1
00:00:06,950 --> 00:00:04,950
hello i'm dc eagle of nasa's jet

2
00:00:08,790 --> 00:00:06,960
propulsion lab we're here to talk about

3
00:00:10,950 --> 00:00:08,800
the science of the grill mission to the

4
00:00:13,990 --> 00:00:10,960
moon here to talk about grail we have

5
00:00:17,189 --> 00:00:15,350
bobby fogle

6
00:00:21,990 --> 00:00:17,199
grail program scientist

7
00:00:27,509 --> 00:00:25,109
maria zuber grill principal investigator

8
00:00:31,669 --> 00:00:27,519
massachusetts institute of technology

9
00:00:35,590 --> 00:00:33,110
sammy asmr

10
00:00:40,229 --> 00:00:35,600
grail deputy project scientist nasa's

11
00:00:44,709 --> 00:00:42,950
and lisa hubbard teacher in residence

12
00:00:47,910 --> 00:00:44,719
sally wright science

13
00:00:51,830 --> 00:00:50,389

and we'll open it up with bobby fogle

14
00:00:53,350 --> 00:00:51,840
thank you dc

15
00:00:55,350 --> 00:00:53,360
you know they say that you can't judge a

16
00:00:56,790 --> 00:00:55,360
book by its cover

17
00:00:59,029 --> 00:00:56,800
but you know

18
00:01:00,950 --> 00:00:59,039
virtually every planetary mission to one

19
00:01:04,229 --> 00:01:00,960
of the inner planets the rocky bodies of

20
00:01:06,630 --> 00:01:04,239
the solar system mercury venus the moon

21
00:01:07,830 --> 00:01:06,640
and mars has done just that

22
00:01:10,310 --> 00:01:07,840
they've gone to investigate the

23
00:01:12,390 --> 00:01:10,320
planetary cover of the planetary surface

24
00:01:13,510 --> 00:01:12,400
slash atmosphere

25
00:01:15,109 --> 00:01:13,520
it's not that scientists aren't

26
00:01:16,789 --> 00:01:15,119
interested in the planetary interiors on

27
00:01:18,149 --> 00:01:16,799
the contrary

28
00:01:19,749 --> 00:01:18,159
we've known for some time that the

29
00:01:21,030 --> 00:01:19,759
interior of planets holds the secret to

30
00:01:23,910 --> 00:01:21,040
their formation

31
00:01:25,590 --> 00:01:23,920
evolution and internal processes

32
00:01:27,030 --> 00:01:25,600
the problem is that investigating the

33
00:01:28,870 --> 00:01:27,040
interior is one of the hardest things to

34
00:01:31,030 --> 00:01:28,880
do in space science

35
00:01:32,630 --> 00:01:31,040
consequently we go to places where we

36
00:01:34,789 --> 00:01:32,640
can actually access

37
00:01:36,630 --> 00:01:34,799
which is the planetary surface and we

38
00:01:39,510 --> 00:01:36,640

look there for clues as to what's going

39
00:01:42,630 --> 00:01:39,520
on in the planetary interior

40
00:01:43,910 --> 00:01:42,640
can i have the animation please

41
00:01:45,350 --> 00:01:43,920
case in point

42
00:01:47,270 --> 00:01:45,360
the moon

43
00:01:49,350 --> 00:01:47,280
this little animation

44
00:01:51,429 --> 00:01:49,360
shows you a little comic

45
00:01:53,270 --> 00:01:51,439
of the various different

46
00:01:55,910 --> 00:01:53,280
missions that nasa and other space

47
00:01:57,590 --> 00:01:55,920
agencies have sent to the moon over the

48
00:01:59,510 --> 00:01:57,600
last 50 years

49
00:02:01,670 --> 00:01:59,520
every single one of them

50
00:02:03,030 --> 00:02:01,680
without exception has focused as its

51
00:02:05,030 --> 00:02:03,040
main goal

52
00:02:07,190 --> 00:02:05,040
to understand the surface of the moon or

53
00:02:08,630 --> 00:02:07,200
some property at the lunar surface such

54
00:02:10,389 --> 00:02:08,640
as radiation

55
00:02:11,270 --> 00:02:10,399
not one of them has really had as its

56
00:02:14,070 --> 00:02:11,280
focus

57
00:02:16,150 --> 00:02:14,080
the internal composition or structure

58
00:02:17,910 --> 00:02:16,160
of the moon

59
00:02:20,949 --> 00:02:17,920
imagine for a second what the state of

60
00:02:24,869 --> 00:02:20,959
medical science would be without the mri

61
00:02:26,390 --> 00:02:24,879
the cat scan the x-ray or the scalpel

62
00:02:27,990 --> 00:02:26,400
everything that you know about the

63
00:02:30,869 --> 00:02:28,000

internal workings of a human being would

64
00:02:32,710 --> 00:02:30,879
have to come from observing their skin

65
00:02:34,390 --> 00:02:32,720
their eyes their hair

66
00:02:36,470 --> 00:02:34,400
you'd have to use those observations to

67
00:02:39,670 --> 00:02:36,480
try to figure out what's going on

68
00:02:42,229 --> 00:02:39,680
inside a person pretty primitive eh

69
00:02:43,670 --> 00:02:42,239
well by analogy this is the state of our

70
00:02:45,589 --> 00:02:43,680
understanding

71
00:02:47,270 --> 00:02:45,599
of the lunar interior and the interiors

72
00:02:48,949 --> 00:02:47,280
of the rocky bodies

73
00:02:50,790 --> 00:02:48,959
at this moment in time

74
00:02:53,670 --> 00:02:50,800
so you can imagine our delight at nassar

75
00:02:55,830 --> 00:02:53,680
headquarters when we selected in 2007

76
00:02:56,710 --> 00:02:55,840
for the discovery mission the grail

77
00:03:00,070 --> 00:02:56,720
mission

78
00:03:02,790 --> 00:03:00,080
interior of

79
00:03:07,910 --> 00:03:04,710
now why do we care

80
00:03:09,990 --> 00:03:07,920
about the lunar interior

81
00:03:11,750 --> 00:03:10,000
well four and a half billion years ago

82
00:03:13,990 --> 00:03:11,760
after the moon formed it started heating

83
00:03:18,869 --> 00:03:14,000
up due to planetary impacts

84
00:03:21,110 --> 00:03:18,879
by asteroids meteorites and comets

85
00:03:23,990 --> 00:03:21,120
the heating also came from the breakdown

86
00:03:26,149 --> 00:03:24,000
of radioactive elements inside the moon

87
00:03:28,229 --> 00:03:26,159
and eventually the melting point of the

88
00:03:30,710 --> 00:03:28,239

moon was exceeded

89
00:03:34,070 --> 00:03:30,720
and a giant ocean of magma magma was

90
00:03:36,229 --> 00:03:34,080
formed this magma ocean was lunar wide

91
00:03:38,229 --> 00:03:36,239
and extended down to depths at least as

92
00:03:40,070 --> 00:03:38,239
great as 400 kilometers

93
00:03:42,309 --> 00:03:40,080
maybe more

94
00:03:44,309 --> 00:03:42,319
now out of this magma ocean

95
00:03:46,470 --> 00:03:44,319
eventually as it started cooling

96
00:03:48,390 --> 00:03:46,480
crystals or minerals started forming

97
00:03:50,710 --> 00:03:48,400
those minerals that were denser than the

98
00:03:51,910 --> 00:03:50,720
surrounding liquid sank

99
00:03:54,229 --> 00:03:51,920
and those that were lighter than

100
00:03:55,830 --> 00:03:54,239
surrounding liquid floated

101
00:03:57,670 --> 00:03:55,840
you know you see a manifestation of this

102
00:03:59,910 --> 00:03:57,680
every time you look up at the moon the

103
00:04:00,869 --> 00:03:59,920
face of the moon that shows itself to us

104
00:04:03,110 --> 00:04:00,879
you see

105
00:04:05,110 --> 00:04:03,120
white areas and dark areas

106
00:04:06,869 --> 00:04:05,120
the white areas are composed

107
00:04:09,270 --> 00:04:06,879
predominantly of a rock type called an

108
00:04:11,509 --> 00:04:09,280
orthocyte and an orthocyte is dominated

109
00:04:13,350 --> 00:04:11,519
by a mineral called anarthite

110
00:04:15,270 --> 00:04:13,360
now anarchite was

111
00:04:17,830 --> 00:04:15,280
lighter than the surrounding magma ocean

112
00:04:20,710 --> 00:04:17,840
so it floated and created

113
00:04:22,550 --> 00:04:20,720

the lunar highlands of the lunar crust

114
00:04:23,670 --> 00:04:22,560
now eventually the magma ocean fully

115
00:04:26,469 --> 00:04:23,680
cooled

116
00:04:28,870 --> 00:04:26,479
and tectonic forces took over and shaped

117
00:04:30,550 --> 00:04:28,880
the moon and its interior even further

118
00:04:32,550 --> 00:04:30,560
and eventually there were basin forming

119
00:04:35,189 --> 00:04:32,560
impacts and there were flood basalts

120
00:04:38,150 --> 00:04:35,199
going into some of the the mari so the

121
00:04:39,670 --> 00:04:38,160
moon has a lot of structure structure

122
00:04:41,670 --> 00:04:39,680
and this is where grail will make

123
00:04:43,270 --> 00:04:41,680
history gorilla will be the first

124
00:04:46,390 --> 00:04:43,280
mission to actually go to the moon with

125
00:04:47,510 --> 00:04:46,400
its primary focus of determining the

126
00:04:49,830 --> 00:04:47,520
structure

127
00:04:50,870 --> 00:04:49,840
and composition of the internal parts of

128
00:04:52,469 --> 00:04:50,880
the moon

129
00:04:54,150 --> 00:04:52,479
now to be sure we've used gravity

130
00:04:56,469 --> 00:04:54,160
science before

131
00:04:58,870 --> 00:04:56,479
to try to gain some insight as to what's

132
00:05:00,710 --> 00:04:58,880
going on inside the moon however these

133
00:05:02,230 --> 00:05:00,720
have been very primitive attempts

134
00:05:04,469 --> 00:05:02,240
compared to what grail will be able to

135
00:05:07,189 --> 00:05:04,479
accomplish if those previous attempts

136
00:05:09,029 --> 00:05:07,199
could be likened to a magnifying glass

137
00:05:11,270 --> 00:05:09,039
grail by contrast would be a

138
00:05:13,029 --> 00:05:11,280

high-powered microscope

139
00:05:16,390 --> 00:05:13,039
so we're delighted that we're here and

140
00:05:20,070 --> 00:05:16,400
we're one day away from launch grail

141
00:05:21,590 --> 00:05:20,080
is ready it's on time and on budget now

142
00:05:22,830 --> 00:05:21,600
if the weather would cooperate we'll

143
00:05:24,629 --> 00:05:22,840
have a great mission

144
00:05:26,310 --> 00:05:24,639
maria

145
00:05:28,390 --> 00:05:26,320
thank you very much um

146
00:05:30,469 --> 00:05:28,400
i'm thrilled to be here uh thrilled to

147
00:05:31,909 --> 00:05:30,479
be at this uh state one day before

148
00:05:33,749 --> 00:05:31,919
launch

149
00:05:35,909 --> 00:05:33,759
and let me tell you a little bit about

150
00:05:38,790 --> 00:05:35,919
the science of the grail mission if i

151
00:05:40,230 --> 00:05:38,800
could have the first graphic please

152
00:05:42,390 --> 00:05:40,240
that's a picture of the near side of the

153
00:05:44,950 --> 00:05:42,400
moon as we view it from earth

154
00:05:47,110 --> 00:05:44,960
nearly every human in history has looked

155
00:05:49,670 --> 00:05:47,120
up and seen that site

156
00:05:52,950 --> 00:05:49,680
aside from the sheer beauty of seeing

157
00:05:54,070 --> 00:05:52,960
the moon in the night sky that moon

158
00:05:56,150 --> 00:05:54,080
surface

159
00:05:58,230 --> 00:05:56,160
holds the record

160
00:05:59,510 --> 00:05:58,240
of the whole history of the evolution of

161
00:06:01,990 --> 00:05:59,520
the moon

162
00:06:04,469 --> 00:06:02,000
a great deal of what you see

163
00:06:06,629 --> 00:06:04,479

on the lunar surface however has been

164
00:06:08,629 --> 00:06:06,639
controlled by processes that have

165
00:06:11,350 --> 00:06:08,639
occurred inside the moon

166
00:06:12,950 --> 00:06:11,360
the next slide

167
00:06:15,510 --> 00:06:12,960
