a wide variety of

767
00:40:21,620 --> 00:40:18,990
these samples were also examined for a

768
00:40:25,320 --> 00:40:21,630
whole variety of physical properties

769
00:40:27,960 --> 00:40:25,330
such as magnetism and seismic wave

770
00:40:31,620 --> 00:40:27,970
velocity it's probably obvious that no

771
00:40:34,950 --> 00:40:31,630
one team could do all could operate with

772
00:40:39,410 --> 00:40:34,960
all of these techniques and methods well

773
00:40:44,220 --> 00:40:41,520
we're looking here at the lunar surface

774
00:40:47,160 --> 00:40:44,230
which you've seen note craters

775
00:40:56,010 --> 00:40:47,170
everywhere fine dust and here are their

776
00:40:58,320 --> 00:40:56,020
rocks sticking up out of it now our team

777
00:40:59,970 --> 00:40:58,330
members like most of you now and for in

778
00:41:02,220 --> 00:40:59,980
the last few days the entire world

779
00:41:04,830 --> 00:41:02,230
actually have looked over Armstrong

780
00:41:07,320 --> 00:41:04,840
shoulder as he zoomed over a battered

781
00:41:10,560 --> 00:41:07,330
war zone of craters of all sizes and

782
00:41:13,500 --> 00:41:10,570
over a pile of rocks to land on a lunar

783
00:41:16,560 --> 00:41:13,510
surface so here we see that surface an

784
00:41:19,380 --> 00:41:16,570
array of small craters standing on the

785
00:41:28,920 --> 00:41:19,390
ladder responding to area earlier

786
00:41:30,840 --> 00:41:28,930
concerns about of course responding to

787
00:41:34,260 --> 00:41:30,850
earlier concerns about the mission and

788
00:41:36,690 --> 00:41:34,270

landing armstrong actually commented in

789
00:41:42,530 --> 00:41:36,700
the live broadcast that the spacecraft

790
00:41:48,870 --> 00:41:46,320
well this hour Nick show a slide that

791
00:41:51,930 --> 00:41:48,880
shows then that the soil looks like

792
00:41:54,810 --> 00:41:51,940
close up the fine soil and the larger

793
00:41:56,180 --> 00:41:54,820
fragments in the larger rock fragments

794
00:41:58,460 --> 00:41:56,190
that you see there

795
00:42:01,099 --> 00:41:58,470
we're all fragments broken in the

796
00:42:04,130 --> 00:42:01,109
intense cratering that had hurled them

797
00:42:06,069 --> 00:42:04,140
to this site there was nothing that we

798
00:42:07,970 --> 00:42:06,079
collected that came from a bedrock

799
00:42:10,099 --> 00:42:07,980
geologists are always taught they have

800
00:42:12,920 --> 00:42:10,109
to collect from bedrock but there was no

801
00:42:15,559 --> 00:42:12,930
bedrock to collect from with great

802
00:42:18,890 --> 00:42:15,569
anticipation we examined as our soil

803
00:42:22,010 --> 00:42:18,900
sample under the microscope and began to

804
00:42:26,380 --> 00:42:22,020
be start our tour of the moon this next

805
00:42:30,190 --> 00:42:26,390
slide shows a handful of Apollo 11 soil

806
00:42:33,500 --> 00:42:30,200
it contains a wide variety of material

807
00:42:34,849 --> 00:42:33,510
it is originally very dusty you have to

808
00:42:37,700 --> 00:42:34,859
blow it off to see these beautiful

809
00:42:39,890 --> 00:42:37,710
particles now impart these are

810
00:42:44,599 --> 00:42:39,900
transported from a very great distance

811
00:42:46,700 --> 00:42:44,609
by multiple cratering events so this

812
00:42:49,730 --> 00:42:46,710
soil provides an answer to the very

813
00:42:53,510 --> 00:42:49,740

first question we're always asked what

814
00:42:56,480 --> 00:42:53,520
is the moon made of one group from

815
00:42:59,420 --> 00:42:56,490
Harvard studied over to own nearly 2,000

816
00:43:00,890 --> 00:42:59,430
of these little fragments just see

817
00:43:03,260 --> 00:43:00,900
exactly what they were under the

818
00:43:06,740 --> 00:43:03,270
microscope about a third of the

819
00:43:10,099 --> 00:43:06,750
fragments were of dark rock derived from

820
00:43:13,700 --> 00:43:10,109
the Mari a careful look identified them

821
00:43:17,089 --> 00:43:13,710
as the salt which is the most common

822
00:43:21,319 --> 00:43:17,099
volcanic rock on earth and it did not

823
00:43:24,109 --> 00:43:21,329
take any special equipment just an

824
00:43:26,650 --> 00:43:24,119
experienced eye and a hand lens to be

825
00:43:30,380 --> 00:43:26,660
able to mak make that determination

826
00:43:32,950 --> 00:43:30,390
about half of them were breakfast a mass

827
00:43:36,170 --> 00:43:32,960
of broken rock fragments cemented by

828
00:43:39,799 --> 00:43:36,180
glass which had formed as a melt during

829
00:43:48,200 --> 00:43:39,809
the impact about five percent the white

830
00:43:52,359 --> 00:43:48,210
ones here myself I finds right in these

831
00:43:58,700 --> 00:43:52,369
white ones are a calcium aluminum of

832
00:44:00,950 --> 00:43:58,710
silicate known as an ER site now the

833
00:44:04,370 --> 00:44:00,960
team looked at these and took a giant

834
00:44:06,529 --> 00:44:04,380
leap they inferred that these had been

835
00:44:08,420 --> 00:44:06,539
transported from the islands the

836
00:44:09,950 --> 00:44:08,430
Highlands were far away and take

837
00:44:12,070 --> 00:44:09,960
multiples

838
00:44:14,900 --> 00:44:12,080

in fact to bring that material

839
00:44:18,250 --> 00:44:14,910
nevertheless the material was abundant

840
00:44:21,050 --> 00:44:18,260
they took an even greater giant leap and

841
00:44:23,960 --> 00:44:21,060
inferred that an early and northa site

842
00:44:28,700 --> 00:44:23,970
that calcium aluminium silicate rich

843
00:44:31,220 --> 00:44:28,710
crust was produced by floating of these

844
00:44:33,490 --> 00:44:31,230
crystals as they crystallized from the

845
00:44:38,600 --> 00:44:33,500
melt so if they floated to the top

846
00:44:42,620 --> 00:44:38,610
toward the surface this idea of an early

847
00:44:45,680 --> 00:44:42,630
ocean of molten rock which became dubbed

848
00:44:47,120 --> 00:44:45,690
the magma ocean was embargoed until the

849
00:44:49,790 --> 00:44:47,130
conference and was created with

850
00:44:54,380 --> 00:44:49,800
considerable surprise maybe even

851
00:44:58,580 --> 00:44:54,390
considerable doubt now we expected to

852
00:45:01,640 --> 00:44:58,590
see irregular glass globs but the

853
00:45:03,200 --> 00:45:01,650
presence of always beautiful spheres was

854
00:45:06,560 --> 00:45:03,210
a great surprise though I should

855
00:45:09,890 --> 00:45:06,570
probably not of it if a mold melt flies

856
00:45:12,920 --> 00:45:09,900
through with the not the atmosphere you

857
00:45:15,380 --> 00:45:12,930
gotta be careful here if it flies

858
00:45:20,120 --> 00:45:15,390
through space even it is going to tend

859
00:45:22,580 --> 00:45:20,130
to become a spherical the next slide

860
00:45:24,080 --> 00:45:22,590
shows some of these because they were so

861
00:45:26,180 --> 00:45:24,090
very intriguing we spent lots of time

862
00:45:28,310 --> 00:45:26,190
playing with the balls there were round

863
00:45:30,320 --> 00:45:28,320

balls and long balls and green balls

864
00:45:35,840 --> 00:45:30,330
they were actually some red balls hollow

865
00:45:40,430 --> 00:45:35,850
balls see the next slide here here is a

866
00:45:42,860 --> 00:45:40,440
half of all which has been broken and on

867
00:45:46,510 --> 00:45:42,870
this fresh surface we see these light

868
00:45:50,660 --> 00:45:46,520
dots or white dots in particular all

869
00:45:54,620 --> 00:45:50,670
through this area here each of those is

870
00:45:58,180 --> 00:45:54,630
an impact crater from a micro meteorite

871
00:46:00,920 --> 00:45:58,190
one of these is shown in the next slide

872
00:46:03,590 --> 00:46:00,930
here we see that we're the impact of the

873
00:46:05,540 --> 00:46:03,600
micro meteorite was it has a molten

874
00:46:11,030 --> 00:46:05,550
shell around it and then there are

875
00:46:14,240 --> 00:46:11,040
radial of outflow of what is now glass

876
00:46:15,680 --> 00:46:14,250
which was the melt then beads going out

877
00:46:18,920 --> 00:46:15,690
further and further in all directions

878
00:46:22,820 --> 00:46:18,930
and if you look on deeper in it there

879
00:46:23,570 --> 00:46:22,830
are fractures underneath it this these

880
00:46:26,000 --> 00:46:23,580
were

881
00:46:27,740 --> 00:46:26,010
these cups like this sometimes broke

882
00:46:35,150 --> 00:46:27,750
loose and we found those cups just

883
00:46:36,860 --> 00:46:35,160
floating in the soil as well now one of

884
00:46:40,820 --> 00:46:36,870
my favorite photos is a cup like this

885
00:46:42,830 --> 00:46:40,830
that actually hit another meteorites or

886
00:46:44,960 --> 00:46:42,840
as a micro a meteorite hitting an iron

887
00:46:49,460 --> 00:46:44,970
meteorite and forming one of those

888
00:46:56,930 --> 00:46:49,470

beautiful these beautiful caps no the

889
00:47:01,850 --> 00:46:56,940
next slide shows the bombardment of the

890
00:47:03,800 --> 00:47:01,860
atmosphere now unlike Earth which is

891
00:47:06,590 --> 00:47:03,810
partly protected by its magnetic field

892
00:47:10,340 --> 00:47:06,600
and Bias atmosphere the layers of the

893
00:47:13,250 --> 00:47:10,350
regolith sampled in the rocks and in

894
00:47:18,500 --> 00:47:13,260
course from each mesh mission preserve a

895
00:47:24,380 --> 00:47:18,510
record of meteorites of cosmic rays and

896
00:47:26,750 --> 00:47:24,390
the solar wind and flares the the energy

897
00:47:28,760 --> 00:47:26,760
of the solar flares differs between the

898
