Servicing in Space

25 Years of Challenges and Achievements

From NASA's Goddard Space Flight Center, Greenbelt, MD

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1
00:00:16,630 --> 00:00:15,030
hey we're live at nasa's goddard space

2
00:00:18,710 --> 00:00:16,640
flight center and we are inside of the

3
00:00:20,390 --> 00:00:18,720
robotics operations center if you look

4
00:00:23,509 --> 00:00:20,400
around there's some of the tools and

5
00:00:24,870 --> 00:00:23,519
technology in here that is for robotic

6
00:00:27,109 --> 00:00:24,880
servicing so

7
00:00:29,830 --> 00:00:27,119
we're celebrating 25 years of hubble

8
00:00:32,069 --> 00:00:29,840
servicing today 25 years ago the first

9
00:00:34,389 --> 00:00:32,079
astronaut mission to the hubble space

10
00:00:37,510 --> 00:00:34,399
telescope to service the telescope and

11
00:00:39,110 --> 00:00:37,520
upgrade its components launched and

12
00:00:42,310 --> 00:00:39,120
we're here to talk all about it and

13
00:00:43,510 --> 00:00:42,320

serve satellite servicing past present

14
00:00:45,190 --> 00:00:43,520
and future

15
00:00:47,510 --> 00:00:45,200
so you may be wondering

16
00:00:49,190 --> 00:00:47,520
what is satellite servicing the same way

17
00:00:51,189 --> 00:00:49,200
you take your car in to get service to

18
00:00:53,830 --> 00:00:51,199
get the tires rotated to get the oil

19
00:00:56,310 --> 00:00:53,840
change or even just to fuel up sometimes

20
00:00:57,110 --> 00:00:56,320
our satellites in space need a little

21
00:00:59,750 --> 00:00:57,120
help

22
00:01:02,869 --> 00:00:59,760
and that's where we've got astronauts

23
00:01:04,390 --> 00:01:02,879
and tools and robotics they all come in

24
00:01:06,789 --> 00:01:04,400
i'm sure you've got a ton of questions

25
00:01:08,630 --> 00:01:06,799
and i do too send them into the hashtag

26
00:01:11,830 --> 00:01:08,640
ask nasa we're streaming live from

27
00:01:13,510 --> 00:01:11,840
facebook twitter instagram and twitch so

28
00:01:15,429 --> 00:01:13,520
start sending them on in we've got our

29
00:01:17,990 --> 00:01:15,439
first guest here today you may have

30
00:01:20,390 --> 00:01:18,000
heard of him his name is charlie bolden

31
00:01:22,310 --> 00:01:20,400
he's a hubble astronaut and he is also

32
00:01:23,749 --> 00:01:22,320
the former administrator of nasa erin

33
00:01:25,109 --> 00:01:23,759
how you doing good to be good to be here

34
00:01:26,950 --> 00:01:25,119
with you i'm so happy to have you thank

35
00:01:28,950 --> 00:01:26,960
you thank you thank you so first and

36
00:01:31,109 --> 00:01:28,960
foremost can we explain to our audience

37
00:01:32,550 --> 00:01:31,119
why we even put satellites into space in

38
00:01:34,310 --> 00:01:32,560

the first place yeah i think most people

39
00:01:35,990 --> 00:01:34,320
are aware of the fact that we use

40
00:01:38,789 --> 00:01:36,000
satellites today everybody thinks about

41
00:01:40,710 --> 00:01:38,799
tv but far more than that we use it for

42
00:01:42,469 --> 00:01:40,720
disaster planning and relief we use it

43
00:01:43,910 --> 00:01:42,479
to help farmers

44
00:01:45,990 --> 00:01:43,920
when they're trying to figure out how

45
00:01:48,230 --> 00:01:46,000
much to water their fields we can get

46
00:01:51,190 --> 00:01:48,240
that data through satellites very simple

47
00:01:52,389 --> 00:01:51,200
things like making your fitbit work and

48
00:01:54,870 --> 00:01:52,399
other kinds of stuff that's all

49
00:01:57,429 --> 00:01:54,880
satellite data and what we've done over

50
00:01:59,830 --> 00:01:57,439
the years is made satellites more and

51
00:02:02,310 --> 00:01:59,840
more capable as you mentioned earlier in

52
00:02:04,389 --> 00:02:02,320
your in your intro such that they do a

53
00:02:06,389 --> 00:02:04,399
lot of the work that we want humans to

54
00:02:08,869 --> 00:02:06,399
be able to do but we don't want to put

55
00:02:11,350 --> 00:02:08,879
the humans at risk so so satellites and

56
00:02:13,750 --> 00:02:11,360
robotic devices have enabled us to get

57
00:02:15,190 --> 00:02:13,760
into places where if it weren't for the

58
00:02:17,270 --> 00:02:15,200
satellite we probably have to send a

59
00:02:18,869 --> 00:02:17,280
human there to get the answers we want

60
00:02:19,990 --> 00:02:18,879
so um

61
00:02:21,910 --> 00:02:20,000
hubble

62
00:02:24,070 --> 00:02:21,920
was designed to be serviced and we sent

63
00:02:26,630 --> 00:02:24,080

astronauts up five different times to do

64
00:02:28,869 --> 00:02:26,640
so what exactly does a human servicing

65
00:02:31,030 --> 00:02:28,879
mission look like well

66
00:02:32,869 --> 00:02:31,040
i i did not fly on one of the servicing

67
00:02:36,070 --> 00:02:32,879
missions the unfortunate thing was i was

68
00:02:37,910 --> 00:02:36,080
the pilot on sts-31 when we left hubble

69
00:02:39,509 --> 00:02:37,920
needing to be serviced when we found out

70
00:02:41,910 --> 00:02:39,519
that it had this thing called a

71
00:02:44,710 --> 00:02:41,920
spherical aberration that that caused it

72
00:02:46,550 --> 00:02:44,720
to need glasses like i do and so we came

73
00:02:48,869 --> 00:02:46,560
up with a device called costar that was

74
00:02:50,869 --> 00:02:48,879
a big telephone booth looking set of

75
00:02:53,110 --> 00:02:50,879
optics that we were able to send the

76
00:02:55,110 --> 00:02:53,120
very first servicing crew up

77
00:02:56,869 --> 00:02:55,120
remove some of the old instruments put

78
00:02:59,350 --> 00:02:56,879
the new optics in

79
00:03:02,070 --> 00:02:59,360
replace the solar arrays and get it to

80
00:03:04,630 --> 00:03:02,080
working and seeing the way that it was

81
00:03:06,390 --> 00:03:04,640
intended to to see when we first sent it

82
00:03:08,470 --> 00:03:06,400
up there so that was the the first

83
00:03:10,630 --> 00:03:08,480
purpose of the initial servicing mission

84
00:03:11,509 --> 00:03:10,640
and that didn't happen terribly long

85
00:03:14,149 --> 00:03:11,519
after

86
00:03:15,430 --> 00:03:14,159
launched three years yeah it depends on

87
00:03:17,110 --> 00:03:15,440
how you look at it if you look at it

88
