



HUBBLE

hangouts

How to Operate the Hubble Space Telescope

Thursday November 13, 2014 3pm EDT 9pm CET

1
00:00:09,770 --> 00:00:08,360
hello everybody and welcome to this

2
00:00:11,270 --> 00:00:09,780
week's Hubble hangout we have another

3
00:00:13,129 --> 00:00:11,280
great planet hangout plan for you this

4
00:00:14,930 --> 00:00:13,139
week my name is Tony Darnell I work at

5
00:00:16,369 --> 00:00:14,940
the Space Telescope Science Institute

6
00:00:20,420 --> 00:00:16,379
but before we get started on today's

7
00:00:23,690 --> 00:00:20,430
hangout I have big news everyone our own

8
00:00:25,580 --> 00:00:23,700
dr. Jason Keller lets be the JWST

9
00:00:27,800 --> 00:00:25,590
project scientist at the Space Telescope

10
00:00:29,450 --> 00:00:27,810
Science Institute has released or

11
00:00:31,960 --> 00:00:29,460
earlier this summer had released an

12
00:00:34,760 --> 00:00:31,970
audio segment for academic minute on

13
00:00:37,100 --> 00:00:34,770

exploring exoplanets and he is up for a

14

00:00:39,020 --> 00:00:37,110

listener's choice award and so I'd like

15

00:00:40,820 --> 00:00:39,030

to have to give a shout-out and ask you

16

00:00:43,310 --> 00:00:40,830

guys if you want to support help support

17

00:00:45,890 --> 00:00:43,320

some of the JWST mission I put a link to

18

00:00:47,720 --> 00:00:45,900

where you can vote on his audio segment

19

00:00:49,490 --> 00:00:47,730

down in the description box on both the

20

00:00:51,500 --> 00:00:49,500

G+ page and the youtube channel so

21

00:00:53,750 --> 00:00:51,510

please click on it and look for his uh

22

00:00:55,580 --> 00:00:53,760

look for his segment listen to it and if

23

00:00:57,890 --> 00:00:55,590

you'd like it even move out it's you

24

00:01:00,530 --> 00:00:57,900

it's a it's a good way to support the

25

00:01:03,200 --> 00:01:00,540

jdub ust project and dr. Jason Keller I

26
00:01:06,320 --> 00:01:03,210
so I encourage you to check it out and

27
00:01:07,880 --> 00:01:06,330
and let us know what you think I'd also

28
00:01:09,290 --> 00:01:07,890
like to take a minute on behalf of the

29
00:01:11,600 --> 00:01:09,300
Space Telescope Science Institute and

30
00:01:16,039 --> 00:01:11,610
give a big congratulations to esa's

31
00:01:18,110 --> 00:01:16,049
rosetta canoe yeah because yesterday

32
00:01:20,930 --> 00:01:18,120
they successfully landed the fillet

33
00:01:22,010 --> 00:01:20,940
lander on comet 67p that's all i'm going

34
00:01:23,390 --> 00:01:22,020
to call it because I can't ever

35
00:01:25,820 --> 00:01:23,400
pronounce the rest of the stuff it was

36
00:01:28,580 --> 00:01:25,830
still awesome it was it was watching it

37
00:01:30,680 --> 00:01:28,590
the separation end and the landing live

38
00:01:34,130 --> 00:01:30,690

and I'm just like Nura on the edge of my

39

00:01:38,030 --> 00:01:34,140

seat like can you believe it we are on a

40

00:01:39,890 --> 00:01:38,040

comet now yeah we live in the Golden Age

41

00:01:41,960 --> 00:01:39,900

of astronomy one groups times anyway

42

00:01:43,940 --> 00:01:41,970

congrats all you guys wonderful work and

43

00:01:46,160 --> 00:01:43,950

we look forward to seeing some science

44

00:01:49,070 --> 00:01:46,170

that come out of this stuff so anyway

45

00:01:52,910 --> 00:01:49,080

good job guys um okay today's hangout

46

00:01:54,980 --> 00:01:52,920

have you ever wondered how people point

47

00:01:56,780 --> 00:01:54,990

the Hubble Space Telescope how do you

48

00:01:58,249 --> 00:01:56,790

use this thing how does it work I mean

49

00:02:00,890 --> 00:01:58,259

we learned a couple of weeks ago that

50

00:02:02,600 --> 00:02:00,900

there's not astronauts up there steering

51
00:02:04,340 --> 00:02:02,610
and driving it around with as far as I

52
00:02:06,590 --> 00:02:04,350
know there's not little hamsters on

53
00:02:08,629 --> 00:02:06,600
wheels running around up there so how do

54
00:02:10,759 --> 00:02:08,639
you point and use the Hubble Space

55
00:02:12,140 --> 00:02:10,769
Telescope and how do you talk to it

56
00:02:13,670 --> 00:02:12,150
woody how do you know if something's

57
00:02:14,430 --> 00:02:13,680
gone wrong well today we've got some

58
00:02:17,850 --> 00:02:14,440
NASA

59
00:02:20,130 --> 00:02:17,860
who are here to help answer all of those

60
00:02:22,950 --> 00:02:20,140
questions and tell us how the Hubble is

61
00:02:25,740 --> 00:02:22,960
operated on a day to day basis before I

62
00:02:29,420 --> 00:02:25,750
get started though let me introduce my

63
00:02:32,340 --> 00:02:29,430

cohorts dr. carol christian from the HST

64

00:02:34,790 --> 00:02:32,350

she's the HSE outreach scientist she's

65

00:02:39,180 --> 00:02:34,800

here I she was every week hi Carol hello

66

00:02:43,500 --> 00:02:39,190

and soon-to-be doctor one day anyway uh

67

00:02:45,390 --> 00:02:43,510

Scott Lewis from talk is I would I don't

68

00:02:48,630 --> 00:02:45,400

know about that oh okay well it was a

69

00:02:51,720 --> 00:02:48,640

good I don't hate myself that much fair

70

00:02:55,170 --> 00:02:51,730

enough he's also here to help us drive

71

00:02:57,120 --> 00:02:55,180

the internet and do all things uh social

72

00:02:58,620 --> 00:02:57,130

media so welcome Scott and while we're

73

00:03:00,450 --> 00:02:58,630

on you why don't you give everybody an

74

00:03:02,730 --> 00:03:00,460

idea how they can interact with us

75

00:03:04,560 --> 00:03:02,740

during this hangout yes so the the

76

00:03:07,140 --> 00:03:04,570

biggest way to interact with us which

77

00:03:08,670 --> 00:03:07,150

just allows us to answer your questions

78

00:03:11,430 --> 00:03:08,680

is on the Q&A app so we have that

79

00:03:12,870 --> 00:03:11,440

enabled on both google+ and youtube if

80

00:03:14,100 --> 00:03:12,880

you're on youtube watching embedded

81

00:03:16,740 --> 00:03:14,110

somewhere will be on a lower left-hand

82

00:03:18,210 --> 00:03:16,750

side and yellow link it pops up and

83

00:03:19,830 --> 00:03:18,220

you're able to ask questions we're able

84

00:03:23,220 --> 00:03:19,840

to select them and answer them live on

85

00:03:25,290 --> 00:03:23,230

air you can leave us our comments on the

86

00:03:28,050 --> 00:03:25,300

event page and google+ or comments on

87

00:03:31,199 --> 00:03:28,060

YouTube we will be seeing those and I am

88

00:03:34,080 --> 00:03:31,209

monitoring the Hubble hangout hashtag on

89

00:03:35,580 --> 00:03:34,090

Twitter and be sending out a bunch of

90

00:03:37,560 --> 00:03:35,590

other things out there too so we'd love

91

00:03:41,520 --> 00:03:37,570

to hear your comments and questions over

92

00:03:43,199 --> 00:03:41,530

on the Twitterverse awesome well done so

93

00:03:45,630 --> 00:03:43,209

let me introduce our guests let me start

94

00:03:48,270 --> 00:03:45,640

we have three engineers all of whom are

95

00:03:50,970 --> 00:03:48,280

in the control room of the Hubble Space

96

00:03:53,280 --> 00:03:50,980

Telescope the nerve center if you will

97

00:03:55,050 --> 00:03:53,290

I'll start with Scotts Wayne he is a

98

00:03:57,150 --> 00:03:55,060

systems engineer in charge of keeping

99

00:03:58,530 --> 00:03:57,160

all the science instruments working it's

100

00:03:59,759 --> 00:03:58,540

his job to keep an eye on all the

101
00:04:01,110 --> 00:03:59,769
science instruments to make sure that

102
00:04:03,750 --> 00:04:01,120
they're working properly and it was

103
00:04:05,870 --> 00:04:03,760
stalled new software to help them do to

104
00:04:09,120 --> 00:04:05,880
help him go even better so welcome Scott

105
00:04:12,210 --> 00:04:09,130
I'm glad to have you here also with me

106
00:04:13,920 --> 00:04:12,220
is uh is Mike when's he is in charge of

107
00:04:15,000 --> 00:04:13,930
the fine guidance sensors on Hubble and

108
00:04:17,670 --> 00:04:15,010
we'll talk about what those are the

109
00:04:20,240 --> 00:04:17,680
Hangout progresses that responsible for

110
00:04:23,940 --> 00:04:20,250
holder for keeping Hubble pointed super

111
00:04:26,969 --> 00:04:23,950
accurately so he will be talking to us

112
00:04:28,189 --> 00:04:26,979
about those hi Mike glad to be here hey

113
00:04:30,659 --> 00:04:28,199

thank you

114

00:04:34,020 --> 00:04:30,669

Morgan van ours arsenal did I pronounce

115

00:04:36,090 --> 00:04:34,030

that right yeah okay she uh she works on

116

00:04:38,010 --> 00:04:36,100

all of it apparently she's a UH she

117

00:04:39,990 --> 00:04:38,020

works on everything so she's going to

118

00:04:41,310 --> 00:04:40,000

give us she's really going to give us a

119

00:04:43,650 --> 00:04:41,320

sort of a look at all the different

120

00:04:45,120 --> 00:04:43,660

aspects but most importantly you're

121

00:04:46,920 --> 00:04:45,130

going to talk about what they do when

122

00:04:48,860 --> 00:04:46,930

something goes wrong on Hubble and and

123

00:04:52,140 --> 00:04:48,870

how they handle it how they know so

124

00:04:53,969 --> 00:04:52,150

welcome guys so let me get started with

125

00:04:56,760 --> 00:04:53,979

what did we just start with you Mike are

126

00:04:59,310 --> 00:04:56,770

I'm sorry Morgan why don't you describe

127

00:05:02,040 --> 00:04:59,320

for us where you are right now where are

128

00:05:04,830 --> 00:05:02,050

you sitting okay so we are in the Space

129

00:05:07,200 --> 00:05:04,840

Telescope operations control center this

130

00:05:09,870 --> 00:05:07,210

room that we're in right now you can see

131

00:05:11,610 --> 00:05:09,880

um I'll hold my computer office for a

132

00:05:14,850 --> 00:05:11,620

second you can see a lot of different

133

00:05:17,159 --> 00:05:14,860

banks of computers a lot of stations and

134

00:05:19,200 --> 00:05:17,169

during activities if we're installing a

135

00:05:21,810 --> 00:05:19,210

new flight software or we have a problem

136

00:05:23,850 --> 00:05:21,820

going on this room will be full of

137

00:05:26,760 --> 00:05:23,860

systems engineers looking at the data

138

00:05:29,279 --> 00:05:26,770

and sending watching commands to the

139

00:05:31,589 --> 00:05:29,289

telescope in the room right next door to

140

00:05:34,439 --> 00:05:31,599

us is the mission operations room and

141

00:05:37,320 --> 00:05:34,449

that's where day-to-day rolling and

142

00:05:39,029 --> 00:05:37,330

commanding comes from so we can that's

143

00:05:40,710 --> 00:05:39,039

where the flight ops team sets when

144

00:05:42,960 --> 00:05:40,720

they're doing operations that's also

145

00:05:45,689 --> 00:05:42,970

where we is really the heart of our

146

00:05:47,460 --> 00:05:45,699

automated operations um oh that's the

147

00:05:49,740 --> 00:05:47,470

room we don't want to be hitting ctrl

148

00:05:55,589 --> 00:05:49,750

alt delete I take it right that's what

149

00:05:57,029 --> 00:05:55,599

they do okay so so Mike want to give us

150

00:05:59,189 --> 00:05:57,039

a little background on what you do what

151
00:06:02,310 --> 00:05:59,199
you do and what your responsibilities

152
00:06:04,409 --> 00:06:02,320
are okay I'm responsible for what is

153
00:06:06,149 --> 00:06:04,419
defined idence sensors on the telescope

154
00:06:10,010 --> 00:06:06,159
these are actually there there there's a

155
00:06:12,540 --> 00:06:10,020
free sepron instrument um is it original

156
00:06:15,360 --> 00:06:12,550
model which mints are actually placed

157
00:06:16,529 --> 00:06:15,370
about 90 degrees apart around Hubble so

158
00:06:18,300 --> 00:06:16,539
I'm actually putting guys who actually

159
00:06:20,999 --> 00:06:18,310
has three separate instruments that I

160
00:06:22,920 --> 00:06:21,009
get responsible for and these actually

161
00:06:26,249 --> 00:06:22,930
help help through the final bit of

162
00:06:28,710 --> 00:06:26,259
holding total lockdown at target to be

163
00:06:31,980 --> 00:06:28,720

able to telescope it moves in very

164

00:06:33,659 --> 00:06:31,990

interesting ways um knock on it exactly

165

00:06:36,360 --> 00:06:33,669

a multitude of different instruments

166

00:06:38,490 --> 00:06:36,370

working sort of been there but to find

167

00:06:41,219 --> 00:06:38,500

items sensors are the last ones they are

168

00:06:42,050 --> 00:06:41,229

to put lock it on supposed perfectly

169

00:06:44,659 --> 00:06:42,060

aligned for those

170

00:06:46,070 --> 00:06:44,669

very very long very funny okay I want to

171

00:06:47,840 --> 00:06:46,080

get to I want to get to some of the

172

00:06:49,310 --> 00:06:47,850

specifics of how Hubble is pointed and

173

00:06:52,670 --> 00:06:49,320

in particular the fine guidance sensor

174

00:06:54,740 --> 00:06:52,680

but so but but for now we'll just say

175

00:06:56,629 --> 00:06:54,750

that these are detectors that are on the

176

00:06:58,940 --> 00:06:56,639

focal plane of the telescope that are

177

00:07:00,560 --> 00:06:58,950

responsible for keeping track of stars

178

00:07:04,250 --> 00:07:00,570

and nearby objects to make sure that's

179

00:07:08,780 --> 00:07:04,260

pointed very precisely correct yes okay

180

00:07:12,920 --> 00:07:08,790

awesome so uh Scott science instruments

181

00:07:15,530 --> 00:07:12,930

all of them really know wow so you're

182

00:07:17,960 --> 00:07:15,540

the man if if it's tough if this stuff

183

00:07:20,800 --> 00:07:17,970

goes down you're having a bad day right

184

00:07:23,030 --> 00:07:20,810

so tell us a little bit about what your

185

00:07:25,219 --> 00:07:23,040

responsibilities are and maybe give us a

186

00:07:28,580 --> 00:07:25,229

quick overview of some of the science

187

00:07:30,170 --> 00:07:28,590

instruments on the on the Hubble um well

188

00:07:31,520 --> 00:07:30,180

we are responsible for all Sciences

189

00:07:34,190 --> 00:07:31,530

prints on Hubble as well as the computer

190

00:07:36,800 --> 00:07:34,200

that controls them there are five

191

00:07:38,469 --> 00:07:36,810

currently on board the first is the

192

00:07:41,060 --> 00:07:38,479

advanced camera for surveys or ACS

193

00:07:42,890 --> 00:07:41,070

second is the near infrared camera and

194

00:07:45,260 --> 00:07:42,900

multi-object spectrometer or Nick moss

195

00:07:47,810 --> 00:07:45,270

we have the space telescope imaging

196

00:07:50,690 --> 00:07:47,820