00:47:31,700 --> 00:47:28,770
wind and the flares and so these

899
00:47:34,280 --> 00:47:31,710
particles come in and are deposited at

900
00:47:36,650 --> 00:47:34,290
different depths the flares who tend to

901
00:47:40,850 --> 00:47:36,660
be deposited deeper in the rock and the

902
00:47:42,470 --> 00:47:40,860
wind higher up the cosmic rays have an

903
00:47:45,650 --> 00:47:42,480
interaction with the material in the

904
00:47:48,350 --> 00:47:45,660
rock and produce new elements which can

905
00:47:51,590 --> 00:47:48,360
be analyzed for so these things can be

906
00:47:55,640 --> 00:47:51,600
used to look at what has been for many

907
00:47:57,470 --> 00:47:55,650
but using all of the spacecraft and

908
00:48:00,620 --> 00:47:57,480
looking at different depths and soils

909
00:48:02,930 --> 00:48:00,630
and different depths and rocks you can

910
00:48:07,670 --> 00:48:02,940
understand what the radiation effects

911
00:48:10,730 --> 00:48:07,680
have been in the return for many many

912
00:48:13,130 --> 00:48:10,740
time one of the interesting things is

913
00:48:16,400 --> 00:48:13,140

that Apollo data showed that the average

914
00:48:18,230 --> 00:48:16,410
Solar Flare activity has not changed

915
00:48:20,810 --> 00:48:18,240
appreciably over the past few million

916
00:48:23,420 --> 00:48:20,820
years and there were many theories up

917
00:48:26,540 --> 00:48:23,430
until then that solar flares were

918
00:48:29,140 --> 00:48:26,550
responsible for climate change but there

919
00:48:33,350 --> 00:48:29,150
has not was has not been that kind of a

920
00:48:36,050 --> 00:48:33,360
sustained now high on our list of

921
00:48:37,490 --> 00:48:36,060
questions fun.we because this is what

922
00:48:40,400 --> 00:48:37,500
the main reason our project

923
00:48:44,540 --> 00:48:40,410
group was chosen with investigate the

924
00:48:46,640 --> 00:48:44,550
dark mari rocks our group of Caltech

925
00:48:49,700 --> 00:48:46,650
received portions of them to study and

926
00:48:52,070 --> 00:48:49,710
to date upon your first sight in the lab

927
00:48:53,000 --> 00:48:52,080
it was very clear that they looked a

928
00:48:58,370 --> 00:48:53,010
little different than terrestrial

929
00:49:00,680 --> 00:48:58,380
basalts the typical volcanics throughout

930
00:49:02,240 --> 00:49:00,690
much of the world and therefore I

931
00:49:03,710 --> 00:49:02,250
quickly answered a question that had

932
00:49:06,290 --> 00:49:03,720
been asked for million years what's the

933
00:49:08,000 --> 00:49:06,300
moon made oh well he knew we couldn't

934
00:49:19,940 --> 00:49:08,010
tell anybody not until we got to use

935
00:49:24,590 --> 00:49:19,950
some the next slide shows a photos of a

936
00:49:26,750 --> 00:49:24,600
thin slice of a rock one of the basaltic

937
00:49:29,150 --> 00:49:26,760
rocks are the one of the Mari Brock's

938
00:49:30,890 --> 00:49:29,160

and this is looking at it under a

939
00:49:32,840 --> 00:49:30,900
microscope which looks at it in plain

940
00:49:35,600 --> 00:49:32,850
light cross polarized light and

941
00:49:39,260 --> 00:49:35,610
reflected light this device then allows

942
00:49:41,120 --> 00:49:39,270
us to identify the different minerals in

943
00:49:44,780 --> 00:49:41,130
the rocks to study the texture for

944
00:49:46,790 --> 00:49:44,790
comparison with basalts on earth and in

945
00:49:49,700 --> 00:49:46,800
particular to see that where are the

946
00:49:52,670 --> 00:49:49,710
last bits of the melt crystallized and

947
00:49:54,620 --> 00:49:52,680
what the composition was now it turns

948
00:49:57,860 --> 00:49:54,630
out that the features which you see

949
00:49:59,900 --> 00:49:57,870
there are little different it could

950
00:50:04,070 --> 00:49:59,910
perfectly well be have been collected

951
00:50:05,860 --> 00:50:04,080
from a frozen flow on Hawaii however

952
00:50:09,050 --> 00:50:05,870
when we look at the very late stage

953
00:50:12,020 --> 00:50:09,060
crystallization we see a distinctive

954
00:50:14,600 --> 00:50:12,030
differences terrestrial basalts always

955
00:50:17,780 --> 00:50:14,610
end up with some water bearing minerals

956
00:50:21,410 --> 00:50:17,790
in the last interspecies typically

957
00:50:23,690 --> 00:50:21,420
little clay minerals these are not

958
00:50:26,620 --> 00:50:23,700
present in the lunar rocks there is no

959
00:50:29,930 --> 00:50:26,630
trace of water they are perfectly clean

960
00:50:32,060 --> 00:50:29,940
and not altered the other thing is that

961
00:50:34,520 --> 00:50:32,070
that little white thing right there and

962
00:50:38,390 --> 00:50:34,530
reflected light is a globule of iron

963
00:50:41,060 --> 00:50:38,400

metal so indicating a reducing state of

964
00:50:43,910 --> 00:50:41,070
that final note that we simply would not

965
00:50:46,250 --> 00:50:43,920
see in a lunar result so the question

966
00:50:50,140 --> 00:50:46,260
sometimes I'm asked is can you tell a

967
00:50:51,890 --> 00:50:50,150
lunar basalt from a terrestrial basalt

968
00:50:55,249 --> 00:50:51,900
well

969
00:50:57,799 --> 00:50:55,259
at first glance they look alight but

970
00:51:02,089 --> 00:50:57,809
indeed from details you can understand

971
00:51:05,420 --> 00:51:02,099
the differences now this next slide is a

972
00:51:08,829 --> 00:51:05,430
little bit complicated it's that's what

973
00:51:13,700 --> 00:51:08,839
we call a strategy and evolution diagram

974
00:51:18,259 --> 00:51:13,710
we received a five samples of them of

975
00:51:20,930 --> 00:51:18,269
the Mari rocks portions of them we dated

976
00:51:24,049 --> 00:51:20,940
them each with ages close to 3.6 five

977
00:51:27,349 --> 00:51:24,059
billion years now the radioactive decay

978
00:51:31,220 --> 00:51:27,359
of rubidium 87 the isotope the strontium

979
00:51:35,480 --> 00:51:31,230
87 isotope with an own half light is the

980
00:51:40,670 --> 00:51:35,490
basis for the dating this diagram shows

981
00:51:43,910 --> 00:51:40,680
a plot of rubidium 87 86 against

982
00:51:45,559 --> 00:51:43,920
rubidium 87 86 because that's a

983
00:51:48,680 --> 00:51:45,569
convenient way to determine them on the

984
00:51:50,420 --> 00:51:48,690
mass spectrometer these ratios are

985
00:51:53,150 --> 00:51:50,430
measured in a number of different

986
00:51:56,420 --> 00:51:53,160
samples taken from a lunar rock now for

987
00:52:00,710 --> 00:51:56,430
ABC which have different compositions

988
00:52:04,130 --> 00:52:00,720

along this line and if they make a

989
00:52:06,460 --> 00:52:04,140
linear line like we see here we can see

990
00:52:10,009 --> 00:52:06,470
that they are had originally formed

991
00:52:13,420 --> 00:52:10,019
along this line and had decayed for the

992
00:52:16,190 --> 00:52:13,430
same amount of time back to that line

993
00:52:18,710 --> 00:52:16,200
this is called an internal isochron and

994
00:52:24,410 --> 00:52:18,720
it's what is used to measure the

995
00:52:26,930 --> 00:52:24,420
rubidium stretching ages and it is they

996
00:52:29,089 --> 00:52:26,940
are probably the most moat the bulk of

997
00:52:32,870 --> 00:52:29,099
the ages from the lunar samples are

998
00:52:34,910 --> 00:52:32,880
rubidium strontium measurements well

999
00:52:37,249 --> 00:52:34,920
again because of the embargo we couldn't

1000
00:52:39,620 --> 00:52:37,259
talk about this exciting date until the

1001
00:52:41,779 --> 00:52:39,630
conference and we learned the other

1002
00:52:45,650 --> 00:52:41,789
group see gotten similar results with

1003
00:52:48,769 --> 00:52:45,660
this and other isotopic techniques these

1004
00:52:50,539 --> 00:52:48,779
results provided an absolute age for the

1005
00:52:53,650 --> 00:52:50,549
right white spit rocks in the Sea of

1006
00:52:56,739 --> 00:52:53,660
Tranquility and later missions dated

1007
00:53:01,749 --> 00:52:56,749
Bari rocks from different basins the

1008
00:53:04,430 --> 00:53:01,759
next slide is a cartoon if you will

1009
00:53:05,710 --> 00:53:04,440
which summarize the time history of the

1010
00:53:10,030 --> 00:53:05,720
events that have

1011
00:53:12,820 --> 00:53:10,040
shaped the lunar history now if we look

1012
00:53:15,370 --> 00:53:12,830
down at the lower part we're looking at

1013
00:53:17,370 --> 00:53:15,380

the oldest part of it and what we see

1014
00:53:20,640 --> 00:53:17,380
there is that it is heavily crated

1015
00:53:23,620 --> 00:53:20,650
cratered no crater can fall without

1016
00:53:26,830 --> 00:53:23,630
parsley obliterated in previous craters

1017
00:53:29,680 --> 00:53:26,840
it's saturated with craters during this

1018
00:53:32,859 --> 00:53:29,690
first half a billion years now within it

1019
00:53:36,910 --> 00:53:32,869
you can see a group of basins these

1020
00:53:39,070 --> 00:53:36,920
basins the apology is surveyor the lunar

1021
00:53:43,630 --> 00:53:39,080
orbiter data in particular that

1022
00:53:48,370 --> 00:53:43,640
photography enabled the photo geologists

1023
00:53:50,890 --> 00:53:48,380
to map these basins and from these bases

1024
00:53:54,460 --> 00:53:50,900
to see what the outflow of ejecta looked

1025
00:53:57,160 --> 00:53:54,470
like in the same manner the various Mari

1026
00:54:01,900 --> 00:53:57,170
basalts are shown here Apollo 1250 in

1027
00:54:05,890 --> 00:54:01,910
lunar 24:16 and each of those had been

1028
00:54:08,230 --> 00:54:05,900
mapped by a proto geologic techniques B