00:03:19,430 --> 00:03:17,120

from the standpoint of nasa and the

89
00:03:21,430 --> 00:03:19,440
astronomers and astrophysicists who were

90
00:03:24,149 --> 00:03:21,440
waiting to get data from hubble it took

91
00:03:25,750 --> 00:03:24,159
way too long if you're from some the

92
00:03:27,910 --> 00:03:25,760
perspective of somebody here at goddard

93
00:03:29,509 --> 00:03:27,920
who's planning all the mission

94
00:03:31,270 --> 00:03:29,519
it was pretty quick

95
00:03:33,110 --> 00:03:31,280
you know trying to figure out what we

96
00:03:34,949 --> 00:03:33,120
needed to do what kind of tools we

97
00:03:36,869 --> 00:03:34,959
needed to come up with the good thing

98
00:03:38,149 --> 00:03:36,879
was we had people you're going to talk

99
00:03:40,309 --> 00:03:38,159
to a couple of them jeff hoffman and

100
00:03:42,869 --> 00:03:40,319
john grunsfeld later who had been with

101
00:03:45,110 --> 00:03:42,879
hubble years before we first flew it and

102
00:03:46,470 --> 00:03:45,120
had already envisioned the kind of tools

103
00:03:48,789 --> 00:03:46,480
that you would need if you're going to

104
00:03:50,470 --> 00:03:48,799
do certain operations that are more than

105
00:03:52,390 --> 00:03:50,480
likely going to be needed changing our

106
00:03:54,390 --> 00:03:52,400
batteries changing gyros changing the

107
00:03:56,390 --> 00:03:54,400
solar rays so some of those tools were

108
00:03:58,630 --> 00:03:56,400
already in place co-star was not in

109
00:04:01,589 --> 00:03:58,640
anybody's plan so

110
00:04:03,350 --> 00:04:01,599
you know the folk over here got to work

111
00:04:05,030 --> 00:04:03,360
and that's what took the extra time was

112
00:04:05,990 --> 00:04:05,040
actually designing the new tools we were

113
00:04:08,390 --> 00:04:06,000

going to me

114
00:04:09,910 --> 00:04:08,400
need and the the tactics techniques and

115
00:04:11,110 --> 00:04:09,920
procedures if you will that the

116
00:04:12,949 --> 00:04:11,120
astronauts were going to follow when

117
00:04:15,589 --> 00:04:12,959
they finally got to the telescope

118
00:04:17,990 --> 00:04:15,599
so you actually have a very interesting

119
00:04:20,150 --> 00:04:18,000
history with nasa so you're an astronaut

120
00:04:21,509 --> 00:04:20,160
you deployed hubble you know you were

121
00:04:22,870 --> 00:04:21,519
part of that mission and then you were

122
00:04:23,830 --> 00:04:22,880
also the administrator so tell us a

123
00:04:25,830 --> 00:04:23,840
little bit about

124
00:04:27,110 --> 00:04:25,840
your experience sometimes i think the

125
00:04:29,270 --> 00:04:27,120
president looked back and said who had

126
00:04:31,590 --> 00:04:29,280
done the worst of causing us trouble

127
00:04:33,830 --> 00:04:31,600
let's let him fix him but i was

128
00:04:36,469 --> 00:04:33,840
privileged to serve for almost all eight

129
00:04:38,230 --> 00:04:36,479
years of president obama's term as uh as

130
00:04:39,830 --> 00:04:38,240
the nasa administrator and during that

131
00:04:40,870 --> 00:04:39,840
period of time or leading up to it

132
00:04:42,790 --> 00:04:40,880
actually

133
00:04:45,909 --> 00:04:42,800
i had an opportunity to spend a lot of

134
00:04:47,749 --> 00:04:45,919
time here at goddard uh actually sit in

135
00:04:50,469 --> 00:04:47,759
on be briefed on a lot of the the

136
00:04:52,230 --> 00:04:50,479
robotic missions that we wanted to fly

137
00:04:53,990 --> 00:04:52,240
things like restore el that are here

138
00:04:55,670 --> 00:04:54,000

where we were actually going to go up

139
00:04:57,350 --> 00:04:55,680
and service a satellite that maybe

140
00:04:58,950 --> 00:04:57,360
needed to be refueled needed to be

141
00:05:00,870 --> 00:04:58,960
serviced because some component wasn't

142
00:05:02,550 --> 00:05:00,880
working and so we got to see quite a bit

143
00:05:03,990 --> 00:05:02,560
of that during my tenure as the nasa

144
00:05:05,350 --> 00:05:04,000
administrator it was quite interesting

145
00:05:06,550 --> 00:05:05,360
and challenging

146
00:05:08,870 --> 00:05:06,560
so

147
00:05:11,510 --> 00:05:08,880
the last servicing mission yeah i

148
00:05:13,510 --> 00:05:11,520
understand that there was a maybe do

149
00:05:15,350 --> 00:05:13,520
maybe don't situation tell us a little

150
00:05:17,909 --> 00:05:15,360
bit again it seems like i pop up in the

151
00:05:20,710 --> 00:05:17,919
strangest places right after i retired

152
00:05:23,189 --> 00:05:20,720
from from the marine corps in 2003

153
00:05:25,430 --> 00:05:23,199
unfortunately the next month we had the

154
00:05:27,029 --> 00:05:25,440
columbia accident and that caused the

155
00:05:28,710 --> 00:05:27,039
president the nasa administrator at the

156
00:05:30,390 --> 00:05:28,720
time to cancel

157
00:05:31,909 --> 00:05:30,400
the hubble servicing mission that was

158
00:05:34,550 --> 00:05:31,919
scheduled and it was going to be the

159
00:05:36,790 --> 00:05:34,560
last planned mission

160
00:05:38,950 --> 00:05:36,800
we were going to try to use robotics to

161
00:05:41,350 --> 00:05:38,960
service the satellite and or the the

162
00:05:42,710 --> 00:05:41,360
observatory and i served on a committee

163
00:05:44,469 --> 00:05:42,720

that actually looked at it and the

164
00:05:46,550 --> 00:05:44,479
technology just wasn't there at the time

165
00:05:48,550 --> 00:05:46,560
so we had to go in and talk to the nasa

166
00:05:50,790 --> 00:05:48,560
administrator explain to him that the

167
00:05:53,830 --> 00:05:50,800
safest and surest way to save hubble was

168
00:05:56,150 --> 00:05:53,840
to accept the risk of flying one more

169
00:05:58,790 --> 00:05:56,160
crude mission to serve as hubble and

170
00:06:00,710 --> 00:05:58,800
that one like the last two was about as

171
00:06:02,629 --> 00:06:00,720
ambitious as you can get where we had

172
00:06:04,309 --> 00:06:02,639
five days in a row of back to back to

173
00:06:07,430 --> 00:06:04,319
back to back to back

174
00:06:08,950 --> 00:06:07,440
evas with tremendous crews things going

175
00:06:10,710 --> 00:06:08,960
wrong every once in a while but because

176
00:06:12,710 --> 00:06:10,720
