
EPISODE 2
AN UNEXPECTED JOURNEY

1
00:00:10,310 --> 00:00:08,070
we have locked and we're going to send

2
00:00:11,910 --> 00:00:10,320
that command

3
00:00:12,870 --> 00:00:11,920
31 minutes and 32 seconds for our

4
00:00:15,270 --> 00:00:12,880
support

5
00:00:17,830 --> 00:00:15,280
[Music]

6
00:00:20,070 --> 00:00:17,840
go for stat spot for dump

7
00:00:22,390 --> 00:00:20,080
because the hubble space telescope is so

8
00:00:24,950 --> 00:00:22,400
scientifically effective right now

9
00:00:26,950 --> 00:00:24,960
scientists are using hubble to

10
00:00:29,269 --> 00:00:26,960
investigate some of the deepest

11
00:00:30,950 --> 00:00:29,279
mysteries of the universe

12
00:00:33,110 --> 00:00:30,960
one of the primary things hubble has

13
00:00:35,430 --> 00:00:33,120

been doing is looking at the atmospheres

14
00:00:36,950 --> 00:00:35,440
around exoplanets

15
00:00:38,389 --> 00:00:36,960
if you had asked the guys who built

16
00:00:41,590 --> 00:00:38,399
hubble and design hubble they would have

17
00:00:42,869 --> 00:00:41,600
sworn hubble could never ever do this

18
00:00:45,430 --> 00:00:42,879
that's one of the things i love about

19
00:00:53,480 --> 00:00:45,440
hubble is that it ends up giving us new

20
00:00:53,490 --> 00:00:57,430
[Music]