1029
00:54:11,680 --> 00:54:08,240
and basically you can look at the

1030
00:54:14,770 --> 00:54:11,690
overlap relations if it's younger it

1031
00:54:17,950 --> 00:54:14,780
laughs on older rocks and there you can

1032
00:54:21,880 --> 00:54:17,960
project this through to get a relative

1033
00:54:27,640 --> 00:54:21,890
time sequence so on the this sequence

1034
00:54:29,680 --> 00:54:27,650
that we see on the right hand side and

1035
00:54:31,960 --> 00:54:29,690
we see on the right hand side shows a

1036
00:54:34,540 --> 00:54:31,970
whole set of features which would have

1037
00:54:38,410 --> 00:54:34,550
been identified in photo geology they

1038
00:54:40,120 --> 00:54:38,420

provided a relative timing relative

1039
00:54:42,820 --> 00:54:40,130
sequence of what had happened on the

1040
00:54:45,220 --> 00:54:42,830
surface of the Moon but in the right

1041
00:54:50,260 --> 00:54:45,230
hand side you'll see that we then have

1042
00:54:55,540 --> 00:54:50,270
dated these various lavas and these then

1043
00:54:59,740 --> 00:54:55,550
allow us to make an absolute scale for

1044
00:55:02,410 --> 00:54:59,750
this timing so this this timescale is

1045
00:55:04,599 --> 00:55:02,420
still used today it's applied to earth

1046
00:55:07,599 --> 00:55:04,609
Mars and other objects and the solar

1047
00:55:10,810 --> 00:55:07,609
system for which we can come up with a

1048
00:55:13,300 --> 00:55:10,820
relative sequence of events but we do

1049
00:55:17,230 --> 00:55:13,310
not have samples yet in order to

1050
00:55:18,849 --> 00:55:17,240
actually measure the age now we will

1051
00:55:19,540 --> 00:55:18,859
come back to this but we will see that

1052
00:55:22,150 --> 00:55:19,550
almost every

1053
00:55:25,480 --> 00:55:22,160
in the moon happened to the verse one

1054
00:55:30,670 --> 00:55:25,490
and a half billion years since then very

1055
00:55:32,950 --> 00:55:30,680
very little has happened to it now then

1056
00:55:36,520 --> 00:55:32,960
the next one I want to talk about in the

1057
00:55:41,920 --> 00:55:36,530
next slide is the mystery of the

1058
00:55:45,850 --> 00:55:41,930
europium anomaly now this sort of a

1059
00:55:47,890 --> 00:55:45,860
detective story of we will the volcanic

1060
00:55:56,920 --> 00:55:47,900
rocks are derived by partial melding

1061
00:55:58,540 --> 00:55:56,930
within the interior of the planet this

1062
00:56:01,420 --> 00:55:58,550
partial valley need well it's the Earth

1063
00:56:04,030 --> 00:56:01,430

or the moon that is that's how these the

1064
00:56:07,360 --> 00:56:04,040
salts form now the major element

1065
00:56:10,420 --> 00:56:07,370
composition of the Mari rocks didn't

1066
00:56:13,440 --> 00:56:10,430
differ greatly from salts but people who

1067
00:56:16,000 --> 00:56:13,450
worked using the rare earth elements

1068
00:56:18,040 --> 00:56:16,010
it's just that these are the whole set

1069
00:56:20,950 --> 00:56:18,050
of rare earth elements which act very

1070
00:56:23,170 --> 00:56:20,960
much alike in most cases because they're

1071
00:56:26,200 --> 00:56:23,180
very similar in their size and their

1072
00:56:29,230 --> 00:56:26,210
charges and the people of us needs to

1073
00:56:31,360 --> 00:56:29,240
understand the difference between the

1074
00:56:33,940 --> 00:56:31,370
salts which were derived from the ocean

1075
00:56:36,580 --> 00:56:33,950
crust and the salts which were derived

1076
00:56:38,560 --> 00:56:36,590
from the continents and as you can see

1077
00:56:41,710 --> 00:56:38,570
there are distinct differences in the

1078
00:56:44,620 --> 00:56:41,720
way the rare earth patterns are from

1079
00:56:47,170 --> 00:56:44,630
those two sources when we look at the

1080
00:56:50,200 --> 00:56:47,180
lunar ones they show a very different

1081
00:56:54,100 --> 00:56:50,210
one but with his striking anomaly of the

1082
00:56:57,460 --> 00:56:54,110
element europium now the interesting

1083
00:57:00,010 --> 00:56:57,470
thing is that europium in which what

1084
00:57:02,910 --> 00:57:00,020
which actually means that the source

1085
00:57:06,220 --> 00:57:02,920
down there had to then get depleted

1086
00:57:08,430 --> 00:57:06,230
somehow this had to be formed and that

1087
00:57:10,600 --> 00:57:08,440
europium had to go somewhere

1088
00:57:13,890 --> 00:57:10,610

well we realized from terrestrial

1089
00:57:18,280 --> 00:57:13,900
examples that the the formation of the

1090
00:57:21,160 --> 00:57:18,290
and artha height feldspar collects

1091
00:57:24,310 --> 00:57:21,170
europium preferentially over any of the

1092
00:57:28,180 --> 00:57:24,320
other minerals and so it could subtract

1093
00:57:33,370 --> 00:57:28,190
it so this team seeing this and noting

1094
00:57:36,070 --> 00:57:33,380
it they inferred that these crystal

1095
00:57:40,260 --> 00:57:36,080
at Forum there's a subtracted the

1096
00:57:43,420 --> 00:57:40,270
europium carried it away and therefore

1097
00:57:46,860 --> 00:57:43,430
they made the interpretation that there

1098
00:57:50,590 --> 00:57:46,870
was an early crust which formed as a

1099
00:57:52,030 --> 00:57:50,600
accumulation of calcium feldspar well if

1100
00:57:55,300 --> 00:57:52,040
you remember back to the start almost

1101
00:57:58,390 --> 00:57:55,310
the start of the talk a group working in

1102
00:58:00,340 --> 00:57:58,400
the East had looked at the particles in

1103
00:58:02,740 --> 00:58:00,350
the soil and where they came from and

1104
00:58:05,350 --> 00:58:02,750
and interpreted the origin of the

1105
00:58:09,850 --> 00:58:05,360
highlands as being accumulation of this

1106
00:58:12,070 --> 00:58:09,860
same mineral an earth I'm so one group

1107
00:58:14,500 --> 00:58:12,080
using geologic approaches and particles

1108
00:58:17,170 --> 00:58:14,510
in the soil came up with the same answer

1109
00:58:19,870 --> 00:58:17,180
as the group using isotopic chemical

1110
00:58:21,520 --> 00:58:19,880
approaches and of course everything was

1111
00:58:23,920 --> 00:58:21,530
constrained until we got to the

1112
00:58:26,110 --> 00:58:23,930
conference so it was very interesting to

1113
00:58:28,330 --> 00:58:26,120

hear this coming from two very very

1114
00:58:29,860 --> 00:58:28,340
different directions and almost from

1115
00:58:40,510 --> 00:58:29,870
research groups that would hardly ever

1116
00:58:42,730 --> 00:58:40,520
talk to each other no this probably

1117
00:58:45,490 --> 00:58:42,740
learned a lot more about this process of

1118
00:58:48,850 --> 00:58:45,500
the floating of the upper crust by study

1119
00:58:50,530 --> 00:58:48,860
of samples from later missions it seems

1120
00:58:53,110 --> 00:58:50,540
to be related to the presence of other

1121
00:58:56,020 --> 00:58:53,120
unusual rock types we're gonna see a

1122
00:59:00,820 --> 00:58:56,030
photo of of a couple of unusual rock

1123
00:59:05,020 --> 00:59:00,830
types the first one is a photograph of a

1124
00:59:06,940 --> 00:59:05,030
true an earth ID in a breccia many of

1125
00:59:10,360 --> 00:59:06,950
these samples were collected from

1126
00:59:12,820 --> 00:59:10,370
breakfast so this is a sample of that

1127
00:59:15,090 --> 00:59:12,830
outermost cross rich in an earth light

1128
00:59:19,420 --> 00:59:15,100
and high-end European Vincentelli

1129
00:59:23,260 --> 00:59:19,430
the next slide shows one of an alumnus

1130
00:59:26,200 --> 00:59:23,270
from Caltech an Apollo 17 collecting a

1131
00:59:29,410 --> 00:59:26,210
done night sample a sample consisting

1132
00:59:32,290 --> 00:59:29,420
almost entirely and there it is right

1133
00:59:34,570 --> 00:59:32,300
there where the X is and he knocked that

1134
00:59:39,840 --> 00:59:34,580
off and brought it back and it shows in

1135
00:59:43,080 --> 00:59:39,850
the next picture the next slide

1136
00:59:45,150 --> 00:59:43,090
and in this case it has been highly

1137
00:59:47,550 --> 00:59:45,160
fractured and crushed up and you can see

1138
00:59:50,910 --> 00:59:47,560

both the thin section and the actual

1139
00:59:53,280 --> 00:59:50,920
rock now tonight's are not uncommon on

1140
00:59:55,440 --> 00:59:53,290
earth we find similar fragments have

1141
01:00:01,380 --> 00:59:55,450
done item basalts that come up in Hawaii

1142
01:00:03,090 --> 01:00:01,390
and in our own desert then another one

1143
01:00:08,460 --> 01:00:03,100
if there are rocks we'll look at the

1144
01:00:11,190 --> 01:00:08,470
next slide this one is a complete puzzle

1145
01:00:14,430 --> 01:00:11,200
I wrote four papers on it and I still

1146
01:00:15,990 --> 01:00:14,440
don't know what it's trouble I ought to

1147
01:00:21,360 --> 01:00:16,000
write another one but I don't know any

1148
01:00:23,790 --> 01:00:21,370
better and iterate this is a rock very

1149
01:00:30,030 --> 01:00:23,800
rich in potassium rare earth elements

1150
01:00:32,310 --> 01:00:30,040
and phosphorus and it's just exceeded

1151
01:00:34,680 --> 01:00:32,320
and usuals in a sense it's like our

1152
01:00:37,470 --> 01:00:34,690
Granite's on earth but we don't know how

1153
01:00:40,290 --> 01:00:37,480
it fits in now each of the samples which

1154
01:00:45,420 --> 01:00:40,300
I pictured we have dated each of them

1155
01:00:47,220 --> 01:00:45,430
has dates of around 4.4 billion years so

1156
01:00:50,490 --> 01:00:47,230
they're telling us something about the

1157
01:00:54,210 --> 01:00:50,500