spectrograph or stiffs the cosmic

197

00:07:54,800 --> 00:07:50,700

origins spectrograph cos and wife is

198

00:07:57,710 --> 00:07:54,810

number three wide field or wfc3 my

199

00:07:59,719 --> 00:07:57,720

personal favorite all on course we also

200

00:08:01,340 --> 00:07:59,729

have a sixth pseudo instrument that's

201
00:08:03,890 --> 00:08:01,350
the Nick most cooling system that we use

202
00:08:06,590 --> 00:08:03,900
to keep the infrared cameras in Nick

203
00:08:07,940 --> 00:08:06,600
moss cool what's in there is it does

204
00:08:09,500 --> 00:08:07,950
that have like liquid nitrogen or

205
00:08:12,920 --> 00:08:09,510
something liquid helium or something

206
00:08:14,540 --> 00:08:12,930
exactly cool helium yes okay and and

207
00:08:17,690 --> 00:08:14,550
what temperatures do these need to be op

208
00:08:18,980 --> 00:08:17,700
kept at when the system is operating

209
00:08:20,300 --> 00:08:18,990
it's currently dormant right now but

210
00:08:24,050 --> 00:08:20,310
when the system is operating and keeps

211
00:08:25,879 --> 00:08:24,060
the detectors at about 72 k ice and then

212
00:08:28,909 --> 00:08:25,889
things why do these instruments need to

213
00:08:30,440 --> 00:08:28,919

be cold uh well if the instant the

214

00:08:32,240 --> 00:08:30,450

infrared instrument especially needs to

215

00:08:34,550 --> 00:08:32,250

be cold because it's really detecting

216

00:08:36,230 --> 00:08:34,560

infrared radiation from you know the

217

00:08:39,350 --> 00:08:36,240

very beginnings of the universe the

218

00:08:41,990 --> 00:08:39,360

cosmic background so it's it's looking

219

00:08:44,089 --> 00:08:42,000

at very long wavelengths I our imagery

220

00:08:46,130 --> 00:08:44,099

so the detector needs to be cold for

221

00:08:47,690 --> 00:08:46,140

that it also needs to be kind of cooled

222

00:08:49,760 --> 00:08:47,700

and kept in an optimum temperature to

223

00:08:51,860 --> 00:08:49,770

keep electronic noise from the detector

224

00:08:53,870 --> 00:08:51,870

away from you know contaminating the

225

00:08:55,920 --> 00:08:53,880

image as well right so the colder it is

226

00:08:58,710 --> 00:08:55,930

the less noise and the less thermal

227

00:09:00,210 --> 00:08:58,720

a signature it has to pick up I'm so

228

00:09:01,680 --> 00:09:00,220

happy I'm doing this hangout because one

229

00:09:04,710 --> 00:09:01,690

question I've been dying to ask somebody

230

00:09:06,450 --> 00:09:04,720

is I've use telescopes a lot and I've

231

00:09:08,340 --> 00:09:06,460

worked on telescopes on the ground in

232

00:09:09,900 --> 00:09:08,350

Chile and places like that and always

233

00:09:13,019 --> 00:09:09,910

whenever you build an instrument a big

234

00:09:14,610 --> 00:09:13,029

concern is stray light uh that's the

235

00:09:16,530 --> 00:09:14,620

light that doesn't you know it's just

236

00:09:18,570 --> 00:09:16,540

kind of reflects off of stuff inside the

237

00:09:21,690 --> 00:09:18,580

optical tube or it just reflects off of

238

00:09:24,930 --> 00:09:21,700

things in the telescope how bad or how

239

00:09:26,970 --> 00:09:24,940

good is the Hubble stray light situation

240

00:09:28,829 --> 00:09:26,980

I mean there is there a lot of a lot of

241

00:09:31,410 --> 00:09:28,839

it in theirs are very little compared to

242

00:09:34,350 --> 00:09:31,420

say a ground-based telescope what's the

243

00:09:36,690 --> 00:09:34,360

sense of that I like a pro actually it's

244

00:09:38,340 --> 00:09:36,700

all okay I'm sorry go ahead Mike well

245

00:09:42,120 --> 00:09:38,350

because I'm actually the one responsible

246

00:09:44,190 --> 00:09:42,130

for focusing the telescope um yeah when

247

00:09:45,870 --> 00:09:44,200

the astronomers come back and say the

248

00:09:47,340 --> 00:09:45,880

telescope isn't perfectly in focus i'm

249

00:09:48,870 --> 00:09:47,350

actually you have to command the

250

00:09:50,730 --> 00:09:48,880

secondary mirror we actually focus the

251

00:09:52,019 --> 00:09:50,740

telescope by moving the mirror you

252

00:09:54,930 --> 00:09:52,029

answered my question I'm just gonna ask

253

00:09:56,519 --> 00:09:54,940

you how it's done good going actually

254

00:09:58,320 --> 00:09:56,529

move it by microns I mean they'll

255

00:10:00,769 --> 00:09:58,330

actually come and say we want the mirror

256

00:10:04,140 --> 00:10:00,779

move by two microns millions of an inch

257

00:10:05,970 --> 00:10:04,150

we can actually actually have it slicing

258

00:10:08,579 --> 00:10:05,980

it up but to answer your question by a

259

00:10:11,340 --> 00:10:08,589

straight line bubbles is extremely

260

00:10:14,280 --> 00:10:11,350

baffled on there actually 24 the tubes

261

00:10:17,850 --> 00:10:14,290

come to cut exactly down on that on the

262

00:10:19,680 --> 00:10:17,860

inside of the telescope is gamblers

263

00:10:22,110 --> 00:10:19,690

different model but it's got a very very

264

00:10:25,829 --> 00:10:22,120

special black paint on it that's baked

265

00:10:28,710 --> 00:10:25,839

not scatter light at all it great pains

266

00:10:31,320 --> 00:10:28,720

at on every anything bright that can

267

00:10:34,470 --> 00:10:31,330

start reflecting off on we actually

268

00:10:36,180 --> 00:10:34,480

can't on cams are very close to the Sun

269

00:10:39,660 --> 00:10:36,190

we actually have a very large angle that

270

00:10:42,690 --> 00:10:39,670

we can't get close next any like we need

271

00:10:44,100 --> 00:10:42,700

parts the 52 the 28 like I need to

272

00:10:46,680 --> 00:10:44,110

interrupt you for just a moment can you

273

00:10:48,449 --> 00:10:46,690

please move closer to the mic all right

274

00:10:50,940 --> 00:10:48,459

thank you yeah you're just at the edge

275

00:10:53,670 --> 00:10:50,950

where it keeps up go ahead I'm sorry to

276

00:10:56,069 --> 00:10:53,680

interrupt no no no profit in it so

277

00:10:58,199 --> 00:10:56,079

mainly we keep this header light down by

278

00:11:01,230 --> 00:10:58,209

making sure we aren't making any sort of

279

00:11:03,960 --> 00:11:01,240

external light entering the IP on the

280

00:11:07,980 --> 00:11:03,970

planet even away from both the balloon

281

00:11:09,750 --> 00:11:07,990

in the Sun all right so so it

282

00:11:11,400 --> 00:11:09,760

the baffles which all telescopes have

283

00:11:15,240 --> 00:11:11,410

sort of reduced as sort of reflectivity

284

00:11:16,829 --> 00:11:15,250

in there and so let's get back to the

285

00:11:18,360 --> 00:11:16,839

focusing now you so you move this so

286

00:11:19,920 --> 00:11:18,370

there's a primary mirror that's the big

287

00:11:21,570 --> 00:11:19,930

mirror at the bottom of the two of the

288

00:11:23,460 --> 00:11:21,580

tube and inside that big cylinder and

289

00:11:25,860 --> 00:11:23,470

then up toward the end of the tube by

290

00:11:28,860 --> 00:11:25,870

the end by the by the cap that opens and

291

00:11:31,230 --> 00:11:28,870

closes is the secondary mirror and that

292

00:11:33,420 --> 00:11:31,240

is what you move back and forth in very

293

00:11:36,930 --> 00:11:33,430

tiny amounts to focus it and you could

294

00:11:38,310 --> 00:11:36,940

do it on order of microns what how it is

295

00:11:40,019 --> 00:11:38,320

that that can't be a stepper motor I

296

00:11:42,810 --> 00:11:40,029

mean what kind of how do you move things

297

00:11:45,510 --> 00:11:42,820

that way actually there there are

298

00:11:48,900 --> 00:11:45,520

separate stepper motors in there ganged

299

00:11:51,570 --> 00:11:48,910

up there's three sets of two reason you

300

00:11:53,190 --> 00:11:51,580

do this is one of those different motors

301
00:11:57,090 --> 00:11:53,200
brakes you want to be able to still

302
00:11:59,970 --> 00:11:57,100
focused telescope all right they are

303
00:12:01,260 --> 00:11:59,980
actually who redundant so we have sort

304
00:12:03,420 --> 00:12:01,270
of three sets of two but they are

305
00:12:05,820 --> 00:12:03,430
stepper motors in there just just gear

306
00:12:08,579 --> 00:12:05,830
down to where each of our steps is

307
00:12:11,280 --> 00:12:08,589
actually we could focus less than 1

308
00:12:16,590 --> 00:12:11,290
micron we actually are steps are about 6

309
00:12:18,240 --> 00:12:16,600
microns it's not hard because that's

310
00:12:20,310 --> 00:12:18,250
point since microns is very little

311
00:12:23,610 --> 00:12:20,320
motion at all but we can actually focus

312
00:12:26,220 --> 00:12:23,620
with when we focus really focusing about

313
00:12:28,319 --> 00:12:26,230

my crop defiance instrument guys come

314

00:12:31,889 --> 00:12:28,329

back and they say oh yeah that's much

315

00:12:34,410 --> 00:12:31,899

better yeah majan really funny no one's

316

00:12:35,880 --> 00:12:34,420

saying much better much better okay so

317

00:12:37,560 --> 00:12:35,890

this may or may not be in your purview

318

00:12:39,690 --> 00:12:37,570

but let me ask you about flexure we all

319

00:12:42,690 --> 00:12:39,700

know that the Hubble is in orbit around

320

00:12:44,519 --> 00:12:42,700

the earth it goes it goes in bright

321

00:12:46,079 --> 00:12:44,529

spots where the temperature gets warm

322

00:12:49,290 --> 00:12:46,089

and then it goes behind the earth if

323

00:12:51,300 --> 00:12:49,300

it's dark and cold so this is this does

324

00:12:53,310 --> 00:12:51,310

the Hubble do much of this expanding and

325

00:12:56,699 --> 00:12:53,320

contracting over the course of an orbit

326

00:12:59,340 --> 00:12:56,709

and do is it much of a worry when you're

327

00:13:02,160 --> 00:12:59,350

trying to focus it yeah actually they

328

00:13:06,090 --> 00:13:02,170

eat telescope doesn't do a lot of

329

00:13:09,840 --> 00:13:06,100

bending lecture because that pipe it all

330

00:13:14,880 --> 00:13:09,850

covered in the insulation or get very

331

00:13:17,760 --> 00:13:14,890

little on thermal changes on it and it's

332

00:13:20,879 --> 00:13:17,770

a graphite epoxy record epoxy structure

333

00:13:25,099 --> 00:13:20,889

to it but what we what's happened is

334

00:13:28,439 --> 00:13:25,109

breathing in telescope actually it go it

335

00:13:31,199 --> 00:13:28,449

moved a little bit in and out um that's

336

00:13:32,489 --> 00:13:31,209

actually that says function of orbital

337

00:13:35,489 --> 00:13:32,499

temperature that's actually something

338

00:13:37,829 --> 00:13:35,499

the scientists have to live if they'd

339

00:13:42,210 --> 00:13:37,839

actually take it out actually for the

340

00:13:44,039 --> 00:13:42,220

temperatures then so we go on the

341

00:13:47,669 --> 00:13:44,049

science data but it actually does change

342

00:13:49,289 --> 00:13:47,679

yeah order not to make month so we're

343

00:13:52,710 --> 00:13:49,299

focusing within two and the breathing is

344

00:13:55,409 --> 00:13:52,720

good Wow so yeah so that I can imagine

345

00:13:57,689 --> 00:13:55,419

that effect being really huge and and so

346

00:13:59,069 --> 00:13:57,699

they have a way of correcting for that

347

00:14:00,359 --> 00:13:59,079

after they get their images that is that

348

00:14:02,429 --> 00:14:00,369

what you're saying yeah yeah it's

349

00:14:05,639 --> 00:14:02,439

actually very well modeled because it's

350

00:14:08,400 --> 00:14:05,649

it's fairly well behaved and so actually

351
00:14:11,639 --> 00:14:08,410
they monitor a bunch of the temperature

352
00:14:12,840 --> 00:14:11,649
uh Elementary they'll actually to take

353
00:14:14,939 --> 00:14:12,850
it out from the data that they'll be

354
00:14:17,220 --> 00:14:14,949
able to wreck the date on the ground no

355
00:14:20,099 --> 00:14:17,230
it's out of focus by this much at this

356
00:14:23,009 --> 00:14:20,109
time so I was just going to say that

357
00:14:25,109 --> 00:14:23,019
that might just said something

358
00:14:26,970 --> 00:14:25,119
interesting you said telemetry so in it

359
00:14:29,429 --> 00:14:26,980
when you're getting images or science

360
00:14:31,590 --> 00:14:29,439
information there's a whole bucket load

361
00:14:34,139 --> 00:14:31,600
of other parameters that come down from

362
00:14:36,629 --> 00:14:34,149
the spacecraft that tell you things like

363
00:14:38,280 --> 00:14:36,639

temperature voltages all that kind of

364

00:14:40,699 --> 00:14:38,290

thing so it turns out that that

365

00:14:43,499 --> 00:14:40,709

engineering data is very useful for

366

00:14:45,179 --> 00:14:43,509

parameterizing these kind of things when

367

00:14:46,559 --> 00:14:45,189

you're trying to calibrate your science

368

00:14:49,139 --> 00:14:46,569

instrument you have to have all those

369

00:14:51,359 --> 00:14:49,149

engineering values it's it's a pain but

370

00:14:54,269 --> 00:14:51,369

the astronomers love to be you know get

371

00:14:56,280 --> 00:14:54,279

the best data that we can and correct

372

00:14:58,889 --> 00:14:56,290

for you know model and correct for

373

00:15:01,979 --> 00:14:58,899

anything we can so that we remove all

374

00:15:05,460 --> 00:15:01,989

that instrument signature or telescope

375

00:15:09,299 --> 00:15:05,470

signature from the data so Morgan in the

376

00:15:10,919 --> 00:15:09,309

description i got from from mike to sort

377

00:15:13,710 --> 00:15:10,929

of describing what you did he used the

378

00:15:15,720 --> 00:15:13,720

term hurting cat so what I guess what

379

00:15:18,389 --> 00:15:15,730

you what a part of your job is you need

380

00:15:19,949 --> 00:15:18,399

to make sure that when the engineers and

381

00:15:22,710 --> 00:15:19,959

all the different subsystems need to be

382

00:15:24,689 --> 00:15:22,720

either worked on or maintained in some

383

00:15:26,249 --> 00:15:24,699

way you kind of coordinate that can you

384

00:15:29,489 --> 00:15:26,259

speaking a little bit about that right

385

00:15:31,229 --> 00:15:29,499

exactly so if you have we have a lot of

386

00:15:33,179 --> 00:15:31,239

different subsystems on the telescope

387

00:15:34,800 --> 00:15:33,189

you have the power subsystem obviously

388

00:15:37,530 --> 00:15:34,810

supplying power and everybody

389

00:15:39,600 --> 00:15:37,540

Scott's science instruments make and

390

00:15:42,330 --> 00:15:39,610