so we've learned a lot about the surface

168
00:06:18,790 --> 00:06:15,520
of the moon from orbital reconnaissance

169
00:06:21,270 --> 00:06:18,800
and uh we've had the fortunate situation

170
00:06:23,270 --> 00:06:21,280
of having 12 humans who've walked on the

171
00:06:24,390 --> 00:06:23,280
surface of the moon who've returned

172
00:06:28,870 --> 00:06:24,400
samples

173
00:06:31,110 --> 00:06:28,880
past 40 years they are still being

174
00:06:32,309 --> 00:06:31,120
analyzed today using the newest

175
00:06:34,150 --> 00:06:32,319
techniques

176
00:06:35,909 --> 00:06:34,160
and they are still providing us with

177
00:06:37,189 --> 00:06:35,919
information

178
00:06:39,510 --> 00:06:37,199
so we have

179
00:06:41,510 --> 00:06:39,520
orbital reconnaissance of the surface

180
00:06:44,070 --> 00:06:41,520
we have lunar samples which we can

181
00:06:46,230 --> 00:06:44,080
analyze in earth labs

182
00:06:49,110 --> 00:06:46,240
the piece of the puzzle that has been

183
00:06:50,309 --> 00:06:49,120
missing in trying to reconstruct lunar

184
00:06:52,309 --> 00:06:50,319
evolution

185
00:06:53,430 --> 00:06:52,319
has been a good understanding of the

186
00:06:56,070 --> 00:06:53,440
interior

187
00:06:58,150 --> 00:06:56,080
and that's what grail hopes to provide

188
00:07:00,870 --> 00:06:58,160

so uh in the next chart i'd like to talk

189
00:07:02,950 --> 00:07:00,880
a little bit about what are some basic

190
00:07:04,469 --> 00:07:02,960
things about the moon that we don't

191
00:07:05,990 --> 00:07:04,479
understand

192
00:07:08,790 --> 00:07:06,000
okay this is a

193
00:07:10,629 --> 00:07:08,800
beautiful wide-angle camera images of

194
00:07:12,550 --> 00:07:10,639
the near side of the moon on the left

195
00:07:14,390 --> 00:07:12,560
that's the side that we see from earth

196
00:07:16,790 --> 00:07:14,400
and on the right hand side

197
00:07:19,670 --> 00:07:16,800
that's the uh the far side of the moon

198
00:07:22,230 --> 00:07:19,680
so as bobby mentioned uh we have on the

199
00:07:23,909 --> 00:07:22,240
near side of the moon bright areas uh

200
00:07:26,390 --> 00:07:23,919
lunar highlands which are areas that

201
00:07:27,990 --> 00:07:26,400
have melted and

202
00:07:29,029 --> 00:07:28,000
light crystals that have floated to the

203
00:07:30,710 --> 00:07:29,039
top

204
00:07:33,189 --> 00:07:30,720
as these cooled off

205
00:07:34,629 --> 00:07:33,199
large impacts battered the surface of

206
00:07:36,550 --> 00:07:34,639
the moon

207
00:07:37,830 --> 00:07:36,560
was the material that was left over from

208
00:07:41,350 --> 00:07:37,840
accretion

209
00:07:43,510 --> 00:07:41,360
and then basaltic magma lavas flooded

210
00:07:45,189 --> 00:07:43,520
these large impact basins

211
00:07:47,589 --> 00:07:45,199
if you look at the right side

212
00:07:49,909 --> 00:07:47,599
you don't see these magmas and we used

213
00:07:51,909 --> 00:07:49,919

to think that there was melting

214
00:07:54,309 --> 00:07:51,919
underneath the near side of the moon and

215
00:07:56,550 --> 00:07:54,319
that flooded the impact basins but on

216
00:07:58,790 --> 00:07:56,560
the far side we didn't have these basins

217
00:08:00,309 --> 00:07:58,800
so the back side of the moon melted in

218
00:08:02,309 --> 00:08:00,319
the interior

219
00:08:04,869 --> 00:08:02,319
but the material was never able to rise

220
00:08:07,029 --> 00:08:04,879
to the surface because of the the lack

221
00:08:08,790 --> 00:08:07,039
of large basins but if you look at the

222
00:08:11,670 --> 00:08:08,800
next hand slide

223
00:08:14,230 --> 00:08:11,680
this is an elevation map of the moon

224
00:08:16,550 --> 00:08:14,240
that was collected from observations

225
00:08:18,950 --> 00:08:16,560
from the laser altimeter on the lunar

226
00:08:20,629 --> 00:08:18,960
reconnaissance orbiter which is mapping

227
00:08:22,150 --> 00:08:20,639
the moon right now

228
00:08:24,230 --> 00:08:22,160
in this map

229
00:08:25,430 --> 00:08:24,240
white and red correspond to high

230
00:08:27,990 --> 00:08:25,440
elevations

231
00:08:29,189 --> 00:08:28,000
and blue and purple correspond to low

232
00:08:31,749 --> 00:08:29,199
elevations

233
00:08:32,469 --> 00:08:31,759
so if you look at the left hand side

234
00:08:36,469 --> 00:08:32,479
the

235
00:08:38,070 --> 00:08:36,479
are actually low areas that were flooded

236
00:08:39,829 --> 00:08:38,080
by magmas

237
00:08:41,750 --> 00:08:39,839
but now if you look at the vantage point

238
00:08:42,630 --> 00:08:41,760

of the third dimension on the right hand

239
00:08:44,710 --> 00:08:42,640
side

240
00:08:45,670 --> 00:08:44,720
you see that uh

241
00:08:48,230 --> 00:08:45,680
that

242
00:08:51,030 --> 00:08:48,240
the the back side of the moon has the

243
00:08:53,829 --> 00:08:51,040
largest and deepest impact crater on the

244
00:08:54,949 --> 00:08:53,839
planet but yet this never got filled by

245
00:08:57,269 --> 00:08:54,959
magma

246
00:08:59,030 --> 00:08:57,279
so what that tells us is that what

247
00:09:01,430 --> 00:08:59,040
happened on the near side of the moon in

248
00:09:02,630 --> 00:09:01,440
the interior uh was quite different than

249
00:09:05,590 --> 00:09:02,640
what happened in the far side of the

250
00:09:08,389 --> 00:09:05,600
moon the backside obviously didn't melt

251
00:09:10,630 --> 00:09:08,399
and and so that's a fundamental question

252
00:09:13,110 --> 00:09:10,640
which has shaped the surface of the moon

253
00:09:14,710 --> 00:09:13,120
which has eluded our understanding

254
00:09:17,030 --> 00:09:14,720
now if you also if we could go back to

255
00:09:18,550 --> 00:09:17,040
the graphic of

256
00:09:19,750 --> 00:09:18,560
the elevation map

257
00:09:24,070 --> 00:09:19,760
that bright

258
00:09:27,509 --> 00:09:24,080
white uh area there near the equator

259
00:09:30,230 --> 00:09:27,519
very recently an idea has come out where

260
00:09:32,710 --> 00:09:30,240
we might not have had one moon but that

261
00:09:33,509 --> 00:09:32,720
originally two moons formed around the

262
00:09:36,630 --> 00:09:33,519
earth

263
00:09:38,870 --> 00:09:36,640

that a small lunar companion formed in

264
00:09:41,670 --> 00:09:38,880
orbit around the earth in the same orbit

265
00:09:45,269 --> 00:09:41,680
as the moon but ahead of it or behind it

266
00:09:47,190 --> 00:09:45,279
and that very slowly over early time

267
00:09:49,590 --> 00:09:47,200
this moon the second moon would have

268
00:09:51,829 --> 00:09:49,600
collided with the first moon but it

269
00:09:53,110 --> 00:09:51,839
would have done so at such a low

270
00:09:55,509 --> 00:09:53,120
velocity

271
00:09:58,550 --> 00:09:55,519
uh that it would have added more

272
00:10:01,190 --> 00:09:58,560
material to the moon than it ejected

273
00:10:04,949 --> 00:10:01,200
and this would actually have caused a

274
00:10:07,110 --> 00:10:04,959
mountain to form rather than a crater

275
00:10:10,870 --> 00:10:07,120
this is a very new idea

276
00:10:12,470 --> 00:10:10,880
and it made specific hypotheses uh for

277
00:10:14,150 --> 00:10:12,480
what the inside of the moon should be

278
00:10:16,389 --> 00:10:14,160
like if this occurred

279
00:10:18,790 --> 00:10:16,399
and these ideas can be tested with the

280
00:10:20,630 --> 00:10:18,800
grail mission if we could have the next

281
00:10:23,030 --> 00:10:20,640
slide please

282
00:10:25,350 --> 00:10:23,040
this is a cross section of our state of

283
00:10:26,389 --> 00:10:25,360
knowledge of the deep interior of the

284
00:10:30,150 --> 00:10:26,399
moon

285
00:10:33,110 --> 00:10:30,160
on the left hand side is the near side

286
00:10:35,910 --> 00:10:33,120
as we view from earth the the right hand

287
00:10:37,030 --> 00:10:35,920
side is the far side that we never see

288
00:10:39,750 --> 00:10:37,040

the purple

289
00:10:41,910 --> 00:10:39,760
uh areas correspond to

290
00:10:43,910 --> 00:10:41,920
uh zones on the front side of the moon

291
00:10:47,269 --> 00:10:43,920
where apollo astronauts left

292
00:10:49,829 --> 00:10:47,279
seismometers which probed the interior

293
00:10:53,190 --> 00:10:49,839
you can see in the dots there there are

294
00:10:54,710 --> 00:10:53,200
some shallow moonquake locations

295
00:10:56,550 --> 00:10:54,720
and you can see

296
00:10:58,630 --> 00:10:56,560
that there are some deeper moon quake

297
00:11:01,590 --> 00:10:58,640
locations shown by the white dots that

298
00:11:03,670 --> 00:11:01,600
are deeper there

299
00:11:05,350 --> 00:11:03,680
these deeper moonquakes they tend to be

300
00:11:07,590 --> 00:11:05,360
triggered by tides

301
00:11:10,470 --> 00:11:07,600
we don't know why the moonquakes occur

302
00:11:12,150 --> 00:11:10,480
at those depths and not shallower depths

303
00:11:13,990 --> 00:11:12,160
we don't know

304
00:11:15,670 --> 00:11:14,000
why whether there are shallower

305
00:11:17,509 --> 00:11:15,680
moonquakes that we're not detecting we

306
00:11:18,949 --> 00:11:17,519
suspect there are

307
00:11:21,350 --> 00:11:18,959
we don't know

308
00:11:23,110 --> 00:11:21,360
anything about seismicity on the far

309
00:11:25,030 --> 00:11:23,120
side of the moon that would tell us

310
00:11:26,870 --> 00:11:25,040
perhaps the structure of the near side

311
00:11:31,430 --> 00:11:26,880
versus the far side and why they're

312
00:11:33,750 --> 00:11:31,440
different the next slide please

313
00:11:34,790 --> 00:11:33,760

okay here's a cross-section of what we

314
00:11:36,470 --> 00:11:34,800
think

315
00:11:37,750 --> 00:11:36,480
the deep interior of the moon might look

316
00:11:39,030 --> 00:11:37,760
like

317
00:11:41,509 --> 00:11:39,040
information

318
00:11:44,069 --> 00:11:41,519
from the apollo seismometers that is

319
00:11:47,430 --> 00:11:44,079
still being analyzed today

320
00:11:48,710 --> 00:11:47,440
and from lunar laser ranging where laser

321
00:11:49,990 --> 00:11:48,720
station

322
00:11:52,150 --> 00:11:50,000
on the earth

323
00:11:53,590 --> 00:11:52,160
shoot lasers up to

324
00:11:56,069 --> 00:11:53,600
retro reflectors that the apollo

325
00:11:57,990 --> 00:11:56,079
astronauts left every month and tell us

326
00:12:00,230 --> 00:11:58,000
about wobbles that give us information

327
00:12:01,829 --> 00:12:00,240
about the subtle structure of the

328
00:12:03,590 --> 00:12:01,839
interior of the moon

329
00:12:05,590 --> 00:12:03,600
the suggestion is that the moon has a

330
00:12:07,750 --> 00:12:05,600
very small

331
00:12:11,269 --> 00:12:07,760
solid iron core

332
00:12:13,350 --> 00:12:11,279
that's surrounded by a liquid iron core

333
00:12:15,110 --> 00:12:13,360