very very early evolution of moon but we

1158
01:00:56,220 --> 01:00:54,220
don't know exactly what not just used a

1159
01:00:58,380 --> 01:00:56,230
few intriguing detective stories and

1160
01:01:01,110 --> 01:00:58,390
every one of the hundreds of scientists

1161
01:01:02,910 --> 01:01:01,120
involved have their own favourites so

1162
01:01:05,610 --> 01:01:02,920
let me close with a summary of what I

1163
01:01:09,300 --> 01:01:05,620

think we learn from the Apollo missions

1164
01:01:11,250 --> 01:01:09,310
from a scientific sense lunar rock

1165
01:01:13,950 --> 01:01:11,260
studies have provided the cornerstone

1166
01:01:16,890 --> 01:01:13,960
for the scientific findings from lunar

1167
01:01:19,380 --> 01:01:16,900
exploration by spacecraft and such

1168
01:01:21,390 --> 01:01:19,390
studies are still ongoing with even

1169
01:01:23,460 --> 01:01:21,400
newer methods and samples that are not

1170
01:01:25,050 --> 01:01:23,470
yet been studied you may have recently

1171
01:01:27,000 --> 01:01:25,060
heard they are about to release some of

1172
01:01:30,660 --> 01:01:27,010
the ones that have been held in reserve

1173
01:01:32,880 --> 01:01:30,670
and will be then available for study and

1174
01:01:34,980 --> 01:01:32,890
and of course we've kept splits of

1175
01:01:37,470 --> 01:01:34,990
everything we worked on and those are

1176
01:01:38,610 --> 01:01:37,480
still available now these findings have

1177
01:01:42,000 --> 01:01:38,620
completely changed our understanding

1178
01:01:45,330 --> 01:01:42,010
moon and its evolution as well of that

1179
01:01:47,100 --> 01:01:45,340
of Earth and the other inter planets we

1180
01:01:49,950 --> 01:01:47,110
now understand that the lunar surface

1181
01:01:53,019 --> 01:01:49,960
features are predominantly the result of

1182
01:01:55,299 --> 01:01:53,029
impact by numerous huge projectiles

1183
01:01:57,909 --> 01:01:55,309
in the first half billion years of lunar

1184
01:02:00,339 --> 01:01:57,919
history and the most of the younger and

1185
01:02:04,179 --> 01:02:00,349
smaller craters were also formed by

1186
01:02:07,779 --> 01:02:04,189
impacts not by volcanism as commonly

1187
01:02:10,149 --> 01:02:07,789
thought the role of volcanism addicted

1188
01:02:13,269 --> 01:02:10,159

predominantly to the filling between

1189
01:02:16,659 --> 01:02:13,279
three and four billion years ago of the

1190
01:02:20,559 --> 01:02:16,669
Mari basins which in the cells resulted

1191
01:02:22,959 --> 01:02:20,569
from much earlier impacts the moon did

1192
01:02:26,349 --> 01:02:22,969
not form by slow aggregation of cold

1193
01:02:29,649 --> 01:02:26,359
particles that slowly heated up as was

1194
01:02:31,959 --> 01:02:29,659
one of the prime theories instead it was

1195
01:02:34,630 --> 01:02:31,969
covered in its early life by molten rock

1196
01:02:38,469 --> 01:02:34,640
from which a calcium aluminium silica

1197
01:02:40,989 --> 01:02:38,479
rich crust formed by floating floating

1198
01:02:44,349 --> 01:02:40,999
in the melt as a crystallized of the

1199
01:02:46,659 --> 01:02:44,359
mineral plagioclase as the outer part of

1200
01:02:50,339 --> 01:02:46,669
the moon became rigid the source of

1201
01:02:53,739 --> 01:02:50,349
volcanic lava migrated downward in depth

1202
01:02:56,529 --> 01:02:53,749
to below 500 kilometers for Nissim

1203
01:02:59,469 --> 01:02:56,539
experiments since three billion years

1204
01:03:03,699 --> 01:02:59,479
ago volcanism volcanic activity has been

1205
01:03:05,559 --> 01:03:03,709
very infrequent and localized one of the

1206
01:03:08,169 --> 01:03:05,569
most important things which we still

1207
01:03:10,509 --> 01:03:08,179
struggle with many geochemical

1208
01:03:13,359 --> 01:03:10,519
similarities show that moon and earth

1209
01:03:15,880 --> 01:03:13,369
must have formed in the same general

1210
01:03:19,269 --> 01:03:15,890
region of the solar system with a

1211
01:03:22,059 --> 01:03:19,279
relationship not yet understood they are

1212
01:03:26,979 --> 01:03:22,069
fundamentally different than your other

1213
01:03:29,789 --> 01:03:26,989

moons so all of this knowledge is a gift

1214
01:03:40,609 --> 01:03:29,799
of Apollo thank you

1215
01:03:46,910 --> 01:03:43,150
to cap off the evening we're going to

1216
01:03:50,239 --> 01:03:46,920
transition to a little discussion on the

1217
01:03:53,180 --> 01:03:50,249
Apollo era as it appeared to us here in

1218
01:03:54,769 --> 01:03:53,190
Pasadena and the legacy of Apollo I'd

1219
01:03:58,509 --> 01:03:54,779
like to welcome back Blaine and of

1220
01:04:01,339 --> 01:03:58,519
course dr. Albee and they're joined by

1221
01:04:07,069 --> 01:04:01,349
one of us JPL's greats who's coming up

1222
01:04:10,969 --> 01:04:07,079
on the stage now in his career in his

1223
01:04:12,799 --> 01:04:10,979
career he served in engineering

1224
01:04:14,509 --> 01:04:12,809
development roles on several early

1225
01:04:17,539 --> 01:04:14,519
launches to Earth orbit and the moon

1226
01:04:19,339 --> 01:04:17,549
including leading design the design team

1227
01:04:22,880 --> 01:04:19,349
for the Ranger spacecraft which Blaine

1228
01:04:24,229 --> 01:04:22,890
spoke of earlier he held senior project

1229
01:04:26,239 --> 01:04:24,239
positions and many of the Mariner

1230
01:04:29,239 --> 01:04:26,249
missions to Mars and Venus and was

1231
01:04:31,279 --> 01:04:29,249
project manager for three minor space

1232
01:04:33,499 --> 01:04:31,289
missions at JPL was involved in I think

1233
01:04:38,059 --> 01:04:33,509
they were called Galileo Cassini and

1234
01:04:41,390 --> 01:04:38,069
Voyager he also served as JPL's chief

1235
01:04:47,430 --> 01:04:41,400
engineer from 1994 to 99 joining Blaine

1236
01:04:51,880 --> 01:04:49,750
well I just I just have to say again

1237
01:04:54,220 --> 01:04:51,890
what an honor it is to be with both of

1238
01:04:56,470 --> 01:04:54,230

you it's it's a privilege what I'm going

1239
01:04:58,720 --> 01:04:56,480
to do is ask a few questions to get us

1240
01:05:01,660 --> 01:04:58,730
going and then I'm sure you have

1241
01:05:03,520 --> 01:05:01,670
questions and you somebody were standing

1242
01:05:04,870 --> 01:05:03,530
and we're so appreciative of being here

1243
01:05:06,790 --> 01:05:04,880
I want to make sure you get a chance to

1244
01:05:07,300 --> 01:05:06,800
ask some questions too before we call it

1245
01:05:10,270 --> 01:05:07,310
a night

1246
01:05:11,650 --> 01:05:10,280
but John we haven't heard from you so

1247
01:05:15,280 --> 01:05:11,660
we're going to give you a few minutes

1248
01:05:17,260 --> 01:05:15,290
here and since you were the you were in

1249
01:05:24,100 --> 01:05:17,270
charge of the design of the Rangers so

1250
01:05:25,420 --> 01:05:24,110
what were you doing wrong what was what

1251
01:05:27,520 --> 01:05:25,430
was your main problem that you were

1252
01:05:31,960 --> 01:05:27,530
having in the early days can you talk

1253
01:05:35,020 --> 01:05:31,970
about the hard time getting these very

1254
01:05:39,010 --> 01:05:35,030
liberal Caltech JPL type people to pay

1255
01:05:40,920 --> 01:05:39,020
any attention I solved that by taking

1256
01:05:47,100 --> 01:05:40,930
them out for a beer and

1257
01:05:48,300 --> 01:05:47,110
no I I you know it wasn't that we had

1258
01:05:49,920 --> 01:05:48,310
never done anything like this before

1259
01:05:50,700 --> 01:05:49,930
nobody had ever done anything like this

1260
01:05:52,890 --> 01:05:50,710
before

1261
01:05:54,960 --> 01:05:52,900
and the JPL at that time had been

1262
01:05:57,360 --> 01:05:54,970
involved with designing guided missiles

1263
01:05:58,770 --> 01:05:57,370

for the army and jato and stuff like

1264
01:06:00,270 --> 01:05:58,780
that and they were a bunch of very good

1265
01:06:02,940 --> 01:06:00,280
people there but they were getting a

1266
01:06:05,100 --> 01:06:02,950
little old like me and Arden are now and

1267
01:06:07,320 --> 01:06:05,110
they didn't want any part of designing

1268
01:06:09,360 --> 01:06:07,330
something that new but they knew what

1269
01:06:11,610 --> 01:06:09,370
the principles were they knew the things

1270
01:06:13,620 --> 01:06:11,620
that had to be done or the way that you

1271
01:06:15,560 --> 01:06:13,630
had to go about doing something very

1272
01:06:19,440 --> 01:06:15,570
complicated to make it successful

1273
01:06:21,630 --> 01:06:19,450
interfaces and making deals and having a

1274
01:06:23,760 --> 01:06:21,640
way of tracking whether your your

1275
01:06:26,160 --> 01:06:23,770
progress against them everybody had a

1276
01:06:28,430 --> 01:06:26,170
product and somebody's product was

1277
01:06:31,200 --> 01:06:28,440
somebody else's input and yeah

1278
01:06:34,520 --> 01:06:31,210
management and that whole concept of

1279
01:06:37,020 --> 01:06:34,530
deliverables receivables schedule

1280
01:06:39,360 --> 01:06:37,030
documenting what you needed to do that's

1281
01:06:41,100 --> 01:06:39,370
what they taught us and there were other

1282
01:06:43,140 --> 01:06:41,110
than that you know the rest of it

1283
01:06:45,960 --> 01:06:43,150
figuring out the nuts and bolts was

1284
01:06:50,130 --> 01:06:45,970
pretty much up to us nobody could help

1285
01:06:52,710 --> 01:06:50,140
us and they were smart enough let us go

1286
01:06:54,150 --> 01:06:52,720
and for the most part we were smart