21
00:01:02,310 --> 00:00:59,670
my name is larry dunham i'm the chief

22
00:01:04,710 --> 00:01:02,320
systems engineer for flight systems here

23
00:01:06,950 --> 00:01:04,720
on the hubble space telescope

24
00:01:09,270 --> 00:01:06,960
i started on the hubble program back in

25
00:01:10,830 --> 00:01:09,280
the summer of 1982 when hubble was being

26
00:01:14,070 --> 00:01:10,840
built out in

27
00:01:15,830 --> 00:01:14,080
california first telescope in space to

28
00:01:18,149 --> 00:01:15,840
be designed so that we've got what we

29
00:01:20,469 --> 00:01:18,159
call orbital replacement units there are

30
00:01:22,630 --> 00:01:20,479
modular boxes with handrails on them so

31
00:01:24,630 --> 00:01:22,640
the astronauts can go up and just pick

32
00:01:25,990 --> 00:01:24,640
and play they've got nice connectors on

33
00:01:28,070 --> 00:01:26,000
them that make it easy for the

34
00:01:31,670 --> 00:01:28,080
astronauts with their big gloves to be

35
00:01:36,630 --> 00:01:34,149
we've had five servicing missions

36
00:01:37,670 --> 00:01:36,640
we have replaced some equipment multiple

37
00:01:39,510 --> 00:01:37,680
times

38
00:01:42,789 --> 00:01:39,520

especially the instruments we're always

39
00:01:45,749 --> 00:01:42,799
going with the advanced technology

40
00:01:47,350 --> 00:01:45,759
the telescope we have today on orbit is

41
00:01:48,550 --> 00:01:47,360
not the telescope that we launched

42
00:01:50,789 --> 00:01:48,560
originally

43
00:01:52,950 --> 00:01:50,799
we've been able to replace all five of

44
00:01:54,389 --> 00:01:52,960
our science instruments with instruments

45
00:01:56,389 --> 00:01:54,399
that have the technology that didn't

46
00:01:58,149 --> 00:01:56,399
even exist when hubble was being built

47
00:02:00,830 --> 00:01:58,159
originally

48
00:02:03,830 --> 00:02:00,840
the hubble space telescope is really an

49
00:02:05,749 --> 00:02:03,840
observatory because it has several

50
00:02:08,469 --> 00:02:05,759
science instruments several modes of

51
00:02:10,469 --> 00:02:08,479
operation we have multiple cameras

52
00:02:12,309 --> 00:02:10,479
multiple spectrographs they each have

53
00:02:14,309 --> 00:02:12,319
different capabilities in terms of their

54
00:02:16,390 --> 00:02:14,319
sensitivities or the kinds of

55
00:02:18,790 --> 00:02:16,400
frequencies they can receive the

56
00:02:20,869 --> 00:02:18,800
electromagnetic spectrum we can also use

57
00:02:22,869 --> 00:02:20,879
hubble in different kinds of intriguing

58
00:02:24,790 --> 00:02:22,879
modes depending on what we're trying to

59
00:02:26,710 --> 00:02:24,800
observe there are different types of

60
00:02:28,070 --> 00:02:26,720
observing scenarios and one of the

61
00:02:29,510 --> 00:02:28,080
things the scientists have been able to

62
00:02:31,589 --> 00:02:29,520
do is they've been able to come up with

63
00:02:32,949 --> 00:02:31,599

very interesting and unique observing

64
00:02:34,229 --> 00:02:32,959
scenarios that allowed them to do

65
00:02:37,270 --> 00:02:34,239
science that they never thought they

66
00:02:39,990 --> 00:02:37,280
could do before because the hubble space

67
00:02:42,949 --> 00:02:40,000
telescope has been operating for a long

68
00:02:45,910 --> 00:02:42,959
time it's giving us what we need to

69
00:02:47,430 --> 00:02:45,920
explore the universe in deep ways that

70
00:02:49,270 --> 00:02:47,440
would never have been possible when

71
00:02:52,070 --> 00:02:49,280
hubble was first launched

72
00:02:54,390 --> 00:02:52,080
for example scientists wondered whether

73
00:02:56,390 --> 00:02:54,400
we could use hubble in an innovative

74
00:02:59,910 --> 00:02:56,400
mode in recent years

75
00:03:02,070 --> 00:02:59,920
basically scanning objects slowly

76
00:03:04,710 --> 00:03:02,080
instead of just staring at them in some

77
00:03:06,790 --> 00:03:04,720
cases that gives us a higher sensitivity

78
00:03:08,790 --> 00:03:06,800
to what we're trying to observe

79
00:03:10,790 --> 00:03:08,800
and we're using that special mode on

80
00:03:13,350 --> 00:03:10,800
hubble now to get better information

81
00:03:16,550 --> 00:03:13,360
about many types of things in space

82
00:03:18,550 --> 00:03:16,560
including to be able to study planets

83
00:03:20,949 --> 00:03:18,560
around other stars what we call

84
00:03:22,630 --> 00:03:20,959
exoplanets planets outside of our own

85
00:03:24,309 --> 00:03:22,640
solar system

86
00:03:26,789 --> 00:03:24,319
what hubble's been able to do is as the

87
00:03:28,789 --> 00:03:26,799
planets go in front of the stars that

88
00:03:31,350 --> 00:03:28,799

they're going around the spectrographs

89
00:03:33,990 --> 00:03:31,360
can detect changes very small changes in

90
00:03:36,949 --> 00:03:34,000
the spectrum this has allowed them to do

91
00:03:38,390 --> 00:03:36,959
exoplanet atmospheric studies

92
00:03:40,229 --> 00:03:38,400
this is something that hubble has sort

93
00:03:43,190 --> 00:03:40,239
of really stepped up to the plate and

94
00:03:44,550 --> 00:03:43,200
has been just phenomenally good at