you had the combination of people here

177
00:06:14,309 --> 00:06:12,720
on the ground and the crew on board we

178
00:06:16,070 --> 00:06:14,319
were able to kind of work our way

179
00:06:18,950 --> 00:06:16,080
through it and had two incredibly

180
00:06:20,629 --> 00:06:18,960
successful missions and left hubble uh

181
00:06:22,230 --> 00:06:20,639
in much better shape today than i think

182
00:06:23,830 --> 00:06:22,240
it was ever envisioned to be by its

183
00:06:25,909 --> 00:06:23,840
original designers

184
00:06:27,510 --> 00:06:25,919
and then another thing that we have um

185
00:06:29,029 --> 00:06:27,520
talked about when it comes to satellite

186
00:06:31,830 --> 00:06:29,039
servicing is the international space

187
00:06:33,189 --> 00:06:31,840
station because it was quite a feat so

188
00:06:35,189 --> 00:06:33,199

can you talk about like where the

189
00:06:37,029 --> 00:06:35,199
international space station falls in on

190
00:06:38,870 --> 00:06:37,039
the timeline of you know the first

191
00:06:40,870 --> 00:06:38,880
servicing mission to hubble and some of

192
00:06:43,670 --> 00:06:40,880
the evolution of servicing some people

193
00:06:45,909 --> 00:06:43,680
will remember we were when when when we

194
00:06:47,990 --> 00:06:45,919
did the the first servicing mission to

195
00:06:49,909 --> 00:06:48,000
hubble we were looking at a space

196
00:06:52,230 --> 00:06:49,919
station but there was no concept of an

197
00:06:53,830 --> 00:06:52,240
international space station the actually

198
00:06:56,309 --> 00:06:53,840
the international space station came

199
00:06:58,070 --> 00:06:56,319
some time later but what it did allow us

200
00:07:00,230 --> 00:06:58,080
to do when we finally made the decision

201
00:07:02,950 --> 00:07:00,240
with our partner agencies and their five

202
00:07:04,710 --> 00:07:02,960
partner agencies including the u.s when

203
00:07:07,430 --> 00:07:04,720
the decision was finally made to fly

204
00:07:10,550 --> 00:07:07,440
this to to build the space station one

205
00:07:12,550 --> 00:07:10,560
of the the side benefits of it was it

206
00:07:14,950 --> 00:07:12,560
gave us a platform where we could

207
00:07:17,830 --> 00:07:14,960
actually demonstrate some of the new

208
00:07:19,670 --> 00:07:17,840
technologies in in robotics for example

209
00:07:22,230 --> 00:07:19,680
the robotic refueling mission uh

210
00:07:24,790 --> 00:07:22,240
something that was a a prize of the folk

211
00:07:27,110 --> 00:07:24,800
here at goddard and i understand we just

212
00:07:29,510 --> 00:07:27,120
launched rm3

213
00:07:32,150 --> 00:07:29,520

so we have now learned how to remove

214
00:07:34,309 --> 00:07:32,160
caps and replace caps to clip wires and

215
00:07:36,629 --> 00:07:34,319
twist wires and now we're getting ready

216
00:07:40,150 --> 00:07:36,639
to actually use the mission to

217
00:07:41,830 --> 00:07:40,160
refuel the landsat satellite maybe

218
00:07:44,550 --> 00:07:41,840
you know but we're going to demonstrate

219
00:07:46,390 --> 00:07:44,560
that we can in fact transfer cryogenic

220
00:07:48,309 --> 00:07:46,400
material and that will be probably the

221
00:07:50,710 --> 00:07:48,319
last step that we need to demonstrate

222
00:07:52,950 --> 00:07:50,720
our capability of doing a completely

223
00:07:54,710 --> 00:07:52,960
robotic mission to service

224
00:07:56,230 --> 00:07:54,720
a satellite on orbit which is something

225
00:07:58,309 --> 00:07:56,240
we really want to do the international

226
00:08:00,629 --> 00:07:58,319
space station presented the laboratory

227
00:08:02,950 --> 00:08:00,639
or the workshop uh where we could

228
00:08:05,110 --> 00:08:02,960
demonstrate that in space and assure

229
00:08:06,629 --> 00:08:05,120
ourselves that give us very good

230
00:08:07,909 --> 00:08:06,639
confidence that the things we saw here

231
00:08:09,270 --> 00:08:07,919
in the lab

232
00:08:10,790 --> 00:08:09,280
really were going to work when we got

233
00:08:13,029 --> 00:08:10,800
them into the microgravity environment

234
00:08:14,790 --> 00:08:13,039
of space that's great and i know we've

235
00:08:16,469 --> 00:08:14,800
got questions for you that are coming in

236
00:08:18,070 --> 00:08:16,479
but i understand that we're going to

237
00:08:19,189 --> 00:08:18,080
meet up with you again later so we're

238
00:08:21,189 --> 00:08:19,199

going to hold off and let people

239
00:08:23,830 --> 00:08:21,199
continue to send in your questions and

240
00:08:25,749 --> 00:08:23,840
uh charlie's got a robot demo for us

241
00:08:27,430 --> 00:08:25,759
well i'm hoping that you'll spend a lot

242
00:08:29,510 --> 00:08:27,440
of time with john and jeff hoffman and

243
00:08:31,749 --> 00:08:29,520
let them show us the tool and maybe run

244
00:08:33,269 --> 00:08:31,759
over so i don't get a chance to to screw

245
00:08:34,870 --> 00:08:33,279
up the robot but i'm really looking

246
00:08:36,630 --> 00:08:34,880
forward to it i don't as a pilot i

247
00:08:38,630 --> 00:08:36,640
didn't get an opportu opportunity to do

248
00:08:39,990 --> 00:08:38,640
too much robotic operation so i want to

249
00:08:41,190 --> 00:08:40,000
apply my trade down here and i'll see

250
00:08:42,790 --> 00:08:41,200
you later all right i'll catch you on

251
00:08:45,509 --> 00:08:42,800
the other side charlie thank you so much

252
00:08:47,030 --> 00:08:45,519
thank you so like he said we're gonna be

253
00:08:48,550 --> 00:08:47,040
down there later but send in your

254
00:08:50,630 --> 00:08:48,560
questions and we'll get to them

255
00:08:53,430 --> 00:08:50,640
throughout the show use the hashtag

256
00:08:54,389 --> 00:08:53,440
asknasa we're on twitter facebook

257
00:08:55,430 --> 00:08:54,399
instagram

258
00:08:57,829 --> 00:08:55,440
twitch

259
00:08:59,910 --> 00:08:57,839
so like charlie also mentioned we've got

260
00:09:02,550 --> 00:08:59,920
two of the hubble astronauts here with

261
00:09:05,590 --> 00:09:02,560
us today that actually went up and

262
00:09:07,430 --> 00:09:05,600
serviced the telescope multiple times

263
00:09:09,750 --> 00:09:07,440

we've got john grunsfeld and we've got