1287
01:06:55,620 --> 01:06:54,160
enough to pay attention to what they

1288
01:06:58,050 --> 01:06:55,630

told us was important then we tried to

1289
01:07:00,030 --> 01:06:58,060
do that and somehow or another it seemed

1290
01:07:03,390 --> 01:07:00,040
to work I remember you telling me once

1291
01:07:05,190 --> 01:07:03,400
that we didn't know what we were trying

1292
01:07:07,770 --> 01:07:05,200
to do and there was no one who could

1293
01:07:09,150 --> 01:07:07,780
tell us what we were trying that's right

1294
01:07:11,220 --> 01:07:09,160
there was nobody that we could go and

1295
01:07:13,230 --> 01:07:11,230
ask you know what about this or what

1296
01:07:16,200 --> 01:07:13,240
about that because that was stuff that

1297
01:07:19,320 --> 01:07:16,210
nobody had ever done before yeah and

1298
01:07:22,920 --> 01:07:19,330
also the Rangers just to be clear about

1299
01:07:24,570 --> 01:07:22,930
this the Rangers had problems that 4/6

1300
01:07:27,450 --> 01:07:24,580
some of those failed just because the

1301
01:07:29,550 --> 01:07:27,460
Rockets weren't working the problem with

1302
01:07:32,160 --> 01:07:29,560
the spacecraft yeah the mission consists

1303
01:07:34,110 --> 01:07:32,170
of two parts right a launch vehicle to

1304
01:07:36,500 --> 01:07:34,120
get whatever you're launching up and

1305
01:07:39,000 --> 01:07:36,510
going and then the thing that you're

1306
01:07:41,760 --> 01:07:39,010
building the spacecraft goes on top of

1307
01:07:43,590 --> 01:07:41,770
the launch vehicle so the launch vehicle

1308
01:07:44,970 --> 01:07:43,600
guys were having problems and the

1309
01:07:47,280 --> 01:07:44,980
spacecraft people were having problems

1310
01:07:49,680 --> 01:07:47,290
Ranger one and two the first two

1311
01:07:51,300 --> 01:07:49,690
spacecraft worked perfectly but they

1312
01:07:53,070 --> 01:07:51,310
didn't but the ignitions were counted as

1313
01:07:53,750 --> 01:07:53,080

a failure because the launch vehicle how

1314
01:07:55,640 --> 01:07:53,760
did the launch

1315
01:07:57,650 --> 01:07:55,650
put it in orbit at the or if they went

1316
01:07:59,480 --> 01:07:57,660
around the earth and then halfway around

1317
01:08:01,370 --> 01:07:59,490
the Year at the first stage of the

1318
01:08:04,220 --> 01:08:01,380
launch vehicle I'll have to ignite a

1319
01:08:06,410 --> 01:08:04,230
second time and accelerate us out of

1320
01:08:09,140 --> 01:08:06,420
Earth orbit well the first time we did

1321
01:08:10,790 --> 01:08:09,150
that it didn't work and it was an Aegina

1322
01:08:12,800 --> 01:08:10,800
upper stage and somebody said well

1323
01:08:15,020 --> 01:08:12,810
there's a relay that didn't work and

1324
01:08:18,650 --> 01:08:15,030
it's a random failure and never happened

1325
01:08:20,809 --> 01:08:18,660
again and so okay and so so we

1326
01:08:22,809 --> 01:08:20,819
did this the stranger - and exactly the

1327
01:08:26,059 --> 01:08:22,819
same thing happened again

1328
01:08:27,620 --> 01:08:26,069
so those counters - Ranger failures but

1329
01:08:30,079 --> 01:08:27,630
those spacecrafts hadn't failed it was

1330
01:08:31,640 --> 01:08:30,089
the launch vehicle but then the Ranger

1331
01:08:33,829 --> 01:08:31,650
three and four of those were broke the

1332
01:08:35,960 --> 01:08:33,839
rainiest spacecraft failures and one of

1333
01:08:38,120 --> 01:08:35,970
them was a another rocket failure so it

1334
01:08:40,880 --> 01:08:38,130
was going back and forth but you know

1335
01:08:44,030 --> 01:08:40,890
from anybody yeah we have our who's our

1336
01:08:47,180 --> 01:08:44,040
community our community is our the

1337
01:08:48,590 --> 01:08:47,190
scientists and the engineers that are

1338
01:08:50,990 --> 01:08:48,600

working on this but also there's a

1339
01:08:52,670 --> 01:08:51,000
political community and the politicians

1340
01:08:54,920 --> 01:08:52,680
who are funding this and the Congress

1341
01:08:56,720 --> 01:08:54,930
and the newspapers I don't give a rat's

1342
01:08:58,550 --> 01:08:56,730
patootie we know whether it was the

1343
01:09:00,499 --> 01:08:58,560
spacecraft that failed or the launch

1344
01:09:03,920 --> 01:09:00,509
vehicle the damn mission didn't work and

1345
01:09:09,499 --> 01:09:03,930
so we had a lot of failures one after

1346
01:09:13,070 --> 01:09:09,509
another what did it do to your morale

1347
01:09:16,789 --> 01:09:13,080
what was it like here well it was sort

1348
01:09:19,970 --> 01:09:16,799
of disappointing but I think it's

1349
01:09:23,120 --> 01:09:19,980
bickering made a good answered that

1350
01:09:25,160 --> 01:09:23,130
question in one of your interview I'll

1351
01:09:28,579 --> 01:09:25,170
let you do that interview so you like

1352
01:09:29,749 --> 01:09:28,589
what he answered what he said was I

1353
01:09:31,700 --> 01:09:29,759
don't know if you picked it up in the

1354
01:09:33,769 --> 01:09:31,710
clip but somebody said wasn't it

1355
01:09:36,559 --> 01:09:33,779
demoralizing whatever all these failures

1356
01:09:39,289 --> 01:09:36,569
and he said no it wasn't he said because

1357
01:09:41,720 --> 01:09:39,299
what it did it made us more unified and

1358
01:09:45,349 --> 01:09:41,730
more committed to find the problem and

1359
01:09:46,340 --> 01:09:45,359
and and everybody pitched in and that's

1360
01:09:47,960 --> 01:09:46,350
where we learned you know it was a

1361
01:09:50,180 --> 01:09:47,970
really person you can't just do your own

1362
01:09:51,970 --> 01:09:50,190
job in this you also have to be looking

1363
01:09:53,960 --> 01:09:51,980

over your shoulder and watching what the

1364
01:09:55,910 --> 01:09:53,970
people next to you are doing because

1365
01:09:57,530 --> 01:09:55,920
what they're do they don't do it right

1366
01:09:59,540 --> 01:09:57,540
the missions not going to work and in

1367
01:10:02,690 --> 01:09:59,550
your old goats right so we everybody

1368
01:10:04,260 --> 01:10:02,700
wanted everybody to work well and so we

1369
01:10:07,470 --> 01:10:04,270
tried to help out and what

1370
01:10:09,000 --> 01:10:07,480
every whatever we could and so I think I

1371
01:10:10,500 --> 01:10:09,010
think that was that was good you know

1372
01:10:12,120 --> 01:10:10,510
it's funny thing about engineers they

1373
01:10:14,310 --> 01:10:12,130
like to solve problems that's what

1374
01:10:16,290 --> 01:10:14,320
engineers do and the heart of the

1375
01:10:17,850 --> 01:10:16,300
problem the better they like it and one

1376
01:10:20,190 --> 01:10:17,860
of the problems we have is you give an

1377
01:10:23,070 --> 01:10:20,200
engineer problem to work on it and if he

1378
01:10:25,520 --> 01:10:23,080
doesn't find it hard enough he'll find a

1379
01:10:28,140 --> 01:10:25,530
way to complexify

1380
01:10:30,780 --> 01:10:28,150
to make it something more fun to work on

1381
01:10:33,000 --> 01:10:30,790
so that was the other problem you know

1382
01:10:35,490 --> 01:10:33,010
it boils down to polishing the cannon

1383
01:10:37,080 --> 01:10:35,500
ball and you know the developed us

1384
01:10:39,210 --> 01:10:37,090
saying the better is the enemy of the

1385
01:10:40,890 --> 01:10:39,220
good you know it doesn't have to be

1386
01:10:42,420 --> 01:10:40,900
better it just has to be good it has to

1387
01:10:44,940 --> 01:10:42,430
be good enough and so and knowing when

1388
01:10:47,580 --> 01:10:44,950

to stop improving in things it's just

1389
01:10:51,540 --> 01:10:47,590
important as the knowing you know when

1390
01:10:58,950 --> 01:10:51,550
the fire a few managers to keep the

1391
01:11:00,870 --> 01:10:58,960
politicians well that's the other thing

1392
01:11:03,030 --> 01:11:00,880
too you know we don't fire a lot of

1393
01:11:06,330 --> 01:11:03,040
people from for making mistakes and in

1394
01:11:08,850 --> 01:11:06,340
fact you know sometimes a person who's

1395
01:11:11,730 --> 01:11:08,860
made a mistake having made that mistake

1396
01:11:13,650 --> 01:11:11,740
makes him more valuable or her more

1397
01:11:14,700 --> 01:11:13,660
valuable in the next assignment because

1398
01:11:16,530 --> 01:11:14,710
they've learned something you've made an

1399
01:11:22,700 --> 01:11:16,540
investment in that person a

1400
01:11:30,590 --> 01:11:26,010
I've been waiting all night to ask you

1401
01:11:35,550 --> 01:11:30,600
this question we know that the Russians

1402
01:11:39,480 --> 01:11:35,560
early on sent up dogs into space and I

1403
01:11:42,600 --> 01:11:39,490
have read that you were among some here

1404
01:11:47,040 --> 01:11:42,610
at JPL thinking about sending dogs to

1405
01:11:49,260 --> 01:11:47,050
the moon well we were part of the

1406
01:11:51,420 --> 01:11:49,270
initial initial task force of trying to

1407
01:11:54,060 --> 01:11:51,430
figure out how to put astronauts on the

1408
01:11:56,160 --> 01:11:54,070
moon so all the all the center's were we

1409
01:11:58,320 --> 01:11:56,170
got a bunch of people they worked under

1410
01:11:59,940 --> 01:11:58,330
a guy by name is Charlie Cole they

1411
01:12:01,320 --> 01:11:59,950
called him Cole's commanders and they

1412
01:12:03,450 --> 01:12:01,330
went back to Washington and they were

1413
01:12:05,610 --> 01:12:03,460

helping do the architecture of this

1414
01:12:07,080 --> 01:12:05,620
whole Apollo program and the whole thing

1415
01:12:08,220 --> 01:12:07,090
was gonna be putting men on the moon and