95
00:03:45,910 --> 00:03:44,560
spectrographs have really sort of been

96
00:03:47,990 --> 00:03:45,920
leading that if you ever see things

97
00:03:48,869 --> 00:03:48,000
about oh a new exoplanet we discovered

98
00:03:50,309 --> 00:03:48,879
that has

99
00:03:52,229 --> 00:03:50,319
this in the atmosphere or that in the

100
00:03:53,750 --> 00:03:52,239
atmosphere we think it's made of this

101
00:03:55,990 --> 00:03:53,760
it's the spectrographs which have shown

102
00:03:57,589 --> 00:03:56,000
you that kind of information

103
00:03:59,030 --> 00:03:57,599
for doing a lot of the exoplanet

104
00:04:01,030 --> 00:03:59,040
observations you have to catch what's

105
00:04:03,429 --> 00:04:01,040
known as the transit one the orbit of

106
00:04:05,589 --> 00:04:03,439
the exoplanet has to be such that it's

107
00:04:07,270 --> 00:04:05,599
going to go between you in the star it's

108
00:04:08,869 --> 00:04:07,280
going around

109
00:04:10,789 --> 00:04:08,879
we can't just do an exoplanet

110
00:04:12,470 --> 00:04:10,799
observation whenever we want or whenever

111
00:04:14,710 --> 00:04:12,480
it's convenient we have to do an

112
00:04:16,789 --> 00:04:14,720
exoplanet observation when it's first

113
00:04:18,949 --> 00:04:16,799

starting to go into the star

114
00:04:20,710 --> 00:04:18,959
so they have to know very accurately the

115
00:04:22,469 --> 00:04:20,720
timing of that we have to schedule it

116
00:04:24,469 --> 00:04:22,479
ahead of time this is not something that

117
00:04:26,629 --> 00:04:24,479
hubble can get around to when it wants

118
00:04:28,790 --> 00:04:26,639
to we have to say no at this point in

119
00:04:30,550 --> 00:04:28,800
time on this date you have to be pointed

120
00:04:32,310 --> 00:04:30,560
here and you have to be looking here

121
00:04:34,150 --> 00:04:32,320
we had to really think about how to

122
00:04:35,350 --> 00:04:34,160
schedule this a lot of thought goes into

123
00:04:38,390 --> 00:04:35,360
it a lot of thought goes into the

124
00:04:40,710 --> 00:04:38,400
planning end of the execution

125
00:04:42,870 --> 00:04:40,720
the hubble operations team are quite

126
00:04:45,830 --> 00:04:42,880
willing and capable of

127
00:04:48,070 --> 00:04:45,840
using the telescope in new modes and new

128
00:04:49,749 --> 00:04:48,080
innovative ways that enable us to

129
00:04:53,110 --> 00:04:49,759
accomplish science that we wouldn't

130
00:04:55,510 --> 00:04:53,120
otherwise be able to accomplish

131
00:04:58,390 --> 00:04:55,520
we asked them would it be possible to

132
00:05:00,790 --> 00:04:58,400
use hubble to track something moving

133
00:05:03,110 --> 00:05:00,800
quickly across the sky and they figured

134
00:05:05,189 --> 00:05:03,120
out a way to use hubble in a vast

135
00:05:07,189 --> 00:05:05,199
tracking mode that enabled us to do

136
00:05:09,510 --> 00:05:07,199
explorations and discoveries that

137
00:05:12,550 --> 00:05:09,520
astronomers didn't envision using hubble

138
00:05:14,150 --> 00:05:12,560

for when it was first designed

139
00:05:15,990 --> 00:05:14,160
now when we're observing our planets

140
00:05:18,870 --> 00:05:16,000
when we're observing jupiter or saturn

141
00:05:20,310 --> 00:05:18,880
or or uranus or neptune

142
00:05:21,510 --> 00:05:20,320
they move also we have to move the

143
00:05:22,870 --> 00:05:21,520
telescope because they're just going

144
00:05:24,310 --> 00:05:22,880
around the sun they're actually moving

145
00:05:26,150 --> 00:05:24,320
because they're really moving so we have

146
00:05:28,230 --> 00:05:26,160
to move with them we're observing

147
00:05:30,240 --> 00:05:28,240
asteroids or comets we have to chase

148
00:05:32,469 --> 00:05:30,250
after them

149
00:05:34,790 --> 00:05:32,479
[Music]

150
00:05:37,749 --> 00:05:34,800
we know came from outside of our solar

151
00:05:39,350 --> 00:05:37,759
system is like a big asteroid that was

152
00:05:41,590 --> 00:05:39,360
detected quizzing through our solar

153
00:05:43,830 --> 00:05:41,600
system we wanted to use hubble to

154
00:05:46,390 --> 00:05:43,840
observe this as well and we were able to

155
00:05:47,830 --> 00:05:46,400
track it this is not a simple operation

156
00:05:49,749 --> 00:05:47,840
it's moving at more than a hundred

157
00:05:52,150 --> 00:05:49,759
thousand miles an hour so being able to

158
00:05:55,110 --> 00:05:52,160
observe this and track it is a wonderful

159
00:05:57,350 --> 00:05:55,120
capability that the operations team has

160
00:05:59,909 --> 00:05:57,360
enabled hubble to have

161
00:06:02,390 --> 00:05:59,919
the telescope is big it's massive it

162
00:06:03,909 --> 00:06:02,400
moves about the same speed as the minute

163
00:06:06,150 --> 00:06:03,919

hand on a clock

164
00:06:07,670 --> 00:06:06,160
so to move from pointing one thing to go

165
00:06:10,150 --> 00:06:07,680
completely around the other one takes us

166
00:06:11,050 --> 00:06:10,160
a half an hour it is not a very fast

167
00:06:12,309 --> 00:06:11,060
motion

168
00:06:13,990 --> 00:06:12,319
[Music]

