1
00:00:09,110 --> 00:00:04,910
NASA's Jet Propulsion Laboratory

2
00:00:11,540 --> 00:00:09,120
presents the von Karman lecture a series

3
00:00:14,180 --> 00:00:11,550
of talks by scientists and engineers who

4
00:00:21,380 --> 00:00:14,190
are exploring our planet our solar

5
00:00:32,000 --> 00:00:29,260
[Music]

6
00:00:33,260 --> 00:00:32,010
hi everybody welcome to the von Karman

7
00:00:34,340 --> 00:00:33,270
series live at the Jet Propulsion

8
00:00:36,710 --> 00:00:34,350
Laboratory

9
00:00:39,500 --> 00:00:36,720
i am brian white from JPL office of

10
00:00:41,210 --> 00:00:39,510
communication and education welcome

11
00:00:42,979 --> 00:00:41,220
thank you for joining us here tonight as

12
00:00:45,440 --> 00:00:42,989
we celebrate the incredible spitzer

13
00:00:48,710 --> 00:00:45,450

space telescope one of NASA's Great

14
00:00:51,380 --> 00:00:48,720
observatories now spitzer lifted the

15
00:00:53,360 --> 00:00:51,390
veil on the infrared universe operating

16
00:00:55,880 --> 00:00:53,370
well beyond what even its designers

17
00:00:58,670 --> 00:00:55,890
expected the five-and-a-half-year prime

18
00:01:00,439 --> 00:00:58,680
mission ended up a 16 year science

19
00:01:02,930 --> 00:01:00,449
extravaganza with far too many

20
00:01:05,630 --> 00:01:02,940
discoveries to discuss in this brief

21
00:01:08,660 --> 00:01:05,640
introduction this is a bit of a Greatest

22
00:01:10,399 --> 00:01:08,670
Hits kind of thing 16 years of a mission

23
00:01:11,750 --> 00:01:10,409
there's no way we're going to get

24
00:01:14,000 --> 00:01:11,760
through everything but we're gonna try

25
00:01:17,330 --> 00:01:14,010
to cover as much as we can I urge you to

26
00:01:20,990 --> 00:01:17,340
visit Spitzer's websites follow Spitzer

27
00:01:22,250 --> 00:01:21,000
along at NASA Spitzer for details about

28
00:01:24,200 --> 00:01:22,260
the end of the mission which will also

29
00:01:26,390 --> 00:01:24,210
talk about at the end of the day but

30
00:01:29,630 --> 00:01:26,400
before we meet the panel that's here on

31
00:01:31,790 --> 00:01:29,640
stage they want and I want to just

32
00:01:35,090 --> 00:01:31,800
remind everybody that this is a small

33
00:01:37,040 --> 00:01:35,100
part of a huge team that made all of

34
00:01:37,990 --> 00:01:37,050
these discoveries and made all of this

35
00:01:40,130 --> 00:01:38,000
possible

36
00:01:41,690 --> 00:01:40,140
but let's talk about the people who are

37
00:01:44,150 --> 00:01:41,700
here tonight to my left

38
00:01:47,240 --> 00:01:44,160

Joseph hunt Spitzer's project manager

39
00:01:50,840 --> 00:01:47,250
next to him suzanne dodd spitzer project

40
00:01:51,500 --> 00:01:50,850
manager from 2010 to 2016 then we have

41
00:01:53,840 --> 00:01:51,510
Robert hurt

42
00:01:55,940 --> 00:01:53,850
Fitzer Spitzer visualization scientist

43
00:01:57,260 --> 00:01:55,950
with iPAQ and Caltech that's why he's

44
00:01:59,900 --> 00:01:57,270
wearing the maroon he's separating

45
00:02:02,150 --> 00:01:59,910
himself from everybody and certainly not

46
00:02:03,560 --> 00:02:02,160
least the Rouge engorge Ian Spitzer

47
00:02:09,749 --> 00:02:03,570
research scientist how about a big hand

48
00:02:13,510 --> 00:02:12,580
soozee we're gonna start with you can

49
00:02:16,000 --> 00:02:13,520
you tell us a little bit about the

50
00:02:17,970 --> 00:02:16,010
mission about your role early on what's

51
00:02:20,530 --> 00:02:17,980
going on with it sure

52
00:02:22,450 --> 00:02:20,540
I'm I think I'm here to give you all a

53
00:02:24,760 --> 00:02:22,460
little bit of background about what

54
00:02:29,140 --> 00:02:24,770
Spitzer is and and how it got started

55
00:02:33,070 --> 00:02:29,150
so Spitzer is part of NASA's Great

56
00:02:34,840 --> 00:02:33,080
observatories the great Observatory

57
00:02:38,280 --> 00:02:34,850
missions include the Hubble Space

58
00:02:41,860 --> 00:02:38,290
Telescope the Chandra x-ray telescope

59
00:02:44,229 --> 00:02:41,870
the Compton gamma-ray telescope and then

60
00:02:46,420 --> 00:02:44,239
the Spitzer Space Space Telescope now

61
00:02:48,430 --> 00:02:46,430
they all measure in different

62
00:02:51,190 --> 00:02:48,440
wavelengths and Spitzer measures an

63
00:02:54,850 --> 00:02:51,200

infrared light infrared light is

64
00:02:56,890 --> 00:02:54,860
essentially a measure of heat how much

65
00:02:58,630 --> 00:02:56,900
heat is being given off by an object if

66
00:03:00,370 --> 00:02:58,640
you're you might be familiar with the

67
00:03:01,690 --> 00:03:00,380
quote-unquote night-vision goggles or

68
00:03:04,570 --> 00:03:01,700
that type of thing that let you see

69
00:03:07,800 --> 00:03:04,580
through smoke so Spitzer is a telescope

70
00:03:11,170 --> 00:03:07,810
that does the same thing for us in space

71
00:03:14,740 --> 00:03:11,180
it's being an infrared telescope and

72
00:03:17,920 --> 00:03:14,750
being cooled to five degrees Kelvin or

73
00:03:23,580 --> 00:03:17,930
so at its coolest it allows us to peer

74
00:03:26,500 --> 00:03:23,590
through dust and diffuse to breathe that

75
00:03:28,330 --> 00:03:26,510
Hubble can't see through in optical and

76
00:03:31,120 --> 00:03:28,340
that our eyes can't through see through

77
00:03:36,460 --> 00:03:31,130
and it just opens up a whole cornucopia

78
00:03:40,810 --> 00:03:36,470
of data on objects like stellar

79
00:03:44,199 --> 00:03:40,820
nurseries star formation areas galaxies

80
00:03:46,000 --> 00:03:44,209
dying galaxies evolving stars just you

81
00:03:47,650 --> 00:03:46,010
know a whole host of objects you can

82
00:03:51,460 --> 00:03:47,660
kind of see on the wall behind me those

83
00:03:54,610 --> 00:03:51,470
are those are objects that that Spitzer

84
00:04:00,130 --> 00:03:54,620
was able to unveil and to get better

85
00:04:02,229 --> 00:04:00,140
information on that's not the correct

86
00:04:04,479 --> 00:04:02,239
way there we go thank you so this is a

87
00:04:07,569 --> 00:04:04,489
image of the telescope I think it was

88
00:04:11,560 --> 00:04:07,579

taken right about the in this spacecraft

89
00:04:14,710 --> 00:04:11,570
assembly facility at the Cape in Florida

90
00:04:18,630 --> 00:04:14,720
and I also have a little model of it

91
00:04:20,170 --> 00:04:18,640
right here in front of me now so this is

92
00:04:22,900 --> 00:04:20,180
1/32

93
00:04:25,180 --> 00:04:22,910
of the size of Spitzer so if you if you

94
00:04:27,219 --> 00:04:25,190
multiply this little model by 32 times

95
00:04:33,969 --> 00:04:27,229
you'll come up with a spacecraft that is

96
00:04:35,730 --> 00:04:33,979
about 13 feet in height it weighed nine

97
00:04:38,499 --> 00:04:35,740
hundred and thirty kilograms

98
00:04:40,749 --> 00:04:38,509
approximately at launch and it's a it's

99
00:04:42,670 --> 00:04:40,759
a kind of a traditional telescope design

100
00:04:46,840 --> 00:04:42,680
that the top part of it is the actual

101
00:04:49,270 --> 00:04:46,850
telescope and inside that that telescope

102
00:04:50,409 --> 00:04:49,280
is where the instruments are kept and

103
00:04:52,629 --> 00:04:50,419
I'll show you an image of that in a

104
00:04:55,629 --> 00:04:52,639
minute and then below that on the bottom

105
00:04:58,330 --> 00:04:55,639
is the spacecraft and the high gain

106
00:05:02,620 --> 00:04:58,340
antenna and the high gain antenna points

107
00:05:04,300 --> 00:05:02,630
out of the bottom of spitzer so this is

108
00:05:06,820 --> 00:05:04,310
this is the participant sir that's going

109
00:05:10,060 --> 00:05:06,830
to point at the earth this high gain

110
00:05:13,150 --> 00:05:10,070
antenna and this part on the side is the

111
00:05:14,860 --> 00:05:13,160
solar panel and we were solar-powered so

112
00:05:16,540 --> 00:05:14,870
what we'd like to do is be in an orbit

113
00:05:19,689 --> 00:05:16,550

where the solar panel is pointed at the

114
00:05:24,700 --> 00:05:19,699
Sun and the high gain antenna is pointed

115
00:05:26,560 --> 00:05:24,710
down at the earth so the instruments

116
00:05:30,730 --> 00:05:26,570
that we had on spitzer we had three of

117
00:05:32,710 --> 00:05:30,740
them there was a an infrared array

118
00:05:34,750 --> 00:05:32,720
camera and that's the instrument that

119
00:05:38,320 --> 00:05:34,760
worked not only during the cold mission

120
00:05:41,649 --> 00:05:38,330
but also in the warmer mission there was

121
00:05:43,750 --> 00:05:41,659
an infrared spectrometer and then a

122
00:05:45,159 --> 00:05:43,760
multi imaging photometer so there were

123
00:05:47,439 --> 00:05:45,169
three instruments and they were able to

124
00:05:50,670 --> 00:05:47,449
measure in the wavelengths from one

125
00:05:55,360 --> 00:05:50,680
point excuse me from three point six

126
00:05:57,070 --> 00:05:55,370
microns out to 180 microns and this is

127
00:05:59,560 --> 00:05:57,080
an image of the telescope the telescope

128
00:06:03,250 --> 00:05:59,570
and that mirror on the bottom is 85

129
00:06:05,529 --> 00:06:03,260
centimeters in diameter and it's made a

130
00:06:06,730 --> 00:06:05,539
beryllium ball aerospace put the

131
00:06:08,740 --> 00:06:06,740
telescope together

132
00:06:10,930 --> 00:06:08,750
Lockheed Martin was the spacecraft

133
00:06:14,200 --> 00:06:10,940
vendor so for the spacecraft piece of it

134
00:06:17,680 --> 00:06:14,210
and those were the commercial vendors

135
00:06:23,320 --> 00:06:17,690
that helped put the spitzer space

136
00:06:25,210 --> 00:06:23,330
telescope together okay I mean show both

137
00:06:26,529 --> 00:06:25,220
of these at the same time so launch

138
00:06:29,589 --> 00:06:26,539

there's a couple funny stories about

139
00:06:33,070 --> 00:06:29,599
launch that I want to share with you we

140
00:06:40,240 --> 00:06:33,080
launched it on August 25th it was

141
00:06:41,920 --> 00:06:40,250
say 135 a.m. Eastern Time in 2003 and so

142
00:06:43,930 --> 00:06:41,930
there's sometimes there's a confusion on

143
00:06:46,270 --> 00:06:43,940
whether you launched in 2000 excuse me

144
00:06:48,369 --> 00:06:46,280
August 24th or August 25th because of

145
00:06:50,980 --> 00:06:48,379
the it was an East Coast time that

146
00:06:52,869 --> 00:06:50,990
determines the launch date

147
00:06:54,700 --> 00:06:52,879
at any rate you'll notice that on the

148
00:06:57,820 --> 00:06:54,710
side of this rocket it doesn't say

149
00:07:00,070 --> 00:06:57,830
Spitzer it says certif okay well what's

150
00:07:03,670 --> 00:07:00,080
what's certif well certif was the name

151
00:07:09,510 --> 00:07:03,680
of the spitzer space telescope up until

152
00:07:11,800 --> 00:07:09,520
about thirty days after launch spitzer

153
00:07:14,170 --> 00:07:11,810
the name spitzer comes from Lyman

154
00:07:16,209 --> 00:07:14,180
Spitzer a very famous astronomer

155
00:07:17,860 --> 00:07:16,219
astronomer physics professor at

156
00:07:20,939 --> 00:07:17,870
Princeton and he was the person that

157
00:07:24,399 --> 00:07:20,949
came up with the idea of launching

158
00:07:26,890 --> 00:07:24,409
telescopes above our atmosphere in order

159
00:07:31,540 --> 00:07:26,900
to take astronomical information and

160
00:07:34,659 --> 00:07:31,550
data so sort of stood for space infrared

161
00:07:37,719 --> 00:07:34,669
telescope facility and even before that

162
00:07:41,620 --> 00:07:37,729
I believe this is correct it stood for a

163
00:07:42,999 --> 00:07:41,630

shuttle infrared telescope facility so

164
00:07:45,550 --> 00:07:43,009
that's going way back where you're going

165
00:07:50,140 --> 00:07:45,560
to put circus in the Bay of the shuttle

166
00:07:52,719 --> 00:07:50,150
and launch it but so that's that's the

167
00:07:56,230 --> 00:07:52,729
history around the name of absurd if and

168
00:08:00,430 --> 00:07:56,240
Spitzer and also we were supposed to

169
00:08:04,869 --> 00:08:00,440
really supposed to launch in May of 2003

170
00:08:10,779 --> 00:08:04,879
and funny thing happened there were some

171
00:08:12,730 --> 00:08:10,789
issues with our with with the supply of

172
00:08:15,969 --> 00:08:12,740
solid rocket motors that go on the side

173
00:08:18,189 --> 00:08:15,979
of these Delta rockets and there was

174
00:08:20,559 --> 00:08:18,199
another mission called Mars Exploration

175
00:08:22,510 --> 00:08:20,569
Rover you might have recall that the

176
00:08:25,809 --> 00:08:22,520
little rover that could the 90 day

177
00:08:30,249 --> 00:08:25,819
mission it was it was scheduled to

178
00:08:32,769 --> 00:08:30,259
launch in May so it took our solid

179
00:08:35,620 --> 00:08:32,779
rocket motors and so Spitzer stayed on

180
00:08:38,110 --> 00:08:35,630
the ground and didn't get a launch until

181
00:08:40,810 --> 00:08:38,120
August so there was sharing amongst

182
00:08:46,290 --> 00:08:40,820
projects here at JPL and in the launch

183
00:08:49,930 --> 00:08:46,300
vehicles okay

184
00:08:51,730 --> 00:08:49,940
so launch is always exciting time this

185
00:08:53,800 --> 00:08:51,740
picture is actually taken in this room

186
00:08:56,260 --> 00:08:53,810
at launch and you can see a lot of

187
00:08:58,510 --> 00:08:56,270
anxious and happy family members just

188
00:09:01,150 --> 00:08:58,520

like you guys are here today friends and

189
00:09:03,010 --> 00:09:01,160
family and it was also a very anxious

190
00:09:04,860 --> 00:09:03,020
time for a few people that you might

191
00:09:07,870 --> 00:09:04,870
notice the guy sitting next to me

192
00:09:10,210 --> 00:09:07,880
Joseph hunt was on console at launch and

193
00:09:12,430 --> 00:09:10,220
to see Joseph sis right there as a

194
00:09:14,320 --> 00:09:12,440
gentleman my name is chuck Scott who is

195
00:09:17,950 --> 00:09:14,330
now the project manager of the insight

196
00:09:20,500 --> 00:09:17,960
Mars Lander and we just throw these in

197
00:09:22,570 --> 00:09:20,510
here so you can see you know we can all

198
00:09:27,080 --> 00:09:22,580
reminisce and you can see how much we've

199
00:09:34,210 --> 00:09:30,510
[Laughter]