1416
01:12:10,800 --> 01:12:08,230
there were some of us back here is that

1417
01:12:13,050 --> 01:12:10,810
is crazy what are you gonna put people

1418
01:12:14,340 --> 01:12:13,060
on the moon hey there's nowhere up there

1419
01:12:15,720 --> 01:12:14,350
gonna breathe here you can put him in

1420
01:12:18,960 --> 01:12:15,730
the spacesuit then you got to get them

1421
01:12:21,870 --> 01:12:18,970
back somebody says well why don't we why

1422
01:12:24,180 --> 01:12:21,880
don't we train some dogs you can train

1423
01:12:25,650 --> 01:12:24,190
dogs to do remarkable things you know we

1424
01:12:27,330 --> 01:12:25,660
can teach them what they need to do in

1425
01:12:29,340 --> 01:12:27,340
the way of a jealous is how to use a

1426
01:12:32,010 --> 01:12:29,350
hammer or something like that put them

1427
01:12:33,630 --> 01:12:32,020
put him in a little space suits and send

1428
01:12:35,910 --> 01:12:33,640
them up the moon and then you know when

1429
01:12:37,110 --> 01:12:35,920
they're done okay they die but the you

1430
01:12:45,840 --> 01:12:37,120
don't have to worry about bringing them

1431
01:12:51,420 --> 01:12:45,850
back so that way we actually I'm neutral

1432
01:12:54,510 --> 01:12:51,430
about dogs but I have a dog have a

1433
01:12:57,500 --> 01:12:54,520
summer way of an affinity for me and

1434
01:12:59,760 --> 01:12:57,510
sort of dotes goats and dogs love me

1435
01:13:05,430 --> 01:12:59,770
I'll tell you the story about the goat

1436
01:13:09,510 --> 01:13:05,440
sometimes so so the idea obviously went

1437
01:13:13,320 --> 01:13:09,520
nowhere very fast yeah so Arden I want

1438
01:13:15,180 --> 01:13:13,330

to ask about the origins of the moon can

1439
01:13:17,700 --> 01:13:15,190
you can you speak about what some of the

1440
01:13:22,110 --> 01:13:17,710
thoughts are that scientists have about

1441
01:13:24,360 --> 01:13:22,120
how our moon came to be well we know

1442
01:13:27,320 --> 01:13:24,370
because of the geochemical similarities

1443
01:13:30,810 --> 01:13:27,330
that earth and moon are closely related

1444
01:13:33,990 --> 01:13:30,820
they were formed from the same if you

1445
01:13:36,060 --> 01:13:34,000
will batch of meteorites what we don't

1446
01:13:38,420 --> 01:13:36,070
know is exactly how they're reared

1447
01:13:41,310 --> 01:13:38,430
whether they collided change matter

1448
01:13:43,620 --> 01:13:41,320
these sorts of things there are a number

1449
01:13:46,140 --> 01:13:43,630
of the basic theory that is now

1450
01:13:49,830 --> 01:13:46,150
operating and which people are working

1451
01:13:51,540 --> 01:13:49,840
in great details of the details of the

1452
01:13:55,220 --> 01:13:51,550
collision process and everything is

1453
01:13:58,860 --> 01:13:55,230
there was a collision between two major

1454
01:14:02,250 --> 01:13:58,870
asteroids one of which basically became

1455
01:14:05,880 --> 01:14:02,260
earth and this collision combined many

1456
01:14:08,550 --> 01:14:05,890
of the materials in the two so that we

1457
01:14:11,070 --> 01:14:08,560
know but exactly the details of it we

1458
01:14:14,210 --> 01:14:11,080
don't every there's an every issue

1459
01:14:17,640 --> 01:14:14,220
there's a new slightly different touch

1460
01:14:20,100 --> 01:14:17,650
but this was the sort of the theory goes

1461
01:14:23,260 --> 01:14:20,110
it was four and a half billion years ago

1462
01:14:25,390 --> 01:14:23,270
about my time right six billion years

1463
01:14:26,470 --> 01:14:25,400

huh about the time of the earth was

1464
01:14:28,030 --> 01:14:26,480
performed too right

1465
01:14:34,360 --> 01:14:28,040
yeah their votes were formed at them

1466
01:14:36,820 --> 01:14:34,370
about at the same time and the key thing

1467
01:14:40,540 --> 01:14:36,830
really that makes them come together are

1468
01:14:43,000 --> 01:14:40,550
the oxygen isotopes they are so similar

1469
01:14:45,220 --> 01:14:43,010
to each other and so different from

1470
01:14:47,950 --> 01:14:45,230
other meteorites and so on so it's a

1471
01:14:52,000 --> 01:14:47,960
unique circumstance sort of the same

1472
01:14:53,680 --> 01:14:52,010
genetic or geologic code right and in

1473
01:14:56,500 --> 01:14:53,690
how can you talk a little bit when you

1474
01:14:59,790 --> 01:14:56,510
when you mentioned the the molten sea

1475
01:15:02,350 --> 01:14:59,800
the ocean is did it cover the entire orb

1476
01:15:05,100 --> 01:15:02,360
sort of have this incredible vision of

1477
01:15:09,790 --> 01:15:05,110
the whole the highlands are that frozen

1478
01:15:13,090 --> 01:15:09,800
magma and they cover everywhere around

1479
01:15:17,160 --> 01:15:13,100
the moon so yes it was a cooling it's

1480
01:15:20,560 --> 01:15:17,170
how the moon cooled and crystallized

1481
01:15:22,350 --> 01:15:20,570
okay so I'd like to throw it open to

1482
01:15:24,340 --> 01:15:22,360
some questions from the audience if

1483
01:15:28,180 --> 01:15:24,350
everyone would like to come up to the

1484
01:15:29,530 --> 01:15:28,190
mic we have a mic over here I'd like to

1485
01:15:31,840 --> 01:15:29,540
ask if there were any differences

1486
01:15:35,560 --> 01:15:31,850
between the different Ranger probes from

1487
01:15:38,350 --> 01:15:35,570
1 to 6 we developed the Rangers sort of

1488
01:15:40,210 --> 01:15:38,360

like the III compared it to Volkswagen

1489
01:15:42,040 --> 01:15:40,220
whoever had owned a bug you know they

1490
01:15:44,050 --> 01:15:42,050
all look the same on the outside but if

1491
01:15:45,490 --> 01:15:44,060
you buy one one year and then you buy

1492
01:15:46,600 --> 01:15:45,500
another one three years from now it

1493
01:15:48,910 --> 01:15:46,610
looks the same but they've made

1494
01:15:51,700 --> 01:15:48,920
improvements under the hood you know and

1495
01:15:53,380 --> 01:15:51,710
a series of gradual gradual improvements

1496
01:15:56,830 --> 01:15:53,390
and that's the way we develop the Ranger

1497
01:15:58,960 --> 01:15:56,840
Ranger 1 & 2 are well the Ranger

1498
01:16:02,680 --> 01:15:58,970
spacecraft had to be 3-axis stabilized

1499
01:16:05,140 --> 01:16:02,690
you know you have roll pitch and yaw and

1500
01:16:07,480 --> 01:16:05,150
when we did first Ranger 1 we only

1501
01:16:11,530 --> 01:16:07,490
controlled it in pitch and yaw we didn't

1502
01:16:13,780 --> 01:16:11,540
worry about roll okay the on the out the

1503
01:16:16,390 --> 01:16:13,790
side we had an antenna that had a point

1504
01:16:18,460 --> 01:16:16,400
to the earth well at the roll position

1505
01:16:20,080 --> 01:16:18,470
matter you know we because that's

1506
01:16:21,940 --> 01:16:20,090
another way of positioning the antenna

1507
01:16:23,560 --> 01:16:21,950
getting the pitch and you alright but

1508
01:16:25,420 --> 01:16:23,570
also the roll but for the four Ranger

1509
01:16:27,700 --> 01:16:25,430
one and two didn't we didn't control

1510
01:16:30,070 --> 01:16:27,710
roll and then and then we didn't have

1511
01:16:32,350 --> 01:16:30,080
any propulsion on it and then Ranger 3 4

1512
01:16:33,200 --> 01:16:32,360
and 5 we put roll control so we could

1513
01:16:35,660 --> 01:16:33,210

point the ant

1514
01:16:37,880 --> 01:16:35,670
and then we added propulsion so we each

1515
01:16:39,890 --> 01:16:37,890
each one of those Rangers had an

1516
01:16:41,840 --> 01:16:39,900
incremental capability that was

1517
01:16:43,640 --> 01:16:41,850
engineered into it but every one of them

1518
01:16:48,050 --> 01:16:43,650
built on the earlier one so it was a

1519
01:16:50,419 --> 01:16:48,060
progressive stepwise development the

1520
01:16:54,410 --> 01:16:50,429
fact that the first project manager told

1521
01:16:56,689 --> 01:16:54,420
me this story that what was thrown at

1522
01:17:00,850 --> 01:16:56,699
the project very early on they had not

1523
01:17:04,189 --> 01:17:00,860
fully anticipated was contamination that

1524
01:17:07,189 --> 01:17:04,199
NASA put the requirement that we

1525
01:17:10,970 --> 01:17:07,199
sterilize the spacecraft and that meant

1526
01:17:12,740 --> 01:17:10,980
baking them and and we were your baking

1527
01:17:14,149 --> 01:17:12,750
your electronics at a point where you

1528
01:17:16,280 --> 01:17:14,159
didn't realize you were going to have to

1529
01:17:17,630 --> 01:17:16,290
bake your electron we didn't that was

1530
01:17:21,310 --> 01:17:17,640
not part of the original design

1531
01:17:24,410 --> 01:17:21,320
requirement and I was running the Ranger

1532
01:17:27,229 --> 01:17:24,420
1/2 program and we had a big battery in

1533
01:17:29,120 --> 01:17:27,239
the middle of it and they said you know

1534
01:17:30,860 --> 01:17:29,130
you got to sterilize this battery I said

1535
01:17:32,600 --> 01:17:30,870
well we did a second we they weren't

1536
01:17:35,510 --> 01:17:32,610
designed to be sterilized well you got

1537
01:17:37,910 --> 01:17:35,520
to do it so we talked to some people and

1538
01:17:41,209 --> 01:17:37,920

say yeah if you heat it up to you know

1539
01:17:44,260 --> 01:17:41,219
125 degrees centigrade for 34 hours that

1540
01:17:46,520 --> 01:17:44,270
ought to kill anything that's in the air

1541
01:17:47,839 --> 01:17:46,530
turned out it killed the battery but we

1542
01:17:51,470 --> 01:17:47,849
didn't know it

1543
01:17:54,050 --> 01:17:51,480
at the time and a few weeks later over

1544
01:17:55,790 --> 01:17:54,060