another group is working on the pointing

391

00:15:43,920 --> 00:15:42,340

and the fine guidance but really it's a

392

00:15:45,720 --> 00:15:43,930

whole system that has to work together

393

00:15:48,390 --> 00:15:45,730

it's a telescope but it's also a

394

00:15:50,220 --> 00:15:48,400

spacecraft and you need everything to

395

00:15:52,650 --> 00:15:50,230

get the picture out at the end right you

396

00:15:54,150 --> 00:15:52,660

need the power to be supplying power to

397

00:15:56,220 --> 00:15:54,160

get the communications and the

398

00:15:58,019 --> 00:15:56,230

instruments all working together so

399

00:15:59,850 --> 00:15:58,029

there are three of us on the systems

400

00:16:02,070 --> 00:15:59,860

management team that really try to make

401
00:16:03,990 --> 00:16:02,080
sure everybody talking to each other

402
00:16:06,480 --> 00:16:04,000
everybody's aware of what's going on on

403
00:16:08,340 --> 00:16:06,490
the telescope and if that needs to

404
00:16:10,650 --> 00:16:08,350
upload some new flight software to one

405
00:16:12,420 --> 00:16:10,660
of the instruments for example that's

406
00:16:14,400 --> 00:16:12,430
going to involve the management group

407
00:16:15,810 --> 00:16:14,410
that's sending up the commands and the

408
00:16:17,340 --> 00:16:15,820
flight software group it's obviously

409
00:16:19,680 --> 00:16:17,350
developing and testing the flight

410
00:16:21,450 --> 00:16:19,690
software and so I'll be involved to make

411
00:16:23,610 --> 00:16:21,460
sure that everything's tested correctly

412
00:16:26,070 --> 00:16:23,620
make sure that all the commands going to

413
00:16:27,660 --> 00:16:26,080

work together correctly and just that

414

00:16:30,210 --> 00:16:27,670

everybody's pointing in the same

415

00:16:31,829 --> 00:16:30,220

direction and on the same page so how

416

00:16:33,240 --> 00:16:31,839

much power does Hubble use let's say

417

00:16:34,860 --> 00:16:33,250

everything's cranking and you're doing

418

00:16:38,310 --> 00:16:34,870

an observation how much power does it

419

00:16:40,710 --> 00:16:38,320

use oh goodness oh this is actually an

420

00:16:43,560 --> 00:16:40,720

interesting number in dissin it's always

421

00:16:45,420 --> 00:16:43,570

amazes me when we're running up with all

422

00:16:49,800 --> 00:16:45,430

the instruments and do from observations

423

00:16:52,350 --> 00:16:49,810

will be pulling 88 on our our buses now

424

00:16:56,220 --> 00:16:52,360

hearing the day during the day the solar

425

00:16:58,320 --> 00:16:56,230

arrays give it by that be for 45 minutes

426
00:16:59,940 --> 00:16:58,330
every orbit we found like a 96 minute

427
00:17:01,800 --> 00:16:59,950
orbit half of its during the day half of

428
00:17:05,970 --> 00:17:01,810
its of the night roughly for half that

429
00:17:08,220 --> 00:17:05,980
night we pull 80 amps out of bad wait a

430
00:17:09,720 --> 00:17:08,230
minute wow that's got to be letting out

431
00:17:12,360 --> 00:17:09,730
some he too so I guess you got to

432
00:17:15,689 --> 00:17:12,370
protect from that as well right yeah

433
00:17:17,160 --> 00:17:15,699
cool okay well uh so-so Hubble's up

434
00:17:20,939 --> 00:17:17,170
there I'm like maybe this one's one for

435
00:17:24,449 --> 00:17:20,949
Scott Swain so we're up Hubble's up

436
00:17:27,419 --> 00:17:24,459
there you're doing some observations do

437
00:17:29,220 --> 00:17:27,429
the images go straight to earth or do

438
00:17:31,950 --> 00:17:29,230

they sit on Hubble for a while for a

439

00:17:35,070 --> 00:17:31,960

transmission period they actually do

440

00:17:37,350 --> 00:17:35,080

they on board for a limited time there's

441

00:17:39,870 --> 00:17:37,360

what we call buffer RAM in each of the

442

00:17:41,640 --> 00:17:39,880

instruments so when an instrument

443

00:17:44,360 --> 00:17:41,650

collects a given image it sits in its

444

00:17:47,220 --> 00:17:44,370

its own buffer ram for a period of time

445

00:17:48,450 --> 00:17:47,230

until the solid-state recorders on board

446

00:17:49,680 --> 00:17:48,460

are available

447

00:17:51,300 --> 00:17:49,690

and then we can move that data to the

448

00:17:53,280 --> 00:17:51,310

solid state quarters that we have on

449

00:17:56,460 --> 00:17:53,290

board we have two of them on board there

450

00:17:58,440 --> 00:17:56,470

are about 12 gate capacity each all is a

451
00:18:00,030 --> 00:17:58,450
solid state drives you mean yeah so

452
00:18:04,110 --> 00:18:00,040
essentially basically solid state hard

453
00:18:06,930 --> 00:18:04,120
drives and about 10 depending on how

454
00:18:09,240 --> 00:18:06,940
much data we collect in a day about 10

455
00:18:12,270 --> 00:18:09,250
to 15 times per day we'll dump those

456
00:18:13,920 --> 00:18:12,280
recorders to the ground and then get

457
00:18:16,890 --> 00:18:13,930
that data on on the ground to be

458
00:18:18,600 --> 00:18:16,900
processed so so let's talk about that

459
00:18:22,800 --> 00:18:18,610
how much data does it generally produce

460
00:18:23,820 --> 00:18:22,810
on average a day ah on average and it's

461
00:18:25,710 --> 00:18:23,830
going to depend on what observations

462
00:18:28,590 --> 00:18:25,720
you're doing and you know what

463
00:18:31,110 --> 00:18:28,600

configuration is but usually it's taking

464

00:18:32,760 --> 00:18:31,120

down about 25 gigabits a day right

465

00:18:35,070 --> 00:18:32,770

because spectrograph data that doesn't

466

00:18:36,600 --> 00:18:35,080

take up as much space to say a whip c3

467

00:18:38,550 --> 00:18:36,610

image might or something like that what

468

00:18:40,080 --> 00:18:38,560

are the okay I just this is a real nerdy

469

00:18:43,200 --> 00:18:40,090

question and most people may not know

470

00:18:46,890 --> 00:18:43,210

and but I want to know what are what is

471

00:18:49,320 --> 00:18:46,900

the bit depth on the on the hip with c3

472

00:18:52,080 --> 00:18:49,330

that is every pixel is is it a is it a

473

00:18:53,940 --> 00:18:52,090

float is it a double because every in a

474

00:18:57,090 --> 00:18:53,950

camera and a CCD just so you know there

475

00:18:59,910 --> 00:18:57,100

are raised of charges that get turned

476
00:19:03,000 --> 00:18:59,920
into a number based on the readout of

477
00:19:04,140 --> 00:19:03,010
the thing and they can be different bit

478
00:19:05,280 --> 00:19:04,150
depths those numbers actually mean

479
00:19:07,680 --> 00:19:05,290
something there are actually a

480
00:19:09,780 --> 00:19:07,690
scientific unit and I'm just curious for

481
00:19:11,130 --> 00:19:09,790
my own my own site what are though what

482
00:19:14,490 --> 00:19:11,140
is the bit depth of the whiskey three

483
00:19:17,190 --> 00:19:14,500
you know well it's a working porque

484
00:19:20,340 --> 00:19:17,200
detector I though you know 16 million

485
00:19:22,230 --> 00:19:20,350
pixels Oh exactly the depth I'm not

486
00:19:23,730 --> 00:19:22,240
exactly sure that would probably be a

487
00:19:25,920 --> 00:19:23,740
better question for one of the detector

488
00:19:27,870 --> 00:19:25,930

or scientists okay I'll ask that too i'm

489

00:19:29,430 --> 00:19:27,880

just you just popped in my head i know

490

00:19:31,410 --> 00:19:29,440

there are some cameras there doubles in

491

00:19:32,520 --> 00:19:31,420

which case there are huge images that

492

00:19:34,110 --> 00:19:32,530

come down and sometimes they're just

493

00:19:36,840 --> 00:19:34,120

regular floats I was just curious about

494

00:19:39,570 --> 00:19:36,850

that yeah so this is okay so is our

495

00:19:41,790 --> 00:19:39,580

their largest image definite okay so in

496

00:19:44,180 --> 00:19:41,800

addition Morgan to the images that Mike

497

00:19:46,380 --> 00:19:44,190

are that that Scott is dealing with or

498

00:19:47,880 --> 00:19:46,390

coordinating there's this thing Carol

499

00:19:50,940 --> 00:19:47,890

talked about with telemetry is that a

500

00:19:53,520 --> 00:19:50,950

constant stream of data or is it only

501

00:19:55,740 --> 00:19:53,530

coming with the other stuff it's only

502

00:19:57,450 --> 00:19:55,750

coming with the other stuff but as Scott

503

00:20:00,630 --> 00:19:57,460

said you have all the reporters on board

504

00:20:02,320 --> 00:20:00,640

so all the telemetry is recorded and

505

00:20:04,090 --> 00:20:02,330

then when we get data back

506

00:20:05,919 --> 00:20:04,100

if we go through a time when we don't

507

00:20:08,799 --> 00:20:05,929

have communication when we get the data

508

00:20:11,440 --> 00:20:08,809

back all of the telemetry comes down so

509

00:20:14,049 --> 00:20:11,450

by be it by the end of any given 24 hour

510

00:20:16,899 --> 00:20:14,059

period will have the telemetry for that

511

00:20:19,419 --> 00:20:16,909

whole day so you know something in real

512

00:20:22,180 --> 00:20:19,429

time will still get it you're not in

513

00:20:27,759 --> 00:20:22,190

actual constant contact then with Hubble

514

00:20:29,889 --> 00:20:27,769

right right hmm I'm close to 50 at the

515

00:20:31,269 --> 00:20:29,899

time when we can see real data versus

516

00:20:33,310 --> 00:20:31,279

the time when we're recording and then

517

00:20:35,049 --> 00:20:33,320

we'll get the data back down and you do

518

00:20:37,419 --> 00:20:35,059

this through is it through the tea dress

519

00:20:40,029 --> 00:20:37,429

system yeah exactly so let's talk about

520

00:20:42,580 --> 00:20:40,039

that a little bit I'll have I think I

521

00:20:44,470 --> 00:20:42,590

have Scott has a graphic of what the

522

00:20:45,700 --> 00:20:44,480

teacher system looks like Morgan are you

523

00:20:48,850 --> 00:20:45,710

the one to talk about that or should I

524

00:20:52,149 --> 00:20:48,860

ask Mike um I think any other scandal

525

00:20:54,610 --> 00:20:52,159

all right ok so the tea dress let's talk

526
00:20:57,430 --> 00:20:54,620
this is the main system that nASA has in

527
00:21:00,549 --> 00:20:57,440
orbit over the planet earth that is

528
00:21:02,830 --> 00:21:00,559
designed to do what so cheaters works

529
00:21:05,500 --> 00:21:02,840
not just with Hubble but with most of

530
00:21:08,019 --> 00:21:05,510
NASA satellites it tracks the satellites

531
00:21:10,149 --> 00:21:08,029
and then also relays the data from the

532
00:21:13,629 --> 00:21:10,159
satellites which may be in lower for bed

533
00:21:16,060 --> 00:21:13,639
or various orbit up to the two satellite

534
00:21:17,740 --> 00:21:16,070
and then down to the ground system so we

535
00:21:20,110 --> 00:21:17,750
don't the ground station so we don't

536
00:21:22,600 --> 00:21:20,120
need to always be within view of the

537
00:21:26,139 --> 00:21:22,610
ground station to be communicating and

538
00:21:28,210 --> 00:21:26,149

is there a primary a zero is there a

539

00:21:30,100 --> 00:21:28,220

primary station that we use for Hubble

540

00:21:33,190 --> 00:21:30,110

or is it just where ever happens to be

541

00:21:36,190 --> 00:21:33,200

in range and the as far as how Scott has

542

00:21:38,470 --> 00:21:36,200

it up now oh great as far as the

543

00:21:40,210 --> 00:21:38,480

satellites go will use whatever to frisk

544

00:21:42,220 --> 00:21:40,220

we're assigned whichever we can see and

545

00:21:45,940 --> 00:21:42,230

then the data for Hubble get sent down

546

00:21:48,399 --> 00:21:45,950

to white sands and they expert out here

547

00:21:50,259 --> 00:21:48,409

via on the ground I usually live in

548

00:21:53,980 --> 00:21:50,269

Alamogordo I didn't know that so Hubble

549

00:21:55,570 --> 00:21:53,990

data goes down to white sands and thinks

550

00:21:58,720 --> 00:21:55,580

that's got another graphic that actually

551

00:22:00,100 --> 00:21:58,730

shows on the sort of data path yeah

552

00:22:02,200 --> 00:22:00,110

there should be a data flow graphic in

553

00:22:09,000 --> 00:22:02,210

there that shows that bad okay well he's

554

00:22:11,409 --> 00:22:09,010

looking that up so the the the the

555

00:22:13,389 --> 00:22:11,419

teedra system which is not as you point

556

00:22:15,399 --> 00:22:13,399

out not necessarily just for Hubble it's

557

00:22:15,910 --> 00:22:15,409

used for lots of other I think GISS uses

558

00:22:26,140 --> 00:22:15,920

it

559

00:22:30,040 --> 00:22:26,150

so uh let's see uh who wants to talk

560

00:22:32,350 --> 00:22:30,050

about this mike is this you um yeah I is

561

00:22:34,330 --> 00:22:32,360

earline can i I mean okay this like this

562

00:22:37,650 --> 00:22:34,340

is this is a schematic showing how data

563

00:22:39,880 --> 00:22:37,660

get off of Hubble and down to Goddard

564

00:22:41,410 --> 00:22:39,890

yeah we actually have what's known as

565

00:22:43,120 --> 00:22:41,420

high gain antennas and those are little

566

00:22:45,040 --> 00:22:43,130

antennas are sticking off the sides and

567

00:22:47,230 --> 00:22:45,050

we actually have to point those at the t

568

00:22:51,010 --> 00:22:47,240

/ satellites those are Hubble earrings

569

00:22:54,100 --> 00:22:51,020

yeah yeah the periods um and so our data

570

00:22:55,750 --> 00:22:54,110

goes to Tigres it's a relay satellite

571

00:22:57,670 --> 00:22:55,760

which means it just bounces it back down

572

00:22:58,900 --> 00:22:57,680

to ground but the nice thing about the

573

00:23:00,460 --> 00:22:58,910

teacher satellites they're always

574

00:23:03,010 --> 00:23:00,470

pointed down they always go down to the

575

00:23:04,750 --> 00:23:03,020

same ground station at White Sands um so

576

00:23:07,180 --> 00:23:04,760

that's coming down you know that's ready

577

00:23:10,330 --> 00:23:07,190

munication from white sands it comes

578

00:23:12,520 --> 00:23:10,340

over here to Goddard it comes across the

579

00:23:15,250 --> 00:23:12,530

data line we actually ship it up to the

580

00:23:17,260 --> 00:23:15,260

Institute so it's actually traveled way

581

00:23:19,030 --> 00:23:17,270

down in there's actually a significant

582

00:23:21,400 --> 00:23:19,040

enough delay we actually have to account

583

00:23:22,840 --> 00:23:21,410

for the light travel time for the data

584

00:23:25,300 --> 00:23:22,850

coming down when we're looking at our

585

00:23:26,590 --> 00:23:25,310

clock signals oh I can imagine yeah

586