but we don't actually know for sure that

334
00:12:18,389 --> 00:12:15,120
that's the case

335
00:12:20,629 --> 00:12:18,399
it's actually quite possible

336
00:12:22,389 --> 00:12:20,639
that

337
00:12:25,509 --> 00:12:22,399
deep inside the moon the core could be

338
00:12:26,790 --> 00:12:25,519

titanium oxide which is a material that

339
00:12:28,949 --> 00:12:26,800
would have

340
00:12:31,110 --> 00:12:28,959
fallen out or condensed out of the

341
00:12:32,550 --> 00:12:31,120
crystallized out of the magma ocean and

342
00:12:34,150 --> 00:12:32,560
sunk to the deep

343
00:12:35,910 --> 00:12:34,160
interior of the moon

344
00:12:37,509 --> 00:12:35,920
and we certainly don't have a good idea

345
00:12:38,389 --> 00:12:37,519
about the thermal state

346
00:12:40,550 --> 00:12:38,399
we think

347
00:12:43,350 --> 00:12:40,560
liquid iron could be melted for the

348
00:12:44,710 --> 00:12:43,360
outer core it's not out of the question

349
00:12:46,470 --> 00:12:44,720
that the

350
00:12:48,870 --> 00:12:46,480
parts of the deep lunar mantle are

351
00:12:51,110 --> 00:12:48,880
actually molten and of course if we want

352
00:12:54,069 --> 00:12:51,120
to try to reconstruct

353
00:12:55,829 --> 00:12:54,079
the evolution of the moon over time we

354
00:12:57,269 --> 00:12:55,839
certainly need to be able to reconstruct

355
00:12:58,389 --> 00:12:57,279
the temperature structure of the moon

356
00:13:01,829 --> 00:12:58,399
right now

357
00:13:03,829 --> 00:13:01,839
so if we can go to the last graphic

358
00:13:05,910 --> 00:13:03,839
so in summary what we're trying to do is

359
00:13:07,829 --> 00:13:05,920
with the grail mission

360
00:13:09,509 --> 00:13:07,839
we're essentially getting a picture into

361
00:13:11,750 --> 00:13:09,519
the interior of the moon

362
00:13:13,509 --> 00:13:11,760
which we intend to combine

363
00:13:15,110 --> 00:13:13,519

with the plethora of orbital

364
00:13:16,790 --> 00:13:15,120
observations that have been taken of the

365
00:13:19,670 --> 00:13:16,800
surface and are being taken of the

366
00:13:21,509 --> 00:13:19,680
surface today and to combine those with

367
00:13:23,750 --> 00:13:21,519
the treasure of the lunar samples that

368
00:13:27,269 --> 00:13:23,760
we continue to analyze

369
00:13:29,910 --> 00:13:27,279
and from those collective observations

370
00:13:31,110 --> 00:13:29,920
we intend to provide a holistic

371
00:13:32,710 --> 00:13:31,120
view

372
00:13:35,509 --> 00:13:32,720
of the origin and the evolution of the

373
00:13:37,990 --> 00:13:35,519
moon and by extension how other rocky

374
00:13:39,990 --> 00:13:38,000
planets in the inner solar system formed

375
00:13:41,829 --> 00:13:40,000
and with that i'll turn it over to sammy

376
00:13:45,350 --> 00:13:41,839
asmar to tell us

377
00:13:47,110 --> 00:13:45,360
how we're going to execute this mission

378
00:13:49,590 --> 00:13:47,120
thank you

379
00:13:51,430 --> 00:13:49,600
the team of scientists and engineers at

380
00:13:53,750 --> 00:13:51,440
all the institutions affiliated with

381
00:13:55,189 --> 00:13:53,760
with the grail mission have worked hard

382
00:13:56,790 --> 00:13:55,199
to ensure that the technique we've

383
00:13:58,069 --> 00:13:56,800
selected to conduct the science

384
00:14:00,230 --> 00:13:58,079
investigation

385
00:14:02,150 --> 00:14:00,240
and the design of the flight system

386
00:14:04,870 --> 00:14:02,160
ground system and mission operation

387
00:14:07,910 --> 00:14:04,880
systems meet the size requirements in

388
00:14:09,829 --> 00:14:07,920

some cases with in with plenty of margin

389
00:14:11,750 --> 00:14:09,839
i'm going to talk briefly about the

390
00:14:13,829 --> 00:14:11,760
technique and the design after hearing

391
00:14:18,710 --> 00:14:13,839
about the science scenarios so if i can

392
00:14:22,069 --> 00:14:20,389
once at the moon the two grail

393
00:14:25,189 --> 00:14:22,079
spacecraft

394
00:14:26,949 --> 00:14:25,199
will orbit at a very low altitude

395
00:14:29,670 --> 00:14:26,959
and we

396
00:14:31,990 --> 00:14:29,680
detect the gravity field by

397
00:14:34,389 --> 00:14:32,000
precisely measuring the changes in the

398
00:14:36,870 --> 00:14:34,399
distance between the two spacecraft so

399
00:14:39,269 --> 00:14:36,880
as the two spacecraft orbit and this

400
00:14:41,670 --> 00:14:39,279
shows that we're gonna the resulting

401
00:14:43,910 --> 00:14:41,680
gravity map of the moon of the moon as

402
00:14:46,150 --> 00:14:43,920
the two spacecraft orbit in this simple

403
00:14:47,590 --> 00:14:46,160
scenario they approach a gravity load

404
00:14:50,230 --> 00:14:47,600
such as a mountain

405
00:14:52,230 --> 00:14:50,240
that pulls on the first spacecraft such

406
00:14:54,069 --> 00:14:52,240
and increasing the distance then the

407
00:14:56,550 --> 00:14:54,079
second spacecraft will sense the same

408
00:14:58,389 --> 00:14:56,560
gravity and the distance will decrease

409
00:15:00,550 --> 00:14:58,399
and then as they move forward the

410
00:15:02,629 --> 00:15:00,560
trailing spacecraft will sense the same

411
00:15:04,629 --> 00:15:02,639
gravity and the distance will increase

412
00:15:06,870 --> 00:15:04,639
again so there's a dance going on

413
00:15:09,030 --> 00:15:06,880

between the two spacecraft as they orbit

414
00:15:09,990 --> 00:15:09,040
every little features of mountains and

415
00:15:11,670 --> 00:15:10,000
craters

416
00:15:13,670 --> 00:15:11,680
now at the end the resulting gravity

417
00:15:15,670 --> 00:15:13,680
field is really

418
00:15:18,310 --> 00:15:15,680
result from after putting all this data

419
00:15:20,710 --> 00:15:18,320
in one big blender and a lot of

420
00:15:22,790 --> 00:15:20,720
processing and we get a high resolution

421
00:15:24,710 --> 00:15:22,800
gravity field of the moon

422
00:15:26,389 --> 00:15:24,720
next slide please

423
00:15:29,829 --> 00:15:26,399
the slide shows that we actually can

424
00:15:30,870 --> 00:15:29,839
tune our instrument to different targets

425
00:15:33,749 --> 00:15:30,880
such

426
00:15:36,069 --> 00:15:33,759
as the local and regional features of

427
00:15:38,629 --> 00:15:36,079
the moon small craters and mountains all

428
00:15:40,470 --> 00:15:38,639
the way to the big global picture

429
00:15:42,470 --> 00:15:40,480
in which we look for

430
00:15:44,550 --> 00:15:42,480
core and tidal effects

431
00:15:46,389 --> 00:15:44,560
the way we tune our instrument is by

432
00:15:49,749 --> 00:15:46,399
changing the separation distance between

433
00:15:51,670 --> 00:15:49,759
the two spacecraft so we start low

434
00:15:54,150 --> 00:15:51,680
altitude and close

435
00:15:56,470 --> 00:15:54,160
distance and then we increase the

436
00:15:57,990 --> 00:15:56,480
distance and raise the altitude and that

437
00:15:59,910 --> 00:15:58,000
will automatically

438
00:16:03,670 --> 00:15:59,920

make us more sensitive optimize the

439
00:16:07,350 --> 00:16:03,680
sensitivity to the global features

440
00:16:11,910 --> 00:16:09,430
this shows the mission design

441
00:16:13,509 --> 00:16:11,920
from launch to

442
00:16:16,870 --> 00:16:13,519
orbit insertion

443
00:16:19,189 --> 00:16:16,880
we have several months actually

444
00:16:21,910 --> 00:16:19,199
which we use very effectively in

445
00:16:23,670 --> 00:16:21,920
addition to navigational aspects on the

446
00:16:25,910 --> 00:16:23,680
science side we benefit from the long

447
00:16:28,150 --> 00:16:25,920
cruise period by

448
00:16:30,629 --> 00:16:28,160
having the spacecraft out gas in the

449
00:16:33,590 --> 00:16:30,639
vacuum of space and having our clock

450
00:16:36,710 --> 00:16:33,600
drift stabilized

451
00:16:39,110 --> 00:16:36,720
next slide please

452
00:16:41,189 --> 00:16:39,120
this shows the radio complexity of the

453
00:16:43,110 --> 00:16:41,199
mission so the two spacecraft have two

454
00:16:45,430 --> 00:16:43,120
types of radio signals going back and

455
00:16:47,829 --> 00:16:45,440
forth between them ka band or 32

456
00:16:49,990 --> 00:16:47,839
gigahertz and that measures the changes

457
00:16:52,310 --> 00:16:50,000
in the distance very precisely and

458
00:16:55,269 --> 00:16:52,320
s-band which is a time synchronization

459
00:16:57,350 --> 00:16:55,279
synchronization exchange of information

460
00:16:59,590 --> 00:16:57,360
when the two spacecraft are then in view

461
00:17:03,509 --> 00:16:59,600
of ground stations they dump or

462
00:17:06,710 --> 00:17:03,519
telemeter the information to the ground

463
00:17:10,150 --> 00:17:07,750

this

464
00:17:11,990 --> 00:17:10,160
graphic i'm using to impress upon you

465
00:17:14,230 --> 00:17:12,000
how sensitive we are to

466
00:17:17,189 --> 00:17:14,240
non-gravitational forces even stuff we

467
00:17:19,429 --> 00:17:17,199
can take for granted such as solar

468
00:17:21,110 --> 00:17:19,439
radiation pressure sunlight

469
00:17:23,189 --> 00:17:21,120
so we had to design the surface

470
00:17:25,510 --> 00:17:23,199
properties of the spacecraft to account

471
00:17:28,390 --> 00:17:25,520
for solar radiation pressure we are a

472
00:17:30,710 --> 00:17:28,400
gravity mission so every force acting on

473
00:17:33,190 --> 00:17:30,720
the spacecraft is a big factor so we

474
00:17:35,510 --> 00:17:33,200
don't want to we don't want to mistake

475
00:17:36,630 --> 00:17:35,520
non-gravitational forces for actual

476
00:17:38,070 --> 00:17:36,640
features from the moon we're

477
00:17:40,150 --> 00:17:38,080
investigating

478
00:17:42,950 --> 00:17:40,160
and then the next slide

479
00:17:45,029 --> 00:17:42,960
we show two other actually features

480
00:17:46,549 --> 00:17:45,039
just reflection of sunlight from the

481
00:17:49,750 --> 00:17:46,559
surface of the moon

482
00:17:51,510 --> 00:17:49,760
and when the moon is in the shade the ir

483
00:17:53,590 --> 00:17:51,520
infrared radiation from the from the

484
00:17:55,750 --> 00:17:53,600
moon these also constitute

485
00:17:59,510 --> 00:17:55,760
non-gravitational forces that we care

486
00:18:02,870 --> 00:17:59,520
about measuring and calibrating

487
00:18:07,750 --> 00:18:05,270
dr ed dwyler of headquarters

488
00:18:10,310 --> 00:18:07,760

called grail a physics mission and this

489
00:18:11,990 --> 00:18:10,320
slide really shows that it is indeed

490
00:18:14,430 --> 00:18:12,000
an intersection of two branches of

491
00:18:16,150 --> 00:18:14,440
physics mechanics or dynamics and

492
00:18:17,430 --> 00:18:16,160
electromagnetism

493
00:18:18,789 --> 00:18:17,440
this

494
00:18:21,270 --> 00:18:18,799
graphic shows

495
00:18:22,549 --> 00:18:21,280
if a spacecraft is orbiting a body a