200
00:09:35,830 --> 00:09:34,220
so Spitzer as is we mentioned a sort of

201
00:09:40,330 --> 00:09:35,840
a combination of lots of different

202
00:09:42,370 --> 00:09:40,340
pieces and this is the flow of our

203
00:09:43,780 --> 00:09:42,380
operations and I'll describe this

204
00:09:45,940 --> 00:09:43,790
starting from the upper right-hand

205
00:09:47,890 --> 00:09:45,950
corner where you see basically

206
00:09:50,650 --> 00:09:47,900
scientists out in the science community

207
00:09:52,510 --> 00:09:50,660
they come up with the ideas for what the

208
00:09:55,750 --> 00:09:52,520
point to telescope out what they want to

209
00:09:57,310 --> 00:09:55,760
discover they send those to the spitzer

210
00:10:01,930 --> 00:09:57,320
science center which is located at

211
00:10:05,340 --> 00:10:01,940
Caltech and along with those commands

212
00:10:07,960 --> 00:10:05,350
the Spitzer Science Center puts into a

213
00:10:10,390 --> 00:10:07,970

string of events or a command sequence

214
00:10:13,660 --> 00:10:10,400
our spacecraft partners at Lockheed

215
00:10:16,030 --> 00:10:13,670
Martin put the spacecraft commands and

216
00:10:17,890 --> 00:10:16,040
those get merged in the center there at

217
00:10:19,990 --> 00:10:17,900
the Jet Propulsion Laboratory so here

218
00:10:23,830 --> 00:10:20,000
and this in the big tall building over

219
00:10:26,440 --> 00:10:23,840
there and once the sequences are all

220
00:10:29,530 --> 00:10:26,450
together both the science commands and

221
00:10:31,600 --> 00:10:29,540
the spacecraft commands they get sent to

222
00:10:34,030 --> 00:10:31,610
the deep space network one of my

223
00:10:40,090 --> 00:10:34,040
favorite pieces of this puzzle right now

224
00:10:42,220 --> 00:10:40,100
under there and I'm the director for the

225
00:10:45,970 --> 00:10:42,230
deep space network now so it's it's

226
00:10:49,150 --> 00:10:45,980
pretty cool without the deep space just

227
00:10:50,030 --> 00:10:49,160
be very clear we'll do another talk on

228
00:10:52,829 --> 00:10:50,040
them

229
00:10:55,530 --> 00:10:52,839
so from the Deep Space Network though

230
00:10:58,139 --> 00:10:55,540
they get sent to the Spitzer telescope

231
00:11:00,030 --> 00:10:58,149
Spitzer takes the observation sends the

232
00:11:02,490 --> 00:11:00,040
data back down through the Deep Space

233
00:11:03,870 --> 00:11:02,500
Network back to JPL Society the

234
00:11:06,750 --> 00:11:03,880
engineering will get sent back to

235
00:11:08,790 --> 00:11:06,760
Lockheed Martin in in Denver the science

236
00:11:10,769 --> 00:11:08,800
will go to Caltech it will go into an

237
00:11:12,570 --> 00:11:10,779
archive and the scientists that can then

238
00:11:15,329 --> 00:11:12,580

pull their data out of the archive so

239
00:11:17,760 --> 00:11:15,339
that's the flow and it really involves

240
00:11:21,060 --> 00:11:17,770
as we said it involves academic partners

241
00:11:33,389 --> 00:11:21,070
it involves NASA JPL and it involves in

242
00:11:35,639 --> 00:11:33,399
industry partners we got it okay ketta

243
00:11:38,370 --> 00:11:35,649
Spitzer success is actually it's very

244
00:11:40,980 --> 00:11:38,380
novel orbit so it's but there's it an

245
00:11:43,680 --> 00:11:40,990
earth trailing orbit which means that

246
00:11:45,660 --> 00:11:43,690
once it's launched it it's in the same

247
00:11:48,150 --> 00:11:45,670
orbit as the earth around the Sun but it

248
00:11:51,949 --> 00:11:48,160
just drifts away slowly

249
00:11:54,900 --> 00:11:51,959
so our original mission the one-year

250
00:11:57,570 --> 00:11:54,910
lifetime requirement was two and a half

251
00:11:59,760 --> 00:11:57,580
years that was our level one goal we

252
00:12:02,730 --> 00:11:59,770
managed to last cold with a crouch in

253
00:12:04,980 --> 00:12:02,740
for five and a half years and then we

254
00:12:07,560 --> 00:12:04,990
got into the extended mission the warm

255
00:12:10,050 --> 00:12:07,570
mission where Iraq was the only

256
00:12:14,100 --> 00:12:10,060
instrument operating at about 27 degrees

257
00:12:17,880 --> 00:12:14,110
Kelvin and that extended mission

258
00:12:20,310 --> 00:12:17,890
continued on out to 2016 when Spitzer

259
00:12:22,710 --> 00:12:20,320
went through I think what would probably

260
00:12:26,760 --> 00:12:22,720
be considered sort of its last review

261
00:12:29,280 --> 00:12:26,770
for the project lifetime and we started

262
00:12:32,280 --> 00:12:29,290
the Spitzer beyond phase and one of the

263
00:12:35,220 --> 00:12:32,290

differences between the warm phase and

264
00:12:37,769 --> 00:12:35,230
the Spitzer beyond phases as you can see

265
00:12:40,140 --> 00:12:37,779
in this orbit picture the the spacecraft

266
00:12:42,060 --> 00:12:40,150
is getting drifting further work further

267
00:12:45,180 --> 00:12:42,070
away from the earth it's also changing

268
00:12:47,130 --> 00:12:45,190
its angle the solar array angle on the

269
00:12:50,310 --> 00:12:47,140
Sun so it's not getting as much direct

270
00:12:56,340 --> 00:12:50,320
light perpendicular onto the solar panel

271
00:12:58,500 --> 00:12:56,350
so we actually had to modify the onboard

272
00:13:00,990 --> 00:12:58,510
fault protection and even disable it so

273
00:13:02,950 --> 00:13:01,000
starting in the Spitzer Beyond mission

274
00:13:04,810 --> 00:13:02,960
we were taking real

275
00:13:06,520 --> 00:13:04,820
the risk of losing the spacecraft if

276
00:13:08,140 --> 00:13:06,530
something went wrong because we no

277
00:13:09,460 --> 00:13:08,150
longer could have the we were

278
00:13:11,830 --> 00:13:09,470
essentially tricking the fall protection

279
00:13:13,660 --> 00:13:11,840
into doing turning it off and and

280
00:13:16,690 --> 00:13:13,670
telling it to do something it was never

281
00:13:19,960 --> 00:13:16,700
designed to do yeah

282
00:13:22,420 --> 00:13:19,970
and the key again here is to be up above

283
00:13:26,320 --> 00:13:22,430
the atmosphere of the earth and away

284
00:13:28,180 --> 00:13:26,330
from the earth moon infrared environment

285
00:13:32,890 --> 00:13:28,190
and that allows us to take these these

286
00:13:35,590 --> 00:13:32,900
awesome pictures that Spitzer took and I

287
00:13:36,910 --> 00:13:35,600
have one last photo here some of you in

288
00:13:38,560 --> 00:13:36,920

the audience might be able to find

289
00:13:40,590 --> 00:13:38,570
yourself in this image but this is a

290
00:13:44,130 --> 00:13:40,600
picture of the Spitzer team at launch

291
00:13:47,380 --> 00:13:44,140
primarily the folks from Caltech and JPL

292
00:13:50,170 --> 00:13:47,390
but it's it's always comes down to the

293
00:13:52,300 --> 00:13:50,180
people on these projects and it's just

294
00:13:55,030 --> 00:13:52,310
super exciting to be involved with them

295
00:13:56,800 --> 00:13:55,040
a little bit sad to see it end but

296
00:13:59,350 --> 00:13:56,810
knowing that there's going to be good

297
00:14:02,560 --> 00:13:59,360
things after this coming with new

298
00:14:05,440 --> 00:14:02,570
missions so that's that's the Spitzer

299
00:14:07,480 --> 00:14:05,450
and maybe five minutes that's that's

300
00:14:08,800 --> 00:14:07,490
yeah boiled down to a lot but did you

301
00:14:11,260 --> 00:14:08,810
talk about the legacy of it yes the

302
00:14:13,120 --> 00:14:11,270
people but another big legacy of spitz

303
00:14:16,870 --> 00:14:13,130
are also these wonderful images that

304
00:14:18,460 --> 00:14:16,880
we've been getting through Roberts let's

305
00:14:21,130 --> 00:14:18,470
talk about these images and first off

306
00:14:22,990 --> 00:14:21,140
how do you even it's not like I'm taking

307
00:14:24,850 --> 00:14:23,000
a Polaroid and we're printing out an

308
00:14:26,980 --> 00:14:24,860
exoplanet or something like that not

309
00:14:30,430 --> 00:14:26,990
quite but actually just start with one

310
00:14:31,780 --> 00:14:30,440
quick anecdote of the infrared image you

311
00:14:33,730 --> 00:14:31,790
saw of Spitzer's launch that was

312
00:14:35,020 --> 00:14:33,740
actually how I engineered my ability to

313
00:14:37,540 --> 00:14:35,030

go to the spitzer Luntz and watch it

314
00:14:39,220 --> 00:14:37,550
because I said hey infrared telescope we

315
00:14:41,350 --> 00:14:39,230
should film it in the infrared when it

316
00:14:42,550 --> 00:14:41,360
launches and so I had the opportunity to

317
00:14:43,870 --> 00:14:42,560
go and run the infrared camera and

318
00:14:45,100 --> 00:14:43,880
that's how I actually got the best seat

319
00:14:46,660 --> 00:14:45,110
in the house because we were with the

320
00:14:48,520 --> 00:14:46,670
press and that's the closest you can get

321
00:14:50,680 --> 00:14:48,530
to the launch you know they don't let

322
00:14:52,300 --> 00:14:50,690
anyone closer to that so I got like you

323
00:14:53,470 --> 00:14:52,310
know ringside seat watching that thing

324
00:14:56,080 --> 00:14:53,480
go up and I was spreading over the

325
00:15:00,100 --> 00:14:56,090
infrared camera the whole time but night

326
00:15:01,780 --> 00:15:00,110
lunches are impressive but yeah the I I

327
00:15:04,450 --> 00:15:01,790
had the privilege over the last 16 years

328
00:15:06,250 --> 00:15:04,460
of being the person to basically take

329
00:15:08,620 --> 00:15:06,260
the data from Spitzer and create its

330
00:15:11,410 --> 00:15:08,630
public-facing version that you see in

331
00:15:13,810 --> 00:15:11,420
press releases and on our website and in

332
00:15:15,910 --> 00:15:13,820
a very real way I think the imagery of a

333
00:15:16,660 --> 00:15:15,920
telescope becomes the the public face of

334
00:15:19,270 --> 00:15:16,670
what that telescope

335
00:15:21,010 --> 00:15:19,280
accomplishes and Spitzer is interesting

336
00:15:23,560 --> 00:15:21,020
because it really was opening up this

337
00:15:25,780 --> 00:15:23,570
whole new regime of infrared light to us

338
00:15:28,330 --> 00:15:25,790

and so my challenge was to go in and

339
00:15:29,950 --> 00:15:28,340
take the data that comes from the

340
00:15:32,800 --> 00:15:29,960
telescope which is not very photogenic

341
00:15:34,180 --> 00:15:32,810
in the raw form that it comes down you

342
00:15:36,190 --> 00:15:34,190
know this is this is this is how the

343
00:15:39,010 --> 00:15:36,200
information comes down lots of metadata

344
00:15:42,100 --> 00:15:39,020
but encoded in this data is the

345
00:15:44,800 --> 00:15:42,110
information you need to make a a gridded

346
00:15:46,750 --> 00:15:44,810
grayscale image rendering what the sky

347
00:15:50,980 --> 00:15:46,760
looks like at a particular wavelength of

348
00:15:53,590 --> 00:15:50,990
light so my job is to start with that

349
00:15:55,780 --> 00:15:53,600
data and render it into a picture that

350
00:15:57,190 --> 00:15:55,790
you can work with well that's not always

351
00:15:58,750 --> 00:15:57,200
as simple as it sounds for instance

352
00:16:00,040 --> 00:15:58,760
here's a lovely galaxy but it doesn't

353
00:16:02,380 --> 00:16:00,050
look terribly interesting because

354
00:16:04,480 --> 00:16:02,390
galaxies have a huge dynamic range of

355
00:16:06,550 --> 00:16:04,490
information the brightest core the core

356
00:16:07,960 --> 00:16:06,560
of a galaxy can be hundreds of thousands

357
00:16:09,820 --> 00:16:07,970
of times brighter than the faint outer

358
00:16:11,860 --> 00:16:09,830
edge so one of the things you have to do

359
00:16:14,050 --> 00:16:11,870
is because science data is intrinsically

360
00:16:15,220 --> 00:16:14,060
very high dynamic range you have to

361
00:16:17,020 --> 00:16:15,230
actually figure out what exposure

362
00:16:19,000 --> 00:16:17,030
effectively you want to apply to the

363
00:16:20,620 --> 00:16:19,010

science data to get the image that you

364
00:16:22,330 --> 00:16:20,630
want to see so you can actually go

365
00:16:24,430 --> 00:16:22,340
through and apply you know magical

366
00:16:26,050 --> 00:16:24,440
transformations to the raw data and as

367
00:16:27,820 --> 00:16:26,060
you do so you can bring out more and

368
00:16:29,530 --> 00:16:27,830
more of the contrast of the image and

369
00:16:30,880 --> 00:16:29,540
really start revealing stuff that you

370
00:16:33,880 --> 00:16:30,890
wouldn't even get at the first glance

371
00:16:35,830 --> 00:16:33,890
it's it's kind of like being running a

372
00:16:38,710 --> 00:16:35,840
photography studio after the data comes

373
00:16:39,820 --> 00:16:38,720
down from the telescope then once you've

374
00:16:41,980 --> 00:16:39,830
done this of course you have to pick out

375
00:16:44,380 --> 00:16:41,990
what is maybe the right level exposure

376
00:16:45,940 --> 00:16:44,390
to use and different objects will

377
00:16:48,010 --> 00:16:45,950
require different amounts of adjustment

378
00:16:49,900 --> 00:16:48,020
to the data so for galaxy I would say

379
00:16:55,080 --> 00:16:49,910
the probably the best use if this might

380
00:16:57,340 --> 00:16:55,090
be the lower left or middle probably and

381
00:16:58,960 --> 00:16:57,350
you basically do that for each band that

382
00:17:01,390 --> 00:16:58,970
you want to pull out and make a picture

383
00:17:03,130 --> 00:17:01,400
but that just gets you to the point that

384
00:17:04,270 --> 00:17:03,140
you have a grayscale image what we want

385
00:17:07,030 --> 00:17:04,280
to see though of these lovely color

386
00:17:09,460 --> 00:17:07,040
images but of course our eyes can't see

387
00:17:11,200 --> 00:17:09,470
infrared color so what are we doing well

388
00:17:14,320 --> 00:17:11,210

every color picture you've ever seen is

389
00:17:14,830 --> 00:17:14,330
just a combination of red green and blue

390
00:17:17,520 --> 00:17:14,840
light

391
00:17:19,960 --> 00:17:17,530
now when Spitzer observes an object we

392
00:17:21,550 --> 00:17:19,970
once you pick out what exposure you want

393
00:17:22,900 --> 00:17:21,560
Spitzer has done it at different

394
00:17:25,750 --> 00:17:22,910
wavelengths different parts of the

395
00:17:27,520 --> 00:17:25,760
spectrum so if we just take grayscale

396
00:17:28,660 --> 00:17:27,530
images from max I'm sorry I'm getting

397
00:17:30,160 --> 00:17:28,670
ahead of myself here lay back up a

398
00:17:32,980 --> 00:17:30,170
second look because I said the spectrum

399
00:17:34,960 --> 00:17:32,990
let me go ahead with the spectrum this

400
00:17:36,790 --> 00:17:34,970
part of the spectrum that Spitzer works

401
00:17:40,270 --> 00:17:36,800
in as Susie point out is on the range

402
00:17:42,010 --> 00:17:40,280
from 3.6 to 160 microns now the two

403
00:17:43,510 --> 00:17:42,020
things I want to teach you about what

404
00:17:45,940 --> 00:17:43,520
you are seeing when you look at infrared

405
00:17:49,090 --> 00:17:45,950
light comes from starlight it comes from

406
00:17:51,010 --> 00:17:49,100
dust starlight like the light our Sun

407
00:17:52,630 --> 00:17:51,020
emits is very strong in what we call the

408
00:17:53,940 --> 00:17:52,640
visible part of the spectrum because

409
00:17:55,780 --> 00:17:53,950
that's the part their eyes are

410
00:17:57,580 --> 00:17:55,790
biologically engineered to be able to

411
00:17:58,720 --> 00:17:57,590
see in but what's interesting is

412
00:18:00,580 --> 00:17:58,730
starlight becomes less and less

413
00:18:02,170 --> 00:18:00,590

significant as you go to longer and

414
00:18:03,100 --> 00:18:02,180
longer wavelengths of light so that by

415
00:18:04,870 --> 00:18:03,110
the time you get into the far infrared

416
00:18:07,600 --> 00:18:04,880
spectrum you hardly see stars at all

417
00:18:10,000 --> 00:18:07,610
that they're gone but the other game in

418
00:18:11,590 --> 00:18:10,010
town is dust dust are these clouds of

419
00:18:14,170 --> 00:18:11,600
soot that fill the interstellar medium

420
00:18:15,610 --> 00:18:14,180
and completely can block our view of the

421
00:18:17,410 --> 00:18:15,620
center of our galaxy and the more

422
00:18:19,420 --> 00:18:17,420
distant parts but dust has a very

423
00:18:21,460 --> 00:18:19,430
interesting property that as you go to

424
00:18:23,920 --> 00:18:21,470
longer wavelengths of light that light

425
00:18:26,050 --> 00:18:23,930
starts to become able to move through

426
00:18:27,460 --> 00:18:26,060
the dust the dust becomes less opaque to

427
00:18:29,860 --> 00:18:27,470
the point that it goes becomes virtually

428
00:18:32,770 --> 00:18:29,870
transparent if you push further into the

429
00:18:35,470 --> 00:18:32,780
infrared the dust itself has a thermal

430
00:18:37,840 --> 00:18:35,480
glow not because it's hot but because

431
00:18:39,790 --> 00:18:37,850
it's typically very very cool spitzer is

432
00:18:41,680 --> 00:18:39,800
looking for the heat emitted by objects

433
00:18:42,610 --> 00:18:41,690
like dust but in this case it's the heat

434
00:18:45,130 --> 00:18:42,620
that's coming from things that are

435
00:18:46,920 --> 00:18:45,140
really really cold maybe a few tens or

436
00:18:50,200 --> 00:18:46,930
hundreds of degrees above absolute zero

437
00:18:51,670 --> 00:18:50,210
so dust has that transition where we

438
00:18:53,800 --> 00:18:51,680

start to see through it in the infrared

439
00:18:55,810 --> 00:18:53,810
and then it itself starts to be a

440
00:18:57,580 --> 00:18:55,820
luminous thing that we're observing so

441
00:18:58,840 --> 00:18:57,590
those two things together shape the bulk

442
00:19:00,790 --> 00:18:58,850
of what you see when you look at a

443
00:19:03,610 --> 00:19:00,800
spitzer image which samples the spectrum

444
00:19:05,410 --> 00:19:03,620
at these four seven different locations

445
00:19:08,230 --> 00:19:05,420
now I'm going to talk mainly about the

446
00:19:09,190 --> 00:19:08,240
the inner five wavelengths of here and

447
00:19:11,050 --> 00:19:09,200
see what happens when you combine

448
00:19:13,420 --> 00:19:11,060
different combinations of those

449
00:19:15,070 --> 00:19:13,430