264
00:09:11,670 --> 00:09:09,760
jeff hoffman here today with us

265
00:09:13,750 --> 00:09:11,680
thanks so much for being here guys

266
00:09:16,150 --> 00:09:13,760
it's great to get back to goddard spent

267
00:09:17,829 --> 00:09:16,160
a lot of happy and busy hours here

268
00:09:20,550 --> 00:09:17,839
getting ready for the first hubble

269
00:09:22,310 --> 00:09:20,560
mission john spent even more time and i

270
00:09:24,310 --> 00:09:22,320
always loved to play with tools i'm sure

271
00:09:26,070 --> 00:09:24,320
you do and we've got a bunch of them

272
00:09:28,070 --> 00:09:26,080
over here it looks like you guys may

273
00:09:30,389 --> 00:09:28,080
know what to do with them so if you

274
00:09:32,630 --> 00:09:30,399
don't mind showing our viewers uh sure

275
00:09:34,949 --> 00:09:32,640
but um you know you see this sign it

276
00:09:37,190 --> 00:09:34,959
says esd work area and i don't want to

277
00:09:38,710 --> 00:09:37,200
shock you but you know how you rub on a

278
00:09:40,949 --> 00:09:38,720
rug and then you touch the door handle

279
00:09:42,310 --> 00:09:40,959
and you get the spark

280
00:09:44,230 --> 00:09:42,320
there's sensitive stuff back here

281
00:09:46,550 --> 00:09:44,240
electronics and the tools that we don't

282
00:09:49,110 --> 00:09:46,560
want to break so we're going to

283
00:09:51,190 --> 00:09:49,120
put on some wristbands to zap that

284
00:09:53,509 --> 00:09:51,200
electricity to a ground

285
00:09:54,949 --> 00:09:53,519
and also we don't want dust to get into

286
00:09:56,949 --> 00:09:54,959
the delic components so we're going to

287
00:09:59,910 --> 00:09:56,959
put on some smocks

288
00:10:03,110 --> 00:09:59,920

so we don't get over the wristbands

289
00:10:08,069 --> 00:10:05,190
awesome so now of course

290
00:10:10,389 --> 00:10:08,079
um when we were working with hubble and

291
00:10:11,350 --> 00:10:10,399
the instruments there was a lot of very

292
00:10:15,910 --> 00:10:11,360
very

293
00:10:17,509 --> 00:10:15,920
uh sensitive optics so contamination was

294
00:10:19,430 --> 00:10:17,519
absolutely critical we had to put on a

295
00:10:21,910 --> 00:10:19,440
lot more than just these smocks i mean

296
00:10:23,670 --> 00:10:21,920
full head gear i had a mustache at the

297
00:10:24,949 --> 00:10:23,680
time john still does that had to be

298
00:10:26,230 --> 00:10:24,959
covered up

299
00:10:27,829 --> 00:10:26,240
um

300
00:10:29,750 --> 00:10:27,839
and little details you never think about

301
00:10:32,230 --> 00:10:29,760
you you know for women

302
00:10:33,990 --> 00:10:32,240
maybe for men too no makeup because that

303
00:10:35,990 --> 00:10:34,000
makeup could contaminate the hubble

304
00:10:37,509 --> 00:10:36,000
optics

305
00:10:39,190 --> 00:10:37,519
i didn't wear any makeup it wasn't the

306
00:10:40,630 --> 00:10:39,200
problem

307
00:10:41,430 --> 00:10:40,640
you look great

308
00:10:43,269 --> 00:10:41,440
so

309
00:10:45,190 --> 00:10:43,279
while you guys are smocking up can you

310
00:10:46,710 --> 00:10:45,200
tell everybody about some of the

311
00:10:48,310 --> 00:10:46,720
missions that you guys were on with

312
00:10:51,269 --> 00:10:48,320
respect to hubble

313
00:10:53,430 --> 00:10:51,279

um i was on the very first servicing

314
00:10:56,069 --> 00:10:53,440
mission you know charlie bolden was on

315
00:10:57,750 --> 00:10:56,079
the mission that put hubble in orbit

316
00:10:58,630 --> 00:10:57,760
and then when we discovered that it

317
00:11:01,350 --> 00:10:58,640
couldn't

318
00:11:04,230 --> 00:11:01,360
focus properly

319
00:11:06,550 --> 00:11:04,240
that of course became a real disaster

320
00:11:08,790 --> 00:11:06,560
it had always been planned that every

321
00:11:11,509 --> 00:11:08,800
two or three years a crew would go up to

322
00:11:13,590 --> 00:11:11,519
service hubble and so we went up about

323
00:11:15,910 --> 00:11:13,600
two and a half years after hubble was

324
00:11:17,910 --> 00:11:15,920
launched but at that point

325
00:11:19,990 --> 00:11:17,920
uh the purpose of the mission was not

326
00:11:20,949 --> 00:11:20,000
just to put in a new instrument which

327
00:11:23,269 --> 00:11:20,959
had all

328
00:11:25,030 --> 00:11:23,279
always been in the plan but actually to

329
00:11:26,550 --> 00:11:25,040
fix all of the optics plus there were

330
00:11:28,790 --> 00:11:26,560
about a dozen other things that had

331
00:11:30,949 --> 00:11:28,800
broken on hubble and and had to be fixed

332
00:11:32,870 --> 00:11:30,959
so it ended up being

333
00:11:37,750 --> 00:11:32,880
at the time the most complex shuttle

334
00:11:41,990 --> 00:11:39,910
given the success of it i think it

335
00:11:45,269 --> 00:11:42,000
really gave people the confidence that

336
00:11:47,670 --> 00:11:45,279
that complex servicing tasks were

337
00:11:49,269 --> 00:11:47,680
possible and and i think led the way to

338
00:11:51,750 --> 00:11:49,279

some of the even more complex things

339
00:11:53,590 --> 00:11:51,760
that that john and his crewmates did on

340
00:11:55,430 --> 00:11:53,600
on some of their hubble missions so

341
00:11:57,509 --> 00:11:55,440
which missions were you on john so i was

342
00:12:01,110 --> 00:11:57,519
on three hubble missions the last three

343
00:12:04,790 --> 00:12:01,120
in fact uh we did a mission in in 1999

344
00:12:06,550 --> 00:12:04,800
and 2002 and then most recent one 2009

345
00:12:08,389 --> 00:12:06,560
and amazingly hubble is still working

346
00:12:10,389 --> 00:12:08,399
great and i think well they left it as

347
00:12:12,629 --> 00:12:10,399
good as new when they when they fixed it

348
00:12:14,550 --> 00:12:12,639
i think what we learned is that almost

349
00:12:16,550 --> 00:12:14,560
anything you can do on the ground you

350
00:12:18,389 --> 00:12:16,560
know maybe wearing you know these suits

351
00:12:20,550 --> 00:12:18,399
and and gloves to protect the hardware

352
00:12:23,030 --> 00:12:20,560
but anything you can do on the ground

353
00:12:24,710 --> 00:12:23,040
we can learn how to do in the big bulky

354
00:12:26,150 --> 00:12:24,720
spacesuits of course it takes us longer