00:23:28,600 --> 00:23:26,600

because it's hot it's all it's high

587

00:23:31,180 --> 00:23:28,610

enough up I would imagine so what about

588

00:23:32,560 --> 00:23:31,190

that data link between New Mexico and

589

00:23:35,380 --> 00:23:32,570

Goddard is that just a regular internet

590

00:23:37,630 --> 00:23:35,390

connection or is it something else it's

591

00:23:40,450 --> 00:23:37,640

a very little high speed being with

592

00:23:42,610 --> 00:23:40,460

special i mean connected dedicated

593

00:23:46,360 --> 00:23:42,620

landline dedicated data connection

594

00:23:48,400 --> 00:23:46,370

between else in there so i think that if

595

00:23:50,190 --> 00:23:48,410

i remember right nasa is upgrading tea

596

00:23:52,810 --> 00:23:50,200

dress as well or maybe they already have

597

00:23:54,880 --> 00:23:52,820

but this is supposed to give us i think

598

00:23:57,040 --> 00:23:54,890

more coverage and more capability as

599

00:23:59,550 --> 00:23:57,050

well so how powerful are those little

600

00:24:04,780 --> 00:23:59,560

earrings there there's old dish antennas

601
00:24:06,990 --> 00:24:04,790
um um not all that powerful i don't off

602
00:24:09,070 --> 00:24:07,000
tell my head i don't remember what the

603
00:24:10,690 --> 00:24:09,080
but they don't need to be that powerful

604
00:24:12,700 --> 00:24:10,700
since the satellites not that far away

605
00:24:14,110 --> 00:24:12,710
all right thing is we have to be able to

606
00:24:16,600 --> 00:24:14,120
point out the satellites we actually

607
00:24:18,940 --> 00:24:16,610
have a only like a five-degree tolerance

608
00:24:21,070 --> 00:24:18,950
we have the chant in as pointed exactly

609
00:24:22,630 --> 00:24:21,080
where tea dresses and we gotta realize

610
00:24:25,030 --> 00:24:22,640
we're zooming around the earth at eight

611
00:24:29,020 --> 00:24:25,040
else might you know 18,000 miles an hour

612
00:24:29,560 --> 00:24:29,030
and theorists are the air geo station

613
00:24:31,390 --> 00:24:29,570

there there

614

00:24:33,100 --> 00:24:31,400

stationary so you have to be swinging

615

00:24:34,960 --> 00:24:33,110

this antenna as we're moving around to

616

00:24:37,030 --> 00:24:34,970

keep peterson subtract and that's part

617

00:24:38,410 --> 00:24:37,040

of what the qur'an board does it knows

618

00:24:39,970 --> 00:24:38,420

where teeters is it knows where the

619

00:24:42,070 --> 00:24:39,980

telescope isn't it therefore it knows

620

00:24:43,630 --> 00:24:42,080

how to move the antennas so you take

621

00:24:45,460 --> 00:24:43,640

some observations you gather some data

622

00:24:46,900 --> 00:24:45,470

you fill up the salt the solid state

623

00:24:49,570 --> 00:24:46,910

hard drives on there and then you got to

624

00:24:52,450 --> 00:24:49,580

point it over at teedra satellite to get

625

00:24:55,240 --> 00:24:52,460

it all off of there right yeah now I

626
00:24:57,010 --> 00:24:55,250
mean a lot of times when we if we can

627
00:24:58,540 --> 00:24:57,020
see it whenever we can see the teeter

628
00:25:00,850 --> 00:24:58,550
satellites will be streaming what we

629
00:25:02,500 --> 00:25:00,860
call real time to limit rate down as

630
00:25:04,750 --> 00:25:02,510
long as the teacher satellites are busy

631
00:25:06,640 --> 00:25:04,760
with someone else let us blim tree down

632
00:25:08,560 --> 00:25:06,650
don't get science data down that way all

633
00:25:11,290 --> 00:25:08,570
the science data comes down and dumps I

634
00:25:13,300 --> 00:25:11,300
mean these are people out there there's

635
00:25:15,340 --> 00:25:13,310
a whole scheduling system of the figure

636
00:25:18,430 --> 00:25:15,350
out how how and when to dump to tape

637
00:25:19,900 --> 00:25:18,440
recorders because um eight recorders are

638
00:25:21,160 --> 00:25:19,910

great because you can be dumping them at

639

00:25:22,570 --> 00:25:21,170

the same time you're filling the other

640

00:25:24,280 --> 00:25:22,580

end of them you're dumping the backside

641

00:25:26,080 --> 00:25:24,290

as you're filling the front end but you

642

00:25:29,410 --> 00:25:26,090

have to this is they don't ever over

643

00:25:32,860 --> 00:25:29,420

right so that's all taken care of by our

644

00:25:34,930 --> 00:25:32,870

ground system computers all pre-planned

645

00:25:38,230 --> 00:25:34,940

everything that happens on hubble free

646

00:25:39,850 --> 00:25:38,240

plan to the second and this is an load

647

00:25:41,200 --> 00:25:39,860

for sending up we actually send up

648

00:25:43,330 --> 00:25:41,210

here's what you're doing for the next

649

00:25:47,140 --> 00:25:43,340

eight hours every second for the next

650

00:25:49,030 --> 00:25:47,150

hours back to what I just had this image

651
00:25:52,270 --> 00:25:49,040
when you said dump have not but not very

652
00:25:57,100 --> 00:25:52,280
scientific terminology ready for the

653
00:25:59,230 --> 00:25:57,110
Hubble dump today today today I just

654
00:26:01,390 --> 00:25:59,240
thought you were talking about I am I'm

655
00:26:03,130 --> 00:26:01,400
like 12 years old I just I can actually

656
00:26:06,430 --> 00:26:03,140
a question no that was brought up last

657
00:26:08,200 --> 00:26:06,440
week in our past Hubble hang out but I

658
00:26:09,580 --> 00:26:08,210
think it really ties in with the

659
00:26:11,650 --> 00:26:09,590
gathering the data and sending it back

660
00:26:15,580 --> 00:26:11,660
is where we talked about the South

661
00:26:17,650 --> 00:26:15,590
Atlantic anomaly and how you guys work

662
00:26:19,630 --> 00:26:17,660
with that and if if if someone could

663
00:26:21,550 --> 00:26:19,640

explain what that is and then what you

664

00:26:26,260 --> 00:26:21,560

have to do to compensate for that sounds

665

00:26:29,920 --> 00:26:26,270

Atlantic anomaly okay I can take a first

666

00:26:31,810 --> 00:26:29,930

practice the South Atlantic anomaly is

667

00:26:34,330 --> 00:26:31,820

it's a region of space where there's

668

00:26:36,910 --> 00:26:34,340

actually just higher radiation than the

669

00:26:38,860 --> 00:26:36,920

normal and so we actually happened to

670

00:26:41,140 --> 00:26:38,870

travel through it orbit takes us through

671

00:26:43,180 --> 00:26:41,150

this alpha lambda novel much once in

672

00:26:44,770 --> 00:26:43,190

orbit they're actually some orbits that

673

00:26:47,670 --> 00:26:44,780

because if you look at the way the orbit

674

00:26:49,990 --> 00:26:47,680

tracks across sometimes we put out of it

675

00:26:52,120 --> 00:26:50,000

then we're inside of it we actually

676
00:26:54,520 --> 00:26:52,130
don't do any observations because um

677
00:26:57,220 --> 00:26:54,530
everyone who passes the computers will

678
00:26:59,170 --> 00:26:57,230
get what we call a zero will turn to a

679
00:27:00,670 --> 00:26:59,180
one in the mills sometimes do something

680
00:27:03,520 --> 00:27:00,680
you don't want them to be viewing so we

681
00:27:05,050 --> 00:27:03,530
tend to shut down um guiding you just

682
00:27:08,080 --> 00:27:05,060
tell the telescope wait until you're out

683
00:27:10,150 --> 00:27:08,090
of here and continue on doing what your

684
00:27:12,310 --> 00:27:10,160
observation is and so we sort of ride

685
00:27:14,500 --> 00:27:12,320
through the Southland not only we sort

686
00:27:18,190 --> 00:27:14,510
of cover our eyes and ears and go okay

687
00:27:19,540 --> 00:27:18,200
we are going for actually something we

688
00:27:23,320 --> 00:27:19,550

can actually do through this health

689

00:27:26,590 --> 00:27:23,330

clinic ok I want to I want to ask about

690

00:27:28,000 --> 00:27:26,600

pointing again the does how so you

691

00:27:29,680 --> 00:27:28,010

you're in charge of the fine guidance

692

00:27:33,970 --> 00:27:29,690

system which is responsible for keeping

693

00:27:37,120 --> 00:27:33,980

Hubble very closely uh in line with what

694

00:27:38,890 --> 00:27:37,130

it's observing well how do you move

695

00:27:41,140 --> 00:27:38,900

Hubble there are their jets on it are

696

00:27:43,960 --> 00:27:41,150

there little little rockets at fire what

697

00:27:46,540 --> 00:27:43,970

what makes Hubble move you know now no

698

00:27:48,190 --> 00:27:46,550

that's actually good one because people

699

00:27:51,160 --> 00:27:48,200

don't know this thing is the size of a

700

00:27:53,050 --> 00:27:51,170

school bus and you about the weight the

701
00:27:55,210 --> 00:27:53,060
question do you move it there are no

702
00:27:57,790 --> 00:27:55,220
jets there are no gas that there's no

703
00:28:00,520 --> 00:27:57,800
propulsion system on it what we have are

704
00:28:04,770 --> 00:28:00,530
what we call reaction they're very big

705
00:28:06,640 --> 00:28:04,780
very very heavy feels that we spend and

706
00:28:08,620 --> 00:28:06,650
imagined a lot of you people have been

707
00:28:10,840 --> 00:28:08,630
at science museums where you take the

708
00:28:12,280 --> 00:28:10,850
spinning bicycle wheel and you twist it

709
00:28:14,200 --> 00:28:12,290
on when you're sitting on the stool and

710
00:28:16,150 --> 00:28:14,210
it turns you well it turns out by these

711
00:28:19,120 --> 00:28:16,160
wheels that you're held at certain

712
00:28:21,220 --> 00:28:19,130
angles when we speed them up it actually

713
00:28:22,930 --> 00:28:21,230

cause it's a telescope to twist its

714

00:28:25,330 --> 00:28:22,940

conservation of angular momentum for you

715

00:28:27,550 --> 00:28:25,340

physics spoke about um and so we

716

00:28:30,850 --> 00:28:27,560

actually move the telescope I spitting

717

00:28:33,130 --> 00:28:30,860

up wheels and it it's a slow way to do

718

00:28:35,380 --> 00:28:33,140

it in fact Hubble takes a long time to

719

00:28:36,970 --> 00:28:35,390

move and the fastest trouble really

720

00:28:41,080 --> 00:28:36,980

moves from one point the sky to the

721

00:28:43,390 --> 00:28:41,090

other is about the scenes on a clock as

722

00:28:46,360 --> 00:28:43,400

is the what on a clock you word and you

723

00:28:48,520 --> 00:28:46,370

committed the minute he no okay the

724

00:28:51,610 --> 00:28:48,530

clock and so for us to do a 90 degrees

725

00:28:53,380 --> 00:28:51,620

flew it takes us about 15 minutes but we

726

00:28:56,560 --> 00:28:53,390

do it like speak about turning up these

727

00:28:58,090 --> 00:28:56,570

needs so we actually we just need

728

00:29:00,100 --> 00:28:58,100

he ducked wheels in either one direction

729

00:29:02,350 --> 00:29:00,110

or the other direction they work the

730

00:29:04,330 --> 00:29:02,360

telescope do it and so we can do that as

731

00:29:06,190 --> 00:29:04,340

long as we have power will never run out

732

00:29:09,009 --> 00:29:06,200

of capability to what speeds them up

733

00:29:10,269 --> 00:29:09,019

electric motors or what yeah yeah yeah

734

00:29:13,060 --> 00:29:10,279

we're actually pulling power off the

735

00:29:14,799 --> 00:29:13,070

batteries and its motor the computer on

736

00:29:16,870 --> 00:29:14,809

board that says I need to move it this

737

00:29:18,159 --> 00:29:16,880

direction so I need to spend up you know

738

00:29:20,830 --> 00:29:18,169

there's three wheels that are spaced

739

00:29:22,840 --> 00:29:20,840

different angles so it knows and one up

740

00:29:25,299 --> 00:29:22,850

this much to up this much up that much

741

00:29:28,029 --> 00:29:25,309

now move the telescope and then it spins

742

00:29:29,230 --> 00:29:28,039

it down to stop up is there any mo is

743

00:29:30,430 --> 00:29:29,240

there any redundancy built in that

744

00:29:32,049 --> 00:29:30,440

system are there more than are there any

745

00:29:35,049 --> 00:29:32,059

backup momentum wheels or anything like

746

00:29:37,119 --> 00:29:35,059

that but we actually have developed ways

747

00:29:39,669 --> 00:29:37,129

we can run with two reaction wheels and

748

00:29:41,860 --> 00:29:39,679

we can actually do it with one you have

749

00:29:44,139 --> 00:29:41,870

to only point certain directions he

750

00:29:46,210 --> 00:29:44,149

takes a long time to get from one point

751
00:29:48,659 --> 00:29:46,220
to the other we only have one reaction

752
00:29:52,149 --> 00:29:48,669
wheel but we've actually developed

753
00:29:54,610 --> 00:29:52,159
suburban modes where we can operate with

754
00:29:57,249 --> 00:29:54,620
or less than three meals because they

755
00:29:59,139 --> 00:29:57,259
aren't redundant okay yeah and Andy are

756
00:30:00,310 --> 00:29:59,149
you hardcore space fans who followed me

757
00:30:01,480 --> 00:30:00,320
for any length of time you will remember

758
00:30:04,779 --> 00:30:01,490
the first time we learned about momentum

759
00:30:06,700 --> 00:30:04,789
wheels was with Kepler when it had a

760
00:30:09,310 --> 00:30:06,710
problem with it and it can no longer

761
00:30:11,680 --> 00:30:09,320
complete its mission as person could no

762
00:30:13,710 --> 00:30:11,690
longer point as precisely as it was

763
00:30:15,639 --> 00:30:13,720

originally designed so they were

764

00:30:17,049 --> 00:30:15,649

repurposing and I I wonder what ever

765

00:30:18,940 --> 00:30:17,059

happened to that I should follow up on

766

00:30:20,110 --> 00:30:18,950

that anyway so that's what we first

767

00:30:23,049 --> 00:30:20,120

learned about him Hubble has them to a

768

00:30:25,470 --> 00:30:23,059

lot it's very common thing Morgan I want

769

00:30:28,269 --> 00:30:25,480

to get to you about commanding Hubble um

770

00:30:31,269 --> 00:30:28,279

how do you do it how do you tell Hubble

771

00:30:32,740 --> 00:30:31,279

what to do give us a real nerdy view of

772

00:30:35,610 --> 00:30:32,750

that what's a tough what's it look like

773

00:30:40,629 --> 00:30:35,620

it's what authority she commands

774

00:30:43,149 --> 00:30:40,639

absolute I command thee we really have

775

00:30:46,450 --> 00:30:43,159

two different ways to command right so

776

00:30:48,850 --> 00:30:46,460

the normal everyday way once a week this

777

00:30:51,129 --> 00:30:48,860

telescope science institute scientists

778

00:30:54,190 --> 00:30:51,139

put together and their schedule what we

779

00:30:55,810 --> 00:30:54,200

want to point out how we're taking what

780

00:30:57,999 --> 00:30:55,820

instruments are going to use and they