169
00:06:16,230 --> 00:06:14,000
we actually use a very interesting

170
00:06:18,150 --> 00:06:16,240
technique it's using newton's third law

171
00:06:20,230 --> 00:06:18,160
we have these very large reaction wheels

172
00:06:22,790 --> 00:06:20,240
on it they're about two feet across very

173
00:06:24,550 --> 00:06:22,800
very heavy very very massive wheels

174
00:06:26,710 --> 00:06:24,560
if you start spinning those wheels one

175
00:06:29,189 --> 00:06:26,720
way the telescope will spin a little bit

176
00:06:30,950 --> 00:06:29,199
in the opposite direction

177
00:06:32,629 --> 00:06:30,960
this is how we can move the telescope

178
00:06:35,350 --> 00:06:32,639
from one part of the sky to another part

179
00:06:36,950 --> 00:06:35,360
of the sky once we've moved the reaction

180
00:06:38,550 --> 00:06:36,960
wheels and we've moved the telescopes

181
00:06:40,870 --> 00:06:38,560
we're in the right spot now we have to

182
00:06:43,029 --> 00:06:40,880
get in the exact location to put the

183
00:06:45,830 --> 00:06:43,039
target in the science instrument

184
00:06:49,430 --> 00:06:47,430
what's going to happen now is where the

185
00:06:51,589 --> 00:06:49,440
fgs's are going to start talking to the

186
00:06:53,670 --> 00:06:51,599
telescope talking to the flight software

187
00:06:56,070 --> 00:06:53,680
computer and saying i want you to move

188
00:06:58,070 --> 00:06:56,080

the telescope over here a little bit to

189
00:06:59,990 --> 00:06:58,080
be able to position the science for the

190
00:07:01,990 --> 00:07:00,000
science aperture

191
00:07:04,469 --> 00:07:02,000
most of the time we use the hubble space

192
00:07:06,870 --> 00:07:04,479
telescope to do observations that have

193
00:07:08,710 --> 00:07:06,880
been planned quite a bit in advance

194
00:07:11,510 --> 00:07:08,720
observers around the world astronomers

195
00:07:13,990 --> 00:07:11,520
will write proposals we will then take

196
00:07:15,749 --> 00:07:14,000
those accepted proposals and observe

197
00:07:17,909 --> 00:07:15,759
whatever it is that the astronomer has

198
00:07:21,589 --> 00:07:17,919
proposed but sometimes there are things

199
00:07:24,309 --> 00:07:21,599
that happen that are unexpected or

200
00:07:25,670 --> 00:07:24,319
rapid events that we need a more rapid

201
00:07:28,390 --> 00:07:25,680
response

202
00:07:31,029 --> 00:07:28,400
we have a capability of what we call a

203
00:07:32,070 --> 00:07:31,039
target of opportunity and that's when

204
00:07:34,550 --> 00:07:32,080
something

205
00:07:37,189 --> 00:07:34,560
unexpected happens in the universe that

206
00:07:39,589 --> 00:07:37,199
astronomers they want to immediately

207
00:07:41,830 --> 00:07:39,599
jump on that as fast as possible with

208
00:07:44,710 --> 00:07:41,840
hubble case in point was the

209
00:07:46,790 --> 00:07:44,720
gravitational wave detection to neutron

210
00:07:49,110 --> 00:07:46,800
stars colliding

211
00:07:51,909 --> 00:07:49,120
a target of opportunity was submitted

212
00:07:53,589 --> 00:07:51,919
for hubble to actually go look at the

213
00:07:55,140 --> 00:07:53,599

remnant

214
00:07:56,629 --> 00:07:55,150
and see if we could find it

215
00:07:58,309 --> 00:07:56,639
[Music]