355
00:12:28,470 --> 00:12:26,160
to get those spacesuits on than the

356
00:12:30,710 --> 00:12:28,480
smocks but anything you can do on the

357
00:12:33,509 --> 00:12:30,720
ground you can find a way to do it in

358
00:12:35,910 --> 00:12:33,519
space if you have the right tools

359
00:12:37,750 --> 00:12:35,920
so that's probably a good queue for us

360
00:12:39,670 --> 00:12:37,760
to go in and show the people what it is

361
00:12:42,069 --> 00:12:39,680
that i checked your static out you're

362
00:12:44,710 --> 00:12:42,079
good give give the people plugged in

363
00:12:47,509 --> 00:12:44,720

here we're grounded

364
00:12:49,030 --> 00:12:47,519
awesome so i guess uh we'll start on the

365
00:12:50,949 --> 00:12:49,040
far side with jeff since you were on

366
00:12:52,710 --> 00:12:50,959
that first servicing mission here any of

367
00:12:54,710 --> 00:12:52,720
the tools on this table were they used

368
00:12:56,230 --> 00:12:54,720
for that well this one i have fond

369
00:12:59,269 --> 00:12:56,240
memories of the

370
00:13:02,470 --> 00:12:59,279
this of course they're all power tools

371
00:13:05,590 --> 00:13:02,480
um we did have manual tools and on a few

372
00:13:07,430 --> 00:13:05,600
occasions we did use manual tools but

373
00:13:10,069 --> 00:13:07,440
power tools you can get the job done so

374
00:13:13,110 --> 00:13:10,079
much faster and and when you're

375
00:13:14,550 --> 00:13:13,120
on an eva mission like this

376
00:13:17,269 --> 00:13:14,560
really

377
00:13:19,750 --> 00:13:17,279
astronaut time outside doing useful work

378
00:13:22,389 --> 00:13:19,760
in a space suit is that's the most

379
00:13:23,910 --> 00:13:22,399
valuable consumable that you have and so

380
00:13:25,910 --> 00:13:23,920
anything you can do to speed up the

381
00:13:27,670 --> 00:13:25,920
process so we so we do use a lot of

382
00:13:30,710 --> 00:13:27,680
power tools now this was first

383
00:13:33,030 --> 00:13:30,720
generation for hubble um we we would

384
00:13:34,870 --> 00:13:33,040
have tool carriers and and so i could

385
00:13:36,550 --> 00:13:34,880
plug this in of course it's pretty heavy

386
00:13:38,069 --> 00:13:36,560
now but it doesn't weigh anything up

387
00:13:40,069 --> 00:13:38,079
there but

388
00:13:41,590 --> 00:13:40,079

everything has to be

389
00:13:43,430 --> 00:13:41,600
tethered

390
00:13:46,230 --> 00:13:43,440
and of course this has a

391
00:13:49,829 --> 00:13:46,240
an interface that you can put long

392
00:13:51,509 --> 00:13:49,839
bolt drivers and uh little pip pins and

393
00:13:54,629 --> 00:13:51,519
and every one of those

394
00:13:57,509 --> 00:13:54,639
uh drivers had to have a a separate

395
00:13:59,750 --> 00:13:57,519
tether just managing all the tethers it

396
00:14:00,949 --> 00:13:59,760
really took a lot of time but

397
00:14:02,949 --> 00:14:00,959
you can't afford to lose you can't

398
00:14:04,470 --> 00:14:02,959
afford to lose a tool and boy you know

399
00:14:06,629 --> 00:14:04,480
when we were doing all the training in

400
00:14:08,790 --> 00:14:06,639
the pool if if your instructors saw that

401
00:14:11,110 --> 00:14:08,800
you hadn't done a tether properly they

402
00:14:13,829 --> 00:14:11,120
they'd get right on your case the other

403
00:14:16,150 --> 00:14:13,839
thing that that we often used a torque

404
00:14:19,269 --> 00:14:16,160
limiter which would of course go on the

405
00:14:21,590 --> 00:14:19,279
end of of this uh between this and the

406
00:14:24,470 --> 00:14:21,600
actual bolt that you were working with a

407
00:14:26,150 --> 00:14:24,480
telescope and and the reason for that is

408
00:14:27,110 --> 00:14:26,160
um

409
00:14:29,829 --> 00:14:27,120
you

410
00:14:31,910 --> 00:14:29,839
want to just put the bolt in with enough

411
00:14:34,710 --> 00:14:31,920
force that it won't come out but you

412
00:14:37,750 --> 00:14:34,720
don't want to over drive it so that it

413
00:14:39,350 --> 00:14:37,760

might get stuck or worst case

414
00:14:41,350 --> 00:14:39,360
you could actually

415
00:14:43,430 --> 00:14:41,360
fracture the bolt in which case you're

416
00:14:46,310 --> 00:14:43,440
never going to get it out so we were

417
00:14:48,069 --> 00:14:46,320
very careful for every job we had uh

418
00:14:49,670 --> 00:14:48,079
there would be an indication in in the

419
00:14:51,590 --> 00:14:49,680
checklist you know set your torque

420
00:14:54,470 --> 00:14:51,600
limiter to such and such a

421
00:14:56,629 --> 00:14:54,480
uh a level and and then chris clark is

422
00:14:59,910 --> 00:14:56,639
how hard you turn something right and

423
00:15:03,509 --> 00:14:59,920
and then also um you know

424
00:15:06,150 --> 00:15:03,519
19 turns clockwise and and

425
00:15:07,910 --> 00:15:06,160
just to let the people 20 not 18. and

426
00:15:09,829 --> 00:15:07,920
and we would actually count them out you

427
00:15:12,629 --> 00:15:09,839
know i'd be there you know doing the

428
00:15:13,590 --> 00:15:12,639
thing and you know it's one

429
00:15:15,509 --> 00:15:13,600
two

430
00:15:17,110 --> 00:15:15,519
and so on that so that the people on the

431
00:15:18,790 --> 00:15:17,120
ground could really follow what we were

432
00:15:20,470 --> 00:15:18,800
doing and that was critical

433
00:15:22,629 --> 00:15:20,480
but then of course this was the first

434
00:15:23,910 --> 00:15:22,639
generation and and when you guys went up

435
00:15:25,670 --> 00:15:23,920
you had

436
00:15:27,430 --> 00:15:25,680
some more developments and and that's

437
00:15:29,430 --> 00:15:27,440
one of the features of the hubble

438
00:15:32,629 --> 00:15:29,440

program at large is as astronauts we got

439
00:15:35,110 --> 00:15:32,639
to work on a daily basis with engineers

440
00:15:37,110 --> 00:15:35,120
and exchange ideas and try things some

441
00:15:40,069 --> 00:15:37,120
things work some things didn't and so

442
00:15:43,030 --> 00:15:40,079
this is the astronaut death ray laser

443
00:15:44,230 --> 00:15:43,040
no this is a power tool that's the next

444
00:15:46,310 --> 00:15:44,240
generation

445
00:15:47,749 --> 00:15:46,320
and this may look a little more like a