weekend in the up with the spray the

1545
01:17:58,490 --> 01:17:55,800
spacecraft with a battery in it up in

1546
01:18:00,319 --> 01:17:58,500
our the building of building 18 that we

1547
01:18:03,260 --> 01:18:00,329
were testing it at a time the battery

1548
01:18:05,330 --> 01:18:03,270
exploded and a electrolyte all over the

1549
01:18:06,740 --> 01:18:05,340
spacecraft and everything else so we

1550
01:18:08,709 --> 01:18:06,750
said holy mackerel you know that's not a

1551
01:18:10,790 --> 01:18:08,719
good idea

1552
01:18:12,500 --> 01:18:10,800
we were probably didn't know for sure

1553
01:18:15,589 --> 01:18:12,510
but we were pretty sure that it was the

1554
01:18:17,240 --> 01:18:15,599
heat sterilization because you know

1555
01:18:21,439 --> 01:18:17,250
people didn't news they do that to

1556
01:18:23,390 --> 01:18:21,449
batteries though Oh after that we put a

1557
01:18:25,819 --> 01:18:23,400
temperature on it and put a new battery

1558
01:18:28,669 --> 01:18:25,829
in and clean it up and we watch the

1559
01:18:32,120 --> 01:18:28,679
temperature every continually and so I

1560
01:18:33,470 --> 01:18:32,130
got a call one one night and I don't

1561
01:18:35,060 --> 01:18:33,480
think it was Thanksgiving but it was

1562
01:18:36,919 --> 01:18:35,070
Thanksgiving weekend and it says the

1563
01:18:39,290 --> 01:18:36,929

temperature's going up John me what are

1564
01:18:41,169 --> 01:18:39,300
you gonna do about it so I said well and

1565
01:18:43,790 --> 01:18:41,179
I called up I said call up a technician

1566
01:18:46,520 --> 01:18:43,800
and have him meet me in there I was in a

1567
01:18:48,200 --> 01:18:46,530
little test chamber outside building 18

1568
01:18:51,919 --> 01:18:48,210
and we climbed up on the chamber up a

1569
01:18:54,890 --> 01:18:51,929
little Derrick kind of a thing and I

1570
01:18:56,330 --> 01:18:54,900
could remember this yeah he said bring

1571
01:19:00,290 --> 01:18:56,340
your drill motor and a quarter inch

1572
01:19:01,640 --> 01:19:00,300
drill and so when we got up in there he

1573
01:19:03,200 --> 01:19:01,650
said what do you want me to do I said I

1574
01:19:04,970 --> 01:19:03,210
want you to drill a hole in the top of

1575
01:19:10,069 --> 01:19:04,980
that battery and he said what are you

1576
01:19:12,119 --> 01:19:10,079
gonna do I'm gonna stand back here but

1577
01:19:15,629 --> 01:19:12,129
it works fine

1578
01:19:17,669 --> 01:19:15,639
yes her earlier this evening we saw a

1579
01:19:20,879 --> 01:19:17,679
picture of the footprint of a surveyor

1580
01:19:23,969 --> 01:19:20,889
on the moon we wouldn't be seeing the

1581
01:19:26,639 --> 01:19:23,979
footprint if the foot pad wasn't in it

1582
01:19:32,549 --> 01:19:26,649
so did surveyor bounce is that why we're

1583
01:19:35,219 --> 01:19:32,559
seeing the footprint my understanding on

1584
01:19:39,629 --> 01:19:35,229
surveyor three because I'd listened to

1585
01:19:41,909 --> 01:19:39,639
the audio of the transcript of beaten

1586
01:19:44,909 --> 01:19:41,919
owl what they were saying through that

1587
01:19:47,580 --> 01:19:44,919
period is that it laid in a bit of a

1588
01:19:50,849 --> 01:19:47,590

incline and so it slid just a little bit

1589
01:19:51,689 --> 01:19:50,859
to get to get to give me that okay thank

1590
01:19:56,099 --> 01:19:51,699
you

1591
01:19:57,569 --> 01:19:56,109
I guess this questions for dr. ellby I

1592
01:20:00,649 --> 01:19:57,579
was wondering if you could tell us a

1593
01:20:03,209 --> 01:20:00,659
little bit about the history and

1594
01:20:06,270 --> 01:20:03,219
mineralogy of the lunar sample that's in

1595
01:20:07,649 --> 01:20:06,280
the museum I don't even know which one

1596
01:20:11,129 --> 01:20:07,659
is in there I don't know whether it's

1597
01:20:13,529 --> 01:20:11,139
the breakfast salt these were

1598
01:20:15,060 --> 01:20:13,539
distributed to the various centers and I

1599
01:20:19,379 --> 01:20:15,070
don't believe I've ever looked at the

1600
01:20:22,109 --> 01:20:19,389
one it's in here what number is on it I

1601
01:20:26,299 --> 01:20:22,119
might know of by that I could check if

1602
01:20:29,279 --> 01:20:26,309
you want or I'll look at afterwards

1603
01:20:34,109 --> 01:20:29,289
person with the name let's get outside

1604
01:20:36,089 --> 01:20:34,119
now wants to ask dr. Albee what it what

1605
01:20:37,709 --> 01:20:36,099
did you think when you first held a

1606
01:20:39,659 --> 01:20:37,719
piece of the moon when you first had

1607
01:20:43,379 --> 01:20:39,669
access to a lunar sample yourself what

1608
01:20:46,859 --> 01:20:43,389
was that like well I try to convey that

1609
01:20:49,679 --> 01:20:46,869
you know when you look at that soil

1610
01:20:55,529 --> 01:20:49,689
sample you just have to go gasp because

1611
01:20:57,589 --> 01:20:55,539
those glass balls just are crazy and you

1612
01:21:01,529 --> 01:20:57,599
know you didn't expect them to be there

1613
01:21:03,209 --> 01:21:01,539

why are you having beautiful spheres but

1614
01:21:05,609 --> 01:21:03,219
you do and they're everywhere on the

1615
01:21:06,089 --> 01:21:05,619
soil and one more question from social

1616
01:21:09,270 --> 01:21:06,099
media

1617
01:21:11,549 --> 01:21:09,280
Joshua Z wants to know what do you you

1618
01:21:14,429 --> 01:21:11,559
guys think are the best ways to expose

1619
01:21:16,349 --> 01:21:14,439
new generations to the legacy of Apollo

1620
01:21:17,669 --> 01:21:16,359
to the vast amount of information and

1621
01:21:19,770 --> 01:21:17,679
what we learned what do you think we

1622
01:21:22,139 --> 01:21:19,780
should be doing to communicate that

1623
01:21:23,939 --> 01:21:22,149
forward there's there's a certain thing

1624
01:21:25,830 --> 01:21:23,949
called the Apollo effect

1625
01:21:28,770 --> 01:21:25,840
have you guys heard about that when the

1626
01:21:30,120 --> 01:21:28,780
Apollo mission it sort of inspired first

1627
01:21:31,830 --> 01:21:30,130
of all we're spending so much money on

1628
01:21:34,169 --> 01:21:31,840
the program and there weren't enough

1629
01:21:36,120 --> 01:21:34,179
engineers or science or technologists

1630
01:21:37,500 --> 01:21:36,130
and involved in the country really to do

1631
01:21:39,600 --> 01:21:37,510
all the work that need to be done and so

1632
01:21:41,910 --> 01:21:39,610
and and it was some exciting ideas

1633
01:21:44,580 --> 01:21:41,920
sending men to the moon and it attracted

1634
01:21:46,500 --> 01:21:44,590
a lot of young people that would have

1635
01:21:49,830 --> 01:21:46,510
otherwise wasted their college years

1636
01:21:51,870 --> 01:21:49,840
being lawyers or doctors didn't have to

1637
01:21:54,570 --> 01:21:51,880
go into science engineering and

1638
01:21:58,350 --> 01:21:54,580

technology and I think that was really

1639
01:22:00,300 --> 01:21:58,360
the thing that hold that that made the

1640
01:22:01,740 --> 01:22:00,310
whole space program eventually possible

1641
01:22:04,169 --> 01:22:01,750
you know all the things that we're doing

1642
01:22:05,669 --> 01:22:04,179
today and done afterwards you know

1643
01:22:08,189 --> 01:22:05,679
whatever they are all happened because

1644
01:22:09,990 --> 01:22:08,199
of that influx and other countries I

1645
01:22:12,000 --> 01:22:10,000
think jumped into the bond about on the

1646
01:22:13,290 --> 01:22:12,010
wagon to it China and India and

1647
01:22:14,520 --> 01:22:13,300
everything else they know about the

1648
01:22:15,030 --> 01:22:14,530
Paulo effect and that's what they're

1649
01:22:16,919 --> 01:22:15,040
doing

1650
01:22:20,610 --> 01:22:16,929
that's and that's why they're in it now

1651
01:22:22,200 --> 01:22:20,620
you know so I think the thing to get

1652
01:22:25,650 --> 01:22:22,210
people get people in is to make sure

1653
01:22:28,260 --> 01:22:25,660
that the missions we do from now on are

1654
01:22:31,470 --> 01:22:28,270
not just science missions you know which

1655
01:22:34,229 --> 01:22:31,480
is good but not just technology missions

1656
01:22:36,120 --> 01:22:34,239
which are good but are publicly engaging

1657
01:22:38,340 --> 01:22:36,130
at our missions that capture the

1658
01:22:41,010 --> 01:22:38,350
imagination of young people and get them

1659
01:22:48,470 --> 01:22:41,020
interested in it and following it that's

1660
01:22:49,979 --> 01:22:48,480
but you know what the hell do I know all

1661
01:22:53,880 --> 01:22:49,989
right thank you

1662
01:22:56,700 --> 01:22:53,890
next question hi as we enter a new era

1663
01:22:58,350 --> 01:22:56,710

of a new era of spaceflight what are the

1664
01:23:01,890 --> 01:22:58,360
most important lessons to remember from

1665
01:23:04,350 --> 01:23:01,900
your era of space exploration well

1666
01:23:07,140 --> 01:23:04,360
there's a continual transept transition

1667
01:23:11,070 --> 01:23:07,150
you have to remember Apollo basically

1668
01:23:14,939 --> 01:23:11,080
had no computers and now a spacecraft is

1669
01:23:17,130 --> 01:23:14,949
filled with computers I mean the the

1670
01:23:19,500 --> 01:23:17,140
whole arrangements of dinner when we

1671
01:23:22,110 --> 01:23:19,510
flew Mars surveyor we basically had a

1672
01:23:24,959 --> 01:23:22,120
network onboard connecting all the

1673
01:23:27,419 --> 01:23:24,969
instruments the spacecraft and all the

1674
01:23:31,709 --> 01:23:27,429