496
00:18:23,590 --> 00:18:22,559
planet

497
00:18:26,230 --> 00:18:23,600
moon

498
00:18:28,390 --> 00:18:26,240
and we

499
00:18:30,789 --> 00:18:28,400
fly over a gravity feature the

500
00:18:33,430 --> 00:18:30,799
spacecraft will literally get pulled

501
00:18:35,590 --> 00:18:33,440
towards the feature and that effect gets

502
00:18:38,390 --> 00:18:35,600
manifested as a doppler shift in the

503
00:18:40,950 --> 00:18:38,400
electromagnetic signal if it flies over

504
00:18:43,029 --> 00:18:40,960
a valley or absence of material it will

505
00:18:44,710 --> 00:18:43,039
slightly get repelled

506
00:18:47,270 --> 00:18:44,720
so this shows the beauty of gravity

507
00:18:48,710 --> 00:18:47,280
science or radio science where we

508
00:18:50,870 --> 00:18:48,720
actually

509
00:18:52,870 --> 00:18:50,880
investigate mechanical forces acting on

510
00:18:54,230 --> 00:18:52,880
the spacecraft via electromagnetic

511
00:18:56,470 --> 00:18:54,240
effects

512
00:18:57,510 --> 00:18:56,480
and now i'll pass it to lisa

513
00:19:00,150 --> 00:18:57,520

great

514
00:19:02,549 --> 00:19:00,160
good morning it's an exciting time to be

515
00:19:04,710 --> 00:19:02,559
here at the cape and you can feel the

516
00:19:06,710 --> 00:19:04,720
the buzz of the excitement start to

517
00:19:08,950 --> 00:19:06,720
increase today as we're narrowing down

518
00:19:10,789 --> 00:19:08,960
the time to launch and hopefully this

519
00:19:11,750 --> 00:19:10,799
time tomorrow we'll be on our way to the

520
00:19:13,990 --> 00:19:11,760
moon

521
00:19:16,710 --> 00:19:14,000
i'm here to explain to you about the

522
00:19:19,909 --> 00:19:16,720
education and public outreach component

523
00:19:22,710 --> 00:19:19,919
of grail which is called grail mooncam

524
00:19:24,390 --> 00:19:22,720
it is led by dr sally ride america's

525
00:19:26,710 --> 00:19:24,400
first woman in space

526
00:19:29,510 --> 00:19:26,720
and her full team at

527
00:19:30,950 --> 00:19:29,520
sally ride science in san diego

528
00:19:33,990 --> 00:19:30,960
one of the unique things about this

529
00:19:34,950 --> 00:19:34,000
mission is it's nasa's first planetary

530
00:19:36,870 --> 00:19:34,960
mission

531
00:19:38,950 --> 00:19:36,880
to include instruments that are fully

532
00:19:39,990 --> 00:19:38,960
dedicated to education and public

533
00:19:41,909 --> 00:19:40,000
outreach

534
00:19:45,190 --> 00:19:41,919
and we intend to tap into that

535
00:19:48,630 --> 00:19:45,200
excitement of science and technology

536
00:19:51,029 --> 00:19:48,640
using the context of lunar exploration

537
00:19:53,190 --> 00:19:51,039
while grail is in orbit and it's doing

538
00:19:56,390 --> 00:19:53,200

its gravitational experiments

539
00:19:59,190 --> 00:19:56,400
mooncam will serve as eyes on the moon

540
00:20:01,510 --> 00:19:59,200
for students

541
00:20:04,549 --> 00:20:01,520
next slide please

542
00:20:06,870 --> 00:20:04,559
we will do this using cameras

543
00:20:09,270 --> 00:20:06,880
there will be four cameras on each

544
00:20:11,590 --> 00:20:09,280
spacecraft there are two that are

545
00:20:13,350 --> 00:20:11,600
pointing forward and after the 60 degree

546
00:20:15,669 --> 00:20:13,360
angle and there are two that are

547
00:20:19,029 --> 00:20:15,679
pointing directly to the surface and

548
00:20:21,430 --> 00:20:19,039
those will be different powered lenses

549
00:20:24,149 --> 00:20:21,440
this program is available at absolutely

550
00:20:25,990 --> 00:20:24,159
no cost to schools or to students

551
00:20:28,070 --> 00:20:26,000
and students will have the opportunity

552
00:20:31,669 --> 00:20:28,080
to use those cameras to take their very

553
00:20:35,669 --> 00:20:33,430
once the

554
00:20:37,750 --> 00:20:35,679
are in orbit the cameras will be

555
00:20:42,149 --> 00:20:37,760
activated and this portion of the

556
00:20:44,149 --> 00:20:42,159
mission will last approximately 80 days

557
00:20:46,070 --> 00:20:44,159
our mission operations center which

558
00:20:48,470 --> 00:20:46,080
would be similar to mission control in

559
00:20:50,630 --> 00:20:48,480
houston is located at the university of

560
00:20:52,549 --> 00:20:50,640
california san diego

561
00:20:55,430 --> 00:20:52,559
and there we have undergraduate students

562
00:20:57,830 --> 00:20:55,440
that have taken a part in the planning

563
00:20:59,669 --> 00:20:57,840

and the operations of this mission

564
00:21:02,549 --> 00:20:59,679
and during the actual

565
00:21:05,350 --> 00:21:02,559
mission of the mooncam phase

566
00:21:09,190 --> 00:21:05,360
we will they will serve as a link to

567
00:21:12,549 --> 00:21:10,470
students will

568
00:21:15,430 --> 00:21:12,559
determine what photographs they want to

569
00:21:18,470 --> 00:21:15,440
take by accessing the website slide

570
00:21:22,789 --> 00:21:20,630
and there are various ways that they can

571
00:21:24,870 --> 00:21:22,799
choose their location just like we learn

572
00:21:27,270 --> 00:21:24,880
in different ways there are

573
00:21:28,789 --> 00:21:27,280
different ways that they can approach it

574
00:21:31,430 --> 00:21:28,799
this slide shows

575
00:21:33,990 --> 00:21:31,440
the latitude longitude

576
00:21:35,909 --> 00:21:34,000
which spacecraft will be orbiting at

577
00:21:38,470 --> 00:21:35,919
what times

578
00:21:40,630 --> 00:21:38,480
next slide

579
00:21:42,710 --> 00:21:40,640
and it's also very interactive students

580
00:21:44,870 --> 00:21:42,720
will be able to zoom in on the moon

581
00:21:46,390 --> 00:21:44,880
they'll be able to rotate it they'll be

582
00:21:48,950 --> 00:21:46,400
able to look at both of the ground

583
00:21:50,630 --> 00:21:48,960
tracks of the orbiters

584
00:21:53,830 --> 00:21:50,640
and they can simply

585
00:21:55,669 --> 00:21:53,840
uh click on the ground tract and decide

586
00:21:58,390 --> 00:21:55,679
you know it will give the information

587
00:22:00,310 --> 00:21:58,400
like latitude and longitude and let them

588
00:22:01,510 --> 00:22:00,320

decide where they want to take their

589
00:22:03,190 --> 00:22:01,520
photographs

590
00:22:05,110 --> 00:22:03,200
once they have made that decision

591
00:22:07,190 --> 00:22:05,120
they'll send their request into our

592
00:22:10,549 --> 00:22:07,200
mission operations center there at

593
00:22:13,430 --> 00:22:10,559
university of california san diego

594
00:22:15,110 --> 00:22:13,440
and there are it our undergrad students

595
00:22:16,950 --> 00:22:15,120
will uh

596
00:22:19,510 --> 00:22:16,960
help facilitate that

597
00:22:21,909 --> 00:22:19,520
and then the images will be available in

598
00:22:24,390 --> 00:22:21,919
a gallery on the website students will

599
00:22:27,430 --> 00:22:24,400
be able to go back later and identify

600
00:22:29,270 --> 00:22:27,440
exactly which picture that they took

601
00:22:31,750 --> 00:22:29,280
they'll be able to annotate

602
00:22:34,310 --> 00:22:31,760
the their images they'll be able to use

603
00:22:36,230 --> 00:22:34,320
them for further investigation they will

604
00:22:37,909 --> 00:22:36,240
have access matter of fact the general

605
00:22:39,029 --> 00:22:37,919
public will have access to all these

606
00:22:41,350 --> 00:22:39,039
images

607
00:22:43,190 --> 00:22:41,360
they'll be able to access other student

608
00:22:46,630 --> 00:22:43,200
photographs as well

609
00:22:49,270 --> 00:22:46,640
to further their investigations

610
00:22:51,909 --> 00:22:49,280
both before during and after the mission

611
00:22:55,110 --> 00:22:51,919
sally ride science is providing support

612
00:22:56,310 --> 00:22:55,120
and training for educators we're linking

613
00:22:59,110 --> 00:22:56,320

them up with

614
00:23:01,669 --> 00:22:59,120
lunar scientists we're helping them with

615
00:23:03,750 --> 00:23:01,679
hands-on activities that address the

616
00:23:05,669 --> 00:23:03,760
standards that educators have to meet in

617
00:23:07,190 --> 00:23:05,679
their classrooms

618
00:23:08,470 --> 00:23:07,200
but more than meeting those standards

619
00:23:11,590 --> 00:23:08,480
this is something that's going to be a

620
00:23:14,870 --> 00:23:11,600
lot of fun for the students and engaging

621
00:23:16,390 --> 00:23:14,880
in real world science is going to help

622
00:23:20,149 --> 00:23:16,400
not just to

623
00:23:21,350 --> 00:23:20,159
help us develop scientifically literate

624
00:23:24,630 --> 00:23:21,360
citizens

625
00:23:26,310 --> 00:23:24,640
but hopefully to encourage students to

626
00:23:29,190 --> 00:23:26,320
enter careers that have to do with

627
00:23:30,630 --> 00:23:29,200
science technology engineering and

628
00:23:33,190 --> 00:23:30,640
mathematics

629
00:23:35,830 --> 00:23:33,200
and you never know what the wow factor

630
00:23:37,510 --> 00:23:35,840
is going to be for a student and

631
00:23:40,149 --> 00:23:37,520
besides the areas of science and

632
00:23:42,149 --> 00:23:40,159
technology you never know what

633
00:23:44,870 --> 00:23:42,159
an image might

634
00:23:48,549 --> 00:23:44,880
evoke out of a student as far as maybe

635
00:23:50,630 --> 00:23:48,559
art or poetry or maybe even music

636
00:23:52,789 --> 00:23:50,640
which are things that we

637
00:23:54,789 --> 00:23:52,799
often tend to forget about combining

638
00:23:55,750 --> 00:23:54,799

with with science

639
00:23:58,230 --> 00:23:55,760
um

640
00:24:00,789 --> 00:23:58,240
it's difficult for us to

641
00:24:02,470 --> 00:24:00,799
to measure the impact

642
00:24:05,590 --> 00:24:02,480
of inspiration

643
00:24:08,470 --> 00:24:05,600
but nasa does have that inspiration

644
00:24:09,990 --> 00:24:08,480
factor and our students certainly need

645
00:24:11,830 --> 00:24:10,000
that and it's something they can get

646
00:24:14,630 --> 00:24:11,840
excited about and it's going to give

647
00:24:16,149 --> 00:24:14,640
them their own ownership of of these

648
00:24:18,149 --> 00:24:16,159
images which

649
00:24:19,590 --> 00:24:18,159
it's been my experience that the kids

650
00:24:21,190 --> 00:24:19,600
get really

651
00:24:22,870 --> 00:24:21,200
jazzed about

652
00:24:25,350 --> 00:24:22,880
i would encourage you next slide to go

653
00:24:31,029 --> 00:24:25,360
to our website

654
00:24:34,870 --> 00:24:33,190
and we would like educators to go there

655
00:24:36,710 --> 00:24:34,880
and register

656
00:24:38,149 --> 00:24:36,720
we would like the general public to go

657
00:24:40,470 --> 00:24:38,159
there and and

658
00:24:41,750 --> 00:24:40,480
read up and become more informed and get

659
00:24:43,110 --> 00:24:41,760
involved

660
00:24:45,750 --> 00:24:43,120
it's also

661
00:24:47,190 --> 00:24:45,760