446
00:15:49,829 --> 00:15:47,759
power screwdriver that you might have at

447
00:15:52,230 --> 00:15:49,839
home and it incorporates the features

448
00:15:54,389 --> 00:15:52,240
and lessons this was the big battery for

449
00:15:56,310 --> 00:15:54,399
this and here you're all built battery's

450
00:15:58,710 --> 00:15:56,320
now in here the torque limiter is in

451
00:16:00,389 --> 00:15:58,720
here and this has electronics that

452
00:16:03,910 --> 00:16:00,399
counts all the turns and tells you what

453
00:16:05,910 --> 00:16:03,920
they are records what was torqued uh and

454
00:16:07,509 --> 00:16:05,920
so this is now the standard work tool

455
00:16:09,829 --> 00:16:07,519
for astronauts in space now it's pretty

456
00:16:13,189 --> 00:16:09,839
heavy here but in space everything

457
00:16:15,030 --> 00:16:13,199
floats so it's nice

458
00:16:16,790 --> 00:16:15,040
this is a tool that's used on virtually

459
00:16:18,710 --> 00:16:16,800
every international space station

460
00:16:21,030 --> 00:16:18,720
spacewalk and so what we developed for

461
00:16:23,430 --> 00:16:21,040
hubble is now used across the space

462
00:16:25,509 --> 00:16:23,440
program but it doesn't necessarily work

463
00:16:26,790 --> 00:16:25,519

for everything you know this was still

464
00:16:28,230 --> 00:16:26,800
too big

465
00:16:30,310 --> 00:16:28,240
and didn't have the capabilities we

466
00:16:32,550 --> 00:16:30,320
needed for some other repairs

467
00:16:34,069 --> 00:16:32,560
that we did on the last mission i had to

468
00:16:36,550 --> 00:16:34,079
remove

469
00:16:38,230 --> 00:16:36,560
a lot of tiny screws in space and what

470
00:16:39,910 --> 00:16:38,240
do you need to remove tiny screws in

471
00:16:41,829 --> 00:16:39,920
space

472
00:16:44,150 --> 00:16:41,839
well you need a tiny tiny screwdriver

473
00:16:46,470 --> 00:16:44,160
yeah we we had that problem exactly on

474
00:16:48,790 --> 00:16:46,480
the first mission with with the our our

475
00:16:50,470 --> 00:16:48,800
final eva task on the solar ray drive

476
00:16:52,710 --> 00:16:50,480
unit where we had little two millimeter

477
00:16:54,949 --> 00:16:52,720
screws that we couldn't that we just

478
00:16:56,389 --> 00:16:54,959
couldn't use this for it it was too big

479
00:16:58,230 --> 00:16:56,399
so we developed what's called the mini

480
00:17:00,069 --> 00:16:58,240
power tool now it's not that many but

481
00:17:01,990 --> 00:17:00,079
it's a lot smaller than these others and

482
00:17:02,870 --> 00:17:02,000
so we have an evolution of tools through

483
00:17:04,630 --> 00:17:02,880
time

484
00:17:06,150 --> 00:17:04,640
that allowed us to do the repairs you

485
00:17:08,069 --> 00:17:06,160
know we all think about these amazing

486
00:17:10,630 --> 00:17:08,079
hubble images jeff and i are both

487
00:17:12,630 --> 00:17:10,640
astronomers and so we love the science

488
00:17:14,230 --> 00:17:12,640

we wouldn't have any of that unless on

489
00:17:15,829 --> 00:17:14,240
the first servicing mission they'd

490
00:17:17,110 --> 00:17:15,839
repaired the optics and put new

491
00:17:18,630 --> 00:17:17,120
instruments in

492
00:17:21,350 --> 00:17:18,640
and on every mission we put new

493
00:17:23,750 --> 00:17:22,230
and

494
00:17:24,949 --> 00:17:23,760
of course

495
00:17:27,350 --> 00:17:24,959
every

496
00:17:29,750 --> 00:17:27,360
new mission we would build on the

497
00:17:31,750 --> 00:17:29,760
capabilities that had been dis

498
00:17:32,549 --> 00:17:31,760
demonstrated on the previous mission so

499
00:17:34,470 --> 00:17:32,559
that

500
00:17:36,390 --> 00:17:34,480
um you know by the time you got to the

501
00:17:38,230 --> 00:17:36,400
final mission which i think you're going

502
00:17:41,270 --> 00:17:38,240
to talk about this

503
00:17:43,430 --> 00:17:41,280
acs but you did things that had people

504
00:17:45,190 --> 00:17:43,440
suggested that they could have been done

505
00:17:46,710 --> 00:17:45,200
at the first servicing mission they'd

506
00:17:48,789 --> 00:17:46,720
have gotten kicked out of the room it's

507
00:17:51,750 --> 00:17:48,799
you know that's just way beyond scope of

508
00:17:54,230 --> 00:17:51,760
what anybody can do but we did it yep

509
00:17:55,990 --> 00:17:54,240
typically if a instrument failed we'd

510
00:17:58,310 --> 00:17:56,000
bring up a whole new instrument the size

511
00:18:00,070 --> 00:17:58,320
of a big bulky refrigerator

512
00:18:01,830 --> 00:18:00,080
on the last mission we couldn't do that

513
00:18:03,909 --> 00:18:01,840

we brought up one new instrument but we

514
00:18:05,909 --> 00:18:03,919
had two that were failed and we were

515
00:18:08,789 --> 00:18:05,919
able to actually to repair it with a

516
00:18:11,110 --> 00:18:08,799
bunch of very special tools

517
00:18:14,470 --> 00:18:11,120
that allowed us to you know this tool

518
00:18:16,789 --> 00:18:14,480
allowed us to cut a metal plate

519
00:18:18,630 --> 00:18:16,799
to remove all those tiny screws without

520
00:18:20,789 --> 00:18:18,640
having them float away we used a

521
00:18:22,950 --> 00:18:20,799
specialized piece of equipment that kept

522
00:18:25,750 --> 00:18:22,960
the screws attached

523
00:18:27,669 --> 00:18:25,760
so that we could remove all those screws

524
00:18:31,110 --> 00:18:27,679
get a metal plate off

525
00:18:33,190 --> 00:18:31,120
maybe i can get the plate off maybe not

526
00:18:35,510 --> 00:18:33,200
do you have any fingernails i have very

527
00:18:38,310 --> 00:18:35,520
small fingernails we can always turn it

528
00:18:39,750 --> 00:18:38,320
over okay

529
00:18:41,590 --> 00:18:39,760
you can't do that you cannot do that in

530
00:18:42,950 --> 00:18:41,600
space

531
00:18:44,870 --> 00:18:42,960
there were four circuit cards and we

532
00:18:47,430 --> 00:18:44,880
were able to pull those out

533
00:18:49,350 --> 00:18:47,440
now this is the idea of being able to

534
00:18:51,909 --> 00:18:49,360
work on the level of

535
00:18:53,140 --> 00:18:51,919
removing and replacing circuit boards

536
00:18:54,470 --> 00:18:53,150
it would just would have been

537
00:18:56,549 --> 00:18:54,480
[Music]