781

00:31:01,269 --> 00:30:58,009

deliver to us I'm usually on Thursday

782

00:31:03,159 --> 00:31:01,279

the week before on the SMS the service

783

00:31:06,460 --> 00:31:03,169

English or the science Mission schedule

784

00:31:08,950 --> 00:31:06,470

and that gets loaded onto the computers

785

00:31:10,140 --> 00:31:08,960

here and there's sort of two parts to it

786

00:31:12,909 --> 00:31:10,150

one that can

787

00:31:14,830 --> 00:31:12,919

the computer that Scott had in the

788

00:31:17,890 --> 00:31:14,840

science computer and then the other that

789

00:31:22,060 --> 00:31:17,900

controls the 46 telescope computer and

790

00:31:25,299 --> 00:31:22,070

so you say 486 sorry what was that did

791

00:31:29,530 --> 00:31:25,309

you say 486 yes it's a known as a

792

00:31:31,870 --> 00:31:29,540

Pentium what that's our upgrade yeah it

793

00:31:33,909 --> 00:31:31,880

was great there's a 486 running the

794

00:31:36,820 --> 00:31:33,919

Hubble Space Telescope reusing those are

795

00:31:43,510 --> 00:31:36,830

the fancy computer thing is there an AOL

796

00:31:45,400 --> 00:31:43,520

disk in there put it in oh that's that's

797

00:31:47,710 --> 00:31:45,410

brilliant i love it okay good that's the

798

00:31:51,100 --> 00:31:47,720

upgrade if i was in there before 286 it

799

00:31:54,610 --> 00:31:51,110

was a two- computer before it was yeah

800

00:31:58,630 --> 00:31:54,620

yeah now to be fair folks Hubble's been

801
00:32:00,909 --> 00:31:58,640
up there for 25 years ne5 me really all

802
00:32:02,830 --> 00:32:00,919
right so 486 is in charge of Hubble okay

803
00:32:04,600 --> 00:32:02,840
all right so throughout throughout the

804
00:32:07,560 --> 00:32:04,610
day automatically these commands are

805
00:32:09,970 --> 00:32:07,570
sent up in the normal course of things

806
00:32:11,740 --> 00:32:09,980
and then if we have to do any real time

807
00:32:14,080 --> 00:32:11,750
commanding either because there's a

808
00:32:17,020 --> 00:32:14,090
problem or because we need to change

809
00:32:18,640 --> 00:32:17,030
configuration or do something up all

810
00:32:21,400 --> 00:32:18,650
sorts of different reasons but we can

811
00:32:23,380 --> 00:32:21,410
also do real-time commanding I'm the

812
00:32:26,169 --> 00:32:23,390
computers in this room in the room next

813
00:32:27,880 --> 00:32:26,179

door and that's literally with one of

814

00:32:31,480 --> 00:32:27,890

the flight ops team sitting down at the

815

00:32:33,880 --> 00:32:31,490

computers behind behind us behind me and

816

00:32:35,980 --> 00:32:33,890

sending the commands straight up to the

817

00:32:38,440 --> 00:32:35,990

telescope okay but what are they typing

818

00:32:41,049 --> 00:32:38,450

are they typing go to m31 are they

819

00:32:44,409 --> 00:32:41,059

typing in some Python code what are they

820

00:32:45,970 --> 00:32:44,419

typing at I'm CCL is the language that

821

00:32:47,980 --> 00:32:45,980

we wrote right missed the real-time

822

00:32:51,370 --> 00:32:47,990

commanding in it's always a special

823

00:32:53,320 --> 00:32:51,380

language then yes commander control

824

00:32:55,450 --> 00:32:53,330

language i think is what's AC L stands

825

00:32:58,870 --> 00:32:55,460

for although I'm not president it make

826
00:33:01,750 --> 00:32:58,880
sense to me is called CCS or there come

827
00:33:05,200 --> 00:33:01,760
in control center system the specific

828
00:33:07,750 --> 00:33:05,210
language is is it's actually it's based

829
00:33:10,539 --> 00:33:07,760
off of TCL which is a standard like Rob

830
00:33:12,610 --> 00:33:10,549
what's good yeah I'd love to get into

831
00:33:13,539 --> 00:33:12,620
what a real-time operating system is but

832
00:33:15,430 --> 00:33:13,549
I don't think we'll have time for that

833
00:33:16,900 --> 00:33:15,440
right this particular time but so yeah

834
00:33:19,299 --> 00:33:16,910
so you're sending in a special commands

835
00:33:22,360 --> 00:33:19,309
and it's just a list it's at is it a

836
00:33:22,799 --> 00:33:22,370
text file do you encrypt it all or you

837
00:33:25,470 --> 00:33:22,809
know

838
00:33:27,570 --> 00:33:25,480

gonna be hacked okay well it's all very

839

00:33:29,100 --> 00:33:27,580

very controlled as you can imagine right

840

00:33:32,100 --> 00:33:29,110

everything that we send off has been

841

00:33:34,110 --> 00:33:32,110

tested many many times um so there's

842

00:33:37,710 --> 00:33:34,120

basically they're just mini scripts many

843

00:33:41,190 --> 00:33:37,720

programs and so the flight up the like

844

00:33:43,529 --> 00:33:41,200

controllers will end you know I'll beat

845

00:33:45,269 --> 00:33:43,539

up to or whatever to transition that's

846

00:33:47,039 --> 00:33:45,279

one of our commands to transition one of

847

00:33:48,899 --> 00:33:47,049

the instruments for example and that

848

00:33:51,629 --> 00:33:48,909

will go through the sequence of commands

849

00:33:55,350 --> 00:33:51,639

to reconfigure whatever you want to be

850

00:33:58,649 --> 00:33:55,360

doing at the time okay how many people

851

00:33:59,999 --> 00:33:58,659

at a time are actually in that control

852

00:34:01,529 --> 00:34:00,009

Mike over there are next door how many

853

00:34:07,230 --> 00:34:01,539

people are in there usually right now

854

00:34:09,780 --> 00:34:07,240

zero I think oh that's not good nobody's

855

00:34:13,710 --> 00:34:09,790

driving Hubble and a few years ago we

856

00:34:15,899 --> 00:34:13,720

switched from 24-7 staffing um for most

857

00:34:19,490 --> 00:34:15,909

the Hubble's history we've been staffed

858

00:34:21,510 --> 00:34:19,500

in there with about five people 24 7 365

859

00:34:23,730 --> 00:34:21,520

but a few years ago we switched to

860

00:34:25,770 --> 00:34:23,740

automated operations so now we actually

861

00:34:28,500 --> 00:34:25,780

have a computer in their sending up the

862

00:34:30,569 --> 00:34:28,510

routine commands and monitoring all the

863

00:34:32,760 --> 00:34:30,579

telemetry and it's tied into an

864

00:34:35,190 --> 00:34:32,770

automated system that will alert us if

865

00:34:36,809 --> 00:34:35,200

anything goes wrong so if we all have

866

00:34:39,419 --> 00:34:36,819

our iphones and we'll all get a text

867

00:34:41,520 --> 00:34:39,429

message if there's a problem the flight

868

00:34:44,040 --> 00:34:41,530

operations team does go in there once a

869

00:34:46,500 --> 00:34:44,050

day to do some maintenance obviously we

870

00:34:48,419 --> 00:34:46,510

check up on things all the time but for

871

00:34:49,919 --> 00:34:48,429

the most part it's automated at this

872

00:34:52,440 --> 00:34:49,929

auto mode okay i want to get back to

873

00:34:53,819 --> 00:34:52,450

getting when the things go wrong in just

874

00:34:56,040 --> 00:34:53,829

a minute but let me ask scott a question

875

00:35:00,000 --> 00:34:56,050

here on the scientific instrumentation

876

00:35:02,430 --> 00:35:00,010

which of the science instruments on on

877

00:35:03,780 --> 00:35:02,440

hubble are the most used and which are

878

00:35:06,120 --> 00:35:03,790

the most complicated for you to have to

879

00:35:07,680 --> 00:35:06,130

deal with in other words which ones do

880

00:35:09,150 --> 00:35:07,690

any of them keep you up at night as far

881

00:35:12,930 --> 00:35:09,160

as oh my god I hope this thing you know

882

00:35:15,059 --> 00:35:12,940

doesn't break down or any of that pretty

883

00:35:17,040 --> 00:35:15,069

much my job is all of them if any of

884

00:35:19,470 --> 00:35:17,050

them down it's going to keep me up at

885

00:35:21,829 --> 00:35:19,480

night they break it's three o'clock in

886

00:35:26,520 --> 00:35:21,839

the morning always and on Friday too

887

00:35:28,140 --> 00:35:26,530

well sometimes yeah yeah Christmas was

888

00:35:32,250 --> 00:35:28,150

was particularly exciting a couple years

889

00:35:34,800 --> 00:35:32,260

ago but now all are pretty well behaved

890

00:35:36,780 --> 00:35:34,810

at this point um it's funny we

891

00:35:38,700 --> 00:35:36,790

definitely attribute

892

00:35:40,980 --> 00:35:38,710

personnel at hubbell and each of the

893

00:35:44,010 --> 00:35:40,990

instruments and we kind of joked that it

894

00:35:47,610 --> 00:35:44,020

knows when holidays and and in certain

895

00:35:51,300 --> 00:35:47,620

mountains are so it knows when to hit us

896

00:35:53,130 --> 00:35:51,310

but um the probably the moon the one

897

00:35:55,710 --> 00:35:53,140

would give me the most consternation

898

00:35:58,230 --> 00:35:55,720

right now be wide field camera 3 just

899

00:36:00,420 --> 00:35:58,240

because it's the most used of the

900

00:36:02,430 --> 00:36:00,430

instruments on board that imagine

901
00:36:03,840 --> 00:36:02,440
accounts for will be fifty to sixty

902
00:36:06,120 --> 00:36:03,850
percent of the observations that we do

903
00:36:08,760 --> 00:36:06,130
right that's the infrared camera that

904
00:36:11,790 --> 00:36:08,770
takes on by the way Tony and everyone

905
00:36:15,180 --> 00:36:11,800
its 16-bit data and each pixel can

906
00:36:17,700 --> 00:36:15,190
accommodate 78,000 electrons when it's

907
00:36:19,950 --> 00:36:17,710
saturated awesome thank you that's a

908
00:36:21,420 --> 00:36:19,960
real I'm sorry that's just nerdy i love

909
00:36:24,480 --> 00:36:21,430
that stuff that's what i like to hear

910
00:36:28,520 --> 00:36:24,490
16-bit numbers okay good well there's

911
00:36:30,930 --> 00:36:28,530
the bit depth of the whiff c3 okay so

912
00:36:32,910 --> 00:36:30,940
you're everything's automated hopefully

913
00:36:34,080 --> 00:36:32,920

you've got a true computer in the in

914

00:36:35,420 --> 00:36:34,090

that other room over there that's a

915

00:36:39,110 --> 00:36:35,430

little more powerful than a 486

916

00:36:42,540 --> 00:36:39,120

controlling it will you said earlier

917

00:36:44,850 --> 00:36:42,550

morgan that you guys get text messages

918

00:36:47,190 --> 00:36:44,860

when something goes wrong right that's

919

00:36:49,470 --> 00:36:47,200

that's your alert what what safeguards

920

00:36:51,930 --> 00:36:49,480

are in place and what do you guys do

921

00:36:53,550 --> 00:36:51,940

when something goes wrong with Hubble it

922

00:36:55,530 --> 00:36:53,560

goes wrong ok so we've literally

923

00:36:57,600 --> 00:36:55,540

thousands of telemetry points that are

924

00:37:00,270 --> 00:36:57,610

being monitored by the automated

925

00:37:02,070 --> 00:37:00,280

computer and when it detects something

926

00:37:04,100 --> 00:37:02,080

out of limits which is just however we

927

00:37:06,630 --> 00:37:04,110

defined it you know if a power gets

928

00:37:09,750 --> 00:37:06,640

drawing too much power or gets too hot

929

00:37:11,910 --> 00:37:09,760

or whatever on the computer sends out

930

00:37:13,830 --> 00:37:11,920

really literally a text message to our

931

00:37:16,710 --> 00:37:13,840

iphones at three in the morning or

932

00:37:19,380 --> 00:37:16,720

whatever and that's when me is the

933

00:37:21,870 --> 00:37:19,390

anomaly response manager will start to

934

00:37:24,450 --> 00:37:21,880

touch base with all the subsystems and

935

00:37:25,890 --> 00:37:24,460

make sure everything everyone not

936

00:37:28,290 --> 00:37:25,900

obviously everything isn't fine but make

937

00:37:30,900 --> 00:37:28,300

sure that the subsystems are all expect

938

00:37:32,760 --> 00:37:30,910

in their expected state and meanwhile

939

00:37:35,460 --> 00:37:32,770

scott and mike and all the other sub

940

00:37:37,110 --> 00:37:35,470

system engineers start looking at their

941

00:37:38,580 --> 00:37:37,120

telemetry like I said sometimes we have

942

00:37:41,130 --> 00:37:38,590

real telemetry real-time telemetry

943

00:37:44,400 --> 00:37:41,140

hopefully we do if not we'll wait till

944

00:37:47,460 --> 00:37:44,410

we get it and evaluate what the real

945

00:37:50,170 --> 00:37:47,470

problem is and so there's two kind of

946

00:37:52,150 --> 00:37:50,180

anomaly responses the first is immediate

947

00:37:55,240 --> 00:37:52,160

and that's going to be sometimes taken

948

00:37:57,610 --> 00:37:55,250

autonomously by the telescope element x

949

00:38:00,190 --> 00:37:57,620

by very quick ground commanding to put

950

00:38:02,440 --> 00:38:00,200

us to a safe skates if you had a problem

951
00:38:05,080 --> 00:38:02,450
we're not sure what's going on we can

952
00:38:07,570 --> 00:38:05,090
just turn off some of the detectors if

953
00:38:10,960 --> 00:38:07,580
it's a very serious issue we can even

954
00:38:13,600 --> 00:38:10,970
close the telescope's aperture door load

955
00:38:15,850 --> 00:38:13,610
shed power if we need to just depending

956
00:38:17,950 --> 00:38:15,860
on exactly what the anomaly was so we

957
00:38:19,840 --> 00:38:17,960
have an initial response to safe the

958
00:38:21,580 --> 00:38:19,850
telescope that's our primary goal at

959
00:38:23,560 --> 00:38:21,590
that moment make sure everything's safe

960
00:38:25,720 --> 00:38:23,570
no more damage is going to get done and

961
00:38:28,330 --> 00:38:25,730
then we can actually start trying to

962
00:38:30,070 --> 00:38:28,340
figure out what happened and if it's

963
00:38:31,840 --> 00:38:30,080

something that we can easily recover

964

00:38:34,990 --> 00:38:31,850

from or if it's something that we need

965

00:38:37,740 --> 00:38:35,000

to figure out how to rig a telescope or

966

00:38:40,330 --> 00:38:37,750

maybe even a new plate software or new

967

00:38:42,700 --> 00:38:40,340

switch to a redundant side or something

968

00:38:44,890 --> 00:38:42,710

like that and that response is going to

969

00:38:47,110 --> 00:38:44,900

happen over the course of weeks rather

970

00:38:48,160 --> 00:38:47,120

than an immediate response you're really

971

00:38:49,480 --> 00:38:48,170

going to take your time and figure it

972

00:38:50,890 --> 00:38:49,490

out and just make sure that you

973

00:38:53,050 --> 00:38:50,900

understand the problem well that's good

974

00:38:54,390 --> 00:38:53,060

okay so this safe mode that you're

975

00:38:56,500 --> 00:38:54,400

talking about this is just a

976
00:38:59,080 --> 00:38:56,510