observations into a picture now as I was

450
00:19:16,720 --> 00:19:15,080
saying each of these observations is

451
00:19:18,070 --> 00:19:16,730
essentially a grayscale image but every

452
00:19:19,900 --> 00:19:18,080
color picture you've ever looked out on

453
00:19:21,850 --> 00:19:19,910
your TV or your phone are really just a

454
00:19:23,380 --> 00:19:21,860
combination of three grayscale images

455
00:19:26,140 --> 00:19:23,390
representing red green and blue

456
00:19:28,330 --> 00:19:26,150
displayed in red green and blue light so

457
00:19:30,190 --> 00:19:28,340
if we go and sample pieces of the

458
00:19:32,200 --> 00:19:30,200
spectrum from Spitzer and select three

459
00:19:34,960 --> 00:19:32,210
of these asign than the colors of red

460
00:19:38,860 --> 00:19:34,970
green and blue bring those together that

461
00:19:40,710 --> 00:19:38,870
reveals a color image this is the color

462
00:19:43,390 --> 00:19:40,720
view of an infrared part of the spectrum

463
00:19:43,720 --> 00:19:43,400

translated into the familiar red green

464
00:19:46,030 --> 00:19:43,730
blue

465
00:19:47,590 --> 00:19:46,040
that we see but we have the flexibility

466
00:19:49,360 --> 00:19:47,600
to pick different parts of the spectrum

467
00:19:51,040 --> 00:19:49,370
we want to represent here I've dropped

468
00:19:53,920 --> 00:19:51,050
out the second band and I brought in the

469
00:19:55,210 --> 00:19:53,930
fourth band and by simply changing which

470
00:19:57,010 --> 00:19:55,220
parts of the spectrum we're going to

471
00:19:58,690 --> 00:19:57,020
sample we can take the same region in

472
00:20:00,730 --> 00:19:58,700
the sky and reveal it in completely

473
00:20:02,020 --> 00:20:00,740
different ways and ways that actually

474
00:20:04,540 --> 00:20:02,030
tell different parts of the science

475
00:20:06,310 --> 00:20:04,550
story of what's going on there so let me

476
00:20:08,530 --> 00:20:06,320
step you through two examples two of the

477
00:20:10,930 --> 00:20:08,540
things that Spitzer imaged a lot of were

478
00:20:12,460 --> 00:20:10,940
star forming regions and galaxies star

479
00:20:14,680 --> 00:20:12,470
forming regions we more commonly call

480
00:20:16,960 --> 00:20:14,690
nebula this is one called the cat's paw

481
00:20:19,000 --> 00:20:16,970
as seen in visible light where red green

482
00:20:20,350 --> 00:20:19,010
and blue is displayed as red green and

483
00:20:23,230 --> 00:20:20,360
blue and my colors got messed up again

484
00:20:25,900 --> 00:20:23,240
that last marker supposed to be red now

485
00:20:28,630 --> 00:20:25,910
when we transition to the infra red

486
00:20:30,460 --> 00:20:28,640
watch carefully how this is perfectly

487
00:20:32,920 --> 00:20:30,470
aligned to be the same image but it's

488
00:20:34,090 --> 00:20:32,930

completely unrecognizable because in the

489
00:20:36,040 --> 00:20:34,100
visible light we were just seeing the

490
00:20:36,490 --> 00:20:36,050
light from the hot gas but with the

491
00:20:38,890 --> 00:20:36,500
infrared

492
00:20:40,750 --> 00:20:38,900
now the extended dark dust becomes the

493
00:20:42,580 --> 00:20:40,760
feature were drawn to here we're

494
00:20:44,950 --> 00:20:42,590
sampling data out from three point six

495
00:20:46,780 --> 00:20:44,960
to eight microns so the dust is showing

496
00:20:48,520 --> 00:20:46,790
up is red the stars are showing up is

497
00:20:49,450 --> 00:20:48,530
blue because they're they fade out by

498
00:20:51,490 --> 00:20:49,460
the time you get to the longer

499
00:20:53,320 --> 00:20:51,500
wavelengths of infrared but if we mix it

500
00:20:55,690 --> 00:20:53,330
up again and say pull the red channel

501
00:20:56,950 --> 00:20:55,700
all the way out to 24 microns we get a

502
00:20:59,050 --> 00:20:56,960
very different rendering of the same

503
00:21:00,850 --> 00:20:59,060
region in this case the red channel is

504
00:21:03,130 --> 00:21:00,860
now sampling the dust that is being

505
00:21:04,840 --> 00:21:03,140
warmed by the stars so it's it's just

506
00:21:06,880 --> 00:21:04,850
the hottest dust that's starting to show

507
00:21:08,830 --> 00:21:06,890
up there and as a result this is really

508
00:21:10,840 --> 00:21:08,840
letting us zero in on the regions where

509
00:21:12,730 --> 00:21:10,850
stars are forming and if you look you

510
00:21:13,990 --> 00:21:12,740
can even see dark lanes of dust that are

511
00:21:15,700 --> 00:21:14,000
still there that we still can't see

512
00:21:17,410 --> 00:21:15,710
through that's because these are regions

513
00:21:19,060 --> 00:21:17,420

that are so dense that even with the

514
00:21:21,220 --> 00:21:19,070
increased transparency of the infrared

515
00:21:22,720 --> 00:21:21,230
we still can't see through them but if

516
00:21:24,970 --> 00:21:22,730
you look along those lanes you can see

517
00:21:26,860 --> 00:21:24,980
little red dots in places and those are

518
00:21:28,330 --> 00:21:26,870
baby stars protostars that are still

519
00:21:30,220 --> 00:21:28,340
swaddled underneath there

520
00:21:32,020 --> 00:21:30,230
they're dusty cocoons still in the

521
00:21:34,060 --> 00:21:32,030
process of forming that someday when

522
00:21:35,650 --> 00:21:34,070
they form will light up and burst out of

523
00:21:38,680 --> 00:21:35,660
their nebula and create the kind of

524
00:21:40,540 --> 00:21:38,690
displays we see here later so if we go

525
00:21:42,340 --> 00:21:40,550
to a galaxy this is the Whirlpool Galaxy

526
00:21:44,350 --> 00:21:42,350
one of my favorite an interacting pair

527
00:21:46,870 --> 00:21:44,360
of galaxies the visible light is very

528
00:21:49,000 --> 00:21:46,880
pretty very pastel but when we switch to

529
00:21:51,040 --> 00:21:49,010
Spitzer's infrared view we find there's

530
00:21:53,470 --> 00:21:51,050
a striking contrast between the two

531
00:21:55,540 --> 00:21:53,480
parts of this galaxy the one on the left

532
00:21:57,100 --> 00:21:55,550
is actually very blue because it's

533
00:21:59,110 --> 00:21:57,110
filled with stars but almost

534
00:22:01,539 --> 00:21:59,120
no dust at all it's a basically a

535
00:22:03,010 --> 00:22:01,549
gas-poor galaxies that's passing through

536
00:22:05,410 --> 00:22:03,020
and interacting with the larger galaxies

537
00:22:07,600 --> 00:22:05,420
the larger one has these lovely spiral

538
00:22:09,760 --> 00:22:07,610

arms but now being able to see the dust

539
00:22:11,320 --> 00:22:09,770
as a glowing element we can actually see

540
00:22:14,410 --> 00:22:11,330
those spiral arms like you might see a

541
00:22:16,870 --> 00:22:14,420
skeleton and an x-ray of an animal where

542
00:22:19,480 --> 00:22:16,880
the dust is building up into ridges and

543
00:22:22,690 --> 00:22:19,490
lanes and spokes and these are tied to

544
00:22:24,640 --> 00:22:22,700
the processes that how gas flows through

545
00:22:26,890 --> 00:22:24,650
a galaxy and builds up and then creates

546
00:22:28,720 --> 00:22:26,900
dense regions that begin the process of

547
00:22:31,270 --> 00:22:28,730
star formation but we can see where the

548
00:22:33,400 --> 00:22:31,280
dust is and the gas that travels with it

549
00:22:36,370 --> 00:22:33,410
but we need to go to the longer

550
00:22:38,200 --> 00:22:36,380
wavelengths of light and pull in the 24

551
00:22:40,720 --> 00:22:38,210
micron to now really highlight where the

552
00:22:42,520 --> 00:22:40,730
stars are actively forming now the warm

553
00:22:44,680 --> 00:22:42,530
dust is popping up as red in this image

554
00:22:46,299 --> 00:22:44,690
so the dots that look so red or orange

555
00:22:48,940 --> 00:22:46,309
the way they're combining with the green

556
00:22:51,070 --> 00:22:48,950
light are the places where all of that

557
00:22:53,440 --> 00:22:51,080
dust is forming vigorously new stars and

558
00:22:55,720 --> 00:22:53,450
basically every red dot in here would

559
00:22:57,010 --> 00:22:55,730
look if we had the resolution like that

560
00:22:59,049 --> 00:22:57,020
last picture I showed you of a

561
00:23:01,030 --> 00:22:59,059
star-forming region but now we see that

562
00:23:04,900 --> 00:23:01,040
mapped out on a global scale across

563
00:23:06,909 --> 00:23:04,910

another galaxy so this just starts to

564
00:23:09,430 --> 00:23:06,919
scratch the tip of the iceberg of the

565
00:23:10,960 --> 00:23:09,440
kind of science that Spitzer can do but

566
00:23:13,780 --> 00:23:10,970
it does help you if you look at some of

567
00:23:15,549 --> 00:23:13,790
our images ask that question what do the

568
00:23:16,780 --> 00:23:15,559
colours mean and water is it telling you

569
00:23:20,340 --> 00:23:16,790
about this that you don't see in visible

570
00:23:22,510 --> 00:23:20,350
light but the rest of the science story

571
00:23:25,960 --> 00:23:22,520
but I do want to point out something

572
00:23:28,480 --> 00:23:25,970
before we move on you too went to grad

573
00:23:47,230 --> 00:23:28,490
school together you two have known each

574
00:23:50,470 --> 00:23:47,240
other for actually deparment astronomy

575
00:23:53,110 --> 00:23:50,480
at that point so we've known each other

576
00:23:55,659 --> 00:23:53,120
for a long time so we passing the torch

577
00:23:57,370 --> 00:23:55,669
back and forth is second nature for us

578
00:23:59,140 --> 00:23:57,380
so how do you start going through all

579
00:24:00,730 --> 00:23:59,150
those reams and reams of data and

580
00:24:02,409 --> 00:24:00,740
everything that he is some of the stuff

581
00:24:06,220 --> 00:24:02,419
you just presented to us well the short

582
00:24:07,950 --> 00:24:06,230
answer is I don't this is the work of an

583
00:24:11,320 --> 00:24:07,960
incredibly large number of scientists

584
00:24:14,350 --> 00:24:11,330
across the world the way NASA operates

585
00:24:17,650 --> 00:24:14,360
its telescopes is that accessibility is

586
00:24:19,930 --> 00:24:17,660
allowed for anybody who has who's an

587
00:24:23,230 --> 00:24:19,940
astronomer and puts in a valid proposal

588
00:24:24,549 --> 00:24:23,240

so all of the different ideas are coming

589
00:24:26,500 --> 00:24:24,559
from all of the astronomers across the

590
00:24:27,760 --> 00:24:26,510
planet of course the United States has

591
00:24:29,260 --> 00:24:27,770
the most number of astronomers so most

592
00:24:32,200 --> 00:24:29,270
of the proposals come from the United

593
00:24:34,720 --> 00:24:32,210
States but fundamentally this really

594
00:24:36,100 --> 00:24:34,730
taps into the creativity of as many

595
00:24:38,290 --> 00:24:36,110
people as possible so that we can do

596
00:24:39,700 --> 00:24:38,300
very interesting creative science with

597
00:24:42,210 --> 00:24:39,710
the tools provided for us by these

598
00:24:46,000 --> 00:24:42,220
incredible engineers and support staff

599
00:24:47,919 --> 00:24:46,010
but NASA for a long time had has had

600
00:24:50,500 --> 00:24:47,929
these very key questions that I think a

601
00:24:52,270 --> 00:24:50,510
lot of us wonder just in general but

602
00:24:54,159 --> 00:24:52,280
these are we've tried to take these

603
00:24:57,250 --> 00:24:54,169
general things that all of us wonder

604
00:24:59,799 --> 00:24:57,260
about as human beings and you know to

605
00:25:02,049 --> 00:24:59,809
really look for them so where are we

606
00:25:03,880 --> 00:25:02,059
going where do we come where do we come

607
00:25:06,730 --> 00:25:03,890
from where are we going and are we alone

608
00:25:09,820 --> 00:25:06,740
and so and Spitzer had to a lot to say

609
00:25:12,100 --> 00:25:09,830
about each of these questions starting

610
00:25:15,190 --> 00:25:12,110
from where we are right now one of the

611
00:25:16,419 --> 00:25:15,200
greatest discoveries in my view just

612
00:25:19,590 --> 00:25:16,429
even though I'm not a planetary

613
00:25:22,540 --> 00:25:19,600

scientist I don't study planets it was

614
00:25:25,659 --> 00:25:22,550
finding the largest ring around Saturn

615
00:25:27,549 --> 00:25:25,669
now Galileo was the first one to see

616
00:25:30,340 --> 00:25:27,559
Saturn and his telescope and he thought

617
00:25:32,080 --> 00:25:30,350
it had ears he didn't have quite the

618
00:25:34,000 --> 00:25:32,090
telescope good enough to resolve the

619
00:25:35,649 --> 00:25:34,010
ring but then once you know they did

620
00:25:37,750 --> 00:25:35,659
were built better telescopes and

621
00:25:39,399 --> 00:25:37,760
Cassini's really saw the idea that there

622
00:25:40,750 --> 00:25:39,409
are rings around Saturn and so we've

623
00:25:42,880 --> 00:25:40,760
been studying those rings for a very

624
00:25:47,020 --> 00:25:42,890
very long time and in this Ardis concept

625
00:25:48,460 --> 00:25:47,030
by Robert we can display what we saw

626
00:25:52,659 --> 00:25:48,470
which is that there's a ring in fact

627
00:25:53,830 --> 00:25:52,669
much much larger than that tiny thing

628
00:25:55,149 --> 00:25:53,840
right at the mid center which is

629
00:25:58,510 --> 00:25:55,159
Saturn's sort of blown up here for you

630
00:26:00,159 --> 00:25:58,520
to see and nobody had seen it why had

631
00:26:01,990 --> 00:26:00,169
anybody not seen it well it was

632
00:26:05,320 --> 00:26:02,000
essentially hidden in plain sight

633
00:26:07,090 --> 00:26:05,330
it was very tenuous which meant it

634
00:26:08,860 --> 00:26:07,100
didn't scatter very much light so

635
00:26:10,390 --> 00:26:08,870
optical light would you know would not

636
00:26:12,730 --> 00:26:10,400
be scattered very much so our regular

637
00:26:14,799 --> 00:26:12,740
optical telescopes would not see it but

638
00:26:16,659 --> 00:26:14,809

it was warm enough to produce infrared

639
00:26:18,820 --> 00:26:16,669
light and Spitzer was sensitive enough

640
00:26:20,290 --> 00:26:18,830
to pick it up so this is the kind of

641
00:26:21,130 --> 00:26:20,300
thing that we were able to see that in

642
00:26:22,600 --> 00:26:21,140
our own backyard

643
00:26:24,730 --> 00:26:22,610
one of the biggest things we had missed

644
00:26:28,660 --> 00:26:24,740
all this time and Spitzer was able to

645
00:26:31,300 --> 00:26:28,670
show it to us going a little bit further

646
00:26:32,380 --> 00:26:31,310
off of course we see comments every now

647
00:26:34,330 --> 00:26:32,390
and then passing through the inner solar

648
00:26:38,080 --> 00:26:34,340
system and they're a fairly common thing

649
00:26:40,720 --> 00:26:38,090
in but what is so important about comets

650
00:26:41,860 --> 00:26:40,730
other than they're very pretty and one

651
00:26:44,440 --> 00:26:41,870
of the things is that these are

652
00:26:48,070 --> 00:26:44,450
essentially dirty snowballs and we think

653
00:26:51,160 --> 00:26:48,080
they are remnants of the formation of

654
00:26:53,320 --> 00:26:51,170
our solar system and the difficulty

655
00:26:54,970 --> 00:26:53,330
though in studying comets is of course

656
00:26:59,440 --> 00:26:54,980
they're volatize the surface keeps

657
00:27:00,490 --> 00:26:59,450
outgassing but also very much like you

658
00:27:02,350 --> 00:27:00,500
know anything that's left outside

659
00:27:04,120 --> 00:27:02,360
there's essentially what you might call

660
00:27:07,630 --> 00:27:04,130
weathering not actual weathering but the

661
00:27:10,150 --> 00:27:07,640
surface gets heated by the Sun and

662
00:27:12,460 --> 00:27:10,160
reprocess so it's not as primordial as

663
00:27:15,280 --> 00:27:12,470

it was it changes over time but the

664
00:27:16,900 --> 00:27:15,290
interior is cold and so NASA had a

665
00:27:21,760 --> 00:27:16,910
mission called deep impact where it

666
00:27:25,150 --> 00:27:21,770
launched a projectile to hit the comet

667
00:27:26,950 --> 00:27:25,160
Tempel 1 and it basically raised a lot

668
00:27:29,080 --> 00:27:26,960
of a material from inside the comet

669
00:27:33,250 --> 00:27:29,090
outside and so that we could study it

670
00:27:34,990 --> 00:27:33,260
using spectroscopy and techniques to get

671
00:27:36,610 --> 00:27:35,000
us a sense of what's inside the comet

672
00:27:38,770 --> 00:27:36,620
which presumably is much more primordial

673
00:27:40,810 --> 00:27:38,780
now this this was an analogy that was

674
00:27:42,370 --> 00:27:40,820
used for particle accelerators but I

675
00:27:45,460 --> 00:27:42,380
believe it applies here so this is a

676
00:27:47,740 --> 00:27:45,470
little bit like smashing you know

677
00:27:49,390 --> 00:27:47,750
smashing your watch with the rock to see

678
00:27:50,500 --> 00:27:49,400
what's going on inside to see all the

679
00:27:52,270 --> 00:27:50,510
gears and everything if you have a

680
00:27:53,950 --> 00:27:52,280
wind-up watch or you know we'll see what

681
00:27:55,630 --> 00:27:53,960
the battery is like on an LCD watch but

682
00:28:00,400 --> 00:27:55,640
that's what we were doing this is a very

683
00:28:02,650 --> 00:28:00,410
sort of violent way of studying the

684
00:28:04,870 --> 00:28:02,660
universe but it but it worked but at the

685
00:28:07,210 --> 00:28:04,880
same time Spitzer was there to study it

686
00:28:09,910 --> 00:28:07,220
and we use spectroscopy spectroscopy is

687
00:28:11,350 --> 00:28:09,920
splitting up of the light very much like

688
00:28:13,930 --> 00:28:11,360

essentially when you put sunlight

689
00:28:16,060 --> 00:28:13,940
through the prism it splits the

690
00:28:17,470 --> 00:28:16,070
wavelength and different chemicals have

691
00:28:19,690 --> 00:28:17,480
different signatures and in particular

692
00:28:22,090 --> 00:28:19,700
there are some very interesting chemical

693
00:28:24,430 --> 00:28:22,100
signatures within infrared spectrum and

694
00:28:26,860 --> 00:28:24,440
this is the spectrum that Spitzer saw of

695
00:28:27,850 --> 00:28:26,870
the comment from the interior and you

696
00:28:30,970 --> 00:28:27,860
can see there's various kinds of

697
00:28:32,620 --> 00:28:30,980
silicates and so on and in and of itself

698
00:28:34,810 --> 00:28:32,630