parts of the spacecraft it basically was

1675
01:23:34,229 --> 01:23:31,719
like a Wi-Fi network so that mounted

1676
01:23:38,569 --> 01:23:34,239
transition happened between Apollo and

1677
01:23:40,950 --> 01:23:38,579
the next few missions at JPL began doing

1678
01:23:42,390 --> 01:23:40,960
what about you John what are you what

1679
01:23:45,930 --> 01:23:42,400
advice would you have to the next

1680
01:23:47,609 --> 01:23:45,940
generation of Engineers and I mean

1681
01:23:50,310 --> 01:23:47,619
there's so many dimensions that question

1682
01:23:52,410 --> 01:23:50,320
if you're talking about what does it

1683
01:23:54,299 --> 01:23:52,420
take in terms of engineering and

1684
01:23:58,049 --> 01:23:54,309
development to make something successful

1685
01:24:00,660 --> 01:23:58,059
or what how do you how do you to coach

1686
01:24:03,240 --> 01:24:00,670
people to do things so that they'll last

1687
01:24:05,280 --> 01:24:03,250
a long while well we learned that very

1688
01:24:07,140 --> 01:24:05,290

slowly and very painfully over a long

1689
01:24:10,319 --> 01:24:07,150
period of time and it used to be the

1690
01:24:13,530 --> 01:24:10,329
main problem was twofold but the first

1691
01:24:16,589 --> 01:24:13,540
one was parts electronic parts you know

1692
01:24:19,560 --> 01:24:16,599
we we didn't most most of the things you

1693
01:24:21,209 --> 01:24:19,570
you had vacuum tubes you know that you

1694
01:24:22,890 --> 01:24:21,219
couldn't depend on a vacuum tube the

1695
01:24:24,540 --> 01:24:22,900
last more than three or four years if

1696
01:24:26,580 --> 01:24:24,550
you had a no none of you are old enough

1697
01:24:28,859 --> 01:24:26,590
to remember television sets with vacuum

1698
01:24:31,169 --> 01:24:28,869
tubes but but you know you'd have to

1699
01:24:33,209 --> 01:24:31,179
call a TV repairman and he'd come up

1700
01:24:36,120 --> 01:24:33,219
with his bag of backing tubes and put

1701
01:24:37,830 --> 01:24:36,130
new vacuum tube in or he'd say to your

1702
01:24:39,270 --> 01:24:37,840
wife you know he want you to plug the

1703
01:24:41,010 --> 01:24:39,280
vacuum cleaner and you got to remember

1704
01:24:43,830 --> 01:24:41,020
when you're through vacuuming to plug

1705
01:24:45,870 --> 01:24:43,840
the TV back in we had a lot of we had a

1706
01:24:48,770 --> 01:24:45,880
lot of calls like that and then things

1707
01:24:52,459 --> 01:24:48,780
would fail and so when we got into AI

1708
01:24:54,839 --> 01:24:52,469
transistors were invented in 1954 or

1709
01:24:56,729 --> 01:24:54,849
1953 I was still in college I was

1710
01:24:58,620 --> 01:24:56,739
learning about vacuums it was and they

1711
01:25:00,060 --> 01:24:58,630
brought these transistors in and is that

1712
01:25:02,459 --> 01:25:00,070
you know you couldn't even get it was

1713
01:25:06,209 --> 01:25:02,469

shock from touching one so people didn't

1714
01:25:08,040 --> 01:25:06,219
believe they could do it anything what

1715
01:25:10,379 --> 01:25:08,050
you could do invent cell phones because

1716
01:25:12,450 --> 01:25:10,389
if you sell a billion cell phones you

1717
01:25:15,060 --> 01:25:12,460
just put an incredible amount of money

1718
01:25:17,310 --> 01:25:15,070
into developing new techniques I mean

1719
01:25:19,200 --> 01:25:17,320
all these micro spacecraft which we're

1720
01:25:21,660 --> 01:25:19,210
talking about oh it directly to

1721
01:25:22,799 --> 01:25:21,670
cellphones but in the development

1722
01:25:24,689 --> 01:25:22,809
program something will go wrong

1723
01:25:26,399 --> 01:25:24,699
something always goes wrong and the

1724
01:25:29,040 --> 01:25:26,409
thing of it is anything that goes wrong

1725
01:25:31,379 --> 01:25:29,050
you have to follow that to the root

1726
01:25:33,930 --> 01:25:31,389
cause you have to drill down and find

1727
01:25:37,109 --> 01:25:33,940
out exactly to the degree that you can

1728
01:25:39,149 --> 01:25:37,119
what happened and didn't do what you can

1729
01:25:40,709 --> 01:25:39,159
do or what you need to do to prevent

1730
01:25:44,160 --> 01:25:40,719
that thing from happening again and

1731
01:25:45,569 --> 01:25:44,170
that's at Aegis and it's you know but

1732
01:25:47,069 --> 01:25:45,579
you have to have that discipline and

1733
01:25:49,500 --> 01:25:47,079
unless you have that discipline and

1734
01:25:52,440 --> 01:25:49,510
instill in the young people you know the

1735
01:25:53,880 --> 01:25:52,450
to do that because they just want to fix

1736
01:25:55,530 --> 01:25:53,890
it and then go on but just fixing in

1737
01:25:57,960 --> 01:25:55,540
going on doesn't mean it's gonna happen

1738
01:26:00,480 --> 01:25:57,970

again you have to do find out why it

1739
01:26:03,210 --> 01:26:00,490
went wrong and fix it and fix the thing

1740
01:26:04,770 --> 01:26:03,220
that caused it to go wrong and and then

1741
01:26:06,600 --> 01:26:04,780
you're then you're on a good track but

1742
01:26:10,710 --> 01:26:06,610
that takes discipline and it takes a lot

1743
01:26:13,260 --> 01:26:10,720
of tedious work and it's not fun always

1744
01:26:14,640 --> 01:26:13,270
you know that's where yeah that's why

1745
01:26:17,640 --> 01:26:14,650
you go out and have a beer at the end of

1746
01:26:19,590 --> 01:26:17,650
the day thank you

1747
01:26:22,680 --> 01:26:19,600
building all that I think the two things

1748
01:26:25,350 --> 01:26:22,690
looking from my perspective I see

1749
01:26:28,860 --> 01:26:25,360
engineers working on is miniaturization

1750
01:26:30,810 --> 01:26:28,870
is very very key and and the second is

1751
01:26:32,940 --> 01:26:30,820
the complexity of the software these

1752
01:26:34,370 --> 01:26:32,950
days it's software oftentimes what's

1753
01:26:36,450 --> 01:26:34,380
going to get you before the hardware

1754
01:26:38,910 --> 01:26:36,460
we've got time for just a couple more

1755
01:26:40,920 --> 01:26:38,920
questions I think so okay so that I do

1756
01:26:42,630 --> 01:26:40,930
brilliant ideas setting off from nuclear

1757
01:26:45,570 --> 01:26:42,640
bomb on the moon is very intriguing to

1758
01:26:47,460 --> 01:26:45,580
me who talked Robert McNamara down and

1759
01:26:51,360 --> 01:26:47,470
what was the story behind that

1760
01:26:53,010 --> 01:26:51,370
no it wasn't McNamara it was I mean it

1761
01:26:54,990 --> 01:26:53,020
was there was someone in the Department

1762
01:26:59,160 --> 01:26:55,000
of Defense in the Air Force working on

1763
01:27:01,800 --> 01:26:59,170

that but you know our Defense

1764
01:27:03,420 --> 01:27:01,810
Department's always working on ideas you

1765
01:27:05,100 --> 01:27:03,430
know crazy ideas they're working on

1766
01:27:07,200 --> 01:27:05,110
crazy ideals now but some of them end up

1767
01:27:11,040 --> 01:27:07,210
being technologically interesting and

1768
01:27:17,010 --> 01:27:11,050
good ideas so this was just one what

1769
01:27:19,230 --> 01:27:17,020
space debris did they know about space

1770
01:27:21,360 --> 01:27:19,240
debris yes yes I'm sure they did but to

1771
01:27:24,090 --> 01:27:21,370
the what it would do in terms of you

1772
01:27:25,680 --> 01:27:24,100
know the quarter million miles away I

1773
01:27:27,360 --> 01:27:25,690
don't know if they were particularly

1774
01:27:30,870 --> 01:27:27,370
worried about that aspect of it okay

1775
01:27:34,200 --> 01:27:30,880
thank you okay hi I'd like to know which

1776
01:27:36,290 --> 01:27:34,210
of the seven Ranger probes cost the most

1777
01:27:42,240 --> 01:27:36,300
based on the parts used to build them

1778
01:27:43,320 --> 01:27:42,250
it's a budget we've got an accountant on

1779
01:27:45,420 --> 01:27:43,330
their hands

1780
01:27:47,670 --> 01:27:45,430
well I don't know if we could actually

1781
01:27:49,110 --> 01:27:47,680
identify the cost of each individual

1782
01:27:51,810 --> 01:27:49,120
Ranger because where they were built as

1783
01:27:53,910 --> 01:27:51,820
a program you know but the the each one

1784
01:27:57,060 --> 01:27:53,920
had more capability and was able to do

1785
01:27:59,850 --> 01:27:57,070
more things and so you know the Ranger 3

1786
01:28:02,610 --> 01:27:59,860
4 5 costs more than Ranger 1 and 2 and

1787
01:28:05,220 --> 01:28:02,620
Rangers 5 6 and cost more than 3 and 4

1788
01:28:07,170 --> 01:28:05,230

and then when and because there were so

1789
01:28:09,480 --> 01:28:07,180
many failures you know then we had to

1790
01:28:11,310 --> 01:28:09,490
bore in on those failures that I was

1791
01:28:13,440 --> 01:28:11,320
talking about before that meant more

1792
01:28:16,020 --> 01:28:13,450
work more people more time more testing

1793
01:28:18,960 --> 01:28:16,030
so each one of them I would say what

1794
01:28:20,820 --> 01:28:18,970
cost more than the one before and so the

1795
01:28:23,130 --> 01:28:20,830
most expensive one which would have been

1796
01:28:25,200 --> 01:28:23,140
the last one which was what Ranger 10 I

1797
01:28:26,520 --> 01:28:25,210
guess that's about all the time we have

1798
01:28:29,100 --> 01:28:26,530
for tonight I'd like to thank everyone

1799
01:28:38,709 --> 01:28:29,110
here and online for joining us and thank

1800
01:28:43,630 --> 01:28:42,040
so join us again next month for our show

1801
01:28:46,420 --> 01:28:43,640
on comets asteroids and dwarf planets

1802
01:28:48,600 --> 01:28:46,430
it's the big science of the small worlds