configuration that you put the telescope

977
00:39:01,030 --> 00:38:59,090
in that is not pointing at the Sun not

978
00:39:02,440 --> 00:39:01,040
pointing anything bad it's you know

979
00:39:05,410 --> 00:39:02,450
you've just got to calm down a little

980
00:39:07,450 --> 00:39:05,420
bit the instruments are are waiting you

981
00:39:12,370 --> 00:39:07,460
to figure it out do you ever have to

982
00:39:13,780 --> 00:39:12,380
reboot Hubble and in in a sense one of

983
00:39:16,180 --> 00:39:13,790
the science instruments the science

984
00:39:20,470 --> 00:39:16,190
computer actually sometimes gets hung up

985
00:39:26,740 --> 00:39:20,480
just locks up I I knew Scott did you do

986
00:39:28,450 --> 00:39:26,750
that yeah Paul actually we had one of

987
00:39:31,120 --> 00:39:28,460
those recently just become the the 20th

988
00:39:32,410 --> 00:39:31,130

of October work essentially the computer

989

00:39:35,080 --> 00:39:32,420

just essentially stops responding

990

00:39:36,640 --> 00:39:35,090

commands and stop sending telemetry the

991

00:39:39,580 --> 00:39:36,650

first time it happened on orbit was

992

00:39:40,960 --> 00:39:39,590

really pretty scary since we didn't know

993

00:39:42,280 --> 00:39:40,970

exactly what state the science

994

00:39:43,810 --> 00:39:42,290

instruments were in we couldn't get any

995

00:39:46,600 --> 00:39:43,820

information about them out of the

996

00:39:48,820 --> 00:39:46,610

telescope but eventually we figured out

997

00:39:51,130 --> 00:39:48,830

kind of what was going on and understood

998

00:39:53,590 --> 00:39:51,140

that the instruments were taking some

999

00:39:55,110 --> 00:39:53,600

action to protect themselves if it's

1000

00:39:58,120 --> 00:39:55,120

elves in a safe state when they lost

1001
00:40:00,130 --> 00:39:58,130
contact with the computer but there for

1002
00:40:02,089 --> 00:40:00,140
a while it was it was not a comfortable

1003
00:40:03,799 --> 00:40:02,099
situation to be in so

1004
00:40:05,359 --> 00:40:03,809
I heard a rumor I heard someone a

1005
00:40:07,430 --> 00:40:05,369
comment somewhere I don't remember where

1006
00:40:09,109 --> 00:40:07,440
and this is for any three of you if you

1007
00:40:12,410 --> 00:40:09,119
want to comment on it the door out front

1008
00:40:14,599 --> 00:40:12,420
Oh is always open you really are sort of

1009
00:40:16,519 --> 00:40:14,609
loath to close it I think of it for fear

1010
00:40:17,749 --> 00:40:16,529
that it won't reopen again is that I

1011
00:40:22,219 --> 00:40:17,759
hear that right or is that just

1012
00:40:23,660 --> 00:40:22,229
something yeah yeah no and you're

1013
00:40:25,519 --> 00:40:23,670

exactly right the reason we leave it

1014

00:40:26,870 --> 00:40:25,529

open is you know if you ever close it

1015

00:40:28,460 --> 00:40:26,880

chances are you know what if you can't

1016

00:40:31,130 --> 00:40:28,470

open it and boy you close that and

1017

00:40:34,759 --> 00:40:31,140

Hubble will not work there's nothing is

1018

00:40:37,069 --> 00:40:34,769

going to go that way in oh we don't ever

1019

00:40:38,569 --> 00:40:37,079

really we don't ever close it the only

1020

00:40:41,390 --> 00:40:38,579

thing that can close it is if the

1021

00:40:43,940 --> 00:40:41,400

computer on board says something's wrong

1022

00:40:46,249 --> 00:40:43,950

I don't know where the telescope is

1023

00:40:48,469 --> 00:40:46,259

pointed or I can't control the telescope

1024

00:40:50,690 --> 00:40:48,479

then it will close it there is actually

1025

00:40:52,219 --> 00:40:50,700

a eponymous closing me it's very rare I

1026
00:40:54,140 --> 00:40:52,229
mean we've done it during the servicing

1027
00:40:56,779 --> 00:40:54,150
mission we've a commanded it closed um

1028
00:40:58,849 --> 00:40:56,789
but but typically um you know we don't

1029
00:41:00,319 --> 00:40:58,859
want to do that I'm even though there's

1030
00:41:02,989 --> 00:41:00,329
redundancy there's there's multiple

1031
00:41:04,579 --> 00:41:02,999
motors up there to open it up but it's

1032
00:41:06,769 --> 00:41:04,589
really the only person really closes the

1033
00:41:08,509 --> 00:41:06,779
door the computer goes into one of these

1034
00:41:10,160 --> 00:41:08,519
say folks or certain levels of state

1035
00:41:12,019 --> 00:41:10,170
mode what own is the computer says I

1036
00:41:14,450 --> 00:41:12,029
know what I'm doing i know where i am

1037
00:41:17,239 --> 00:41:14,460
and i can control the telescope but if

1038
00:41:19,519 --> 00:41:17,249

when we lose a gyro or if we lose one of

1039

00:41:21,049 --> 00:41:19,529

the reaction wheels it's locked control

1040

00:41:23,959 --> 00:41:21,059

of the telescope it says i don't have

1041

00:41:25,670 --> 00:41:23,969

the control i need i can't point it so

1042

00:41:27,920 --> 00:41:25,680

i'm going to close the door just make

1043

00:41:29,779 --> 00:41:27,930

sure because we can't ever get bumped

1044

00:41:31,279 --> 00:41:29,789

down in here um if the Sun ever does

1045

00:41:34,039 --> 00:41:31,289

shine down in here really bad things

1046

00:41:36,019 --> 00:41:34,049

happen right and closing the door is a

1047

00:41:37,069 --> 00:41:36,029

really good way to break the whole thing

1048

00:41:38,719 --> 00:41:37,079

even though everything it could be

1049

00:41:39,739 --> 00:41:38,729

working perfectly but if no light gets

1050

00:41:43,279 --> 00:41:39,749

to the primary and then you've got

1051
00:41:45,709 --> 00:41:43,289
nothing so yeah I can understand that so

1052
00:41:48,910 --> 00:41:45,719
I want to address the gyros for a minute

1053
00:41:52,640 --> 00:41:48,920
a really huge important part of Hubble

1054
00:41:55,039 --> 00:41:52,650
what do they do and they were recently

1055
00:41:58,099 --> 00:41:55,049
replaced in service mission for it

1056
00:42:00,259 --> 00:41:58,109
basically gave Hubble new life basically

1057
00:42:01,700 --> 00:42:00,269
it's like the the heart of the Hubble

1058
00:42:05,559 --> 00:42:01,710
Space Telescope isn't it who wants to

1059
00:42:08,450 --> 00:42:05,569
tell us about those the gyros well I'll

1060
00:42:10,099 --> 00:42:08,460
try Mike okay go ahead yeah we'll see

1061
00:42:12,739 --> 00:42:10,109
what they are how important they are on

1062
00:42:14,690 --> 00:42:12,749
what they do well the gyroscope are what

1063
00:42:16,000 --> 00:42:14,700

you think of as a gyroscope it's they

1064

00:42:17,920 --> 00:42:16,010

aren't very go there

1065

00:42:19,480 --> 00:42:17,930

larger they have a very good spinning

1066

00:42:21,540 --> 00:42:19,490

wheel inside of own and essentially

1067

00:42:24,670 --> 00:42:21,550

they're very sensitive to motion

1068

00:42:27,970 --> 00:42:24,680

gyroscopes tell us how to telescope is

1069

00:42:30,190 --> 00:42:27,980

moving on and so we have six gyroscopes

1070

00:42:31,870 --> 00:42:30,200

on board we've actually been replaced it

1071

00:42:33,790 --> 00:42:31,880

pretty much every servicing mission we

1072

00:42:36,370 --> 00:42:33,800

try to replace as many as we can on

1073

00:42:38,290 --> 00:42:36,380

these are actually mechanical gyroscopes

1074

00:42:40,390 --> 00:42:38,300

there's a spinning gyroscope that's

1075

00:42:42,970 --> 00:42:40,400

spinning it at very high revolutions I'm

1076

00:42:44,620 --> 00:42:42,980

very extremely precise of these were

1077

00:42:47,020 --> 00:42:44,630

probably some of the most the mole

1078

00:42:50,740 --> 00:42:47,030

precise mechanical gyroscopes ever made

1079

00:42:52,300 --> 00:42:50,750

um in fact we will be tardy they don't

1080

00:42:53,860 --> 00:42:52,310

make them mechanically this more and

1081

00:42:56,740 --> 00:42:53,870

more they've gone to optical and laser

1082

00:42:58,090 --> 00:42:56,750

gyroscopes but what they do is they

1083

00:42:59,800 --> 00:42:58,100

allowed a telescope know where it's

1084

00:43:02,260 --> 00:42:59,810

plumb gyroscopes when the telescope's

1085

00:43:04,480 --> 00:43:02,270

moving gyroscope is eating a signal

1086

00:43:06,580 --> 00:43:04,490

saying remove this direction at this

1087

00:43:08,110 --> 00:43:06,590

rate so we've got six of them that

1088

00:43:09,810 --> 00:43:08,120

they're also their their axes are

1089

00:43:12,340 --> 00:43:09,820

pointed at different locations so they

1090

00:43:14,140 --> 00:43:12,350

computer know-how to telescopes moving

1091

00:43:15,880 --> 00:43:14,150

as when the computer is moving it's a l

1092

00:43:17,620 --> 00:43:15,890

need to move with the telescope 90

1093

00:43:19,810 --> 00:43:17,630

degrees this way how does it know what

1094

00:43:22,300 --> 00:43:19,820

90 degrees that way it looks at the

1095

00:43:25,570 --> 00:43:22,310

gyros but the gyros aren't the first way

1096

00:43:28,720 --> 00:43:25,580

we point telescope the information from

1097

00:43:32,380 --> 00:43:28,730

the gyros now arrows are extremely

1098

00:43:33,760 --> 00:43:32,390

accurate over small distances they can

1099

00:43:35,380 --> 00:43:33,770

actually hold the telescope they are

1100

00:43:37,480 --> 00:43:35,390

actually primary will help the whole

1101

00:43:40,030 --> 00:43:37,490

telescope but if you did a big slew

1102

00:43:41,710 --> 00:43:40,040

build up this little bit of error in and

1103

00:43:44,530 --> 00:43:41,720

builds up and so we have all these other

1104

00:43:47,560 --> 00:43:44,540

instruments that allow us to bind to the

1105

00:43:49,690 --> 00:43:47,570

pointing afterwards um but jaros without

1106

00:43:53,320 --> 00:43:49,700

gyros you can't point the telescope oh

1107

00:43:56,880 --> 00:43:53,330

now we have six of them had various lots

1108

00:43:59,860 --> 00:43:56,890

of them Gail on different years um

1109

00:44:01,750 --> 00:43:59,870

actually science and for many many years

1110

00:44:03,340 --> 00:44:01,760

we actually did science on two of them

1111

00:44:04,990 --> 00:44:03,350

and we actually have what's known to

1112

00:44:08,620 --> 00:44:05,000

gyro and we actually figured out a way

1113

00:44:11,080 --> 00:44:08,630

we only need one gyro good it's because

1114

00:44:13,210 --> 00:44:11,090

of these other instruments one gyro if

1115

00:44:15,670 --> 00:44:13,220

you can get yourself onto the fine

1116

00:44:18,610 --> 00:44:15,680

guidance sensors you can do science and

1117

00:44:20,230 --> 00:44:18,620

we need one gyro to get there it takes a

1118

00:44:22,990 --> 00:44:20,240

little bit longer sometimes but only

1119

00:44:24,340 --> 00:44:23,000

need one to actually do science and so

1120

00:44:26,080 --> 00:44:24,350

that that's why we're thinking we're

1121

00:44:27,970 --> 00:44:26,090

pretty good off still I think it's a

1122

00:44:29,170 --> 00:44:27,980

good point to put up that pickle diagram

1123

00:44:31,930 --> 00:44:29,180

you were talking about can you

1124

00:44:34,809 --> 00:44:31,940

can you put that up for Scott when you

1125

00:44:36,400 --> 00:44:34,819

get chance this is a picture Oh pickle

1126
00:44:37,870 --> 00:44:36,410
by the way something completely

1127
00:44:39,849 --> 00:44:37,880
different now you're thinking obvious

1128
00:44:41,950 --> 00:44:39,859
call pickle no hubble hubble needs

1129
00:44:45,930 --> 00:44:41,960
pickles I mean as you know what are they

1130
00:44:49,660 --> 00:44:45,940
sweet you know are they ill I've got her

1131
00:44:51,970 --> 00:44:49,670
here we go so this is an image of the

1132
00:44:52,780 --> 00:44:51,980
well i'll let you describe it Bob Mike

1133
00:44:55,089 --> 00:44:52,790
why don't you tell us what we're looking

1134
00:44:57,010 --> 00:44:55,099
at okay this is for like if you were in

1135
00:45:00,250 --> 00:44:57,020
the back end of Hubble sort of looking

1136
00:45:02,319 --> 00:45:00,260
out this is how Hubble sees the sky what

1137
00:45:03,760 --> 00:45:02,329
what you sort of see you know you see a

1138
00:45:05,859 --> 00:45:03,770

stars in the background there there's

1139

00:45:08,440 --> 00:45:05,869

active galaxies in the middle um and you

1140

00:45:10,690 --> 00:45:08,450

see outlines of the big outline is the

1141

00:45:13,420 --> 00:45:10,700

telescope that's the higher area of sky

1142

00:45:15,490 --> 00:45:13,430

the telescope could ever see the little

1143

00:45:17,230 --> 00:45:15,500

thing directly in the center that's sort

1144

00:45:19,780 --> 00:45:17,240

of what the wide field camera is see on

1145

00:45:21,339 --> 00:45:19,790

the other little circles to decide those

1146

00:45:23,290 --> 00:45:21,349

are the other instruments those are part

1147

00:45:25,660 --> 00:45:23,300

of the sky that they can see those big

1148

00:45:28,359 --> 00:45:25,670

parks on the edge those are what we call

1149

00:45:31,540 --> 00:45:28,369

the pickles because it looked like bent

1150

00:45:33,280 --> 00:45:31,550

pickles um know about that my guess

1151
00:45:36,549 --> 00:45:33,290
that's pretty fast pretty big stretch

1152
00:45:37,780 --> 00:45:36,559
but go ahead I think it was created by

1153
00:45:39,760 --> 00:45:37,790
some software engineers who were

1154
00:45:43,030 --> 00:45:39,770
defining the name well that explains it

1155
00:45:46,900 --> 00:45:43,040
that explains it ok that's the software

1156
00:45:49,690 --> 00:45:46,910
engineer yeah you don't want to trust us

1157
00:45:51,730 --> 00:45:49,700
as far as you can throw us know so

1158
00:45:53,589 --> 00:45:51,740
that's what fine guidance sensors can

1159
00:45:55,569 --> 00:45:53,599
see so each one of those a ones fine

1160
00:45:57,940 --> 00:45:55,579
guidance sensor one one's a fine

1161
00:45:59,500 --> 00:45:57,950
guidance sensor to do 13 and you notice

1162
00:46:01,690 --> 00:45:59,510
that there start there would be sparse

1163
00:46:03,910 --> 00:46:01,700

sitting there into what we do is we

1164

00:46:06,250 --> 00:46:03,920

actually these fine guidance sensors go

1165

00:46:08,079 --> 00:46:06,260

out they can move anywhere they're kind

1166

00:46:10,569 --> 00:46:08,089

of weird instruments we can move

1167

00:46:12,460 --> 00:46:10,579

anywhere around in that little arc where

1168

00:46:14,020 --> 00:46:12,470

that big in that pickle and much of you

1169

00:46:15,760 --> 00:46:14,030

don't want me to say to turn anywhere in

1170