it's like oh that's interesting but

699
00:28:36,820 --> 00:28:34,820
what's interesting in addition to the

700
00:28:39,730 --> 00:28:36,830
is that once we started looking at other

701
00:28:41,769 --> 00:28:39,740
stars that have that are just forming we

702
00:28:45,070 --> 00:28:41,779
were seeing the same chemical signatures

703
00:28:46,600 --> 00:28:45,080
as what was inside comet Tempel 1 so

704
00:28:49,200 --> 00:28:46,610
that what that's really telling us is

705
00:28:52,149 --> 00:28:49,210
that how planets formed seems to be

706
00:28:54,129 --> 00:28:52,159
following a common path how our solar

707
00:28:56,019 --> 00:28:54,139
system formed seems to be similar at

708
00:28:58,210 --> 00:28:56,029
least in the building blocks as how

709
00:29:00,279 --> 00:28:58,220
other solar systems are forming so that

710
00:29:01,870 --> 00:29:00,289
was a really exciting result that I felt

711
00:29:03,820 --> 00:29:01,880
that you know again it's one of those

712
00:29:06,220 --> 00:29:03,830
things that multiple angles came in but

713
00:29:08,350 --> 00:29:06,230

Spitzer's sensitivity and the ability to

714
00:29:10,240 --> 00:29:08,360
do the spectroscopy in the infrared

715
00:29:13,210 --> 00:29:10,250
provided us with an incredibly new

716
00:29:15,249 --> 00:29:13,220
result the next thing I'm gonna skip a

717
00:29:16,749 --> 00:29:15,259
little bit about star formation of

718
00:29:18,669 --> 00:29:16,759
course Spitzer made incredible strides

719
00:29:20,649 --> 00:29:18,679
in star formation but Robert was just

720
00:29:22,779 --> 00:29:20,659
showing you where stars are born we

721
00:29:24,759 --> 00:29:22,789
could penetrate the dust to see that but

722
00:29:27,340 --> 00:29:24,769
then after stars are born the next

723
00:29:31,119 --> 00:29:27,350
question is about you know other planets

724
00:29:32,499 --> 00:29:31,129
now when Spitzer was being designed and

725
00:29:35,499 --> 00:29:32,509
they were contemplating what it was

726
00:29:37,090 --> 00:29:35,509
going to do the merest possibility of

727
00:29:38,799 --> 00:29:37,100
studying another planet have not even

728
00:29:40,960 --> 00:29:38,809
begun an inkling of crossing any

729
00:29:44,049 --> 00:29:40,970
astronomers mind in terms of being

730
00:29:45,909 --> 00:29:44,059
studied by Spitzer in fact the first

731
00:29:48,519 --> 00:29:45,919
exoplanet as they're called planets

732
00:29:49,990 --> 00:29:48,529
around other stars the way we define

733
00:29:52,810 --> 00:29:50,000
them today it was really not discovered

734
00:29:54,610 --> 00:29:52,820
until around 1995 the planets around

735
00:29:56,860 --> 00:29:54,620
stars like that's similar to our Sun and

736
00:29:59,080 --> 00:29:56,870
one of the techniques that came along

737
00:30:00,249 --> 00:29:59,090
was this one which is called the transit

738
00:30:02,860 --> 00:30:00,259

technique the transit technique

739
00:30:04,450 --> 00:30:02,870
basically says if you have a star and

740
00:30:06,340 --> 00:30:04,460
you have a planet around it and they're

741
00:30:08,230 --> 00:30:06,350
aligned just right there's no guarantee

742
00:30:10,299 --> 00:30:08,240
that they would be but some stars will

743
00:30:11,980 --> 00:30:10,309
be around aligned just their planets

744
00:30:13,419 --> 00:30:11,990
would be aligned just right so that they

745
00:30:16,450 --> 00:30:13,429
would pass in front of it and if you

746
00:30:18,879 --> 00:30:16,460
monitor the brightness of the star you

747
00:30:20,680 --> 00:30:18,889
will see that as the planet passes in

748
00:30:22,690 --> 00:30:20,690
front of it the star gets just a little

749
00:30:24,999 --> 00:30:22,700
bit dimmer we've exaggerated it here for

750
00:30:26,919 --> 00:30:25,009
effect but here's the interesting thing

751
00:30:28,690 --> 00:30:26,929
about the infrared is that the planet

752
00:30:30,820 --> 00:30:28,700
has a de side and a night side this is

753
00:30:32,470 --> 00:30:30,830
the night side but the day side is

754
00:30:34,570 --> 00:30:32,480
warmer which means as it goes around

755
00:30:37,450 --> 00:30:34,580
it's actually providing infrared light

756
00:30:40,419 --> 00:30:37,460
and so when it goes behind the star in

757
00:30:41,830 --> 00:30:40,429
fact now we're seeing more infrared

758
00:30:43,480 --> 00:30:41,840
light from the planet but then behind

759
00:30:45,970 --> 00:30:43,490
the star it doesn't so we see get this

760
00:30:48,520 --> 00:30:45,980
second dip which means we're literally

761
00:30:49,870 --> 00:30:48,530
seeing the nitesite of a planet and the

762
00:30:52,630 --> 00:30:49,880
dayside of a planet or at least we

763
00:30:54,280 --> 00:30:52,640

should and spitzer looked at one of

764
00:30:55,930 --> 00:30:54,290
these planets that had been discovered

765
00:30:58,270 --> 00:30:55,940
it didn't discover the planet was there

766
00:31:00,010 --> 00:30:58,280
but the planet had been discovered and

767
00:31:04,150 --> 00:31:00,020
we looked at it and that's exactly what

768
00:31:06,580 --> 00:31:04,160
we saw we saw this change of bright dim

769
00:31:08,950 --> 00:31:06,590
bright dim bright presumably when the

770
00:31:10,990 --> 00:31:08,960
planets warm side was towards us dim as

771
00:31:13,210 --> 00:31:11,000
we saw turned around and showed us the

772
00:31:16,150 --> 00:31:13,220
night sight so think about this we are

773
00:31:17,140 --> 00:31:16,160
able to see day and night on a planet

774
00:31:21,299 --> 00:31:17,150
around another star

775
00:31:26,620 --> 00:31:21,309
thanks to Spitzer's infrared sensitivity

776
00:31:28,539 --> 00:31:26,630
but that's not wait there's more so one

777
00:31:30,130 --> 00:31:28,549
of the other things was that by doing

778
00:31:31,990 --> 00:31:30,140
this we weren't able to do this for many

779
00:31:34,000 --> 00:31:32,000
planets because again Spitzer's

780
00:31:35,919 --> 00:31:34,010
sensitivity is great but it's not as

781
00:31:37,270 --> 00:31:35,929
good as you know some of them later

782
00:31:38,620 --> 00:31:37,280
telescopes that are going to be coming

783
00:31:40,210 --> 00:31:38,630
that were designed for this but it was

784
00:31:42,340 --> 00:31:40,220
good enough that we did several and

785
00:31:44,169 --> 00:31:42,350
there's this one planet that we saw that

786
00:31:45,880 --> 00:31:44,179
had again a day side temperature in a

787
00:31:47,530 --> 00:31:45,890
night side temperature but the day and

788
00:31:49,090 --> 00:31:47,540

night temperatures were not as different

789
00:31:50,919 --> 00:31:49,100
as we would have expected it's around a

790
00:31:52,419 --> 00:31:50,929
very hot star so we would have expected

791
00:31:53,890 --> 00:31:52,429
that the day sight and the night side

792
00:31:55,630 --> 00:31:53,900
would be very different now both of

793
00:31:57,610 --> 00:31:55,640
these planets are much more Jupiter like

794
00:32:00,190 --> 00:31:57,620
they're not earth-like planets

795
00:32:01,960 --> 00:32:00,200
so they're basically gaseous but for the

796
00:32:03,640 --> 00:32:01,970
for there to be that much it's that

797
00:32:05,409 --> 00:32:03,650
little of a difference relatively

798
00:32:08,380 --> 00:32:05,419
speaking between the day temperature and

799
00:32:09,490 --> 00:32:08,390
the night temperature the answer had to

800
00:32:11,890 --> 00:32:09,500
be that the temperature had to be

801
00:32:13,419 --> 00:32:11,900
redistributed to redistribute the

802
00:32:15,760 --> 00:32:13,429
temperature around a planet you need to

803
00:32:17,350 --> 00:32:15,770
have a wind and we knew the size of the

804
00:32:19,630 --> 00:32:17,360
planet because you know if we know the

805
00:32:20,860 --> 00:32:19,640
size of the star weave there's an

806
00:32:22,720 --> 00:32:20,870
enormous amount of astrophysics that

807
00:32:25,330 --> 00:32:22,730
helps us understand the size of a star

808
00:32:27,370 --> 00:32:25,340
but then the size of the planet gives

809
00:32:29,049 --> 00:32:27,380
you the size of the shadows so based on

810
00:32:32,260 --> 00:32:29,059
the shadow of the planet we know its

811
00:32:35,230 --> 00:32:32,270
size and so based on the size we could

812
00:32:37,000 --> 00:32:35,240
determine how quickly that temperature

813
00:32:39,520 --> 00:32:37,010

had to be redistributed and it needed to

814
00:32:42,030 --> 00:32:39,530
be redistributed by winds that were

815
00:32:44,860 --> 00:32:42,040
going 6,000 miles per hour

816
00:32:46,659 --> 00:32:44,870
so that in and of itself is incredibly

817
00:32:48,789 --> 00:32:46,669
impressive I mean now we've discussed

818
00:32:50,080 --> 00:32:48,799
just based on the dayside temperature in

819
00:32:52,090 --> 00:32:50,090
the night site temperature we are

820
00:32:53,080 --> 00:32:52,100
getting oh this planet has to

821
00:32:54,490 --> 00:32:53,090
redistribute the temperature that

822
00:32:57,760 --> 00:32:54,500
temperature which means it has to have

823
00:32:59,680 --> 00:32:57,770
these fast fast winds but in addition to

824
00:33:01,570 --> 00:32:59,690
that look at what we're doing

825
00:33:04,060 --> 00:33:01,580
this is the weather report on another

826
00:33:06,190 --> 00:33:04,070
planet under around another star you

827
00:33:08,440 --> 00:33:06,200
know children tonight you know oh hey

828
00:33:09,730 --> 00:33:08,450
look it's nice winds are gonna be 6,000

829
00:33:17,260 --> 00:33:09,740
miles per hour make sure you bring your

830
00:33:20,650 --> 00:33:17,270
space pods and space cats in and Julie

831
00:33:22,090 --> 00:33:20,660
knows here but yeah so this is again one

832
00:33:23,740 --> 00:33:22,100
of the most impressive things I think

833
00:33:25,840 --> 00:33:23,750
that was able to be accomplished by you

834
00:33:27,400 --> 00:33:25,850
know having the sensitivity to be able

835
00:33:32,170 --> 00:33:27,410
to detect these exoplanets around these

836
00:33:33,670 --> 00:33:32,180
stars so the last bit that we were able

837
00:33:35,860 --> 00:33:33,680
to do was we can do this also with

838
00:33:38,410 --> 00:33:35,870

spectroscopy and so you can take the

839
00:33:40,210 --> 00:33:38,420
spectrum again we're not distinguishing

840
00:33:42,250 --> 00:33:40,220
this planet separately from the start

841
00:33:45,070 --> 00:33:42,260
it's a dot when Spitzer is looking at it

842
00:33:46,480 --> 00:33:45,080
these are too far away but then once we

843
00:33:49,540 --> 00:33:46,490
know that the planet is going around

844
00:33:52,060 --> 00:33:49,550
that star we can take an image can take

845
00:33:55,840 --> 00:33:52,070
a spectrum when the planet is next to

846
00:33:56,950 --> 00:33:55,850
the star and a planet is in front of the

847
00:33:58,750 --> 00:33:56,960
star or behind the star and then

848
00:34:01,150 --> 00:33:58,760
subtract the two and we get a spectrum

849
00:34:02,770 --> 00:34:01,160
again which has the chemical signatures

850
00:34:04,600 --> 00:34:02,780
and in particular for a couple of the

851
00:34:06,850 --> 00:34:04,610
planets in several planets we were able

852
00:34:08,020 --> 00:34:06,860
to detect water vapor in the atmospheres

853
00:34:11,169 --> 00:34:08,030
of these planets again they're not

854
00:34:13,390 --> 00:34:11,179
earth-like planets but it is again

855
00:34:14,770 --> 00:34:13,400
encouraging that water vapor exists

856
00:34:16,180 --> 00:34:14,780
again since we think water is so

857
00:34:18,520 --> 00:34:16,190
intimately connected to the kind of life

858
00:34:22,419 --> 00:34:18,530
that we know and so Spitzer was able to

859
00:34:24,360 --> 00:34:22,429
detect that as well the final result

860
00:34:27,960 --> 00:34:24,370
which turned out to be truly spectacular

861
00:34:31,330 --> 00:34:27,970
was a system called Trappist one

862
00:34:32,800 --> 00:34:31,340
Trappist one again was not discovered by

863
00:34:34,570 --> 00:34:32,810

spitzer in the sense that there were

864
00:34:36,100 --> 00:34:34,580
other telescopes that are monitoring

865
00:34:38,020 --> 00:34:36,110
large numbers of stars and then looking

866
00:34:39,669 --> 00:34:38,030
for that tiny dip of the planet passing

867
00:34:41,770 --> 00:34:39,679
in front of it and this was a group of

868
00:34:44,110 --> 00:34:41,780
belgian astronomers using a telescope in

869
00:34:46,570 --> 00:34:44,120
Chile in South America and they were

870
00:34:49,060 --> 00:34:46,580
looking at the system and they labeled a

871
00:34:53,409 --> 00:34:49,070
Trappist one if you know Belgian beers

872
00:34:55,030 --> 00:34:53,419
you'll know why so they were looking at

873
00:34:56,650 --> 00:34:55,040
it but notice that this isn't that dip I

874
00:35:00,430 --> 00:34:56,660
was showing you before it has multiple

875
00:35:04,120 --> 00:35:00,440
dips all on top of each other and so

876
00:35:06,250 --> 00:35:04,130
they were like oh this must mean there

877
00:35:08,140 --> 00:35:06,260
are multiple planets but then they

878
00:35:12,070 --> 00:35:08,150
couldn't disentangle really how many

879
00:35:12,790 --> 00:35:12,080
planets there were because well the

880
00:35:13,180 --> 00:35:12,800
Earth rotates

881
00:35:14,890 --> 00:35:13,190
there's the

882
00:35:18,430 --> 00:35:14,900
the night cycle you can only monitor it

883
00:35:20,140 --> 00:35:18,440
at best you know 12 hours of night for

884
00:35:22,960 --> 00:35:20,150
observing for the telescope on the

885
00:35:24,609 --> 00:35:22,970
ground Spitzer didn't have that

886
00:35:27,069 --> 00:35:24,619
limitation in fact because it's not in

887
00:35:29,980 --> 00:35:27,079
Earth orbit we don't have the day/night

888
00:35:32,349 --> 00:35:29,990

cycles at all so they came to Spitzer

889
00:35:34,690 --> 00:35:32,359
and said could you stare at this for a

890
00:35:39,460 --> 00:35:34,700
long time what do you mean a long time

891
00:35:42,010 --> 00:35:39,470
200 hours but sure this sounds like a

892
00:35:43,839 --> 00:35:42,020
good project and in fact that's what

893
00:35:45,849 --> 00:35:43,849
Spitzer did and it was able to

894
00:35:47,829 --> 00:35:45,859
disentangle all of these different dips

895
00:35:52,120 --> 00:35:47,839
and in fact it found that there were

896
00:35:54,370 --> 00:35:52,130
seven planets around this one star now

897
00:35:56,140 --> 00:35:54,380
it's not this star's much dimmer than

898
00:35:58,780 --> 00:35:56,150
ours and so all the planets actually in

899
00:36:00,819 --> 00:35:58,790
fact orbit a lot closer to that star so

900
00:36:02,770 --> 00:36:00,829
on the same scale as our solar system

901
00:36:05,530 --> 00:36:02,780
they would all be within the orbit of

902
00:36:06,760 --> 00:36:05,540
mercury but the idea here is in fact the

903
00:36:08,470 --> 00:36:06,770
system that you should imagine because

904
00:36:10,050 --> 00:36:08,480
the star is a lot smaller it's a little

905
00:36:13,030 --> 00:36:10,060
bit closer to Jupiter and its moons

906
00:36:15,550 --> 00:36:13,040
scale wise but there are several things

907
00:36:17,770 --> 00:36:15,560
that the Spitzer also was able to do was

908
00:36:19,870 --> 00:36:17,780
by monitoring the orbits of the planets

909
00:36:21,880 --> 00:36:19,880
for such a long time we were they were

910
00:36:23,680 --> 00:36:21,890
we were able to pick up transit timing

911
00:36:26,980 --> 00:36:23,690
variations that's a very fancy way of

912
00:36:28,839 --> 00:36:26,990
saying the orbits of the planets affect

913
00:36:30,490 --> 00:36:28,849

each other that is depending on what the

914
00:36:32,079 --> 00:36:30,500
mass of one planet is it affects the

915
00:36:33,520 --> 00:36:32,089
orbit of the other ones obviously if

916
00:36:35,079 --> 00:36:33,530
it's more massive than its gonna tug a

917
00:36:38,260 --> 00:36:35,089
little bit more on the others so would

918
00:36:40,720 --> 00:36:38,270
slightly shift the transit times that

919
00:36:44,020 --> 00:36:40,730
that shadow of when it was passing based

920
00:36:46,240 --> 00:36:44,030
on that we could tell what the masses of

921
00:36:47,470 --> 00:36:46,250
the planets were based on the fact that

922
00:36:49,870 --> 00:36:47,480
we know what kind of started they're

923
00:36:52,420 --> 00:36:49,880
orbiting and the size of their shadows

924
00:36:55,030 --> 00:36:52,430
we know the size of each planet so we

925
00:36:58,000 --> 00:36:55,040
know size and mass size and mass gives

926
00:37:00,220 --> 00:36:58,010
you density which meant we could say

927
00:37:02,380 --> 00:37:00,230
what the types of planets were wasn't

928
00:37:04,120 --> 00:37:02,390
they know how big is it we have an idea

929
00:37:07,120 --> 00:37:04,130
how massive it is okay we have that idea

930
00:37:10,210 --> 00:37:07,130
so it turns out that they're all rocky

931
00:37:12,160 --> 00:37:10,220
type planets they're not giant gas gas

932
00:37:15,190 --> 00:37:12,170
giants or ice giants like Jupiter or

933
00:37:16,359 --> 00:37:15,200
Uranus so based on that and the fact

934
00:37:19,180 --> 00:37:16,369
that we know how much light is coming

935
00:37:23,020 --> 00:37:19,190
off of the star we've it will surmise

936
00:37:24,640 --> 00:37:23,030
that three of the planets have or in

937
00:37:26,510 --> 00:37:24,650
what's called the habitable zone that is

938
00:37:28,940 --> 00:37:26,520

they're likely to have

939
00:37:31,250 --> 00:37:28,950
they have the temperatures appropriate

940
00:37:33,099 --> 00:37:31,260
to have liquid water now it doesn't

941
00:37:36,290 --> 00:37:33,109
guarantee that they have liquid water

942
00:37:38,750 --> 00:37:36,300
but that's the thing so this system the

943
00:37:41,599 --> 00:37:38,760
Trappist one system is in fact now the

944
00:37:43,010 --> 00:37:41,609
best studied and we have we know more

945
00:37:46,790 --> 00:37:43,020
about the system than any other system

946
00:37:47,870 --> 00:37:46,800
that are out there other than our own

947
00:37:50,300 --> 00:37:47,880