very timely to let you know that we now

662
00:24:49,029 --> 00:24:47,200
also have an app

663
00:24:51,510 --> 00:24:49,039

for grail moon cam

664
00:24:54,470 --> 00:24:51,520
it is free on itunes you can go there

665
00:24:56,470 --> 00:24:54,480
and you can download it and

666
00:24:58,710 --> 00:24:56,480
once images start coming in from moon

667
00:25:00,870 --> 00:24:58,720
cam you'll be able to view the images

668
00:25:02,310 --> 00:25:00,880
there through that app you'll also be

669
00:25:05,510 --> 00:25:02,320
able to

670
00:25:08,710 --> 00:25:05,520
track the spacecraft during the mission

671
00:25:11,350 --> 00:25:08,720
and we're also a grail moon cam is

672
00:25:14,549 --> 00:25:11,360
available on facebook so we'd hope you

673
00:25:16,870 --> 00:25:14,559
go and check that out and on twitter so

674
00:25:19,110 --> 00:25:16,880
i hope you'll come along with us on this

675
00:25:20,549 --> 00:25:19,120
journey thank you

676
00:25:22,710 --> 00:25:20,559
thank you lisa

677
00:25:24,549 --> 00:25:22,720
we'll open it up to questions here from

678
00:25:25,909 --> 00:25:24,559
the media at the kennedy space center

679
00:25:26,950 --> 00:25:25,919
press site

680
00:25:29,269 --> 00:25:26,960
please state your name and media

681
00:25:31,990 --> 00:25:29,279
affiliation marcia um marcia done

682
00:25:36,149 --> 00:25:32,000
associated press the 82-day science

683
00:25:38,789 --> 00:25:36,159
phase when exactly does it begin um

684
00:25:41,510 --> 00:25:38,799
via calendar and might it move up sooner

685
00:25:44,230 --> 00:25:41,520
if you get your orbits precise enough

686
00:25:46,390 --> 00:25:44,240
quick enough okay uh march 8th i believe

687
00:25:49,669 --> 00:25:46,400
is the day okay um

688
00:25:52,390 --> 00:25:49,679

so the the 82-day science phase is uh

689
00:25:55,430 --> 00:25:52,400
the the beginning of that is based on

690
00:25:56,870 --> 00:25:55,440
uh both how long it takes the spacecraft

691
00:25:58,310 --> 00:25:56,880
to get into their

692
00:26:00,470 --> 00:25:58,320
lower

693
00:26:02,070 --> 00:26:00,480
circular mapping orbit

694
00:26:04,230 --> 00:26:02,080
and then line themselves up so that they

695
00:26:05,750 --> 00:26:04,240
start to range to each other but it is

696
00:26:08,549 --> 00:26:05,760
also based on

697
00:26:10,549 --> 00:26:08,559
when the sun angle to the solar panels

698
00:26:13,029 --> 00:26:10,559
provides enough

699
00:26:14,470 --> 00:26:13,039
sunlight to power them

700
00:26:16,230 --> 00:26:14,480
so

701
00:26:17,990 --> 00:26:16,240
if all goes well

702
00:26:20,390 --> 00:26:18,000
it's possible that that could be

703
00:26:22,470 --> 00:26:20,400
somewhat earlier

704
00:26:24,390 --> 00:26:22,480
however you know of course we're taking

705
00:26:26,870 --> 00:26:24,400
the conservative approach of making sure

706
00:26:29,590 --> 00:26:26,880
that it that it operates

707
00:26:31,830 --> 00:26:29,600
well okay

708
00:26:34,149 --> 00:26:31,840
the chart with all the

709
00:26:35,669 --> 00:26:34,159
moon missions over the decades i

710
00:26:37,350 --> 00:26:35,679
i believe you said at a previous

711
00:26:39,029 --> 00:26:37,360
briefing that was 109 but i can't

712
00:26:41,430 --> 00:26:39,039
remember the number and that includes

713
00:26:44,470 --> 00:26:41,440

apollo landings as well um how many of

714
00:26:45,830 --> 00:26:44,480
those 109 missions actually studied

715
00:26:47,350 --> 00:26:45,840
the far side of the moon i'm just

716
00:26:48,230 --> 00:26:47,360
wondering how

717
00:26:49,990 --> 00:26:48,240
much

718
00:26:53,669 --> 00:26:50,000
still is to be learned about the far

719
00:26:55,750 --> 00:26:53,679
side okay so um uh

720
00:26:57,269 --> 00:26:55,760
let me think about that okay so the um

721
00:26:59,669 --> 00:26:57,279
the er i don't know the exact numbers

722
00:27:01,350 --> 00:26:59,679
but i can i can um call it out to what

723
00:27:02,149 --> 00:27:01,360
happened so the early

724
00:27:03,990 --> 00:27:02,159
uh

725
00:27:07,990 --> 00:27:04,000
the early reconnaissance missions to the

726
00:27:09,510 --> 00:27:08,000
moon um went into an equatorial orbit

727
00:27:11,510 --> 00:27:09,520
around the moon because they were

728
00:27:13,750 --> 00:27:11,520
interested in doing reconnaissance of

729
00:27:16,549 --> 00:27:13,760
the far side equator which was the

730
00:27:19,269 --> 00:27:16,559
easiest place to get to the astronauts

731
00:27:21,750 --> 00:27:19,279
to energetically okay from an energetic

732
00:27:24,230 --> 00:27:21,760
standpoint so

733
00:27:27,110 --> 00:27:24,240
so information was gained about the

734
00:27:30,630 --> 00:27:27,120
equatorial area of the far side and

735
00:27:32,470 --> 00:27:30,640
there was very little uh information

736
00:27:34,230 --> 00:27:32,480
on

737
00:27:36,470 --> 00:27:34,240
in polar orbit where you would be

738
00:27:38,470 --> 00:27:36,480

getting the whole uh far side so there

739
00:27:41,190 --> 00:27:38,480
was uh i know there was one lunar

740
00:27:44,230 --> 00:27:41,200
orbiter uh that did that early on but uh

741
00:27:46,549 --> 00:27:44,240
and actually there was a soviet zond uh

742
00:27:48,230 --> 00:27:46,559
orbiter that that also um

743
00:27:49,669 --> 00:27:48,240
but but very little and then the more

744
00:27:51,909 --> 00:27:49,679
recent uh

745
00:27:53,510 --> 00:27:51,919
missions to the moon however uh you know

746
00:27:54,630 --> 00:27:53,520
lunar prospector

747
00:27:56,549 --> 00:27:54,640
um

748
00:27:58,389 --> 00:27:56,559
and uh lunar reconnaissance orbiter they

749
00:28:00,870 --> 00:27:58,399
of course are in a um

750
00:28:01,830 --> 00:28:00,880
uh global so um

751
00:28:07,029 --> 00:28:01,840
so

752
00:28:11,029 --> 00:28:07,039
in terms of studying the interior

753
00:28:12,549 --> 00:28:11,039
there is a vast amount to learn because

754
00:28:14,710 --> 00:28:12,559
other missions have studied lunar

755
00:28:16,789 --> 00:28:14,720
gravity but because of the moon being in

756
00:28:18,870 --> 00:28:16,799
the unusual position where it's in

757
00:28:20,070 --> 00:28:18,880
synchronous rotation where we only see

758
00:28:21,909 --> 00:28:20,080
one side

759
00:28:24,310 --> 00:28:21,919
the way that we typically measure

760
00:28:26,630 --> 00:28:24,320
planetary gravity is to track the radio

761
00:28:30,470 --> 00:28:26,640
signal of a spacecraft in orbit while

762
00:28:32,789 --> 00:28:30,480
the while the planet rotates um uh under

763
00:28:34,389 --> 00:28:32,799

the spacecraft but if you never see the

764
00:28:36,630 --> 00:28:34,399
far side of the moon you can never track

765
00:28:38,389 --> 00:28:36,640
it directly and so the two spacecraft

766
00:28:42,630 --> 00:28:38,399
actually have to use that so that they

767
00:28:47,110 --> 00:28:45,269
i'm high irene klotz with uh reuters um

768
00:28:48,870 --> 00:28:47,120
for dr zuber

769
00:28:50,630 --> 00:28:48,880
you mentioned that one of the

770
00:28:52,149 --> 00:28:50,640
scenarios for the

771
00:28:54,710 --> 00:28:52,159
core of the moon is that it might have

772
00:28:56,389 --> 00:28:54,720
titanium oxide and i was just wondering

773
00:28:57,909 --> 00:28:56,399
how once you get these measurements from

774
00:28:59,750 --> 00:28:57,919
grail you're going to be able to

775
00:29:01,510 --> 00:28:59,760
distinguish between

776
00:29:04,149 --> 00:29:01,520
the different um

777
00:29:06,789 --> 00:29:04,159
the different materials and how much of

778
00:29:09,830 --> 00:29:06,799
each might be and just how

779
00:29:11,350 --> 00:29:09,840
precisely you anticipate being able to

780
00:29:12,630 --> 00:29:11,360
definitively

781
00:29:15,110 --> 00:29:12,640
know

782
00:29:17,590 --> 00:29:15,120
what's inside the moon okay so so first

783
00:29:19,590 --> 00:29:17,600
of all gravity is a potential field

784
00:29:24,710 --> 00:29:19,600
measurement so um

785
00:29:27,269 --> 00:29:24,720
so uh so you you can come up with

786
00:29:30,070 --> 00:29:27,279
many different uh compositions that

787
00:29:33,269 --> 00:29:30,080
could satisfy the gravitational field

788
00:29:36,310 --> 00:29:33,279

that you measure um which is why you

789
00:29:38,950 --> 00:29:36,320
never want to analyze gravity or

790
00:29:42,870 --> 00:29:38,960
magnetics or any other potential in

791
00:29:46,549 --> 00:29:42,880
isolation so uh so the actual the value

792
00:29:47,750 --> 00:29:46,559
of analyzing um the the gravity data is

793
00:29:50,149 --> 00:29:47,760
that we have a great deal of

794
00:29:52,789 --> 00:29:50,159
compositional data of uh from the

795
00:29:55,430 --> 00:29:52,799
surface which is which allows us to zero

796
00:29:56,870 --> 00:29:55,440
in on the bulk composition and what we

797
00:29:59,830 --> 00:29:56,880
will be able to do about the deep

798
00:30:02,549 --> 00:29:59,840
interior is greatly reduce the error

799
00:30:05,750 --> 00:30:02,559
bars and what the radial distribution of

800
00:30:08,470 --> 00:30:05,760
masses and combine that with

801
00:30:10,149 --> 00:30:08,480
models of the bulk composition and and

802
00:30:11,830 --> 00:30:10,159
from that we expect to be able to

803
00:30:14,389 --> 00:30:11,840
distinguish

804
00:30:16,789 --> 00:30:14,399
iron versus not iron something like

805
00:30:18,950 --> 00:30:16,799
titanium oxide okay

806
00:30:21,909 --> 00:30:18,960
and over to bill harwood bill harwood

807
00:30:23,750 --> 00:30:21,919
cbs i would i have three questions um

808
00:30:25,590 --> 00:30:23,760
one is just for the sheer precision of

809
00:30:27,990 --> 00:30:25,600
your experiment can you guys give me

810
00:30:29,510 --> 00:30:28,000
some sense of like your graphics show

811
00:30:31,350 --> 00:30:29,520
you know little dips and little rises

812
00:30:32,870 --> 00:30:31,360
over what's what's actually happening to

813
00:30:34,549 --> 00:30:32,880

the spacecraft in terms of the real

814
00:30:36,549 --> 00:30:34,559
dimensions is it dropping a meter is it

815
00:30:38,149 --> 00:30:36,559
dropping a few inches and and can you

816
00:30:39,350 --> 00:30:38,159
tell me a little bit about the accuracy

817
00:30:41,190 --> 00:30:39,360
of the

818
00:30:42,870 --> 00:30:41,200
the distance measurement required in

819
00:30:46,630 --> 00:30:42,880
other words at 100 kilometers how much

820
00:30:48,789 --> 00:30:46,640
is it actually what's actually happening

821
00:30:51,909 --> 00:30:48,799
so if over the distances between the two

822
00:30:53,110 --> 00:30:51,919
spacecraft which range between 65 to 225

823
00:30:55,669 --> 00:30:53,120
kilometers

824
00:30:57,110 --> 00:30:55,679