00:46:18,099 --> 00:46:15,770

that pickle we can actually go and find

1171

00:46:22,210 --> 00:46:18,109

a star there and call what we say we

1172

00:46:24,789 --> 00:46:22,220

lock onto it so like in his image if you

1173

00:46:27,039 --> 00:46:24,799

wanted to observe that galaxies pick one

1174

00:46:28,660 --> 00:46:27,049

of the stars the pickle on the right and

1175

00:46:30,609 --> 00:46:28,670

one of the stars in the pickle on left

1176
00:46:33,250 --> 00:46:30,619
and you tell your fine guidance sensors

1177
00:46:36,609 --> 00:46:33,260
go out there and find these stars lock

1178
00:46:39,220 --> 00:46:36,619
on to them in Holmby exactly perfectly

1179
00:46:41,589 --> 00:46:39,230
still so that decides instrument can get

1180
00:46:42,480 --> 00:46:41,599
its name those momentum wheels right

1181
00:46:43,770 --> 00:46:42,490
those that we talked

1182
00:46:46,230 --> 00:46:43,780
about earlier they keep this pointed

1183
00:46:49,320 --> 00:46:46,240
straight or is that just move yeah okay

1184
00:46:53,190 --> 00:46:49,330
well well no they will move I did they

1185
00:46:54,690 --> 00:46:53,200
also yeah they will move it you'll find

1186
00:46:56,280 --> 00:46:54,700
you too because you I realize we're

1187
00:46:58,109 --> 00:46:56,290
spinning around that 18,000 miles an

1188
00:47:00,630 --> 00:46:58,119

hour trying to point something out space

1189

00:47:03,540 --> 00:47:00,640

we've got you know we're moving we have

1190

00:47:05,160 --> 00:47:03,550

to move these things in and how accurate

1191

00:47:07,920 --> 00:47:05,170

doesn't do that I mean does it can you

1192

00:47:10,650 --> 00:47:07,930

keep the stars within a pixel are moving

1193

00:47:13,109 --> 00:47:10,660

keep stars within six milliseconds then

1194

00:47:15,120 --> 00:47:13,119

less than 6 million a few milli arcs and

1195

00:47:18,090 --> 00:47:15,130

so point zero zero one arc seconds if if

1196

00:47:21,150 --> 00:47:18,100

that takes go yeah that's pretty darn

1197

00:47:23,160 --> 00:47:21,160

accurate all right good and it has to do

1198

00:47:25,290 --> 00:47:23,170

that while orbiting the earth yeah well

1199

00:47:27,480 --> 00:47:25,300

this is 18,000 miles an hour that's

1200

00:47:29,580 --> 00:47:27,490

right I mean essentially it's like we're

1201
00:47:31,200 --> 00:47:29,590
looking at a dime a dime at the top of

1202
00:47:33,900 --> 00:47:31,210
the Empire State Building and we can

1203
00:47:35,910 --> 00:47:33,910
hold Hubble pointed at that time ice

1204
00:47:37,170 --> 00:47:35,920
very nice I like this picture because it

1205
00:47:38,970 --> 00:47:37,180
shows all of the seems like there's a

1206
00:47:40,500 --> 00:47:38,980
lot of wasted space so what do you think

1207
00:47:43,859 --> 00:47:40,510
about this Scott you have any comments

1208
00:47:46,290 --> 00:47:43,869
on this week the what are some of these

1209
00:47:48,450 --> 00:47:46,300
other circles that that Mike alluded to

1210
00:47:50,430 --> 00:47:48,460
well the image that we've got up on the

1211
00:47:51,710 --> 00:47:50,440
screen now this is actually at the

1212
00:47:54,750 --> 00:47:51,720
instrument complement we had before

1213
00:47:56,790 --> 00:47:54,760

servicing mission three be all right I

1214

00:47:58,650 --> 00:47:56,800

just saw this boops one that you've got

1215

00:48:00,870 --> 00:47:58,660

in the center there is the the old wide

1216

00:48:03,030 --> 00:48:00,880

field planetary camera 2 which was

1217

00:48:06,510 --> 00:48:03,040

actually a conveyor a shin of for ccds

1218

00:48:08,430 --> 00:48:06,520

okay well it has that shape the if the

1219

00:48:10,040 --> 00:48:08,440

two circles just to the above and to the

1220

00:48:13,230 --> 00:48:10,050

left of that of the faint object camera

1221

00:48:14,910 --> 00:48:13,240

the circle and the inscribed squares

1222

00:48:16,859 --> 00:48:14,920

those are actually the three nick moss

1223

00:48:18,570 --> 00:48:16,869

cameras that we have the infrared

1224

00:48:21,390 --> 00:48:18,580

instrument and those are still on board

1225

00:48:23,220 --> 00:48:21,400

and then the circle with the square and

1226

00:48:26,280 --> 00:48:23,230

then the X kind of inscribed in it

1227

00:48:29,160 --> 00:48:26,290

that's the disc field of view so that's

1228

00:48:31,080 --> 00:48:29,170

our imaging spectrograph okay on if you

1229

00:48:32,400 --> 00:48:31,090

want to go to the next I think what are

1230

00:48:36,000 --> 00:48:32,410

the next images that we've gotten that

1231

00:48:38,099 --> 00:48:36,010

package there should be an upgraded view

1232

00:48:40,740 --> 00:48:38,109

of this field of view projection it's

1233

00:48:44,340 --> 00:48:40,750

not on the sky but that show yep the one

1234

00:48:46,470 --> 00:48:44,350

back one yeah there you go okay get over

1235

00:48:48,780 --> 00:48:46,480

there it gives you the the upgraded

1236

00:48:51,270 --> 00:48:48,790

fields of view with with ACS installed

1237

00:48:52,650 --> 00:48:51,280

that replaced an optic camera and then

1238

00:48:54,180 --> 00:48:52,660

you there you cease tests and then

1239

00:48:55,859 --> 00:48:54,190

capture cosmic origins spectrograph

1240

00:48:59,249 --> 00:48:55,869

which replaced

1241

00:49:01,349 --> 00:48:59,259

costar which was our optical pointing

1242

00:49:02,609 --> 00:49:01,359

correction by instrument so which is why

1243

00:49:04,499 --> 00:49:02,619

you didn't see anything in the bottom

1244

00:49:06,210 --> 00:49:04,509

left-hand corner of that that image add

1245

00:49:08,160 --> 00:49:06,220

up before and then you could see the

1246

00:49:09,630 --> 00:49:08,170

Nick cameras there Bradford Nick moss

1247

00:49:11,220 --> 00:49:09,640

and then of course in the center we have

1248

00:49:14,370 --> 00:49:11,230

wide field camera 3 now instead of would

1249

00:49:18,089 --> 00:49:14,380

do are those fine guidance sensors all

1250

00:49:20,370 --> 00:49:18,099

these see CDs okay there are actually

1251

00:49:22,380 --> 00:49:20,380

interferometers um which they did

1252

00:49:25,890 --> 00:49:22,390

they're actually amazing instruments um

1253

00:49:27,150 --> 00:49:25,900

because um air do the little Michelson

1254

00:49:30,359 --> 00:49:27,160

interferometer ziff you know what those

1255

00:49:32,009 --> 00:49:30,369

are yeah actually um have thinner bunch

1256

00:49:34,759 --> 00:49:32,019

of mirrors in them that'd slit the light

1257

00:49:37,680 --> 00:49:34,769

and recombine it and allow them to

1258

00:49:41,400 --> 00:49:37,690

extremely accurately grab on to preach

1259

00:49:42,839 --> 00:49:41,410

sources um but they actually be used as

1260

00:49:44,819 --> 00:49:42,849

science instruments we always like to

1261

00:49:46,380 --> 00:49:44,829

say you know Scott will say well I have

1262

00:49:48,359 --> 00:49:46,390

all these signs systems and I say well

1263

00:49:50,430 --> 00:49:48,369

I've got three science instruments here

1264

00:49:52,859 --> 00:49:50,440

because each fine guidance sensors can

1265

00:49:55,079 --> 00:49:52,869

actually use to do science in there's

1266

00:49:57,960 --> 00:49:55,089

what's known as the speckle science

1267

00:49:59,819 --> 00:49:57,970

that public does and as the measurement

1268

00:50:01,589 --> 00:49:59,829

of positions in the sky right astrometry

1269

00:50:04,650 --> 00:50:01,599

you can measure in stars find positions

1270

00:50:07,259 --> 00:50:04,660

on the day turn extremely sensitive to

1271

00:50:09,269 --> 00:50:07,269

because they can't detect these

1272

00:50:11,729 --> 00:50:09,279

positions to hold the telescope to

1273

00:50:13,829 --> 00:50:11,739

within like story arc second they

1274

00:50:16,920 --> 00:50:13,839

actually can really find a fine double

1275

00:50:18,900 --> 00:50:16,930

stars on really well any stars of you

1276
00:50:20,460 --> 00:50:18,910
from the ground that people say oh it's

1277
00:50:21,779 --> 00:50:20,470
only once or it's one star Hubble will

1278
00:50:24,630 --> 00:50:21,789
actually say no no it's actually two

1279
00:50:26,160 --> 00:50:24,640
stars you can actually measure their

1280
00:50:28,620 --> 00:50:26,170
separation and measure some of their

1281
00:50:31,319 --> 00:50:28,630
properties you'll do actually really

1282
00:50:33,359 --> 00:50:31,329
really high accuracy precision between

1283
00:50:34,859 --> 00:50:33,369
one star star the next star in the next

1284
00:50:36,960 --> 00:50:34,869
stars it's doing this drama tree

1285
00:50:38,370 --> 00:50:36,970
observations so they were just a while

1286
00:50:41,160 --> 00:50:38,380
back called the Hubble guide star

1287
00:50:43,170 --> 00:50:41,170
catalogue was that made in using that or

1288
00:50:46,650 --> 00:50:43,180

was that something else i'm thinking of

1289

00:50:48,390 --> 00:50:46,660

that's actually made I mean people when

1290

00:50:50,729 --> 00:50:48,400

I said well we were gonna go back you

1291

00:50:52,829 --> 00:50:50,739

know well there's that star there how do

1292

00:50:54,450 --> 00:50:52,839

we know exactly where that star is the

1293

00:50:57,420 --> 00:50:54,460

Hubble guides our catalog is actually

1294

00:50:59,789 --> 00:50:57,430

catalog of many many hundreds of

1295

00:51:01,349 --> 00:50:59,799

thousands of stars in very accurate

1296

00:51:03,660 --> 00:51:01,359

positions because we need to know

1297

00:51:05,309 --> 00:51:03,670

exactly where those stars are to be

1298

00:51:07,799 --> 00:51:05,319

able to tell those stars is where to go to

1299

00:51:09,480 --> 00:51:07,809

find them so double star catalogue

1300

00:51:11,100 --> 00:51:09,490

is the star Oh

1301

00:51:12,300 --> 00:51:11,110

I thought yeah okay I was wondering if

1302

00:51:14,820 --> 00:51:12,310

it was related but it sounds like it's

1303

00:51:15,870 --> 00:51:14,830

not so okay I want to get to work

1304

00:51:17,430 --> 00:51:15,880

running out of time and I want to get

1305

00:51:20,220 --> 00:51:17,440

some comments here I have one from

1306

00:51:22,290 --> 00:51:20,230

Daniel no sato on the Q&A app he is

1307

00:51:25,109 --> 00:51:22,300

asking do you think a private company

1308

00:51:27,030 --> 00:51:25,119

like SpaceX might take over the

1309

00:51:29,580 --> 00:51:27,040

maintenance and control of Hubble once

1310

00:51:31,890 --> 00:51:29,590

NASA converts over to JWST and perhaps

1311

00:51:34,230 --> 00:51:31,900

set up a crowdfunding system like slew

1312

00:51:37,800 --> 00:51:34,240

for anyone to point Hubble sure would be

1313

00:51:38,970 --> 00:51:37,810

cool it's a great idea uh Carol is that

1314

00:51:45,060 --> 00:51:38,980

something you'd want to comment on maybe

1315

00:51:48,720 --> 00:51:45,070

you're sure um so just for all you fans

1316

00:51:50,850 --> 00:51:48,730

of SpaceX and Elon Musk Elon Musk has

1317

00:51:54,270 --> 00:51:50,860

actually received quite a bit of NASA

1318

00:51:56,340 --> 00:51:54,280

funding to get his little enterprise off

1319

00:51:58,380 --> 00:51:56,350

the ground as we say so he's not

1320

00:52:02,850 --> 00:51:58,390

completely independent of NASA number

1321

00:52:06,870 --> 00:52:02,860

one and number two this kind of

1322

00:52:10,230 --> 00:52:06,880

exploration is and and use of scientific

1323

00:52:12,570 --> 00:52:10,240

instruments is really something that

1324

00:52:14,910 --> 00:52:12,580

requires a national effort and a

1325

00:52:16,650 --> 00:52:14,920

national will and so like a lot of the

1326
00:52:18,420 --> 00:52:16,660
ground-based telescopes are funded

1327
00:52:20,250 --> 00:52:18,430
through the National Science Foundation

1328
00:52:23,550 --> 00:52:20,260
because it's very hard for private

1329
00:52:25,530 --> 00:52:23,560
institutions to afford such facilities

1330
00:52:27,599 --> 00:52:25,540
now there are a few cases in the old

1331
00:52:30,450 --> 00:52:27,609
days of ground-based observatories that

1332
00:52:32,520 --> 00:52:30,460
were very capable that were privately

1333
00:52:34,760 --> 00:52:32,530
funded by people who had a lot of money

1334
00:52:37,710 --> 00:52:34,770
but in when we start talking about

1335
00:52:40,320 --> 00:52:37,720
sending rockets into space and then

1336
00:52:42,480 --> 00:52:40,330
putting astronomical instruments on them

1337
00:52:45,060 --> 00:52:42,490
it's very difficult so maybe sometime

1338
00:52:47,880 --> 00:52:45,070

downstream it might be possible to

1339

00:52:51,599 --> 00:52:47,890

privatize right now NASA is really the

1340

00:52:54,060 --> 00:52:51,609

only name of the game and note you know

1341

00:52:56,790 --> 00:52:54,070

the science part of NASA is not for

1342

00:53:00,300 --> 00:52:56,800

profit and in fact we we give away all

1343

00:53:03,840 --> 00:53:00,310

of our data so to then start talking

1344

00:53:06,120 --> 00:53:03,850

about commercial space and then applying

1345

00:53:08,400 --> 00:53:06,130

that to scientific research is really

1346

00:53:10,530 --> 00:53:08,410

scary for people like me because that

1347

00:53:13,050 --> 00:53:10,540

means that the costs are what going to

1348

00:53:16,230 --> 00:53:13,060

go way up and it's not going to really

1349

00:53:18,960 --> 00:53:16,240

be possible for many of us to to do the

1350

00:53:20,430 --> 00:53:18,970

science unless it's federally funded

1351

00:53:22,830 --> 00:53:20,440

we have this arrangement with the

1352

00:53:25,350 --> 00:53:22,840

European Space Agency so it's two very

1353

00:53:27,360 --> 00:53:25,360

large agencies putting together their

1354

00:53:29,070 --> 00:53:27,370

resources and expertise so that

1355

00:53:33,780 --> 00:53:29,080

scientists can do the research sorry

1356

00:53:36,060 --> 00:53:33,790

it's an interesting idea but it does

1357

00:53:38,190 --> 00:53:36,070

require significant resources and

1358

00:53:40,440 --> 00:53:38,200

expertise to to keep these things

1359

00:53:42,780 --> 00:53:40,450

running and you're only you're seeing

1360

00:53:45,510 --> 00:53:42,790

three of great experts on mobile and

1361

00:53:47,160 --> 00:53:45,520

there are many more right yeah so it's

1362

00:53:50,490 --> 00:53:47,170

easy so it's a very expensive endeavor

1363

00:53:52,260 --> 00:53:50,500