solar system

948
00:37:53,060 --> 00:37:50,310
thanks again by just observations of

949
00:37:55,339 --> 00:37:53,070
these dips of light passing in front of

950
00:37:57,320 --> 00:37:55,349
them by being able to do it on a very

951
00:37:58,640 --> 00:37:57,330
long time scale spitzer has gone back

952
00:38:00,140 --> 00:37:58,650
for yet another two hundred hours but

953
00:38:01,849 --> 00:38:00,150
not all continuously to really

954
00:38:03,740 --> 00:38:01,859
characterize each of those transits as

955
00:38:06,079 --> 00:38:03,750
well so this has been I think one of

956
00:38:07,760 --> 00:38:06,089
both the most surprising result as well

957
00:38:12,230 --> 00:38:07,770
as just one of the most amazing results

958
00:38:14,690 --> 00:38:12,240
that we have that came from Spitzer but

959
00:38:16,280 --> 00:38:14,700
we got to continue because then we got

960
00:38:18,349 --> 00:38:16,290
to go into the area that I like which is

961
00:38:19,010 --> 00:38:18,359
extra galactic stuff so outside of our

962
00:38:21,320 --> 00:38:19,020
own galaxy

963
00:38:23,560 --> 00:38:21,330

now Robert also showed you wonderful

964
00:38:26,540 --> 00:38:23,570
pictures of the spiral galaxies and

965
00:38:28,550 --> 00:38:26,550
there's the the Whirlpool galaxy which

966
00:38:29,930 --> 00:38:28,560
all by the way when galaxies interact is

967
00:38:32,930 --> 00:38:29,940
a really nice word for that one it's

968
00:38:36,099 --> 00:38:32,940
called galactic cannibalism because yes

969
00:38:39,740 --> 00:38:36,109
one of them will eat the other one but

970
00:38:41,630 --> 00:38:39,750
the structures that get galaxies make up

971
00:38:44,000 --> 00:38:41,640
they're not just all lonely by

972
00:38:46,579 --> 00:38:44,010
themselves oftentimes galaxies are in

973
00:38:49,339 --> 00:38:46,589
either groups or in clusters but how do

974
00:38:50,810 --> 00:38:49,349
you find these clusters of galaxies well

975
00:38:53,270 --> 00:38:50,820
you know we're sitting in our own galaxy

976
00:38:55,730 --> 00:38:53,280
about a several hundred billion stars

977
00:38:56,960 --> 00:38:55,740
and when you're looking at the stars of

978
00:38:59,300 --> 00:38:56,970
the galaxies that are further away they

979
00:39:01,430 --> 00:38:59,310
look like dots the stars in our galaxy

980
00:39:02,930 --> 00:39:01,440
even they're closer but they still look

981
00:39:05,180 --> 00:39:02,940
like thoughts so which dots are the

982
00:39:06,530 --> 00:39:05,190
galaxies and which dots aren't so you

983
00:39:08,540 --> 00:39:06,540
can sort of pick out the fuzzy ones

984
00:39:10,040 --> 00:39:08,550
which are nearby galaxies but as soon as

985
00:39:11,390 --> 00:39:10,050
you get further away where you're going

986
00:39:12,470 --> 00:39:11,400
to get more and more clusters that you

987
00:39:14,570 --> 00:39:12,480
can detect becomes more and more

988
00:39:16,220 --> 00:39:14,580

difficult but there's one thing that

989
00:39:18,440 --> 00:39:16,230
happens with the expansion of the

990
00:39:20,630 --> 00:39:18,450
universe that's called redshift the

991
00:39:22,520 --> 00:39:20,640
light from the galaxies gets shifted

992
00:39:25,310 --> 00:39:22,530
into the longer wavelengths into

993
00:39:28,339 --> 00:39:25,320
specifically the infrared wavelengths so

994
00:39:31,040 --> 00:39:28,349
how does that help you well galaxies

995
00:39:33,200 --> 00:39:31,050
tend to have a peak of emission and if

996
00:39:35,089 --> 00:39:33,210
they have a lot of you know stars they

997
00:39:36,440 --> 00:39:35,099
tend to peak around 1 micron it's a

998
00:39:38,180 --> 00:39:36,450
little bit longer than our eyes can see

999
00:39:38,599 --> 00:39:38,190
so very much a little bit into the

1000
00:39:39,620 --> 00:39:38,609
infrared

1001
00:39:42,319 --> 00:39:39,630
but the

1002
00:39:43,789 --> 00:39:42,329
main ideas they have a peak and if if

1003
00:39:46,339 --> 00:39:43,799
they're redshifted enough that peak

1004
00:39:48,710 --> 00:39:46,349
shifts into the wavelengths that Spitzer

1005
00:39:50,150 --> 00:39:48,720
sees so when you make the kinds of

1006
00:39:52,339 --> 00:39:50,160
pictures that Robert was talking about

1007
00:39:54,650 --> 00:39:52,349
you can suddenly see that the same

1008
00:39:57,920 --> 00:39:54,660
region when you're looking at where the

1009
00:40:00,049 --> 00:39:57,930
peaks of those galaxies emission has

1010
00:40:01,729 --> 00:40:00,059
shifted it's very easy to pick out a

1011
00:40:03,769 --> 00:40:01,739
cluster and in this case there it is

1012
00:40:06,489 --> 00:40:03,779
it's just this line of bright red dots

1013
00:40:09,680 --> 00:40:06,499

these are all galaxies in a cluster and

1014
00:40:11,390 --> 00:40:09,690
Spitzer discovered more galaxies than

1015
00:40:13,009 --> 00:40:11,400
any other mission previous to it

1016
00:40:15,890 --> 00:40:13,019
in fact it doubled the number of

1017
00:40:19,339 --> 00:40:15,900
clusters that had been detected and in

1018
00:40:21,019 --> 00:40:19,349
the surveys that it did then this is the

1019
00:40:23,059 --> 00:40:21,029
part that is nearest and dearest to my

1020
00:40:24,859 --> 00:40:23,069
heart which is supermassive valid yeah

1021
00:40:29,120 --> 00:40:24,869
supermassive black holes at the Centers

1022
00:40:32,269 --> 00:40:29,130
of galaxies black holes are black hence

1023
00:40:33,920 --> 00:40:32,279
the name but that means that emissions

1024
00:40:36,200 --> 00:40:33,930
directly from you we don't get any light

1025
00:40:38,719 --> 00:40:36,210
from them but as material falls into

1026
00:40:40,670 --> 00:40:38,729
them that material heats up and you can

1027
00:40:42,890 --> 00:40:40,680
study that and it tells you something

1028
00:40:44,420 --> 00:40:42,900
about the black hole itself and they the

1029
00:40:46,999 --> 00:40:44,430
supermassive black holes tend to reside

1030
00:40:49,219 --> 00:40:47,009
at the Centers of galaxies with and they

1031
00:40:52,099 --> 00:40:49,229
seem to have an intimate connection to

1032
00:40:53,809 --> 00:40:52,109
the evolution of a galaxy and so what

1033
00:40:55,400 --> 00:40:53,819
happened was we really want to see where

1034
00:40:57,920 --> 00:40:55,410
all of these supermassive black holes

1035
00:40:59,989 --> 00:40:57,930
are but at the Centers of galaxies it's

1036
00:41:02,209 --> 00:40:59,999
often shrouded in dust so the optical

1037
00:41:04,339 --> 00:41:02,219
image doesn't show you anything but in

1038
00:41:06,950 --> 00:41:04,349

the infrared we can pick up the emission

1039
00:41:08,749 --> 00:41:06,960
of material falling into I'm just super

1040
00:41:10,400 --> 00:41:08,759
massive black hole and match it up with

1041
00:41:13,489 --> 00:41:10,410
the Chandra x-ray Observatory because

1042
00:41:16,249 --> 00:41:13,499
the x-rays also penetrate that dust so

1043
00:41:18,469 --> 00:41:16,259
that was a so Spitzer allowed us to

1044
00:41:21,170 --> 00:41:18,479
again look at things lift the cosmic

1045
00:41:22,789 --> 00:41:21,180
veil and see these supermassive black

1046
00:41:26,120 --> 00:41:22,799
holes that we couldn't see previously

1047
00:41:28,249 --> 00:41:26,130
and then at the very edge of the

1048
00:41:29,989 --> 00:41:28,259
universe or and what the further you

1049
00:41:31,489 --> 00:41:29,999
look out the further back in time you're

1050
00:41:34,519 --> 00:41:31,499
looking because that's how long like

1051
00:41:35,719 --> 00:41:34,529
takes to get you Spitzer was able to

1052
00:41:37,700 --> 00:41:35,729
exploit along with the Hubble Space

1053
00:41:40,940 --> 00:41:37,710
Telescope the ability to detect very

1054
00:41:43,459 --> 00:41:40,950
young galaxies and galaxies have you

1055
00:41:44,870 --> 00:41:43,469
know or made up of stars stars are made

1056
00:41:47,900 --> 00:41:44,880
up of hydrogen and hydrogen when it's

1057
00:41:50,980 --> 00:41:47,910
heated known as the stories heat them or

1058
00:41:54,070 --> 00:41:50,990
have this step-like spectrum

1059
00:41:55,570 --> 00:41:54,080
is it they give out like at a particular

1060
00:41:57,160 --> 00:41:55,580
little bit longer wavelength there's

1061
00:41:58,450 --> 00:41:57,170
then there's a drop at a shorter

1062
00:42:02,470 --> 00:41:58,460
wavelength this is this particular one

1063
00:42:04,840 --> 00:42:02,480

is called the bomber edge and but but

1064
00:42:08,050 --> 00:42:04,850
once its redshift at that edge shifts

1065
00:42:09,910 --> 00:42:08,060
and that excess light comes out comes

1066
00:42:12,400 --> 00:42:09,920
now in the infrared and so Spitzer

1067
00:42:15,460 --> 00:42:12,410
looked and at various surveys and we

1068
00:42:16,960 --> 00:42:15,470
were able to find these galaxies at very

1069
00:42:18,790 --> 00:42:16,970
very early on in the history of the

1070
00:42:20,410 --> 00:42:18,800
universe but what's interesting is based

1071
00:42:22,500 --> 00:42:20,420
on studying how much light was coming

1072
00:42:24,700 --> 00:42:22,510
relative what this bomber edge was like

1073
00:42:28,600 --> 00:42:24,710
it tells us that this is actually coming

1074
00:42:30,430 --> 00:42:28,610
from fairly mature stars and what does

1075
00:42:31,690 --> 00:42:30,440
that mean well it's it was a little bit

1076
00:42:34,210 --> 00:42:31,700
hard to put it all together but that

1077
00:42:35,590 --> 00:42:34,220
means that star formation started very

1078
00:42:37,840 --> 00:42:35,600
early on after the beginning of the

1079
00:42:39,640 --> 00:42:37,850
universe and they clumped they form

1080
00:42:41,340 --> 00:42:39,650
galaxies and the stars have time to

1081
00:42:43,690 --> 00:42:41,350
evolve them and become mature and

1082
00:42:46,690 --> 00:42:43,700
science news had sort of this version of

1083
00:42:48,010 --> 00:42:46,700
it so that is you know I'm sure you have

1084
00:42:50,440 --> 00:42:48,020
a lot of baby stars but then we were

1085
00:42:52,720 --> 00:42:50,450
finding some mature stars mixed in with

1086
00:42:54,700 --> 00:42:52,730
all of those baby stars but that was

1087
00:42:58,000 --> 00:42:54,710
sort of that's the main point here is

1088
00:42:59,410 --> 00:42:58,010

that by looking by being able to detect

1089
00:43:01,960 --> 00:42:59,420
these in the infrared combining them

1090
00:43:04,570 --> 00:43:01,970
with the optical with Hubble it really

1091
00:43:06,609 --> 00:43:04,580
allowed us the ability to figure out

1092
00:43:08,380 --> 00:43:06,619
that galaxy formation started very early

1093
00:43:10,450 --> 00:43:08,390
and these galaxies started evolving very

1094
00:43:12,280 --> 00:43:10,460
early on so that's again another

1095
00:43:13,720 --> 00:43:12,290
wonderful thing that the James Webb

1096
00:43:16,210 --> 00:43:13,730
Space Telescope will be able to follow

1097
00:43:18,010 --> 00:43:16,220
up and I'll finish up with this image

1098
00:43:20,859 --> 00:43:18,020
which is one of the first images taken

1099
00:43:22,510 --> 00:43:20,869
by the Spitzer Space Telescope if you

1100
00:43:24,460 --> 00:43:22,520
notice that my name is under it that's

1101
00:43:26,620 --> 00:43:24,470
because I led the team that took this

1102
00:43:28,330 --> 00:43:26,630
image it was an early release science it

1103
00:43:30,010 --> 00:43:28,340
was sort of the early kinds of science

1104
00:43:31,330 --> 00:43:30,020
to show the community of astronomers is

1105
00:43:33,220 --> 00:43:31,340
what we could do in Robert was on my

1106
00:43:37,390 --> 00:43:33,230
team for this and I'm not just trying it

1107
00:43:39,849 --> 00:43:37,400
just to wax nostalgic or just you know

1108
00:43:41,770 --> 00:43:39,859
saying you know showing my stuff but in

1109
00:43:44,080 --> 00:43:41,780
particular I think this came to me as a

1110
00:43:46,470 --> 00:43:44,090
good metaphor of spitzer itself this is

1111
00:43:49,930 --> 00:43:46,480
first of all this is what's called a

1112
00:43:51,730 --> 00:43:49,940
supernova remnant this is where there

1113
00:43:53,710 --> 00:43:51,740

was a star and it exploded and you see

1114
00:43:56,530 --> 00:43:53,720
that loop and it's basically the shock

1115
00:43:58,390 --> 00:43:56,540
wave of after the star exploded and a

1116
00:44:02,440 --> 00:43:58,400
shock wave went out and it happened to

1117
00:44:04,660 --> 00:44:02,450
hit this gas cloud over here and that

1118
00:44:06,130 --> 00:44:04,670
impact star caused compression

1119
00:44:08,200 --> 00:44:06,140
to happen within that gas cloud and you

1120
00:44:10,359 --> 00:44:08,210
have an enormous amount of young star

1121
00:44:12,430 --> 00:44:10,369
formation happening and to me this is

1122
00:44:14,770 --> 00:44:12,440
really the metaphor of what Spitzer is

1123
00:44:18,880 --> 00:44:14,780
the explosion of knowledge from Spitzer

1124
00:44:20,799 --> 00:44:18,890
is going out and is now going to trigger

1125
00:44:22,089 --> 00:44:20,809
an enormous amount of new science and

1126
00:44:23,079 --> 00:44:22,099
the telescopes that are going to be

1127
00:44:24,880 --> 00:44:23,089
coming out the James Webb Space

1128
00:44:27,190 --> 00:44:24,890
Telescope and the wide field Infrared

1129
00:44:33,849 --> 00:44:27,200
Survey telescope all you know to go

1130
00:44:36,069 --> 00:44:33,859
further into the future that's just the

1131
00:44:38,230 --> 00:44:36,079
greatest hits and even then I don't

1132
00:44:41,170 --> 00:44:38,240
think they were all there's still more

1133
00:44:43,270 --> 00:44:41,180
you could do a 12-hour von-karman and

1134
00:44:45,130 --> 00:44:43,280
even then I would have to apologize to

1135
00:44:47,230 --> 00:44:45,140
tons of colleagues I'm sorry I didn't

1136
00:44:49,240 --> 00:44:47,240
get your work that was incredible - but

1137
00:44:50,440 --> 00:44:49,250
there's a lot of incredible stuff that

1138
00:44:52,539 --> 00:44:50,450

has been done this was just trying to

1139
00:44:56,170 --> 00:44:52,549
hit the highlights and even then this is

1140
00:44:58,120 --> 00:44:56,180
you know a minimum highlights reel so

1141
00:44:59,319 --> 00:44:58,130
Joseph you you we saw that picture of

1142
00:45:00,700 --> 00:44:59,329
you at the very beginning and you had

1143
00:45:03,280 --> 00:45:00,710
your lucky peanuts in your hand you were

1144
00:45:04,720 --> 00:45:03,290
ready to go I think you have a portrait

1145
00:45:05,829 --> 00:45:04,730
and an attic somewhere because I can't

1146
00:45:12,579 --> 00:45:05,839
though any difference between that is

1147
00:45:15,760 --> 00:45:12,589
now my pleasure but you've had this

1148
00:45:23,859 --> 00:45:15,770
relationship with the spacecraft how do

1149
00:45:25,630 --> 00:45:23,869
you end a mission like this with there's

1150
00:45:28,240 --> 00:45:25,640
a couple people in the audience they can

1151
00:45:30,490 --> 00:45:28,250
answer this question I mean 16 years of

1152
00:45:32,859 --> 00:45:30,500
a mission plus it's quite a long time

1153
00:45:35,710 --> 00:45:32,869
right and obviously across that time

1154
00:45:37,329 --> 00:45:35,720
span technology has changed right so the

1155
00:45:39,099 --> 00:45:37,339
first question I know it's about two

1156
00:45:41,319 --> 00:45:39,109
people in here - can probably answer

1157
00:45:43,599 --> 00:45:41,329
this when I first started out on a

1158
00:45:47,319 --> 00:45:43,609
mission and Susie showed a graph that

1159
00:45:50,109 --> 00:45:47,329
showed this distribution of facilities

1160
00:45:52,569 --> 00:45:50,119
the Lockheed folks Caltech into various

1161
00:45:55,420 --> 00:45:52,579
locations we had to collaborate on a lot

1162
00:45:57,760 --> 00:45:55,430
of information to make things work so

1163
00:46:00,339 --> 00:45:57,770

they had this machine that you took a

1164
00:46:02,799 --> 00:46:00,349
view graph and you put a view graph on

1165
00:46:05,170 --> 00:46:02,809
this machine and it digitized it and

1166
00:46:07,120 --> 00:46:05,180
sent it out to the other facilities uh

1167
00:46:10,569 --> 00:46:07,130
anyone here know the name of that

1168
00:46:15,060 --> 00:46:10,579
machine will remember that machine Dave

1169
00:46:21,160 --> 00:46:17,980
I wouldn't try and remember the date but

1170
00:46:23,859 --> 00:46:21,170
but yes so imagine you know just to

1171
00:46:26,380 --> 00:46:23,869
measure in time how far you come about

1172
00:46:29,440 --> 00:46:26,390
in technology and Susie are were also

1173
00:46:31,720 --> 00:46:29,450
elaborated on the geometry to orbit

1174
00:46:33,220 --> 00:46:31,730
geometry that we have and and to be

1175
00:46:36,910 --> 00:46:33,230
honest we've gone through several

1176
00:46:39,730 --> 00:46:36,920
mission phases as she mentioned but the

1177
00:46:41,800 --> 00:46:39,740
most critical part in that is when we

1178
00:46:44,530 --> 00:46:41,810
downlink the data from the spacecraft

1179
00:46:46,810 --> 00:46:44,540
you have to point that hi gang antenna

1180
00:46:49,420 --> 00:46:46,820
she was talking about to the earth early

1181
00:46:52,030 --> 00:46:49,430
on it was designed to be off at 30

1182
00:46:55,030 --> 00:46:52,040
degrees right and at 30 degrees you

1183
00:46:56,890 --> 00:46:55,040
stayed power positive so you're still on

1184
00:46:57,940 --> 00:46:56,900
the Sun and you downlink in the data

1185
00:47:01,240 --> 00:46:57,950
today

1186
00:47:03,580 --> 00:47:01,250
this week we had about 54 degrees okay

1187
00:47:06,040 --> 00:47:03,590
so you can see it was never designed to

1188
00:47:08,170 --> 00:47:06,050

be that to operate like that but the

1189
00:47:09,850 --> 00:47:08,180
ingenuity and the engineers worked out

1190
00:47:12,520 --> 00:47:09,860
all the different things that we would

1191
00:47:15,910 --> 00:47:12,530
have to do based on going back to NASA

1192
00:47:18,670 --> 00:47:15,920
and getting the different extensions and

1193
00:47:21,460 --> 00:47:18,680
a new science that they were providing

1194
00:47:24,070 --> 00:47:21,470
to us so when you point this thing at