we are sensitive to changes down to one

825
00:30:58,950 --> 00:30:57,120
micron

826
00:31:00,950 --> 00:30:58,960
so that's really on the order of a size

827
00:31:03,110 --> 00:31:00,960
of a red blood cell

828
00:31:05,669 --> 00:31:03,120
that's how accurate the measurement or

829
00:31:07,750 --> 00:31:05,679
the distances

830
00:31:09,750 --> 00:31:07,760
in the up and down that it's doing if it

831
00:31:11,430 --> 00:31:09,760
goes over mass cons or mountains or

832
00:31:14,230 --> 00:31:11,440
whatever well that was that was just an

833
00:31:16,389 --> 00:31:14,240
abstract illustrator exactly okay

834
00:31:18,870 --> 00:31:16,399
and for dr gilbert the heat of the core

835
00:31:20,870 --> 00:31:18,880
of the moon after this much time is that

836
00:31:22,470 --> 00:31:20,880
radioactive does it keep it hot it would

837
00:31:23,830 --> 00:31:22,480
keep a liquid core i mean what's keeping

838
00:31:25,830 --> 00:31:23,840

it looking it's

839
00:31:26,870 --> 00:31:25,840
well there's uh several contributions to

840
00:31:29,590 --> 00:31:26,880
the heat

841
00:31:30,549 --> 00:31:29,600
part of the contribution is uh

842
00:31:32,470 --> 00:31:30,559
is

843
00:31:34,950 --> 00:31:32,480
the potential energy of the in-falling

844
00:31:37,430 --> 00:31:34,960
material uh as it accreted the moon so

845
00:31:38,950 --> 00:31:37,440
there would be some accretional heat

846
00:31:41,269 --> 00:31:38,960
that would be left over

847
00:31:43,269 --> 00:31:41,279
and uh and the rest of the residual heat

848
00:31:44,230 --> 00:31:43,279
would be due to the decay of radioactive

849
00:31:46,389 --> 00:31:44,240
elements

850
00:31:48,470 --> 00:31:46,399
so um so bobby actually talked about the

851
00:31:50,389 --> 00:31:48,480
fact that the exterior of the moon we

852
00:31:52,310 --> 00:31:50,399
think it largely melted

853
00:31:55,350 --> 00:31:52,320
and um and

854
00:31:57,190 --> 00:31:55,360
the big heavy elements like uranium

855
00:31:59,669 --> 00:31:57,200
thorium potassium that are the heat

856
00:32:02,149 --> 00:31:59,679
producing radioactive elements those are

857
00:32:03,990 --> 00:32:02,159
actually the heaviest and so the the

858
00:32:05,750 --> 00:32:04,000
idea is that they could have

859
00:32:08,549 --> 00:32:05,760
they may have sunk part way into the

860
00:32:10,549 --> 00:32:08,559
moon they may have conceivably sunk all

861
00:32:13,430 --> 00:32:10,559
the way to the core where they would be

862
00:32:15,430 --> 00:32:13,440
providing this uh this residual heat

863
00:32:17,909 --> 00:32:15,440

and actually one of the one of the

864
00:32:20,630 --> 00:32:17,919
interesting conundrums

865
00:32:23,110 --> 00:32:20,640
uh is that

866
00:32:25,750 --> 00:32:23,120
we think that the moon

867
00:32:28,789 --> 00:32:25,760
is some is molten in the deep interior

868
00:32:31,269 --> 00:32:28,799
today due to these heat sources yet

869
00:32:33,430 --> 00:32:31,279
despite the fact that the moon

870
00:32:34,549 --> 00:32:33,440
early in its history we believe was

871
00:32:36,950 --> 00:32:34,559
molten

872
00:32:38,070 --> 00:32:36,960
on the exterior it looks like the

873
00:32:41,350 --> 00:32:38,080
surface

874
00:32:43,430 --> 00:32:41,360
cooled off extremely fast

875
00:32:45,269 --> 00:32:43,440
because of the large size of the gravity

876
00:32:47,990 --> 00:32:45,279
anomalies that we see over those near

877
00:32:48,789 --> 00:32:48,000
side basins so there was uh we used to

878
00:32:51,590 --> 00:32:48,799
think

879
00:32:53,190 --> 00:32:51,600
so the near side basins have lava flows

880
00:32:55,669 --> 00:32:53,200
that are more dense than the

881
00:32:57,990 --> 00:32:55,679
surroundings and we thought that if we

882
00:33:00,149 --> 00:32:58,000
could subtract away the gravitational

883
00:33:02,470 --> 00:33:00,159
attraction of those lava flows that we

884
00:33:04,389 --> 00:33:02,480
would see no gravity anomalies

885
00:33:06,389 --> 00:33:04,399
um but in fact

886
00:33:08,389 --> 00:33:06,399
we've had near side gravity before and

887
00:33:10,230 --> 00:33:08,399
we've done that and they're still

888
00:33:11,830 --> 00:33:10,240

whopping anomalies and what that means

889
00:33:13,509 --> 00:33:11,840
is that the

890
00:33:16,230 --> 00:33:13,519
at least on the near side the moon on

891
00:33:18,549 --> 00:33:16,240
the outside cooled off fast enough so it

892
00:33:19,590 --> 00:33:18,559
was able to maintain strength

893
00:33:22,310 --> 00:33:19,600
and

894
00:33:23,750 --> 00:33:22,320
so we have this odd situation where the

895
00:33:26,149 --> 00:33:23,760
deep interior of the moon still looks

896
00:33:27,990 --> 00:33:26,159
like it's hot but the outside that we

897
00:33:29,590 --> 00:33:28,000
know was molten

898
00:33:31,509 --> 00:33:29,600
cooled off apparently

899
00:33:35,350 --> 00:33:31,519
much more rapidly than the models would

900
00:33:37,029 --> 00:33:35,360
indicate so it's a it's a fascinating

901
00:33:39,590 --> 00:33:37,039
topic a fascinating question in

902
00:33:41,509 --> 00:33:39,600
planetary evolution

903
00:33:44,310 --> 00:33:41,519
and one more quick one from me i'm sorry

904
00:33:46,070 --> 00:33:44,320
um the second moon uh theory that you

905
00:33:47,830 --> 00:33:46,080
were mentioning to us i'm assuming or i

906
00:33:49,509 --> 00:33:47,840
don't know what i'm assuming but it was

907
00:33:51,029 --> 00:33:49,519
this a small body that then accreted on

908
00:33:52,789 --> 00:33:51,039
the far side and that made the highlands

909
00:33:54,870 --> 00:33:52,799
or is this a larger body that deposited

910
00:33:57,830 --> 00:33:54,880
material and then somehow left the scene

911
00:33:59,669 --> 00:33:57,840
uh the i the um the simulations show so

912
00:34:02,710 --> 00:33:59,679
the the authors ran a range of

913
00:34:03,590 --> 00:34:02,720

simulations and the simulation that they

914
00:34:05,909 --> 00:34:03,600
um

915
00:34:08,230 --> 00:34:05,919
that they interpreted that worked so to

916
00:34:10,069 --> 00:34:08,240
speak to produce the far side highlands

917
00:34:11,669 --> 00:34:10,079
is one where you have

918
00:34:15,190 --> 00:34:11,679
a moon that's about a third of the size

919
00:34:16,230 --> 00:34:15,200
of the new moon slowly drifted and stuck

920
00:34:18,149 --> 00:34:16,240
okay

921
00:34:21,109 --> 00:34:18,159
and

922
00:34:23,349 --> 00:34:21,119
so there may be there may be uh other

923
00:34:26,069 --> 00:34:23,359
scenarios for making this happen

924
00:34:28,550 --> 00:34:26,079
and uh it's such an exciting idea i i

925
00:34:30,790 --> 00:34:28,560
i'm guessing the modelers are hard at

926
00:34:33,349 --> 00:34:30,800
work right now trying to find whether

927
00:34:35,030 --> 00:34:33,359
there are different scenarios that might

928
00:34:37,510 --> 00:34:35,040
explain that in all in an alternative

929
00:34:42,950 --> 00:34:39,750
i'm todd halverson of florida today

930
00:34:45,109 --> 00:34:42,960
probably for sammy um

931
00:34:47,109 --> 00:34:45,119
is there a planetary window associated

932
00:34:50,149 --> 00:34:47,119
with this launch in other words how many

933
00:34:52,550 --> 00:34:50,159
days do you have to get this launch off

934
00:34:54,149 --> 00:34:52,560
the ground and what happens if you don't

935
00:34:56,310 --> 00:34:54,159
fly

936
00:34:59,030 --> 00:34:56,320
in that window

937
00:35:00,790 --> 00:34:59,040
geometrically speaking we have about 42

938
00:35:03,109 --> 00:35:00,800

days to launch but i think from a

939
00:35:05,910 --> 00:35:03,119
practical point of view it's down to

940
00:35:07,750 --> 00:35:05,920
30 32 days having to do with fueling the

941
00:35:08,870 --> 00:35:07,760
rocket for a limited

942
00:35:10,870 --> 00:35:08,880
period

943
00:35:12,230 --> 00:35:10,880
if we missed the entire opportunity then

944
00:35:13,430 --> 00:35:12,240
we would have to wait on the order of

945
00:35:15,670 --> 00:35:13,440
six months

946
00:35:17,030 --> 00:35:15,680
so that when we arrive we avoid solar

947
00:35:20,150 --> 00:35:17,040
eclipses

948
00:35:22,630 --> 00:35:20,160
at the spacecraft on the moon

949
00:35:25,510 --> 00:35:22,640
thanks and this one's probably for you

950
00:35:28,710 --> 00:35:25,520
too i was wondering if you could discuss

951
00:35:31,349 --> 00:35:28,720
the low energy trajectory that you're

952
00:35:33,589 --> 00:35:31,359
taking to the moon why it was selected

953
00:35:37,349 --> 00:35:33,599
and whether your arrival date at the

954
00:35:39,270 --> 00:35:37,359
moon would change if the launch was

955
00:35:41,589 --> 00:35:39,280
pushed back a week or

956
00:35:44,069 --> 00:35:41,599
30 days or whatever

957
00:35:47,349 --> 00:35:44,079
so the low energy trajectory was

958
00:35:48,870 --> 00:35:47,359
selected basically to save on cost so

959
00:35:50,390 --> 00:35:48,880
you do not you do not have to use a

960
00:35:53,030 --> 00:35:50,400
bigger rocket

961
00:35:54,870 --> 00:35:53,040
to get you to the moon faster but also

962
00:35:56,310 --> 00:35:54,880
even if you do that you would need once

963
00:35:59,589 --> 00:35:56,320

you arrive at the moon you would need to

964
00:36:01,670 --> 00:35:59,599
break to reduce that velocity and that

965
00:36:03,829 --> 00:36:01,680
would require carrying additional fuel

966
00:36:05,589 --> 00:36:03,839
on board the spacecraft so this avoids

967
00:36:08,390 --> 00:36:05,599
that entire problem

968
00:36:11,109 --> 00:36:08,400
and also gives us this flexibility so

969
00:36:12,870 --> 00:36:11,119
we arrive at the moon on new year's eve

970
00:36:14,390 --> 00:36:12,880
than new year's day regardless of the

971
00:36:17,190 --> 00:36:14,400
launch date so that's a very nice

972
00:36:18,550 --> 00:36:17,200
flexibility in the mission design and as

973
00:36:20,710 --> 00:36:18,560
i mentioned earlier it turns out there

974
00:36:22,550 --> 00:36:20,720
are additional benefits to having a

975
00:36:24,950 --> 00:36:22,560
relatively long cruise period on the

976
00:36:26,390 --> 00:36:24,960
order of weeks to allow for outgassing

977
00:36:28,470 --> 00:36:26,400
of the spacecraft

978
00:36:31,670 --> 00:36:28,480
clocks to stabilize the operations team

979
00:36:33,270 --> 00:36:31,680
to learn how to fly the mission

980
00:36:35,670 --> 00:36:33,280
wayne over here

981
00:36:37,750 --> 00:36:35,680
hi ken kramer for space flight magazine

982
00:36:39,990 --> 00:36:37,760
for maria to follow up on this idea of

983
00:36:41,670 --> 00:36:40,000
the second moon proposal i wonder if you

984
00:36:44,790 --> 00:36:41,680
could explain a little bit more about

985
00:36:46,790 --> 00:36:44,800