538
00:18:58,230 --> 00:18:56,559

unthinkable at when people first started

539
00:19:00,549 --> 00:18:58,240
to think about what astronauts could do

540
00:19:02,549 --> 00:19:00,559
in servicing but as we gradually got

541
00:19:03,590 --> 00:19:02,559
more confidence one mission after the

542
00:19:05,830 --> 00:19:03,600
other

543
00:19:07,909 --> 00:19:05,840
you actually did it and each mission we

544
00:19:10,230 --> 00:19:07,919
did try things that folks said no you

545
00:19:11,590 --> 00:19:10,240
can't do that we would go do it and so

546
00:19:13,430 --> 00:19:11,600
this is sort of state of the art for

547
00:19:14,950 --> 00:19:13,440
people in space now

548
00:19:16,710 --> 00:19:14,960
and something that i think

549
00:19:17,909 --> 00:19:16,720
in the realm of today

550
00:19:20,150 --> 00:19:17,919
you know you really need the human

551
00:19:22,150 --> 00:19:20,160
dexterity to do

552
00:19:24,710 --> 00:19:22,160
but i think a lot of the tasks that we

553
00:19:26,230 --> 00:19:24,720
did removing the large bulky objects

554
00:19:27,750 --> 00:19:26,240
today we could do that with robots

555
00:19:29,990 --> 00:19:27,760
probably could our robots have gotten a

556
00:19:30,870 --> 00:19:30,000
lot more sophisticated and of course

557
00:19:33,270 --> 00:19:30,880
they're

558
00:19:36,150 --> 00:19:33,280
working on robotic servicing here at

559
00:19:39,430 --> 00:19:36,160
goddard now for this is the landsat and

560
00:19:40,390 --> 00:19:39,440
refuel it and yep you know frankly i

561
00:19:42,390 --> 00:19:40,400
mean i

562
00:19:43,909 --> 00:19:42,400
i love putting on a spacesuit and going

563
00:19:46,310 --> 00:19:43,919

outside but if there's something that

564
00:19:49,430 --> 00:19:46,320
can be done by a robot we ought to let

565
00:19:51,270 --> 00:19:49,440
robots do it uh design the the servicing

566
00:19:53,510 --> 00:19:51,280
for robots and then if you run into

567
00:19:55,510 --> 00:19:53,520
problems that the robots can't handle

568
00:19:56,870 --> 00:19:55,520
you've got a simpler interface for the

569
00:19:58,789 --> 00:19:56,880
people who

570
00:20:01,430 --> 00:19:58,799
have to actually go and do it and if you

571
00:20:03,830 --> 00:20:01,440
look at the robotic tools

572
00:20:05,590 --> 00:20:03,840
they look kind of like evolutionary

573
00:20:07,669 --> 00:20:05,600
tools from the hand tools that we use

574
00:20:09,909 --> 00:20:07,679
they're just built into the hand of the

575
00:20:11,590 --> 00:20:09,919
robot so i i i'm really excited about

576
00:20:12,870 --> 00:20:11,600
that development

577
00:20:14,230 --> 00:20:12,880
i mean we

578
00:20:17,350 --> 00:20:14,240
uh

579
00:20:20,470 --> 00:20:17,360
the the idea of being able to recycle

580
00:20:22,070 --> 00:20:20,480
satellites and and to improve the

581
00:20:23,350 --> 00:20:22,080
capabilities which is what we've done

582
00:20:24,230 --> 00:20:23,360
with hubble

583
00:20:27,350 --> 00:20:24,240
um

584
00:20:29,590 --> 00:20:27,360
it it's been a game changer for hubble

585
00:20:31,750 --> 00:20:29,600
and uh hopefully as we go into the

586
00:20:33,190 --> 00:20:31,760
future in the latter part of the 21st

587
00:20:35,510 --> 00:20:33,200
century that's going to be standard

588
00:20:37,430 --> 00:20:35,520

operating procedure it's so much more

589
00:20:39,590 --> 00:20:37,440
efficient makes a lot of sense and of

590
00:20:41,750 --> 00:20:39,600
course as we go out and explore planets

591
00:20:43,350 --> 00:20:41,760
mars you're going to want robots

592
00:20:44,549 --> 00:20:43,360
out exploring before we can get there

593
00:20:47,270 --> 00:20:44,559
even when we're there and you'll need

594
00:20:49,190 --> 00:20:47,280
robots to repair the robots so

595
00:20:50,470 --> 00:20:49,200
that was awesome thank you so much for

596
00:20:52,310 --> 00:20:50,480
sharing those tools and we've got a

597
00:20:53,909 --> 00:20:52,320
bunch of questions coming in from social

598
00:20:55,750 --> 00:20:53,919
media i know you're sending them in on

599
00:20:56,789 --> 00:20:55,760
facebook and instagram and twitter and

600
00:20:59,510 --> 00:20:56,799
twitch and

601
00:21:01,750 --> 00:20:59,520
we've got some good ones um so jeff the

602
00:21:03,669 --> 00:21:01,760
first question i have for you was

603
00:21:05,510 --> 00:21:03,679
what was the experience kind of

604
00:21:08,070 --> 00:21:05,520
emotionally of being on the first

605
00:21:09,590 --> 00:21:08,080
servicing mission

606
00:21:11,750 --> 00:21:09,600
of course

607
00:21:14,950 --> 00:21:11,760
everybody knew how critical

608
00:21:16,870 --> 00:21:14,960
this situation was and as an astronomer

609
00:21:18,630 --> 00:21:16,880
i had lots of

610
00:21:20,470 --> 00:21:18,640
astronomer friends

611
00:21:22,950 --> 00:21:20,480
who would call us up and say you know

612
00:21:25,110 --> 00:21:22,960
can nasa really fix this you know people

613
00:21:27,270 --> 00:21:25,120

who had devoted large parts of their

614
00:21:29,590 --> 00:21:27,280
career to hubble so you know first of

615
00:21:32,549 --> 00:21:29,600
all it was really exciting

616
00:21:34,470 --> 00:21:32,559
being put on the crew

617
00:21:36,950 --> 00:21:34,480
this was a primo mission everybody knew

618
00:21:39,110 --> 00:21:36,960
how important it was and then

619
00:21:40,310 --> 00:21:39,120
you know as an astronomer and an

620
00:21:42,310 --> 00:21:40,320