good what good point there if Tony I

1364

00:53:55,470 --> 00:53:52,270

think there's definitely going to be

1365

00:53:57,960 --> 00:53:55,480

good overlap between JWST and Hubble so

1366

00:54:00,180 --> 00:53:57,970

it's not like once jwst is on orbit

1367

00:54:02,010 --> 00:54:00,190

Hubble's just gonna get turned off okay

1368

00:54:03,600 --> 00:54:02,020

hold that thought oh that's not hold

1369

00:54:07,110 --> 00:54:03,610

that thought there Morgan because brooke

1370

00:54:09,060 --> 00:54:07,120

van der be a Q&A app is it yeah we get

1371

00:54:11,250 --> 00:54:09,070

this almost every time how long are we

1372

00:54:18,000 --> 00:54:11,260

going to keep using Hubble why would it

1373

00:54:20,250 --> 00:54:18,010

stop being usable I continue please stop

1374

00:54:21,900 --> 00:54:20,260

right at least until 2020 and like I

1375

00:54:24,960 --> 00:54:21,910

said we're really hoping to get a few

1376
00:54:27,750 --> 00:54:24,970
years of overlap between Hubble and jwst

1377
00:54:29,700 --> 00:54:27,760
we can both telescopes can be observing

1378
00:54:32,880 --> 00:54:29,710
the same thing and get data from the

1379
00:54:34,110 --> 00:54:32,890
different instruments and I you know my

1380
00:54:36,210 --> 00:54:34,120
instinct is that we're going to be able

1381
00:54:38,940 --> 00:54:36,220
to operate longer than 20 20 and

1382
00:54:42,960 --> 00:54:38,950
certainly as instruments dyers the gyros

1383
00:54:45,120 --> 00:54:42,970
die um the capabilities might be lower

1384
00:54:47,010 --> 00:54:45,130
than they are right now and but we have

1385
00:54:49,680 --> 00:54:47,020
a lot of contingency built-in we have a

1386
00:54:51,870 --> 00:54:49,690
lot of engineers working on all sorts of

1387
00:54:54,300 --> 00:54:51,880
life extension projects to keep Hubble

1388
00:54:56,100 --> 00:54:54,310

going just as long as we possibly can so

1389

00:54:58,170 --> 00:54:56,110

what about the second part of that

1390

00:54:59,760 --> 00:54:58,180

question why would it stop being usable

1391

00:55:03,390 --> 00:54:59,770

what are some of the things that would

1392

00:55:05,640 --> 00:55:03,400

make it no not not a thing we can use

1393

00:55:07,980 --> 00:55:05,650

anymore certainly like Mike said we have

1394

00:55:12,120 --> 00:55:07,990

science modes that can operate with 10

1395

00:55:15,060 --> 00:55:12,130

um so the gyros are 11 and if all of the

1396

00:55:17,040 --> 00:55:15,070

instruments end up having we've had some

1397

00:55:19,290 --> 00:55:17,050

power issues on the instruments

1398

00:55:21,990 --> 00:55:19,300

historically so if the instruments just

1399

00:55:24,990 --> 00:55:22,000

stop not being able to literally not get

1400

00:55:27,000 --> 00:55:25,000

power Mike we gave you one of the

1401

00:55:29,160 --> 00:55:27,010

doomsday scenarios of we go into a

1402

00:55:31,140 --> 00:55:29,170

regular safe mode we close the door so

1403

00:55:32,190 --> 00:55:31,150

there's lots of different things that

1404

00:55:33,839 --> 00:55:32,200

could go wrong

1405

00:55:36,630 --> 00:55:33,849

but we have multiple layers of

1406

00:55:39,390 --> 00:55:36,640

redundancy built in so we need lots of

1407

00:55:40,560 --> 00:55:39,400

problems Dalton well that leads me I'm

1408

00:55:41,700 --> 00:55:40,570

sorry to be rushing but I'm running out

1409

00:55:43,290 --> 00:55:41,710

of time I'll make sure I get some of

1410

00:55:45,660 --> 00:55:43,300

these that leads me to Tony Lynch's

1411

00:55:47,730 --> 00:55:45,670

question which is how do you this is

1412

00:55:50,190 --> 00:55:47,740

another limiting factor on Hubble how do

1413

00:55:52,740 --> 00:55:50,200

you keep Hubble in its actual altitude

1414

00:55:55,650 --> 00:55:52,750

in his orbital altitude how do we keep

1415

00:55:58,560 --> 00:55:55,660

it up there what do we do go it's a

1416

00:56:00,990 --> 00:55:58,570

quite it's just sitting up there it in

1417

00:56:03,240 --> 00:56:01,000

and it's actually slowly falling down I

1418

00:56:05,849 --> 00:56:03,250

mean the trouble is this thing has very

1419

00:56:07,950 --> 00:56:05,859

big wings on it and these things I mean

1420

00:56:09,900 --> 00:56:07,960

even though we're at yo 340 miles above

1421

00:56:12,120 --> 00:56:09,910

the atmosphere we get atmospheric drag

1422

00:56:14,609 --> 00:56:12,130

we are slowly coming down and there's

1423

00:56:17,640 --> 00:56:14,619

nothing we can do about that I mean you

1424

00:56:19,950 --> 00:56:17,650

know you that is the most life limiting

1425

00:56:21,750 --> 00:56:19,960

thing I mean what it will do or 'but and

1426

00:56:23,490 --> 00:56:21,760

so but that's out you know this

1427

00:56:25,680 --> 00:56:23,500

estimates now are pushing that out you

1428

00:56:28,620 --> 00:56:25,690

know 2035 something like that we come

1429

00:56:29,760 --> 00:56:28,630

down by ourselves right so and I think

1430

00:56:32,250 --> 00:56:29,770

the limit the outer limit on that

1431

00:56:36,569 --> 00:56:32,260

somewhere around the middle mid-2020s

1432

00:56:38,130 --> 00:56:36,579

where that might be a real problem so so

1433

00:56:42,270 --> 00:56:38,140

yeah so that that's another limiting

1434

00:56:43,829 --> 00:56:42,280

issue so here is let me just respond to

1435

00:56:45,359 --> 00:56:43,839

this comment shungo for is asking is

1436

00:56:47,370 --> 00:56:45,369

there any way to rewatch this once it's

1437

00:56:49,230 --> 00:56:47,380

over yes this will be archived on our

1438

00:56:51,150 --> 00:56:49,240

youtube channel hubble slight channel

1439

00:56:52,829 --> 00:56:51,160

which if you haven't subscribed you are

1440

00:56:55,650 --> 00:56:52,839

wrong you need to go over to youtube and

1441

00:56:58,010 --> 00:56:55,660

subscribe to our channel yeah I don't

1442

00:57:00,420 --> 00:56:58,020

feel how do you feel about that Tony

1443

00:57:01,890 --> 00:57:00,430

I'll subscribe that way you'll also be

1444

00:57:04,500 --> 00:57:01,900

notified of any future hangouts on air

1445

00:57:06,930 --> 00:57:04,510

and also wanted a shout out to we just

1446

00:57:09,630 --> 00:57:06,940

broke four million followers and Google+

1447

00:57:11,069 --> 00:57:09,640

so thank you all in Google+ and make

1448

00:57:13,620 --> 00:57:11,079

sure to follow us over at Twitter we're

1449

00:57:15,690 --> 00:57:13,630

at Hubble telescope yes thank you for

1450

00:57:18,120 --> 00:57:15,700

that Michael job in one final comment

1451

00:57:21,569 --> 00:57:18,130

and then so you don't torque with the

1452

00:57:24,930 --> 00:57:21,579

CMG's you don't torque on the CMG's with

1453

00:57:29,790 --> 00:57:24,940

actuators to move it CMG's what are

1454

00:57:31,859 --> 00:57:29,800

those i'm not sure but but no to move it

1455

00:57:34,230 --> 00:57:31,869

all because spin the wheels yeah you

1456

00:57:39,930 --> 00:57:34,240

just spin the wheels alligators cool

1457

00:57:41,339 --> 00:57:39,940

mini gremlins and Nnanji yeah i'm not

1458

00:57:43,349 --> 00:57:41,349

question what those are Michael but

1459

00:57:44,700 --> 00:57:43,359

thanks for that and so yeah there's the

1460

00:57:45,750 --> 00:57:44,710

momentum wheels that are there solely

1461

00:57:47,610 --> 00:57:45,760

responsible for moving

1462

00:57:48,660 --> 00:57:47,620

I I forgetting anything Scott that I

1463

00:57:51,450 --> 00:57:48,670

haven't looked at the queue at the

1464

00:57:54,720 --> 00:57:51,460

Hubble of the YouTube nope at the

1465

00:57:56,970 --> 00:57:54,730

YouTube I'm thinking the only thing here

1466

00:57:58,800 --> 00:57:56,980

Twitter actually has been great and a

1467

00:58:00,990 --> 00:57:58,810

lot of our questions has been and thank

1468

00:58:04,710 --> 00:58:01,000

what I need though you has been greater

1469

00:58:07,830 --> 00:58:04,720

on Twitter um la let's see here there's

1470

00:58:10,640 --> 00:58:07,840

more of comments you know so for you

1471

00:58:12,840 --> 00:58:10,650

guys for our amazing guests lots of

1472

00:58:15,090 --> 00:58:12,850

thankful comments and actually

1473

00:58:18,390 --> 00:58:15,100

understanding how Hubble works so this

1474

00:58:19,860 --> 00:58:18,400

one is from da roc caelius Hubble is a

1475

00:58:21,420 --> 00:58:19,870

beautiful series of instruments this

1476

00:58:24,090 --> 00:58:21,430

video is helping me to understand the

1477

00:58:26,060 --> 00:58:24,100

fascinating simplicity and complexity in

1478

00:58:30,360 --> 00:58:26,070

the structure of the telescope thank you

1479

00:58:33,270 --> 00:58:30,370

which also know that yes and I think

1480

00:58:37,200 --> 00:58:33,280

this is a good question maybe in general

1481

00:58:40,670 --> 00:58:37,210

this from Chris Marshall here it says if

1482

00:58:42,930 --> 00:58:40,680

there was see here if there was a

1483

00:58:46,020 --> 00:58:42,940

spacecraft available the service Hubble

1484

00:58:47,760 --> 00:58:46,030

again what changes would you make is

1485

00:58:52,110 --> 00:58:47,770

there anything you guys would would

1486

00:58:54,200 --> 00:58:52,120

change I'd get a new key number I've

1487

00:58:58,320 --> 00:58:54,210

been to a pentium class or something i

1488

00:59:00,720 --> 00:58:58,330

don't look not broken yeah that's a good

1489

00:59:03,360 --> 00:59:00,730

philosophy of those problems instruments

1490

00:59:04,830 --> 00:59:03,370

i mean the the ability to change of

1491

00:59:06,600 --> 00:59:04,840

science which means is really what has

1492

00:59:08,040 --> 00:59:06,610

given Hubble the long life in the

1493

00:59:11,250 --> 00:59:08,050

ability if you put a new science

1494

00:59:13,140 --> 00:59:11,260

instrument up there the whole new yep

1495

00:59:15,390 --> 00:59:13,150

that's what happened so if you could all

1496

00:59:17,340 --> 00:59:15,400

one thing up on Hubble even a say you

1497

00:59:19,080 --> 00:59:17,350

had lost half your gyros in one wheel

1498

00:59:20,400 --> 00:59:19,090

you would put a science instrument up

1499

00:59:23,010 --> 00:59:20,410

there because it's going to give you

1500

00:59:25,350 --> 00:59:23,020

more science um yeah and I would say

1501
00:59:26,910 --> 00:59:25,360
that if we were face well if we had an

1502
00:59:30,270 --> 00:59:26,920
opportunity to do that and we were

1503
00:59:31,950 --> 00:59:30,280
pretty confident that wife ocala 3 was

1504
00:59:33,960 --> 00:59:31,960
going to continue operation i think the

1505
00:59:37,950 --> 00:59:33,970
science community would like then maybe

1506
00:59:40,650 --> 00:59:37,960
to expand the UV capability because this

1507
00:59:42,450 --> 00:59:40,660
is the last telescope for a very long

1508
00:59:45,600 --> 00:59:42,460
time that we'll be able to look in the

1509
00:59:47,730 --> 00:59:45,610
ultraviolet so that we're going to lose

1510
00:59:49,890 --> 00:59:47,740
that capability when we use Hubble and

1511
00:59:51,660 --> 00:59:49,900
in fact we have noticed that the number

1512
00:59:55,110 --> 00:59:51,670
of there's a whole campaign but the

1513
00:59:58,350 --> 00:59:55,120

number of proposals that have gone in

1514

00:59:59,220 --> 00:59:58,360

have emphasized some of the ultraviolet

1515

01:00:00,810 --> 00:59:59,230

capability

1516

01:00:03,090 --> 01:00:00,820

but the great thing is to have the wide

1517

01:00:05,760 --> 01:00:03,100

field camera there not only with the you

1518

01:00:07,820 --> 01:00:05,770

biz but but the infrared capability as

1519

01:00:10,170 --> 01:00:07,830

well so it's it's all of that together

1520

01:00:11,730 --> 01:00:10,180

so we have to think as a science

1521

01:00:15,120 --> 01:00:11,740

community what really is the highest

1522

01:00:17,670 --> 01:00:15,130

priority so I guess Elena looked it up

1523

01:00:20,430 --> 01:00:17,680

and said CMG is control moment gyroscope

1524

01:00:22,830 --> 01:00:20,440

so I guess we just didn't hold it oh you

1525

01:00:26,310 --> 01:00:22,840

know yeah no I guess that's what that

1526

01:00:27,570 --> 01:00:26,320

CMG is okay well I think that's all of

1527

01:00:29,910 --> 01:00:27,580

it I think that will conclude this

1528

01:00:31,020 --> 01:00:29,920

week's this week's hanging out I want to

1529

01:00:32,060 --> 01:00:31,030

thank everybody for watch I want to

1530

01:00:34,920 --> 01:00:32,070

thank our guests you guys were awesome

1531

01:00:36,300 --> 01:00:34,930

so thank you all this was a lot of fun

1532

01:00:37,320 --> 01:00:36,310

I've been dying to learn about the nuts

1533

01:00:39,570 --> 01:00:37,330

and bolts of the Hubble Space Telescope

1534

01:00:41,099 --> 01:00:39,580

and how its operated so thank you all

1535

01:00:45,300 --> 01:00:41,109

thank you all for taking the time out to

1536

01:00:49,470 --> 01:00:45,310

join us from Goddard and Carol next week

1537

01:00:52,770 --> 01:00:49,480

all it says is a bill 2744 Z equals 10

1538

01:00:54,960 --> 01:00:52,780

that's that's a frontier fields frontier

1539

01:00:59,280 --> 01:00:54,970

fields is that a discovery of a very

1540

01:01:01,170 --> 01:00:59,290

very distant galaxies using not only the

1541

01:01:02,940 --> 01:01:01,180

standard techniques of measuring its

1542

01:01:06,540 --> 01:01:02,950

color because we can't measure its

1543

01:01:09,690 --> 01:01:06,550

spectrum but it's also studying the lens

1544

01:01:11,790 --> 01:01:09,700

model and that this object was found by

1545

01:01:15,510 --> 01:01:11,800

examining the lens mom so we'll be able

1546

01:01:16,920 --> 01:01:15,520

to really talk about okay we did these

1547

01:01:18,960 --> 01:01:16,930

clusters we know their gravitational

1548

01:01:20,640 --> 01:01:18,970

lenses now how do you model that and

1549

01:01:23,070 --> 01:01:20,650

what can you learn so it could all be

1550

01:01:26,940 --> 01:01:23,080

pretty cool I also tune in to see what Z

1551

01:01:32,160 --> 01:01:26,950

equals 10 mins so we means it really far

1552

01:01:33,720 --> 01:01:32,170

away that really far away we'll get a

1553

01:01:36,390 --> 01:01:33,730

frontier fields update next week on

1554

01:01:38,520 --> 01:01:36,400

Thursday three o'clock eastern time so

1555

01:01:42,500 --> 01:01:38,530

we hope you guys a little tune in thank