216
00:08:00,550 --> 00:07:58,319
we had the engineers run through it we

217
00:08:02,550 --> 00:08:00,560
got new commanding sequences from the

218
00:08:04,150 --> 00:08:02,560
space telescope science institute we're

219
00:08:06,070 --> 00:08:04,160
able to run all that through and then we

220
00:08:08,790 --> 00:08:06,080
execute it on orbit

221
00:08:13,029 --> 00:08:08,800
we have to respond very fast we produce

222
00:08:14,950 --> 00:08:13,039
a new schedule and set of command loads

223
00:08:17,350 --> 00:08:14,960
we can modify a lot of the flight

224
00:08:19,749 --> 00:08:17,360
software modify how the instruments are

225
00:08:23,589 --> 00:08:19,759
commanded it allows us to change we can

226
00:08:27,670 --> 00:08:26,070
what hubble has done compared to what we

227
00:08:30,309 --> 00:08:27,680
were thinking hubble could do is just

228
00:08:32,070 --> 00:08:30,319
amazing hubble's had its fingers in a

229
00:08:33,190 --> 00:08:32,080
almost everything a neutron star

230
00:08:35,430 --> 00:08:33,200
collision

231
00:08:37,430 --> 00:08:35,440
looking for all the supernova

232
00:08:39,430 --> 00:08:37,440
all this stuff going on with dark matter

233
00:08:41,750 --> 00:08:39,440
dark energy exoplanets

234
00:08:43,430 --> 00:08:41,760
hubble has just been constantly finding

235
00:08:44,710 --> 00:08:43,440
new things now we're looking at these

236
00:08:47,590 --> 00:08:44,720
interstellar comets and these

237
00:08:50,790 --> 00:08:47,600
interstellar asteroids visiting us

238
00:08:52,710 --> 00:08:50,800

it's really been spectacular to watch

239
00:08:55,430 --> 00:08:52,720
there really are two key aspects to

240
00:08:57,269 --> 00:08:55,440
hubble's design that have enabled us to

241
00:08:59,670 --> 00:08:57,279
last the 30 years that we have and that

242
00:09:01,590 --> 00:08:59,680
is really the redundancy that we have on

243
00:09:03,670 --> 00:09:01,600
board and then it's the servicing

244
00:09:05,829 --> 00:09:03,680
putting in new and improved instruments

245
00:09:08,070 --> 00:09:05,839
and being able to improve the hardware

246
00:09:10,470 --> 00:09:08,080
with lessons learned over the 30 years

247
00:09:12,150 --> 00:09:10,480
of hubble operations we are now at our

248
00:09:15,110 --> 00:09:12,160
peak performance

249
00:09:17,350 --> 00:09:15,120
the hubble space telescope has had a

250
00:09:19,190 --> 00:09:17,360
profound impact

251
00:09:22,630 --> 00:09:19,200
not only on astronomy

252
00:09:25,190 --> 00:09:22,640
it showed that humans in space and

253
00:09:28,389 --> 00:09:25,200
science can go hand in hand

254
00:09:30,630 --> 00:09:28,399
to enable us to explore space in richer

255
00:09:33,030 --> 00:09:30,640
ways than we could ever do with either

256
00:09:35,269 --> 00:09:33,040
just astronauts alone or just with

257
00:09:36,790 --> 00:09:35,279
instrumentation alone by using these

258
00:09:39,509 --> 00:09:36,800
skills together

259
00:09:41,509 --> 00:09:39,519
new vistas of exploration are open to us

260
00:09:43,350 --> 00:09:41,519
and that lesson is something we're still

261
00:09:47,590 --> 00:09:43,360
benefiting from as we envision future

262
00:09:51,509 --> 00:09:48,829
okay

263
00:09:53,509 --> 00:09:51,519

charlie it's amazing with a program

264
00:09:55,269 --> 00:09:53,519
that's lasted the duration that hubble

265
00:09:57,030 --> 00:09:55,279
has lasted that the astronomers up at

266
00:09:58,790 --> 00:09:57,040
the space telescope science institute

267
00:10:00,949 --> 00:09:58,800
continue to come up with new things that

268
00:10:02,550 --> 00:10:00,959
they want to try to do with hubble and

269
00:10:04,069 --> 00:10:02,560
we certainly hope that we'll be able to

270
00:10:06,710 --> 00:10:04,079
continue to provide that kind of

271
00:10:08,140 --> 00:10:06,720
capability to them into the late 2020s

272
00:10:09,130 --> 00:10:08,150
and beyond

273
00:10:11,370 --> 00:10:09,140
[Music]

274
00:10:21,030 --> 00:10:11,380
[Applause]