1195
00:47:27,160 --> 00:47:24,080
earth at 54 degrees what happens now yes

1196
00:47:29,050 --> 00:47:27,170
you start getting Sun on the backside of

1197
00:47:31,570 --> 00:47:29,060
it so there's a possibility

1198
00:47:33,970 --> 00:47:31,580
Sun is going up behind the high-gain

1199
00:47:36,190 --> 00:47:33,980
antenna is heating up the struts now we

1200
00:47:38,580 --> 00:47:36,200
off the Sun we're totally using the

1201
00:47:41,230 --> 00:47:38,590
battery power so we got to calculate now

1202
00:47:43,000 --> 00:47:41,240
how much the data we have how long can

1203
00:47:45,730 --> 00:47:43,010
we steal on earth to downlink that down

1204
00:47:47,620 --> 00:47:45,740
okay so that was very significant of

1205
00:47:50,470 --> 00:47:47,630
what Susan was saying with the orbit

1206
00:47:52,780 --> 00:47:50,480
geometry Robert over here is pretty

1207
00:47:54,820 --> 00:47:52,790
interesting character because sometime I

1208
00:47:56,770 --> 00:47:54,830
see some of the images and I'm thinking

1209
00:47:59,349 --> 00:47:56,780
maybe Roberts not feeling too good right

1210
00:48:01,180 --> 00:47:59,359
within folks like Bergeron and the

1211
00:48:02,920 --> 00:48:01,190
science team come back and they analyze

1212
00:48:05,020 --> 00:48:02,930
the data and you start understanding the

1213
00:48:07,180 --> 00:48:05,030

composition of what they really are

1214
00:48:09,220 --> 00:48:07,190
showing you from the discoveries and it

1215
00:48:11,200 --> 00:48:09,230
all kind of makes sense so I think your

1216
00:48:12,820 --> 00:48:11,210
team is there was a really good job with

1217
00:48:16,120 --> 00:48:12,830
bringing together what it's spitzer is

1218
00:48:18,099 --> 00:48:16,130
all about one of the other things that

1219
00:48:20,859 --> 00:48:18,109
was significant to me on the mission was

1220
00:48:25,330 --> 00:48:20,869
if you guys tried to date me a little

1221
00:48:26,560 --> 00:48:25,340
bit was one quick thing was on this

1222
00:48:28,560 --> 00:48:26,570
panel i was

1223
00:48:31,860 --> 00:48:28,570
so yes how do you get to that job

1224
00:48:38,980 --> 00:48:35,080
patience right so I'll exercise my

1225
00:48:42,520 --> 00:48:38,990
patience I waited to my turn so very

1226
00:48:45,100 --> 00:48:42,530
good so so but you can never take away

1227
00:48:46,930 --> 00:48:45,110
when you see all this great imagery the

1228
00:48:48,580 --> 00:48:46,940
folks that works on this stuff a very

1229
00:48:51,700 --> 00:48:48,590
proud if were to share it with their

1230
00:48:54,940 --> 00:48:51,710
family and the kids and so forth to be a

1231
00:48:57,760 --> 00:48:54,950
part of it the operations element is not

1232
00:48:59,920 --> 00:48:57,770
really mentioned a whole lot or sometime

1233
00:49:03,130 --> 00:48:59,930
not mentioned enough right on what it

1234
00:49:05,500 --> 00:49:03,140
really takes from the many folks that's

1235
00:49:08,170 --> 00:49:05,510
doing things wrong the navigation

1236
00:49:11,110 --> 00:49:08,180
aspects of it to the each subsystem of

1237
00:49:13,570 --> 00:49:11,120
the spacecraft to Sue's his lovely DSN

1238
00:49:16,630 --> 00:49:13,580

folks with the ground receivers to make

1239
00:49:18,430 --> 00:49:16,640
it possible to receive information early

1240
00:49:20,950 --> 00:49:18,440
on in a mission one of the first things

1241
00:49:24,040 --> 00:49:20,960
that I was really proud about was the

1242
00:49:26,950 --> 00:49:24,050
picture you saw me in the MSA to be able

1243
00:49:30,070 --> 00:49:26,960
to actually send the very first command

1244
00:49:32,710 --> 00:49:30,080
to the spacecraft the spacecraft before

1245
00:49:35,620 --> 00:49:32,720
it launched at Kennedy there was a

1246
00:49:38,080 --> 00:49:35,630
process where you do the RFS checkout

1247
00:49:40,510 --> 00:49:38,090
and we had the facility built here and

1248
00:49:42,700 --> 00:49:40,520
really ready to go so we sent the first

1249
00:49:44,740 --> 00:49:42,710
command right so maybe this is not good

1250
00:49:46,750 --> 00:49:44,750
telling a story because it dates me so

1251
00:49:49,570 --> 00:49:46,760
next week we'll be sending a final

1252
00:49:52,300 --> 00:49:49,580
command right so but I've worked through

1253
00:49:55,690 --> 00:49:52,310
the whole lifecycle of the mission which

1254
00:49:57,790 --> 00:49:55,700
is very very excited I've also had the

1255
00:50:00,580 --> 00:49:57,800
opportunity with the change in all of

1256
00:50:03,370 --> 00:50:00,590
the technology that we have not just the

1257
00:50:06,100 --> 00:50:03,380
facts about the viewgraph machine but we

1258
00:50:07,690 --> 00:50:06,110
faxed a lot of items around right you

1259
00:50:10,210 --> 00:50:07,700
think about this technology with facts

1260
00:50:12,220 --> 00:50:10,220
and things I think we had pagers to

1261
00:50:14,080 --> 00:50:12,230
communicate right not like some of the

1262
00:50:18,670 --> 00:50:14,090
young kids down here with iPhones and

1263
00:50:20,830 --> 00:50:18,680

things like that so over the course of

1264
00:50:23,440 --> 00:50:20,840
time but the change in technology one of

1265
00:50:26,050 --> 00:50:23,450
the things that was always embraced by

1266
00:50:29,890 --> 00:50:26,060
the management of this project was the

1267
00:50:32,260 --> 00:50:29,900
imperative people that had processes and

1268
00:50:34,180 --> 00:50:32,270
we're doing things so we brought in a

1269
00:50:36,220 --> 00:50:34,190
lot of students one of the things we

1270
00:50:37,930 --> 00:50:36,230
always brought in summer students we

1271
00:50:41,500 --> 00:50:37,940
gave them smaller requirements

1272
00:50:43,300 --> 00:50:41,510
- vo new tools and processes and then a

1273
00:50:44,800 --> 00:50:43,310
lot of those things those kids are

1274
00:50:46,690 --> 00:50:44,810
pretty good right they came out of

1275
00:50:47,680 --> 00:50:46,700
school they brought things to a that

1276
00:50:50,890 --> 00:50:47,690
looks really good

1277
00:50:52,300 --> 00:50:50,900
we would give it over to our more senior

1278
00:50:54,960 --> 00:50:52,310
developers and develop some very

1279
00:50:57,970 --> 00:50:54,970
sophisticated ways of doing our

1280
00:51:00,490 --> 00:50:57,980
operations so by doing so we automated

1281
00:51:02,170 --> 00:51:00,500
quite a few things this helped really in

1282
00:51:04,420 --> 00:51:02,180
our training and cross-training of new

1283
00:51:05,950 --> 00:51:04,430
people coming onto the mission so it's

1284
00:51:07,540 --> 00:51:05,960
been a lot of those types of things that

1285
00:51:10,150 --> 00:51:07,550
I think it really contributes to the

1286
00:51:12,849 --> 00:51:10,160
success of Spitzer now going back to

1287
00:51:13,690 --> 00:51:12,859
Brian's question well in an omission

1288
00:51:16,359 --> 00:51:13,700

right

1289
00:51:19,599 --> 00:51:16,369
that's a very sensitive statement

1290
00:51:22,089 --> 00:51:19,609
because and I hope no project scientists

1291
00:51:25,210 --> 00:51:22,099
other than for Arizona's here you really

1292
00:51:27,250 --> 00:51:25,220
can't say in or people will come to me

1293
00:51:29,700 --> 00:51:27,260
and ask how you kill the spacecraft oh

1294
00:51:32,020 --> 00:51:29,710
we don't want to bring that up right so

1295
00:51:34,390 --> 00:51:32,030
over the course of the next week of

1296
00:51:36,579 --> 00:51:34,400
course just like we've been doing for 16

1297
00:51:39,760 --> 00:51:36,589
years we'll be doing a lot of the last

1298
00:51:43,839 --> 00:51:39,770
of the science observations we have put

1299
00:51:46,180 --> 00:51:43,849
in plants a process to recover the last

1300
00:51:48,819 --> 00:51:46,190
of the science and then what we're gonna

1301
00:51:51,190 --> 00:51:48,829
do is there's a mode for the spacecraft

1302
00:51:53,620 --> 00:51:51,200
that was designed for it if it had a

1303
00:51:55,599 --> 00:51:53,630
fault right a fault meaning it had a

1304
00:51:58,210 --> 00:51:55,609
functional failure something on board

1305
00:52:00,460 --> 00:51:58,220
went wrong the spacecraft goes to a Sun

1306
00:52:02,859 --> 00:52:00,470
point altitude to keep the charge right

1307
00:52:05,980 --> 00:52:02,869
puts the solar panel on the Sun clones

1308
00:52:08,740 --> 00:52:05,990
about the Sun line line and wait to hear

1309
00:52:10,599 --> 00:52:08,750
from us on the ground so next week what

1310
00:52:15,750 --> 00:52:10,609
we're gonna do is we're gonna send a

1311
00:52:22,180 --> 00:52:18,339
so we're gonna send a command to it and

1312
00:52:26,440 --> 00:52:22,190
what the command is gonna do is go to

1313
00:52:29,050 --> 00:52:26,450

the spacecraft tell it to go into what

1314
00:52:32,190 --> 00:52:29,060
we call the safe mode to make it think

1315
00:52:35,440 --> 00:52:32,200
it had a fault and it's going to go and

1316
00:52:37,300 --> 00:52:35,450
point us hi gang antenna right at the

1317
00:52:40,420 --> 00:52:37,310
Sun and it's going to cone about the Sun

1318
00:52:43,900 --> 00:52:40,430
line and then drift away and then about

1319
00:52:46,059 --> 00:52:43,910
53 years or so it'll come back past the

1320
00:52:50,050 --> 00:52:46,069
earth and then head out in the opposite

1321
00:52:51,000 --> 00:52:50,060
direction so that were in the spirits of

1322
00:52:54,930 --> 00:52:51,010
mission

1323
00:52:59,000 --> 00:52:54,940
January 30 30th about to 32 to 40

1324
00:53:01,770 --> 00:52:59,010
we're decommissioned the spacecraft now

1325
00:53:03,930 --> 00:53:01,780
one of the good things about that that

1326
00:53:05,850 --> 00:53:03,940
folks must understand over 16 and a half

1327
00:53:08,910 --> 00:53:05,860
years with all the science data that has

1328
00:53:12,450 --> 00:53:08,920
been collected the data will continue to

1329
00:53:16,050 --> 00:53:12,460
be mined by astronomers and Sciences

1330
00:53:19,380 --> 00:53:16,060
because there's a archive of all of this

1331
00:53:21,960 --> 00:53:19,390
infrared data down to a pack Caltech so

1332
00:53:23,730 --> 00:53:21,970
even though Spitzer is in what you would

1333
00:53:25,920 --> 00:53:23,740
think of there's a hibernation mode

1334
00:53:28,020 --> 00:53:25,930
folks don't like you to say hibernate

1335
00:53:29,880 --> 00:53:28,030
believe me it was really hard to come up

1336
00:53:32,400 --> 00:53:29,890
with a term that everyone agreed on

1337
00:53:34,920 --> 00:53:32,410
based on the final state right there

1338
00:53:36,720 --> 00:53:34,930

that we're beyond but the legacy of

1339
00:53:38,430 --> 00:53:36,730
spirit sir will live long because the

1340
00:53:41,910 --> 00:53:38,440
data is there for people to go back in

1341
00:53:45,330 --> 00:53:41,920
mind so thank you for sharing that with

1342
00:53:48,030 --> 00:53:45,340
us we're gonna open it up for here for

1343
00:53:49,890 --> 00:53:48,040
questions here in just a second but one

1344
00:53:50,970 --> 00:53:49,900
of the final things I also we've kind of

1345
00:53:52,710 --> 00:53:50,980
been bookending it and we've been

1346
00:53:54,810 --> 00:53:52,720
talking about it throughout but one of

1347
00:53:56,960 --> 00:53:54,820
the main things that you said to me is

1348
00:54:00,990 --> 00:53:56,970
the biggest legacy of Spitzer really is

1349
00:54:03,480 --> 00:54:01,000
the people yes right then again I

1350
00:54:05,910 --> 00:54:03,490
mentioned earlier about the ops teams

1351
00:54:08,550 --> 00:54:05,920
but not just the ops team it's just a

1352
00:54:11,580 --> 00:54:08,560
whole spits of family in its entirety

1353
00:54:13,680 --> 00:54:11,590
right the people are really what makes

1354
00:54:19,350 --> 00:54:13,690
the sign as possible right and the

1355
00:54:21,360 --> 00:54:19,360
people on this mission feel really real

1356
00:54:23,790 --> 00:54:21,370
ownership right to the parts that they

1357
00:54:26,490 --> 00:54:23,800
have worked on and supported and when I

1358
00:54:30,090 --> 00:54:26,500
say that is can you imagine you've had

1359
00:54:32,100 --> 00:54:30,100
people on this mission 10 12 years ago

1360
00:54:34,140 --> 00:54:32,110
and you have someone normally but they

1361
00:54:36,510 --> 00:54:34,150
have become the domain expert in that

1362
00:54:39,330 --> 00:54:36,520
particular area you don't even have to

1363
00:54:40,890 --> 00:54:39,340

ask when they find out you online on the

1364
00:54:44,760 --> 00:54:40,900
telephone they're supporting the

1365
00:54:47,130 --> 00:54:44,770
recovery our recoveries from any anomaly

1366
00:54:49,650 --> 00:54:47,140
mode has been very rapid to keep us on

1367
00:54:51,390 --> 00:54:49,660
orbit so they reach back what all of the

1368
00:54:52,860 --> 00:54:51,400
people wanted to just stay a part of

1369
00:54:54,330 --> 00:54:52,870
this mission has just been tremendous

1370
00:54:56,190 --> 00:54:54,340
very cool

1371
00:54:57,990 --> 00:54:56,200
all right folks we're gonna open it up

1372
00:54:59,160 --> 00:54:58,000
for a few questions just a reminder if

1373
00:55:00,720 --> 00:54:59,170
you're asking a question in the house

1374
00:55:02,280 --> 00:55:00,730
you can step up to those microphones

1375
00:55:03,660 --> 00:55:02,290
right over there or that microphone

1376
00:55:04,630 --> 00:55:03,670
right over there we'll also be getting

1377
00:55:07,080 --> 00:55:04,640
some of your question

1378
00:55:10,870 --> 00:55:07,090
online as well those work their way up

1379
00:55:12,220 --> 00:55:10,880
here while we're waiting to see if

1380
00:55:16,750 --> 00:55:12,230
anybody steps up for question I've got

1381
00:55:18,670 --> 00:55:16,760
one this mission has been apart we

1382
00:55:20,290 --> 00:55:18,680
talked about Trappist as part of the

1383
00:55:22,510 --> 00:55:20,300
google doodle which has got to be pretty

1384
00:55:25,510 --> 00:55:22,520
amazing got to be a good feeling but

1385
00:55:27,820 --> 00:55:25,520
also robert you had that image that we

1386
00:55:30,640 --> 00:55:27,830
saw was yours you were a part of that

1387
00:55:32,740 --> 00:55:30,650
making that an illustration but that was

1388
00:55:36,490 --> 00:55:32,750

also the on the front page of the New

1389
00:55:38,080 --> 00:55:36,500
York Times yeah I mean of course I think

1390
00:55:39,610 --> 00:55:38,090
it's the goal of every mission to make

1391
00:55:41,140 --> 00:55:39,620
it on the front cover of the New York

1392
00:55:43,420 --> 00:55:41,150
Times above the fold and that was

1393
00:55:45,520 --> 00:55:43,430
certainly a stated goal we had when

1394
00:55:46,780 --> 00:55:45,530
Spitzer launched and you know it took a

1395
00:55:48,250 --> 00:55:46,790
while we were sweating for a while but

1396
00:55:49,840 --> 00:55:48,260
the fact that you know that just the the

1397
00:55:54,040 --> 00:55:49,850
remarkable nature of the Trappist one

1398
00:55:56,470 --> 00:55:54,050
system discovery got that science onto

1399
00:55:59,560 --> 00:55:56,480
like mainstream media at a level that

1400
00:56:02,290 --> 00:55:59,570
that had really very seldom seen out of

1401
00:56:03,580 --> 00:56:02,300
NASA it was I I don't remember the exact

1402
00:56:06,990 --> 00:56:03,590
numbers but when you looked at social

1403
00:56:09,610 --> 00:56:07,000
media and then repost that was

1404
00:56:12,730 --> 00:56:09,620
groundbreaking in terms of the reach it

1405
00:56:14,980 --> 00:56:12,740
had for NASA science results so but but

1406
00:56:17,440 --> 00:56:14,990
yeah it's it's really proud to go in and

1407
00:56:22,960 --> 00:56:17,450
say yep that's our mission right here up

1408
00:56:24,790 --> 00:56:22,970
front I surely do beats we were all we

1409
00:56:30,510 --> 00:56:24,800
were all scrambling to like what carries

1410
00:56:38,380 --> 00:56:32,680
thanks for this this is really a great

1411
00:56:41,050 --> 00:56:38,390
presentation so the mission is ending

1412
00:56:43,150 --> 00:56:41,060
and my understanding of the reasons for

1413
00:56:45,490 --> 00:56:43,160

the mission ending or that it's it's

1414
00:56:46,600 --> 00:56:45,500
sort of a bureaucratic explanation it's

1415
00:56:48,430 --> 00:56:46,610
not it's not like it's running out of

1416
00:56:50,440 --> 00:56:48,440
fuel it's not even necessarily that it

1417
00:56:55,330 --> 00:56:50,450
lacks funding but that there there was

1418
00:56:56,710 --> 00:56:55,340
some sort of requirement to sort of show

1419
00:56:57,850 --> 00:56:56,720
that the mission could be ended up

1420
00:57:01,540 --> 00:56:57,860
speaking to some of the gentleman from

1421
00:57:03,430 --> 00:57:01,550
Caltech who is I guess runs this

1422
00:57:05,050 --> 00:57:03,440
download center they on Monday night

1423
00:57:06,490 --> 00:57:05,060
about this and he didn't go into a lot

1424
00:57:08,620 --> 00:57:06,500
of detail I was wondering if if you're

1425
00:57:11,260 --> 00:57:08,630
able to I may have this all wrong but if

1426
00:57:13,600 --> 00:57:11,270
if if you could explain why the mission

1427
00:57:17,160 --> 00:57:13,610
is ending now and then just on a related

1428
00:57:18,579 --> 00:57:17,170
note to what extent is the W first

1429
00:57:22,809 --> 00:57:18,589
telescope going

1430
00:57:24,370 --> 00:57:22,819
to replace this mission or you know what

1431
00:57:27,849 --> 00:57:24,380
will it be able to do that Spitzer

1432
00:57:30,479 --> 00:57:27,859
wasn't able to do thank you so with

1433
00:57:33,039 --> 00:57:30,489
moving on moving on from this mission

1434
00:57:34,690 --> 00:57:33,049
kind of what are some of the reasons and

1435
00:57:37,329 --> 00:57:34,700
is their connection with future

1436
00:57:40,509 --> 00:57:37,339
telescopes w first James Webb possibly

1437
00:57:44,849 --> 00:57:40,519
any of those well I mean absolutely w

1438
00:57:47,589 --> 00:57:44,859

first can do 100 times the type of

1439
00:57:51,039 --> 00:57:47,599
photometry in spectroscopy that Spitzer

1440
00:57:53,049 --> 00:57:51,049
is capable of doing w first is going to