how grail could help confirm this theory

986
00:36:48,710 --> 00:36:46,800
and i'm also wondering

987
00:36:50,870 --> 00:36:48,720
at these spots do we know is the

988
00:36:53,670 --> 00:36:50,880

composition different

989
00:36:55,510 --> 00:36:53,680
is that why we think the second moon oh

990
00:36:57,190 --> 00:36:55,520
okay so yeah i'd be happy to address

991
00:36:58,630 --> 00:36:57,200
that okay so um

992
00:37:02,230 --> 00:36:58,640
so because

993
00:37:03,829 --> 00:37:02,240
this second moon this lunar companion

994
00:37:06,790 --> 00:37:03,839
would have accreted

995
00:37:10,230 --> 00:37:06,800
from the same material that that our

996
00:37:12,069 --> 00:37:10,240
moon formed from it should have the same

997
00:37:13,270 --> 00:37:12,079
composition okay

998
00:37:15,349 --> 00:37:13,280
however

999
00:37:17,750 --> 00:37:15,359
because it's a smaller body

1000
00:37:20,950 --> 00:37:17,760
uh it should have cooled off

1001
00:37:23,990 --> 00:37:20,960
more quickly than our moon did

1002
00:37:27,190 --> 00:37:24,000
all right so um so one way to test this

1003
00:37:29,430 --> 00:37:27,200
is to look at the crystallization age of

1004
00:37:31,109 --> 00:37:29,440
minerals of material in the lunar

1005
00:37:33,030 --> 00:37:31,119
highlands there compared to the

1006
00:37:34,950 --> 00:37:33,040
crystallization crystallization age of

1007
00:37:37,190 --> 00:37:34,960
lunar highlands away from that

1008
00:37:39,829 --> 00:37:37,200
however there are no plans on the books

1009
00:37:42,630 --> 00:37:39,839
right now to send a

1010
00:37:45,030 --> 00:37:42,640
lander to the moon to bring back samples

1011
00:37:46,550 --> 00:37:45,040
from those far side highlands to earth

1012
00:37:48,550 --> 00:37:46,560
because you can't make that measurement

1013
00:37:50,390 --> 00:37:48,560

in situ that has to be done in a lab on

1014
00:37:52,069 --> 00:37:50,400
earth so we need we need to actually

1015
00:37:55,670 --> 00:37:52,079
bring samples back

1016
00:37:56,630 --> 00:37:55,680
however what you what you can test okay

1017
00:38:00,550 --> 00:37:56,640
um

1018
00:38:02,550 --> 00:38:00,560
is i told you that

1019
00:38:03,430 --> 00:38:02,560
the idea was that the boon had a magma

1020
00:38:06,550 --> 00:38:03,440
ocean

1021
00:38:09,430 --> 00:38:06,560
and and it was light crystals of a

1022
00:38:10,470 --> 00:38:09,440
mineral called plagioclase um that rose

1023
00:38:13,430 --> 00:38:10,480
to the top

1024
00:38:15,030 --> 00:38:13,440
and then heavy minerals uh such as the

1025
00:38:16,150 --> 00:38:15,040
uranium thorium potassium they would

1026
00:38:19,750 --> 00:38:16,160
have sunk

1027
00:38:20,710 --> 00:38:19,760
and and as this uh companion accreted to

1028
00:38:22,630 --> 00:38:20,720
the moon

1029
00:38:25,829 --> 00:38:22,640
the simulations show

1030
00:38:28,630 --> 00:38:25,839
that the these heavy materials would

1031
00:38:29,589 --> 00:38:28,640
have been pushed to the near side of the

1032
00:38:31,510 --> 00:38:29,599
moon

1033
00:38:34,069 --> 00:38:31,520
and that should have formed left a

1034
00:38:35,910 --> 00:38:34,079
residual on the near side of the moon

1035
00:38:37,990 --> 00:38:35,920
which because they're heavier they would

1036
00:38:41,109 --> 00:38:38,000
be detectable with gravity

1037
00:38:43,030 --> 00:38:41,119
so um and and we have some idea of what

1038
00:38:46,630 --> 00:38:43,040

the thickness of the magma ocean is so

1039
00:38:48,230 --> 00:38:46,640
we have some idea of the depth of where

1040
00:38:50,310 --> 00:38:48,240
this residual

1041
00:38:51,670 --> 00:38:50,320
density anomaly should be so this is

1042
00:38:53,910 --> 00:38:51,680
something that we can test very

1043
00:38:56,150 --> 00:38:53,920
precisely so it's a it's a very it's

1044
00:38:58,870 --> 00:38:56,160
very good hypothesis testing because it

1045
00:38:59,829 --> 00:38:58,880
made a prediction uh that can be tested

1046
00:39:03,910 --> 00:38:59,839
with

1047
00:39:07,829 --> 00:39:06,390
just uh i want to follow up if you

1048
00:39:09,430 --> 00:39:07,839
survived the

1049
00:39:10,630 --> 00:39:09,440
lunar eclipse

1050
00:39:13,430 --> 00:39:10,640
i was talking

1051
00:39:15,670 --> 00:39:13,440
yesterday with some of your colleagues

1052
00:39:18,390 --> 00:39:15,680
what's the possibility to extend this

1053
00:39:23,030 --> 00:39:20,710
okay i'll address that sure okay

1054
00:39:24,790 --> 00:39:23,040
uh okay so that the every about every

1055
00:39:27,190 --> 00:39:24,800
six months

1056
00:39:29,670 --> 00:39:27,200
there is a solar eclipse

1057
00:39:32,310 --> 00:39:29,680
that causes the spacecraft to uh to be

1058
00:39:35,349 --> 00:39:32,320
in lunar shadow for several hours okay

1059
00:39:36,870 --> 00:39:35,359
and the the spacecraft were not designed

1060
00:39:37,910 --> 00:39:36,880
to make it through those eclipses

1061
00:39:39,829 --> 00:39:37,920
because the

1062
00:39:41,910 --> 00:39:39,839
they we were designed to do the mission

1063
00:39:44,310 --> 00:39:41,920

during um that period

1064
00:39:45,910 --> 00:39:44,320
however

1065
00:39:50,150 --> 00:39:45,920
spacecraft

1066
00:39:52,470 --> 00:39:50,160
often um exceed the performance that you

1067
00:39:53,190 --> 00:39:52,480
design them at so if

1068
00:39:55,910 --> 00:39:53,200
if

1069
00:39:58,230 --> 00:39:55,920
the the two spacecraft made it through

1070
00:39:59,510 --> 00:39:58,240
the lunar eclipse in june

1071
00:40:00,470 --> 00:39:59,520
and both of them would have to make it

1072
00:40:01,910 --> 00:40:00,480
through

1073
00:40:03,990 --> 00:40:01,920
then what would have to happen is

1074
00:40:06,309 --> 00:40:04,000
actually because of the solar geometry

1075
00:40:10,069 --> 00:40:06,319
you'd have to move the back spacecraft

1076
00:40:12,390 --> 00:40:10,079
to the front for uh for ranging purposes

1077
00:40:15,430 --> 00:40:12,400
and you'd need to line them up again and

1078
00:40:17,030 --> 00:40:15,440
and that would take uh well we think it

1079
00:40:19,510 --> 00:40:17,040
would take less time than it took the

1080
00:40:21,990 --> 00:40:19,520
first time because the uh the mission

1081
00:40:25,670 --> 00:40:22,000
operations team would have a better idea

1082
00:40:27,430 --> 00:40:25,680
um how to uh analyze uh or how to

1083
00:40:28,950 --> 00:40:27,440
operate the spacecraft

1084
00:40:31,349 --> 00:40:28,960
um then

1085
00:40:33,750 --> 00:40:31,359
they could conceivably uh begin to range

1086
00:40:36,309 --> 00:40:33,760
again and there's another lunar eclipse

1087
00:40:39,270 --> 00:40:36,319
or another solar eclipse excuse me in

1088
00:40:41,510 --> 00:40:39,280

in december that one relatively speaking

1089
00:40:42,550 --> 00:40:41,520
is rather benign compared to the one in

1090
00:40:45,750 --> 00:40:42,560
june

1091
00:40:48,550 --> 00:40:45,760
and um and so so they could conceivably

1092
00:40:51,030 --> 00:40:48,560
uh keep going but um but if we were

1093
00:40:52,470 --> 00:40:51,040
going to do that we would we we fully

1094
00:40:54,150 --> 00:40:52,480
expect to

1095
00:40:56,790 --> 00:40:54,160
achieve the mission objectives during

1096
00:40:58,550 --> 00:40:56,800
the primary mission and so

1097
00:41:00,470 --> 00:40:58,560
we've been focused on achieving the

1098
00:41:03,910 --> 00:41:00,480
primary objectives which is the job of

1099
00:41:05,589 --> 00:41:03,920
the team right now and after we get

1100
00:41:06,390 --> 00:41:05,599
get the spacecraft on the way to the

1101
00:41:08,550 --> 00:41:06,400
moon

1102
00:41:11,270 --> 00:41:08,560
uh we can begin to think about whether

1103
00:41:13,430 --> 00:41:11,280
new science uh would be possible that

1104
00:41:16,150 --> 00:41:13,440
would uh you know enhance our

1105
00:41:19,030 --> 00:41:16,160
understanding of the moon for for a very

1106
00:41:21,829 --> 00:41:19,040
small uh investment and and we're we're

1107
00:41:23,589 --> 00:41:21,839
sufficiently under budget that uh

1108
00:41:28,230 --> 00:41:23,599
we we probably wouldn't even have to ask

1109
00:41:33,270 --> 00:41:30,069
provide you the money to then do that

1110
00:41:39,589 --> 00:41:36,230
he he shouldn't have to that's it so

1111
00:41:42,069 --> 00:41:39,599
and i understand we have a call online

1112
00:41:45,349 --> 00:41:42,079
hi thanks denise ciao at space.com um

1113
00:41:46,870 --> 00:41:45,359

question for either dr fogel or dr zuber

1114
00:41:49,430 --> 00:41:46,880
could you explain in more detail about

1115
00:41:50,390 --> 00:41:49,440
how having lunar gravity maps could help

1116
00:41:52,470 --> 00:41:50,400
with

1117
00:41:55,990 --> 00:41:52,480
planning future either robotic or manned

1118
00:42:02,390 --> 00:41:58,150
well if you have a very high precision

1119
00:42:05,030 --> 00:42:02,400
gravity map then it's a benefit to both

1120
00:42:06,390 --> 00:42:05,040
none of both human exploration as well

1121
00:42:08,470 --> 00:42:06,400
as

1122
00:42:09,589 --> 00:42:08,480
robotic exploration you can get to your

1123
00:42:15,030 --> 00:42:09,599
your point

1124
00:42:19,430 --> 00:42:16,870
and then just as a follow-up um with

1125
00:42:21,270 --> 00:42:19,440
yesterday's release of the lro pictures

1126
00:42:23,430 --> 00:42:21,280
of the three apollo landing sites and

1127
00:42:25,510 --> 00:42:23,440
then also this upcoming grail mission um

1128
00:42:27,430 --> 00:42:25,520
do you feel that these events will

1129
00:42:30,470 --> 00:42:27,440
uh perhaps inject new public interest in

1130
00:42:35,829 --> 00:42:30,480
the moon

1131
00:42:39,670 --> 00:42:35,839
a fantastic uh

1132
00:42:41,750 --> 00:42:39,680
body in terms of uh its study um in

1133
00:42:46,470 --> 00:42:41,760
terms of learning about early planets

1134
00:42:48,870 --> 00:42:46,480
it's a it's nearby it's accessible um

1135
00:42:51,750 --> 00:42:48,880
and uh and it preserves the record of

1136
00:42:53,349 --> 00:42:51,760
what early planets were like so the um

1137
00:42:54,870 --> 00:42:53,359
you know the surface of the moon four

1138
00:42:55,990 --> 00:42:54,880

billion years ago

1139
00:42:57,829 --> 00:42:56,000
uh

1140
00:43:00,309 --> 00:42:57,839
other planets in the inner part of the

1141
00:43:02,150 --> 00:43:00,319
solar system uh have gone through the

1142
00:43:05,030 --> 00:43:02,160
same processes that the moon has gone

1143
00:43:06,870 --> 00:43:05,040
through and um and because we've studied

1144
00:43:09,750 --> 00:43:06,880
the moon so significantly and we're

1145
00:43:11,349 --> 00:43:09,760
studying it uh i actually i actually

1146
00:43:13,109 --> 00:43:11,359
think in the next five years we're