1441
00:57:55,089 --> 00:57:53,059
work at basically the same wave bands

1442
00:57:57,339 --> 00:57:55,099
that Spitzer has through the whole war

1443
00:58:02,019 --> 00:57:57,349
mission but like you say with much

1444
00:58:05,410 --> 00:58:02,029
larger area coverage if you when you say

1445
00:58:07,989 --> 00:58:05,420
a bureaucratic or the bureaucracy

1446
00:58:11,079 --> 00:58:07,999
I think Susie or someone they'll operate

1447
00:58:13,269 --> 00:58:11,089
it early on that NASA half the scene

1448
00:58:15,359 --> 00:58:13,279
reviews right so nASA has not just

1449
00:58:18,819 --> 00:58:15,369
Spitzer right they have many flight

1450
00:58:21,609 --> 00:58:18,829
assets right just like you have your

1451
00:58:25,329 --> 00:58:21,619
checkbook and things that you have for

1452
00:58:26,380 --> 00:58:25,339
your investment portfolio or what's

1453
00:58:29,440 --> 00:58:26,390
going on at home

1454
00:58:33,729 --> 00:58:29,450
NASA reviews these things right and have

1455
00:58:35,440 --> 00:58:33,739
to make a submit assessment on I have

1456
00:58:36,940 --> 00:58:35,450
new missions coming up that's going to

1457
00:58:38,440 --> 00:58:36,950
have certain capabilities I have

1458
00:58:41,890 --> 00:58:38,450
missions that's current that's going to

1459
00:58:44,739 --> 00:58:41,900
have certain capabilities so the answer

1460
00:58:51,370 --> 00:58:44,749
and this is countable quote from Paul

1461
00:58:54,190 --> 00:58:51,380
Hertz program exec is that the 2018 same

1462
00:58:56,079 --> 00:58:54,200
review 2016 senior review they made that

1463
00:58:59,019 --> 00:58:56,089

assessment right and it was already

1464
00:59:02,769 --> 00:58:59,029
determined back in 2016 that they were

1465
00:59:06,039 --> 00:59:02,779
going to decommission or shut down the

1466
00:59:09,489 --> 00:59:06,049
Spitzer operation however when JWST came

1467
00:59:13,539 --> 00:59:09,499
along there was a 20-18 type launch

1468
00:59:16,329 --> 00:59:13,549
timeframe and the idea was to breach the

1469
00:59:19,450 --> 00:59:16,339
time of operation to Spitzer to reduce

1470
00:59:22,559 --> 00:59:19,460
the on-orbit time for some of the

1471
00:59:26,019 --> 00:59:22,569
science observation that the JWST would

1472
00:59:32,109 --> 00:59:26,029
be doing so there was always a plan in

1473
00:59:33,549 --> 00:59:32,119
place to end a specimen right so is

1474
00:59:35,999 --> 00:59:33,559
you can think of it as brilliant

1475
00:59:40,329 --> 00:59:36,009
bureaucratic but I think it was a plan

1476
00:59:42,370 --> 00:59:40,339
me myself and several others especially

1477
00:59:45,089 --> 00:59:42,380
the scientists you know anyone data

1478
00:59:49,650 --> 00:59:45,099
analysts they want data forever right

1479
00:59:52,209 --> 00:59:49,660
which is okay but one of the things is

1480
00:59:55,420 --> 00:59:52,219
which was probably not a factor but

1481
00:59:58,209 --> 00:59:55,430
could play into being a factor years to

1482
01:00:01,569 --> 00:59:58,219
come mr. orbit geometry that Susy

1483
01:00:08,380 --> 01:00:01,579
mentioned it poses other challenges and

1484
01:00:10,809 --> 01:00:08,390
risks I'm sorry about this but I don't

1485
01:00:14,170 --> 01:00:10,819
know how to do it without this alarm

1486
01:00:17,019 --> 01:00:14,180
system but anyway yes so so has always

1487
01:00:18,549 --> 01:00:17,029
been in a plan and I'm sure if you ask

1488
01:00:20,009 --> 01:00:18,559

the scientists and different folks

1489
01:00:23,620 --> 01:00:20,019
you're going to get different answers

1490
01:00:25,509 --> 01:00:23,630
and that's okay there's a good

1491
01:00:27,370 --> 01:00:25,519
connection question with Astro Gate

1492
01:00:29,949 --> 01:00:27,380
online and then we'll get to you

1493
01:00:31,299 --> 01:00:29,959
Astro Gate on YouTube asks is there

1494
01:00:35,769 --> 01:00:31,309
going to be a gap in the infrared

1495
01:00:37,779 --> 01:00:35,779
coverage after Spitzer essentially yes

1496
01:00:39,099 --> 01:00:37,789
there's another there's an all-sky

1497
01:00:40,719 --> 01:00:39,109
survey that's still going on called the

1498
01:00:42,969 --> 01:00:40,729
wide field Infrared Survey Explorer but

1499
01:00:44,380 --> 01:00:42,979
that will be coming to an end as well so

1500
01:00:46,299 --> 01:00:44,390
there's still a little bit further

1501
01:00:48,429 --> 01:00:46,309
beyond Spitzer there'll be some infrared

1502
01:00:52,029 --> 01:00:48,439
coverage the Hubble Space Telescope

1503
01:00:53,739 --> 01:00:52,039
there's peers into the what's called the

1504
01:00:55,089 --> 01:00:53,749
near-infrared not the same wavelengths

1505
01:00:57,160 --> 01:00:55,099
of Spitzer but there's some infrared

1506
01:00:58,449 --> 01:00:57,170
coverage from Hubble as well but the in

1507
01:01:00,219 --> 01:00:58,459
the wavelengths that Spitzer's are

1508
01:01:03,969 --> 01:01:00,229
functioning now yes there will be a gap

1509
01:01:06,009 --> 01:01:03,979
but that's the James Webb's launch date

1510
01:01:08,529 --> 01:01:06,019
is a year from now basically a little

1511
01:01:10,650 --> 01:01:08,539
bit more than that so the gap shouldn't

1512
01:01:13,059 --> 01:01:10,660
be very long but also I mean the the

1513
01:01:14,949 --> 01:01:13,069

archive essentially in terms of all the

1514
01:01:17,109 --> 01:01:14,959
scientific studies that have been done

1515
01:01:19,499 --> 01:01:17,119
already we've just scratched the surface

1516
01:01:23,349 --> 01:01:19,509
so all of that is currently being mined

1517
01:01:25,299 --> 01:01:23,359
for the general by the general

1518
01:01:28,329 --> 01:01:25,309
astronomical community as a way to

1519
01:01:31,059 --> 01:01:28,339
really build upon G and relating to your

1520
01:01:32,380 --> 01:01:31,069
question of to building on the James for

1521
01:01:35,709 --> 01:01:32,390
the James Webb Space Telescope to take

1522
01:01:37,449 --> 01:01:35,719
advantage of that as well as the white

1523
01:01:39,660 --> 01:01:37,459
Hill infrared survey telescope w first

1524
01:01:42,309 --> 01:01:39,670
to take advantage of that so all of that

1525
01:01:44,410 --> 01:01:42,319
so the gap itself is not going to be

1526
01:01:47,859 --> 01:01:44,420
critical at this point

1527
01:01:49,029 --> 01:01:47,869
but ideally you know we if if you have

1528
01:01:51,309 --> 01:01:49,039
the choice you don't want it but that's

1529
01:01:56,849 --> 01:01:51,319
the thing is that this is the the gap

1530
01:02:02,529 --> 01:01:59,200
don't know a lot about space but I'm

1531
01:02:05,140 --> 01:02:02,539
fascinated by what I do know two

1532
01:02:07,690 --> 01:02:05,150
questions I'd like to know how many

1533
01:02:10,630 --> 01:02:07,700
miles away Spitzer is from the earth

1534
01:02:12,940 --> 01:02:10,640
right now and I'd also like to know if

1535
01:02:15,370 --> 01:02:12,950
there's the emotional side of shutting

1536
01:02:17,049 --> 01:02:15,380
this project down and the hundreds of

1537
01:02:19,329 --> 01:02:17,059
people that have worked on it and so on

1538
01:02:22,690 --> 01:02:19,339

do they go on to other employment other

1539
01:02:25,000 --> 01:02:22,700
projects things like that but more so

1540
01:02:30,190 --> 01:02:25,010
just the emotional side they've invested

1541
01:02:35,970 --> 01:02:30,200
an awful lot in this emotionally so 160

1542
01:02:39,430 --> 01:02:35,980
to 165 million miles away okay the

1543
01:02:42,339 --> 01:02:39,440
second part of your question about the

1544
01:02:45,789 --> 01:02:42,349
motion side and whether the people jobs

1545
01:02:48,460 --> 01:02:45,799
go away one of the things that we have

1546
01:02:51,599 --> 01:02:48,470
to do or we did once we start talking

1547
01:02:55,150 --> 01:02:51,609
about decommissioning the space craft

1548
01:02:57,309 --> 01:02:55,160
there's a closeout plan right that you

1549
01:03:01,779 --> 01:02:57,319
have to put together and you have to go

1550
01:03:04,660 --> 01:03:01,789
to a decommissioning dispose of review

1551
01:03:07,539 --> 01:03:04,670
and within that closeout plan it talks

1552
01:03:10,569 --> 01:03:07,549
about dis positioning the flight the

1553
01:03:13,960 --> 01:03:10,579
ground assets what do you do with the

1554
01:03:16,710 --> 01:03:13,970
people so once we determine the date

1555
01:03:20,410 --> 01:03:16,720
that we're gonna declare the mission

1556
01:03:23,200 --> 01:03:20,420
decommission we start early on to meet

1557
01:03:25,029 --> 01:03:23,210
with the organizations that provide the

1558
01:03:28,569 --> 01:03:25,039
personnel that's working on the mission

1559
01:03:32,190 --> 01:03:28,579
now one of the things that to keep in

1560
01:03:35,890 --> 01:03:32,200
mind we've been over the course of time

1561
01:03:38,920 --> 01:03:35,900
we don't have a lot of full-time people

1562
01:03:41,170 --> 01:03:38,930
right sorry if I told you we had 15 what

1563
01:03:43,720 --> 01:03:41,180

we call full-time equivalents there may

1564
01:03:46,930 --> 01:03:43,730
be three people but the rest of them

1565
01:03:49,029 --> 01:03:46,940
could be thirty at point a fraction of

1566
01:03:51,400 --> 01:03:49,039
some hours right that they're working on

1567
01:03:53,559 --> 01:03:51,410
it which is a good thing because one of

1568
01:03:56,079 --> 01:03:53,569
the things we did and allowed on Spitzer

1569
01:03:58,099 --> 01:03:56,089
was for people to cross train right so

1570
01:04:00,769 --> 01:03:58,109
if you was doing one job we

1571
01:04:03,019 --> 01:04:00,779
it's them to try and learn what the

1572
01:04:04,039 --> 01:04:03,029
other guy person is doing right and what

1573
01:04:06,920 --> 01:04:04,049
we did

1574
01:04:08,329 --> 01:04:06,930
what happened by doing so it enabled the

1575
01:04:12,440 --> 01:04:08,339
people that have worked on a split

1576
01:04:14,779 --> 01:04:12,450
submission it was an easy transition for

1577
01:04:16,970 --> 01:04:14,789
them to go to other project as a matter

1578
01:04:19,430 --> 01:04:16,980
of fact at one time I thought we were

1579
01:04:21,440 --> 01:04:19,440
becoming in a training ground and we

1580
01:04:23,390 --> 01:04:21,450
really didn't want to expose that we had

1581
01:04:28,700 --> 01:04:23,400
good people because the newer missions

1582
01:04:31,940 --> 01:04:28,710
would just come along and take we'll get

1583
01:04:33,559 --> 01:04:31,950
these two questions and then when we are

1584
01:04:35,450 --> 01:04:33,569
done if you have questions for our

1585
01:04:36,979 --> 01:04:35,460
panelists they'll stick around for a

1586
01:04:38,329 --> 01:04:36,989
couple minutes afterwards please come on

1587
01:04:41,390 --> 01:04:38,339
up and ask but we'll get through these

1588
01:04:44,539 --> 01:04:41,400

two first all right so if I heard right

1589
01:04:46,599 --> 01:04:44,549
then I think one of you said that the

1590
01:04:49,430 --> 01:04:46,609
temperature of the Spitzer is around

1591
01:04:52,430 --> 01:04:49,440
five degrees Kelvin and obviously that's

1592
01:04:54,849 --> 01:04:52,440
very cold and so I'm assuming that the

1593
01:04:59,299 --> 01:04:54,859
reason for that would be so that it can

1594
01:05:01,489 --> 01:04:59,309
measure Oh larger range of temperatures

1595
01:05:03,170 --> 01:05:01,499
so anything above that and so I was

1596
01:05:05,450 --> 01:05:03,180
wondering is there any is there anything

1597
01:05:07,220 --> 01:05:05,460
special that had to be done to the

1598
01:05:09,279 --> 01:05:07,230
spacecraft so it could operate like that

1599
01:05:12,109 --> 01:05:09,289
or is it just part of the regular

1600
01:05:13,849 --> 01:05:12,119
preparations for something going into

1601
01:05:16,370 --> 01:05:13,859
space because it's that much gift over

1602
01:05:18,319 --> 01:05:16,380
this a little bit in my overview but the

1603
01:05:20,839 --> 01:05:18,329
three instruments that I showed you all

1604
01:05:22,039 --> 01:05:20,849
sit in what's called a cryo stat so

1605
01:05:27,729 --> 01:05:22,049
they're they're cooled with liquid

1606
01:05:31,249 --> 01:05:27,739
helium and that's what allows the

1607
01:05:32,809 --> 01:05:31,259
instruments to get down to five degrees

1608
01:05:34,849 --> 01:05:32,819
Kelvin and stay down there it was only

1609
01:05:37,309 --> 01:05:34,859
really one instrument that needed to be

1610
01:05:38,749 --> 01:05:37,319
that cold the mips I think was the one

1611
01:05:43,400 --> 01:05:38,759
that wanted to be that cold a longer

1612
01:05:45,680 --> 01:05:43,410
wavelength instrument but one of the key

1613
01:05:49,549 --> 01:05:45,690

and novel things about spitzer too is

1614
01:05:51,829 --> 01:05:49,559
what we only cooled the instruments we

1615
01:05:53,690 --> 01:05:51,839
didn't cool the whole telescope previous

1616
01:05:55,579 --> 01:05:53,700
missions had to cool the whole telescope

1617
01:05:57,559 --> 01:05:55,589
and the instruments and that's a huge

1618
01:06:00,999 --> 01:05:57,569
amount of liquid helium which is heavy

1619
01:06:03,589 --> 01:06:01,009
and by coming up with this novel design

1620
01:06:06,890 --> 01:06:03,599
primarily developed by a gentleman who's

1621
01:06:11,780 --> 01:06:06,900
standing behind you we were able to

1622
01:06:15,740 --> 01:06:14,150
a much smaller rocket which made the

1623
01:06:18,110 --> 01:06:15,750
mission much cheaper and we've got the

1624
01:06:20,000 --> 01:06:18,120
same performance out of it so it was it

1625
01:06:22,460 --> 01:06:20,010
was a novel design between the telescope

1626
01:06:23,780 --> 01:06:22,470
and the cryostat but you're you're

1627
01:06:25,970 --> 01:06:23,790
exactly light that you want that

1628
01:06:30,310 --> 01:06:25,980
temperature so that you can you can see

1629
01:06:34,100 --> 01:06:30,320
very very cool objects in the in the sky

1630
01:06:36,320 --> 01:06:34,110
we just toss out that one of the reasons

1631
01:06:38,660 --> 01:06:36,330
we got five and a half years of cryogen

1632
01:06:39,680 --> 01:06:38,670
is that into the mission we started to

1633
01:06:42,200 --> 01:06:39,690
become very clever

1634
01:06:44,300 --> 01:06:42,210
we the engineers and the science being

1635
01:06:45,740 --> 01:06:44,310
very clever about really understanding

1636
01:06:47,690 --> 01:06:45,750
how cold did it have to be at any given

1637
01:06:49,610 --> 01:06:47,700
point and really conserving the liquid

1638
01:06:51,470 --> 01:06:49,620

helium in a way that stretched out far

1639
01:06:54,260 --> 01:06:51,480
past what you know are even most

1640
01:06:56,710 --> 01:06:54,270
optimistic ideas were at lunch so a lot

1641
01:06:59,420 --> 01:06:56,720
of what made Spitzer so amazing was

1642
01:07:01,100 --> 01:06:59,430
after it was you know out of reach you

1643
01:07:04,040 --> 01:07:01,110
know we could only transmit signals to

1644
01:07:05,900 --> 01:07:04,050
it we were able to optimize the way we

1645
01:07:07,610 --> 01:07:05,910
used the facility and we could even send

1646
01:07:09,380 --> 01:07:07,620
it software updates that actually made

1647
01:07:11,300 --> 01:07:09,390
it more powerful than it was the day

1648
01:07:12,890 --> 01:07:11,310
that it launched Wow

1649
01:07:14,570 --> 01:07:12,900
thank you very much thank you for that

1650
01:07:16,550 --> 01:07:14,580
great question all right last question

1651
01:07:18,080 --> 01:07:16,560
in the house and then I've got a good

1652
01:07:21,200 --> 01:07:18,090
one on here that everybody can think

1653
01:07:23,690 --> 01:07:21,210
about all of you for your dedication and

1654
01:07:26,150 --> 01:07:23,700
passion for this project I just wanted

1655
01:07:28,700 --> 01:07:26,160
to know if this project would continue

1656
01:07:30,680 --> 01:07:28,710
for another 16 years as a team what

1657
01:07:32,630 --> 01:07:30,690
would be a priority for you as you've

1658
01:07:34,520 --> 01:07:32,640
seen all these images and the growth and

1659
01:07:36,470 --> 01:07:34,530
all the amazing things that you shared

1660
01:07:38,300 --> 01:07:36,480
with us today if it would continue what

1661
01:07:42,050 --> 01:07:38,310
would be maybe a goal or priority you

1662
01:07:44,330 --> 01:07:42,060
guys might look into if it continued for

1663
01:07:53,510 --> 01:07:44,340

16 more years you imagine that picture

1664
01:07:56,390 --> 01:07:53,520
that Suzy was showing you what I would

1665
01:07:58,940 --> 01:07:56,400
say is I think a lot of what we would

1666
01:08:00,650 --> 01:07:58,950
look like look scientifically look for

1667
01:08:03,080 --> 01:08:00,660
in the next 16 years we may not even

1668
01:08:04,850 --> 01:08:03,090
know today which is an example with the

1669
01:08:06,770 --> 01:08:04,860
exoplanets when Spitzer launched we

1670
01:08:08,990 --> 01:08:06,780
didn't know we're gonna be looking at

1671
01:08:10,970 --> 01:08:09,000
exoplanets and discovering exoplanets so

1672
01:08:12,860 --> 01:08:10,980
if we were to have another 16 years it's

1673
01:08:15,530 --> 01:08:12,870
it's not clear to me that the scientists

1674
01:08:19,880 --> 01:08:15,540
understanding what will be the hot field

1675
01:08:22,820 --> 01:08:19,890
in 16 more years yeah I mean at every

1676
01:08:25,079 --> 01:08:22,830
point in astronomy we ask the questions

1677
01:08:27,240 --> 01:08:25,089
that are based on the

1678
01:08:29,010 --> 01:08:27,250
the observations we have to this day and

1679
01:08:31,650 --> 01:08:29,020
that generates a new question which then

1680
01:08:33,420 --> 01:08:31,660
we design new telescopes to specifically

1681
01:08:35,340 --> 01:08:33,430
address some of those points you know

1682
01:08:37,680 --> 01:08:35,350
Spitzer was designed to answer a certain

1683
01:08:38,910 --> 01:08:37,690
set of high profile questions on you

1684
01:08:40,740 --> 01:08:38,920
know the age of the universe and the

1685
01:08:43,800 --> 01:08:40,750
nature of star formation and how planets

1686
01:08:45,660 --> 01:08:43,810