1147
00:43:16,150 --> 00:43:13,119
really going to rewrite the book in our

1148
00:43:19,910 --> 00:43:16,160
understanding of of the early planets

1149
00:43:21,829 --> 00:43:19,920
also remember the moon is your backyard

1150
00:43:23,510 --> 00:43:21,839
if you had a house the moon would be the

1151
00:43:25,829 --> 00:43:23,520
house next door

1152
00:43:28,069 --> 00:43:25,839
and the other closest planets like mars

1153
00:43:30,870 --> 00:43:28,079
would be miles away

1154
00:43:32,230 --> 00:43:30,880
so it pays to understand your nearest

1155
00:43:34,150 --> 00:43:32,240
neighbor

1156
00:43:36,710 --> 00:43:34,160
and the moon has affected life on this

1157
00:43:38,230 --> 00:43:36,720
earth in many different ways and um i

1158
00:43:41,670 --> 00:43:38,240
think the continuing study of the moon

1159
00:43:43,990 --> 00:43:41,680
is always going to be a profitable thing

1160
00:43:46,309 --> 00:43:44,000
great and back here at ksc

1161
00:43:48,710 --> 00:43:46,319
march at nap for miss hubbard um will

1162
00:43:50,150 --> 00:43:48,720
your cameras be providing like streaming

1163
00:43:51,670 --> 00:43:50,160

down live

1164
00:43:53,589 --> 00:43:51,680
pictures images of the moon i didn't

1165
00:43:55,750 --> 00:43:53,599
know if that was going to be possible to

1166
00:43:58,790 --> 00:43:55,760
click on and see live views of the moon

1167
00:44:01,750 --> 00:43:58,800
and will the children or will it be the

1168
00:44:03,910 --> 00:44:01,760
um team in san diego be actually taking

1169
00:44:06,230 --> 00:44:03,920
the pictures

1170
00:44:09,670 --> 00:44:06,240
who snaps the picture

1171
00:44:12,069 --> 00:44:09,680
i believe that the actual

1172
00:44:14,309 --> 00:44:12,079
the students send the request to the

1173
00:44:16,309 --> 00:44:14,319
mission operations center and then the

1174
00:44:19,510 --> 00:44:16,319
mission operations center is what

1175
00:44:20,870 --> 00:44:19,520
actually takes yes the the photograph

1176
00:44:22,550 --> 00:44:20,880
and what was the first part of your

1177
00:44:25,109 --> 00:44:22,560
question again i'm sorry live streaming

1178
00:44:26,550 --> 00:44:25,119
from the moon pictures images

1179
00:44:31,030 --> 00:44:26,560
i

1180
00:44:32,790 --> 00:44:31,040
yet um

1181
00:44:34,950 --> 00:44:32,800
do we yeah

1182
00:44:37,030 --> 00:44:34,960
so the the way that we were able to get

1183
00:44:39,910 --> 00:44:37,040
this experiment on the mission

1184
00:44:41,670 --> 00:44:39,920
was to make it entirely best efforts

1185
00:44:42,870 --> 00:44:41,680
okay so um

1186
00:44:45,030 --> 00:44:42,880
so

1187
00:44:47,589 --> 00:44:45,040
the the science mission must take place

1188
00:44:51,430 --> 00:44:47,599

and must take priority and then

1189
00:44:53,190 --> 00:44:51,440
whatever data rate is left so so it's

1190
00:44:55,030 --> 00:44:53,200
it's conceivable that we can string

1191
00:44:57,190 --> 00:44:55,040
together uh some images and bring them

1192
00:44:58,309 --> 00:44:57,200
down they wouldn't be quite live because

1193
00:45:00,230 --> 00:44:58,319
we're not going to

1194
00:45:02,150 --> 00:45:00,240
take the extraordinary efforts that

1195
00:45:05,750 --> 00:45:02,160
would be required to do live streaming

1196
00:45:07,349 --> 00:45:05,760
video but we could get conceivably some

1197
00:45:10,069 --> 00:45:07,359
you know enough images taken that we

1198
00:45:11,030 --> 00:45:10,079
could make short videos so it would be

1199
00:45:14,870 --> 00:45:11,040
somewhat

1200
00:45:21,990 --> 00:45:16,550
thanks did you um any of you have an

1201
00:45:27,270 --> 00:45:24,390
i haven't had time to look at my email

1202
00:45:28,710 --> 00:45:27,280
this morning so

1203
00:45:30,230 --> 00:45:28,720
also

1204
00:45:32,550 --> 00:45:30,240
just to follow on a little bit what you

1205
00:45:33,910 --> 00:45:32,560
were saying earlier to bill about the um

1206
00:45:35,270 --> 00:45:33,920
the micron

1207
00:45:37,990 --> 00:45:35,280
measurements

1208
00:45:40,230 --> 00:45:38,000
is it is it correct to say that a

1209
00:45:43,030 --> 00:45:40,240
mountain would move it would move the

1210
00:45:44,630 --> 00:45:43,040
one of the grail spacecraft or both over

1211
00:45:46,309 --> 00:45:44,640
time

1212
00:45:48,150 --> 00:45:46,319
just a micron or would it be several

1213
00:45:50,390 --> 00:45:48,160

microns for a mountain and can you give

1214
00:45:52,870 --> 00:45:50,400
it is there any way to kind of

1215
00:45:55,349 --> 00:45:52,880
uh to say like match up a certain size

1216
00:45:57,109 --> 00:45:55,359
feature with how much of an impact you

1217
00:45:59,430 --> 00:45:57,119
think it would have on the spacecraft's

1218
00:46:02,550 --> 00:45:59,440
altitude

1219
00:46:04,069 --> 00:46:02,560
and in fact the amount of change in the

1220
00:46:06,630 --> 00:46:04,079
range or the distance between the two

1221
00:46:09,349 --> 00:46:06,640
spacecraft will depend on the this load

1222
00:46:11,510 --> 00:46:09,359
the gravity feature so if it's a small

1223
00:46:13,349 --> 00:46:11,520
feature it will move it a little bit if

1224
00:46:15,510 --> 00:46:13,359
it's a bigger feature we'll move it a

1225
00:46:17,829 --> 00:46:15,520
lot but the interesting part is that

1226
00:46:19,510 --> 00:46:17,839
sometimes you'll see a big mountain

1227
00:46:20,550 --> 00:46:19,520
and you would expect a high gravity

1228
00:46:22,309 --> 00:46:20,560
signal

1229
00:46:23,910 --> 00:46:22,319
and then in reality you get

1230
00:46:25,190 --> 00:46:23,920
no gravity signal

1231
00:46:26,950 --> 00:46:25,200
and that's where it gets interesting

1232
00:46:29,349 --> 00:46:26,960
from the geophysics point of view

1233
00:46:30,390 --> 00:46:29,359
because the planet has compensated for

1234
00:46:32,470 --> 00:46:30,400
the weight

1235
00:46:35,270 --> 00:46:32,480
of this load

1236
00:46:37,910 --> 00:46:35,280
and for a net zero effect

1237
00:46:39,589 --> 00:46:37,920
or you fly over a flat region and

1238
00:46:41,270 --> 00:46:39,599

obviously you look at the topography and

1239
00:46:42,470 --> 00:46:41,280
images and it's flat you expect no

1240
00:46:43,430 --> 00:46:42,480
gravity signal

1241
00:46:45,430 --> 00:46:43,440
but then

1242
00:46:46,870 --> 00:46:45,440
our instrument will measure a gravity

1243
00:46:49,190 --> 00:46:46,880
high

1244
00:46:53,030 --> 00:46:49,200
again another puzzle then it turns out

1245
00:46:55,670 --> 00:46:53,040
there are mass cons or subsurface buried

1246
00:46:58,470 --> 00:46:55,680
features or higher density material that

1247
00:47:00,150 --> 00:46:58,480
can only be probed through gravity

1248
00:47:03,270 --> 00:47:00,160
so it's a very

1249
00:47:05,349 --> 00:47:03,280
complex and exciting science that way

1250
00:47:06,870 --> 00:47:05,359
and to bill for a follow-up yeah it's

1251
00:47:08,950 --> 00:47:06,880
really a follow-up to denise's question

1252
00:47:10,950 --> 00:47:08,960
earlier from space.com about

1253
00:47:12,710 --> 00:47:10,960
the value of this data for future

1254
00:47:15,109 --> 00:47:12,720
missions i mean you're talking about

1255
00:47:18,230 --> 00:47:15,119
such subtle effects from these changes

1256
00:47:19,750 --> 00:47:18,240
in gravity as a vehicle orbits it's hard

1257
00:47:21,349 --> 00:47:19,760
for the non-engineer to imagine how that

1258
00:47:22,950 --> 00:47:21,359
would have any impact on landing an

1259
00:47:24,870 --> 00:47:22,960
unmanned spacecraft

1260
00:47:27,109 --> 00:47:24,880
or whatever on the moon they seem to be

1261
00:47:28,870 --> 00:47:27,119
the effects seem to be too subtle to to

1262
00:47:30,470 --> 00:47:28,880
make that a valid selling point as it

1263
00:47:32,230 --> 00:47:30,480

were so i'm obviously missing something

1264
00:47:34,870 --> 00:47:32,240
yeah so i should so i should say that

1265
00:47:37,910 --> 00:47:34,880
this mission was selected um

1266
00:47:40,230 --> 00:47:37,920
completely on the basis of uh scientific

1267
00:47:42,630 --> 00:47:40,240
merit so this this mission was not an

1268
00:47:45,030 --> 00:47:42,640
exploration mission it was the highest

1269
00:47:47,109 --> 00:47:45,040
rated science proposal of the two dozen

1270
00:47:51,030 --> 00:47:47,119
or so that was received

1271
00:47:56,390 --> 00:47:54,069
look at what we've uh gone through

1272
00:47:59,030 --> 00:47:56,400
in recent landings on mars

1273
00:48:01,510 --> 00:47:59,040
where the error ellipses have gone you

1274
00:48:04,470 --> 00:48:01,520
know from being quite substantial

1275
00:48:07,190 --> 00:48:04,480
to being uh to being very small to the

1276
00:48:09,510 --> 00:48:07,200
point where with the mars science lab

1277
00:48:10,790 --> 00:48:09,520
we're going to be able to put that uh

1278
00:48:13,349 --> 00:48:10,800
lander down

1279
00:48:16,549 --> 00:48:13,359
very close to the central peak of a

1280
00:48:17,349 --> 00:48:16,559
crater that preserves the stratigraphy

1281
00:48:23,990 --> 00:48:17,359
of

1282
00:48:26,390 --> 00:48:24,000
so so on the moon after grail

1283
00:48:27,589 --> 00:48:26,400
you know we we now have imaging of the

1284
00:48:30,230 --> 00:48:27,599
surface

1285
00:48:34,150 --> 00:48:30,240
where uh where we can resolve

1286
00:48:35,910 --> 00:48:34,160
uh you know outcrop scale features and

1287
00:48:38,230 --> 00:48:35,920
if you want to land

1288
00:48:39,990 --> 00:48:38,240

right next to a particular outcrop

1289
00:48:42,870 --> 00:48:40,000
you're going to be able to do it

1290
00:48:44,390 --> 00:48:42,880
okay so there there will be no reason to

1291
00:48:47,030 --> 00:48:44,400
do another gravity experiment of the

1292
00:48:49,510 --> 00:48:47,040
moon in any of our lifetimes if there's

1293
00:48:51,349 --> 00:48:49,520
a particular sample return that we want

1294
00:48:53,270 --> 00:48:51,359
to do a particular reconnaissance in a

1295
00:48:56,309 --> 00:48:53,280
particular area of the moon

1296
00:49:00,710 --> 00:48:56,319
you will be able to go exactly there and

1297
00:49:04,630 --> 00:49:02,630
great any more questions here at kennedy

1298
00:49:06,230 --> 00:49:04,640
space center

1299
00:49:09,109 --> 00:49:06,240
all right well thank you very much for

1300
00:49:11,670 --> 00:49:09,119
joining us this morning uh grail launch

1301
00:49:14,549 --> 00:49:11,680
day coverage which is tomorrow of course

1302
00:49:17,670 --> 00:49:14,559
weather willing will begin at 6 00 a.m

1303
00:49:19,510 --> 00:49:17,680
eastern on nasa tv as well as ustream

1304
00:49:23,750 --> 00:49:19,520
for more information about grail please

1305
00:49:27,430 --> 00:49:23,760
visit us on the web at www.nasa.gov