form we in flight discovered how to

1687
01:08:47,220 --> 01:08:45,670
answer other questions it wasn't

1688
01:08:49,550 --> 01:08:47,230

designed for but some of which we could

1689
01:08:52,140 --> 01:08:49,560
do simple software updates do to enable

1690
01:08:53,430 --> 01:08:52,150
where as and just as a point of contrast

1691
01:08:55,320 --> 01:08:53,440
you know the Hubble Space Telescope

1692
01:08:56,490 --> 01:08:55,330
actually had the benefit of servicing

1693
01:08:58,620 --> 01:08:56,500
missions where we could actually send

1694
01:09:00,720 --> 01:08:58,630
new hardware and replace it we could

1695
01:09:02,309 --> 01:09:00,730
never reach Spitzer the day after it was

1696
01:09:03,960 --> 01:09:02,319
launched we had no craft they could get

1697
01:09:07,320 --> 01:09:03,970
there so all of our updates had to be

1698
01:09:09,750 --> 01:09:07,330
just pure software updates but but

1699
01:09:11,550 --> 01:09:09,760
Spitzer has given us that grounding of

1700
01:09:13,620 --> 01:09:11,560
information that is now helping us

1701
01:09:15,059 --> 01:09:13,630
design the next generation and the

1702
01:09:17,910 --> 01:09:15,069
generation after that so we actually

1703
01:09:19,680 --> 01:09:17,920
build telescopes each time with new

1704
01:09:21,900 --> 01:09:19,690
capabilities or focused different ways

1705
01:09:23,970 --> 01:09:21,910
to let us access the things that we

1706
01:09:31,050 --> 01:09:23,980
couldn't quite solve with the previous

1707
01:09:32,700 --> 01:09:31,060
generation I'm gonna give you a moment

1708
01:09:34,050 --> 01:09:32,710
to think I'm gonna ask the question I'm

1709
01:09:37,170 --> 01:09:34,060
gonna say some more stuff and then I'm

1710
01:09:39,570 --> 01:09:37,180
gonna come back to you because it's it's

1711
01:09:41,309 --> 01:09:39,580
from got Wi-Fi on YouTube and they asked

1712
01:09:44,640 --> 01:09:41,319
in your opinion what was Spitzer's

1713
01:09:46,590 --> 01:09:44,650

greatest accomplishment I know we talked

1714
01:09:49,260 --> 01:09:46,600
for a whole hour about all the great

1715
01:09:50,760 --> 01:09:49,270
things that happened so I want to give

1716
01:09:51,750 --> 01:09:50,770
you all a second and while they're

1717
01:09:53,790 --> 01:09:51,760
thinking about that

1718
01:09:55,950 --> 01:09:53,800
I want to ask you all to join us next

1719
01:09:58,170 --> 01:09:55,960
month we're gonna be talking about

1720
01:09:59,970 --> 01:09:58,180
beyond the pale blue dot seeing distant

1721
01:10:03,090 --> 01:09:59,980
planets it's gonna be celebrating in the

1722
01:10:05,190 --> 01:10:03,100
30th anniversary of the famous pale blue

1723
01:10:07,710 --> 01:10:05,200
dot image but also looking at our quest

1724
01:10:09,540 --> 01:10:07,720
to image exoplanets orbiting another

1725
01:10:11,280 --> 01:10:09,550
star which sounds very familiar to what

1726
01:10:13,050 --> 01:10:11,290
we're talking about today so now that

1727
01:10:14,100 --> 01:10:13,060
I've given you all 30 seconds to think

1728
01:10:19,160 --> 01:10:14,110
about it we're gonna start from over

1729
01:10:21,510 --> 01:10:19,170
there work our way over here so so I

1730
01:10:23,070 --> 01:10:21,520
mentioned what my personal favorites

1731
01:10:26,580 --> 01:10:23,080
were before but I think as sort of

1732
01:10:30,270 --> 01:10:26,590
overall when Robert and I were in grad

1733
01:10:32,910 --> 01:10:30,280
school infrared astronomy was not the

1734
01:10:34,830 --> 01:10:32,920
dominant concept of astronomy that as

1735
01:10:36,390 --> 01:10:34,840
most people still did a lot of optical

1736
01:10:37,450 --> 01:10:36,400
Astronomy and there's x-ray astronomy

1737
01:10:40,180 --> 01:10:37,460
had been done for a long time

1738
01:10:41,500 --> 01:10:40,190

but in many ways Spitzer made infrared

1739
01:10:47,100 --> 01:10:41,510
astronomers out of most Sofia

1740
01:10:52,540 --> 01:10:50,410
I had to go to much shorter wavelengths

1741
01:10:54,220 --> 01:10:52,550
to get for the action was yeah but that

1742
01:10:56,200 --> 01:10:54,230
was the thing is that infrared astronomy

1743
01:10:58,330 --> 01:10:56,210
has been done from the ground for a long

1744
01:11:00,370 --> 01:10:58,340
time but it's very difficult to do from

1745
01:11:01,750 --> 01:11:00,380
the ground because well your telescope

1746
01:11:03,430 --> 01:11:01,760
is warm which means your telescope is

1747
01:11:05,080 --> 01:11:03,440
emitting in Fred light the atmosphere is

1748
01:11:06,310 --> 01:11:05,090
warm which means the atmosphere is also

1749
01:11:09,100 --> 01:11:06,320
emitting infrared light so you're trying

1750
01:11:11,470 --> 01:11:09,110
to detect infrared light from outside of

1751
01:11:13,540 --> 01:11:11,480
the atmosphere oh wait there's clouds

1752
01:11:15,460 --> 01:11:13,550
and water vapor it doesn't have to be

1753
01:11:17,700 --> 01:11:15,470
cloudy water vapor is one of the most

1754
01:11:20,200 --> 01:11:17,710
important greenhouse gases there is Oh

1755
01:11:21,370 --> 01:11:20,210
which means it absorbs all that light

1756
01:11:22,870 --> 01:11:21,380
coming from outer space

1757
01:11:24,580 --> 01:11:22,880
- it doesn't let stuff leave but it

1758
01:11:26,830 --> 01:11:24,590
doesn't let stuff come from above as

1759
01:11:28,480 --> 01:11:26,840
well so doing infrared astronomy from

1760
01:11:31,300 --> 01:11:28,490
the ground is has been said it's the

1761
01:11:34,030 --> 01:11:31,310
equivalent of doing optical Astronomy

1762
01:11:36,820 --> 01:11:34,040
except you have a glowing telescope made

1763
01:11:41,050 --> 01:11:36,830

out of neon tubes during it during the

1764
01:11:42,670 --> 01:11:41,060
day so infrared telescopes have been up

1765
01:11:45,850 --> 01:11:42,680
there before had been very successful

1766
01:11:50,170 --> 01:11:45,860
but really Spitzer the accessibility the

1767
01:11:52,060 --> 01:11:50,180
quality and the broad range of science

1768
01:11:53,770 --> 01:11:52,070
that it allowed made a lot of people who

1769
01:11:55,570 --> 01:11:53,780
had not done infrared astronomy before

1770
01:11:57,580 --> 01:11:55,580
become infrared astronomers or certainly

1771
01:11:59,230 --> 01:11:57,590
incorporate and fret astronomy as part

1772
01:12:01,600 --> 01:11:59,240
of what they were doing so I think that

1773
01:12:04,060 --> 01:12:01,610
probably is the maybe the biggest legacy

1774
01:12:06,850 --> 01:12:04,070
beyond any individual great scientific

1775
01:12:09,520 --> 01:12:06,860
accomplishment cool well that's that's

1776
01:12:11,100 --> 01:12:09,530
hard to follow up on big picture and I

1777
01:12:13,810 --> 01:12:11,110
mean I would certainly say that

1778
01:12:15,550 --> 01:12:13,820
personally the Trappist one system

1779
01:12:17,080 --> 01:12:15,560
discoveries is quite incredible it's why

1780
01:12:19,480 --> 01:12:17,090
it was part of the Spitzer beyond logo

1781
01:12:20,770 --> 01:12:19,490
design but I'll just throw out something

1782
01:12:22,210 --> 01:12:20,780
that maybe not the greatest thing that's

1783
01:12:24,610 --> 01:12:22,220
done but one of the greatest things that

1784
01:12:26,230 --> 01:12:24,620
has done right in these final days is

1785
01:12:28,090 --> 01:12:26,240
that while we did not have the

1786
01:12:30,280 --> 01:12:28,100
opportunity to overlap with the James

1787
01:12:32,740 --> 01:12:30,290
Webb Space Telescope as was the original

1788
01:12:35,380 --> 01:12:32,750

extension and what the intent was there

1789
01:12:37,810 --> 01:12:35,390
it did open up this unexpected

1790
01:12:40,300 --> 01:12:37,820
opportunity to overlap with NASA's tests

1791
01:12:41,770 --> 01:12:40,310
exoplanet finding mission and you know

1792
01:12:42,940 --> 01:12:41,780
Tesla's mission that's basically serving

1793
01:12:44,500 --> 01:12:42,950
the whole sky looking for these

1794
01:12:45,940 --> 01:12:44,510
transiting signals but because of the

1795
01:12:47,830 --> 01:12:45,950
nature of the way it's looking for

1796
01:12:50,140 --> 01:12:47,840
planets it is going to predominately

1797
01:12:50,890 --> 01:12:50,150
find planets around these smaller stars

1798
01:12:53,380 --> 01:12:50,900
that Spitzer

1799
01:12:56,439 --> 01:12:53,390
is specifically sensitive to detect and

1800
01:12:58,030 --> 01:12:56,449
so we have a whole range of test science

1801
01:12:59,709 --> 01:12:58,040
follow-up that is still being executed

1802
01:13:02,050 --> 01:12:59,719
right now

1803
01:13:04,180 --> 01:13:02,060
and you know we'll be hearing more of in

1804
01:13:06,610 --> 01:13:04,190
in coming months but as a for instance

1805
01:13:09,850 --> 01:13:06,620
of just how amazing that could be we did

1806
01:13:13,419 --> 01:13:09,860
a press release just a few months ago

1807
01:13:15,790 --> 01:13:13,429
where version was showing these pictures

1808
01:13:17,770 --> 01:13:15,800
of how he had the measured the light

1809
01:13:19,510 --> 01:13:17,780
from these hot Jupiter planets and how

1810
01:13:20,979 --> 01:13:19,520
we were able to make weather predictions

1811
01:13:22,450 --> 01:13:20,989
based on how we saw the temperature

1812
01:13:24,430 --> 01:13:22,460
distribution there

1813
01:13:26,590 --> 01:13:24,440

well Spitzer was able to do that same

1814
01:13:29,110 --> 01:13:26,600
kind of work but on an earth-sized

1815
01:13:31,090 --> 01:13:29,120
planet that was orbiting a small star in

1816
01:13:33,010 --> 01:13:31,100
a very close orbit so it's a very hot

1817
01:13:34,930 --> 01:13:33,020
very unfriendly earth-sized planet but

1818
01:13:37,720 --> 01:13:34,940
we were actually able to measure the

1819
01:13:39,910 --> 01:13:37,730
amount of infrared glow from all sides

1820
01:13:42,220 --> 01:13:39,920
of that planet as a orbited star and

1821
01:13:43,959 --> 01:13:42,230
from that we could actually figure out

1822
01:13:47,140 --> 01:13:43,969
that it didn't have much of an

1823
01:13:49,300 --> 01:13:47,150
atmosphere that it had to be absorbing

1824
01:13:50,530 --> 01:13:49,310
the bulk of light falling on it to be

1825
01:13:52,870 --> 01:13:50,540
able to heat up to the temperatures we

1826
01:13:54,550 --> 01:13:52,880
saw and that actually provided enough

1827
01:13:57,399 --> 01:13:54,560
information that we could start to talk

1828
01:13:59,649 --> 01:13:57,409
what these surface minerals must be like

1829
01:14:00,970 --> 01:13:59,659
that basically when you looked at you

1830
01:14:04,120 --> 01:14:00,980
know the spread of common minerals we

1831
01:14:05,320 --> 01:14:04,130
expect to find on planets basalt was the

1832
01:14:07,780 --> 01:14:05,330
only thing that really fit the

1833
01:14:09,370 --> 01:14:07,790
properties that we needed to make that

1834
01:14:11,290 --> 01:14:09,380
light and so you know here we have a

1835
01:14:13,060 --> 01:14:11,300
planet we can't even begin to see that

1836
01:14:14,950 --> 01:14:13,070
planet directly because it is so small

1837
01:14:17,410 --> 01:14:14,960
so distant so close to its star but we

1838
01:14:19,240 --> 01:14:17,420

can actually say that we think that 80%

1839
01:14:20,770 --> 01:14:19,250
of the surface is covered with basalt

1840
01:14:22,120 --> 01:14:20,780
minerals and we know something about

1841
01:14:25,899 --> 01:14:22,130
physically what it's like and I think

1842
01:14:28,090 --> 01:14:25,909
that kind of indirect ability to learn

1843
01:14:31,180 --> 01:14:28,100
incredibly detailed things about other

1844
01:14:32,740 --> 01:14:31,190
worlds is just a great symbol of just

1845
01:14:36,580 --> 01:14:32,750
the kind of science that Spitzer has

1846
01:14:38,709 --> 01:14:36,590
enabled for the last 16 years planet

1847
01:14:40,959 --> 01:14:38,719
finding using the testator and the

1848
01:14:43,830 --> 01:14:40,969
confirmation yes by following up the

1849
01:14:46,870 --> 01:14:43,840
this is the at the WS meeting the the

1850
01:14:49,660 --> 01:14:46,880
habitable zone planet that fits around

1851
01:14:51,010 --> 01:14:49,670
and to be honest I was so busy at that

1852
01:14:55,590 --> 01:14:51,020
meeting since we didn't do that press

1853
01:14:57,760 --> 01:14:55,600
release I wasn't up on that science just

1854
01:14:59,800 --> 01:14:57,770
talking about what Spitzer is doing now

1855
01:15:01,950 --> 01:14:59,810
there's a great tool call that you can

1856
01:15:03,660 --> 01:15:01,960
go to eyes NASA gov and

1857
01:15:05,790 --> 01:15:03,670
sir is in there and it has all of the

1858
01:15:07,830 --> 01:15:05,800
exact things that it's not an animation

1859
01:15:09,630 --> 01:15:07,840
of maybe sort of kind of like it is

1860
01:15:11,400 --> 01:15:09,640
exactly where Spitzer is looking so if

1861
01:15:13,470 --> 01:15:11,410
you can go if you go there between now

1862
01:15:15,180 --> 01:15:13,480
and January 30th you will see all of the

1863
01:15:17,490 --> 01:15:15,190

things that it will be doing as well as

1864
01:15:19,380 --> 01:15:17,500
the responding to the final command so

1865
01:15:21,420 --> 01:15:19,390
you can actually follow spitzer all the

1866
01:15:23,490 --> 01:15:21,430
way through and also see them still it's

1867
01:15:29,130 --> 01:15:23,500
doing vital signs all the way till the

1868
01:15:30,630 --> 01:15:29,140
last day Susie I'm gonna change themes

1869
01:15:33,600 --> 01:15:30,640
here because the scientists like to talk

1870
01:15:35,160 --> 01:15:33,610
about science all joseph i maybe maybe

1871
01:15:36,450 --> 01:15:35,170
will talk about the engineering i don't

1872
01:15:38,550 --> 01:15:36,460
think people really appreciate the young

1873
01:15:41,850 --> 01:15:38,560
gentleman's question really hit it home

1874
01:15:44,490 --> 01:15:41,860
though the the warm launch a spitzer

1875
01:15:46,410 --> 01:15:44,500
where the telescope was not cooled only

1876
01:15:49,530 --> 01:15:46,420
the instrument was cool that's the first

1877
01:15:52,350 --> 01:15:49,540
time that ever been done it's now done

1878
01:15:54,450 --> 01:15:52,360
all the time that way okay so that was a

1879
01:15:58,950 --> 01:15:54,460
revolutionary engineering partner

1880
01:16:00,780 --> 01:15:58,960
spitzer that's commonplace now and you

1881
01:16:03,360 --> 01:16:00,790
know it's proud being part of that it's

1882
01:16:05,400 --> 01:16:03,370
proud being a part of the development

1883
01:16:07,470 --> 01:16:05,410
team you know we were at each other's

1884
01:16:09,000 --> 01:16:07,480
throats before launch and i know we

1885
01:16:11,280 --> 01:16:09,010
never thought the flight software would

1886
01:16:13,590 --> 01:16:11,290
work and here it's worked for you know

1887
01:16:15,540 --> 01:16:13,600
16 and a half years perfectly well

1888
01:16:17,490 --> 01:16:15,550

beyond the design limits it's it's

1889
01:16:20,340 --> 01:16:17,500
amazing when you look back on the

1890
01:16:23,459 --> 01:16:20,350
history of it because because it was

1891
01:16:24,180 --> 01:16:23,469
really dicey and testy at the beginning

1892
01:16:26,580 --> 01:16:24,190
before launch

1893
01:16:28,770 --> 01:16:26,590
but it's successful and its successful

1894
01:16:30,690 --> 01:16:28,780
because of a lot of people in this room

1895
01:16:33,450 --> 01:16:30,700
not just the four of us up here on this

1896
01:16:35,550 --> 01:16:33,460
is aged one thing you've said about the

1897
01:16:37,229 --> 01:16:35,560
warm lunch designed and is i got for one

1898
01:16:38,970 --> 01:16:37,239
thing just when you look at Spitzer and

1899
01:16:44,060 --> 01:16:38,980
you see what it looks like it looks very

1900
01:16:50,250 --> 01:16:47,340
this whole idea of a passively cooled

1901
01:16:52,260 --> 01:16:50,260
telescope that that would cool off on

1902
01:16:54,630 --> 01:16:52,270
sir just just that paint job the

1903
01:16:56,130 --> 01:16:54,640
brilliance of design of hey if we paint

1904
01:16:58,530 --> 01:16:56,140
the outward-facing side of that

1905
01:17:00,510 --> 01:16:58,540
telescope black that will automatically

1906
01:17:03,479 --> 01:17:00,520
radiate heat for us you know moving

1907
01:17:05,040 --> 01:17:03,489
parts that that just that paint job was

1908
01:17:06,990 --> 01:17:05,050
one of the most active brilliant

1909
01:17:10,530 --> 01:17:07,000
innovations of what maids but you're

1910
01:17:12,510 --> 01:17:10,540
capable of doing what it did it looks

1911
01:17:14,250 --> 01:17:12,520
cool

1912
01:17:16,830 --> 01:17:14,260
I'm gonna be short with it since the

1913
01:17:20,040 --> 01:17:16,840

scientists like Susie said I've kind of

1914
01:17:23,670 --> 01:17:20,050
given all of the detail explanation on

1915
01:17:26,850 --> 01:17:23,680
compositions but the trap is one and the

1916
01:17:29,060 --> 01:17:26,860
reason being is when we started the

1917
01:17:32,490 --> 01:17:29,070
mission and the cryogenic phase we had a

1918
01:17:35,910 --> 01:17:32,500
set of science objectives that we wanted

1919
01:17:38,910 --> 01:17:35,920
to achieve and what I learned and what

1920
01:17:41,280 --> 01:17:38,920
was Lana gets fired a project was you in

1921
01:17:43,020 --> 01:17:41,290
this misstate you never know right when

1922
01:17:45,210 --> 01:17:43,030
you're flying a mission like that when

1923
01:17:50,640 --> 01:17:45,220
that makes great discoveries going to be

1924
01:17:52,230 --> 01:17:50,650
so the track this one is far most my

1925
01:17:54,030 --> 01:17:52,240
favorite argue with Trappist one yeah

1926
01:17:56,250 --> 01:17:54,040
for sure

1927
01:17:58,350 --> 01:17:56,260
well thank you for all the many great

1928
01:18:04,100 --> 01:17:58,360
discoveries with this mission can we get

1929
01:18:08,460 --> 01:18:06,570
thank you very much for joining us all

1930
01:18:09,720 --> 01:18:08,470
tonight have a great rest your night

1931
01:18:10,850 --> 01:18:09,730
wherever it leads you thank you very

1932
01:18:12,680 --> 01:18:10,860
much for coming folks

1933
01:18:29,950 --> 01:18:12,690
[Applause]