astronaut

621
00:21:44,470 --> 00:21:42,320
to and you must have had this

622
00:21:47,110 --> 00:21:44,480
you know to be able to put

623
00:21:49,190 --> 00:21:47,120
our two hands on the greatest telescope

624
00:21:50,789 --> 00:21:49,200
in the world up in space

625
00:21:52,390 --> 00:21:50,799
i mean you know that's something i'll

626
00:21:54,390 --> 00:21:52,400
never forget that that was that's the

627
00:21:55,750 --> 00:21:54,400
light i think i saw your handprints on

628
00:21:57,110 --> 00:21:55,760
on the hubble

629
00:21:59,430 --> 00:21:57,120
but i did i did have a similar

630
00:22:00,470 --> 00:21:59,440
experience uh you know we got up to

631
00:22:02,470 --> 00:22:00,480
hubble

632
00:22:04,390 --> 00:22:02,480
and it was my third space flight but my

633
00:22:07,110 --> 00:22:04,400
first spacewalk you had already done a

634
00:22:08,630 --> 00:22:07,120
spacewalk yeah and i was on the robotic

635
00:22:10,310 --> 00:22:08,640
arm and i was being moved back towards

636
00:22:12,310 --> 00:22:10,320
the hubble and there was just a moment

637
00:22:14,710 --> 00:22:12,320
there you know which is the pinch me

638
00:22:15,990 --> 00:22:14,720

moment where i reached out with a finger

639
00:22:17,510 --> 00:22:16,000
of course i'm wearing a glove and a

640
00:22:18,870 --> 00:22:17,520
spacesuit but i reached out with a

641
00:22:20,390 --> 00:22:18,880
finger and touched the hubble just to

642
00:22:22,630 --> 00:22:20,400
make sure it was all real

643
00:22:25,350 --> 00:22:22,640
yeah i mean it's it's an

644
00:22:28,470 --> 00:22:25,360
it's a beautiful telescope that it

645
00:22:30,870 --> 00:22:28,480
it's covered with reflective uh material

646
00:22:32,549 --> 00:22:30,880
that reflects the colors of the earth

647
00:22:34,950 --> 00:22:32,559
below it and

648
00:22:36,950 --> 00:22:34,960
uh i mean

649
00:22:39,590 --> 00:22:36,960
for those of us who

650
00:22:41,510 --> 00:22:39,600
got to play a part in the history of the

651
00:22:43,270 --> 00:22:41,520
hubble space telescope i think it for

652
00:22:44,549 --> 00:22:43,280
all of us it was a highlight of our

653
00:22:46,310 --> 00:22:44,559
careers

654
00:22:47,350 --> 00:22:46,320
that's great we've got one more question

655
00:22:50,230 --> 00:22:47,360
and

656
00:22:52,870 --> 00:22:50,240
i'll send it over to john so you did it

657
00:22:55,190 --> 00:22:52,880
three times but how long does it take to

658
00:22:59,029 --> 00:22:55,200
get to hubble

659
00:23:00,710 --> 00:22:59,039
well that's a great question because

660
00:23:02,870 --> 00:23:00,720
launching from planet earth to get to

661
00:23:05,669 --> 00:23:02,880
earth orbit only takes eight and a half

662
00:23:07,990 --> 00:23:05,679
minutes kind of a rough ride

663
00:23:09,750 --> 00:23:08,000

but once you get there it took us a

664
00:23:10,630 --> 00:23:09,760
couple of days to reconfigure the

665
00:23:13,190 --> 00:23:10,640
shuttle

666
00:23:15,350 --> 00:23:13,200
and to chase down hubble so that on the

667
00:23:17,350 --> 00:23:15,360
third day we grabbed the hubble with the

668
00:23:19,110 --> 00:23:17,360
robotic arm of the shuttle

669
00:23:20,870 --> 00:23:19,120
and put it into the payload bay so we

670
00:23:22,630 --> 00:23:20,880
could work on it so it takes about three

671
00:23:25,190 --> 00:23:22,640
days and then on day four we started the

672
00:23:26,870 --> 00:23:25,200
space walks they keep you busy up there

673
00:23:28,230 --> 00:23:26,880
yep oh it's a very busy and it's

674
00:23:30,230 --> 00:23:28,240
exciting when you're doing that

675
00:23:32,870 --> 00:23:30,240
rendezvous you know when you when you

676
00:23:35,110 --> 00:23:32,880
first you get your first glimpse of the

677
00:23:37,430 --> 00:23:35,120
telescope and it's just a little point

678
00:23:39,750 --> 00:23:37,440
of light and then every orbit you get a

679
00:23:42,630 --> 00:23:39,760
little bit closer and then you can start

680
00:23:44,710 --> 00:23:42,640
to see its form and it gets bigger and

681
00:23:47,350 --> 00:23:44,720
when it finally gets close to you it's

682
00:23:50,230 --> 00:23:47,360
big you know 50 feet from top to bottom

683
00:23:52,470 --> 00:23:50,240
and it's just really exciting

684
00:23:54,549 --> 00:23:52,480
thank you guys so much for being here so

685
00:23:56,390 --> 00:23:54,559
everybody if you just tuned in

686
00:23:58,470 --> 00:23:56,400
we have hubble astronauts we got jeff

687
00:24:00,470 --> 00:23:58,480
hoffman we got john grunsfeld talking

688
00:24:02,870 --> 00:24:00,480

about hubble tools thank you so much

689
00:24:04,950 --> 00:24:02,880
both our pleasure we love it that's been

690
00:24:06,870 --> 00:24:04,960
fun with real nostalgia getting to pick

691
00:24:08,789 --> 00:24:06,880
these things up again wish i could take

692
00:24:10,310 --> 00:24:08,799
it into space but we'll leave that for

693
00:24:11,909 --> 00:24:10,320
the younger guys i guess we'll work on

694
00:24:15,110 --> 00:24:11,919
that we'll see what we can do we'll

695
00:24:16,789 --> 00:24:15,120
phone a friend so we're here in the

696
00:24:20,470 --> 00:24:16,799
robotics

697
00:24:22,470 --> 00:24:20,480
you know area for goddard and

698
00:24:24,149 --> 00:24:22,480
we talked about hubble and we talked

699
00:24:25,350 --> 00:24:24,159
about servicing and we talked about

700
00:24:26,230 --> 00:24:25,360
humans

701
00:24:28,630 --> 00:24:26,240
but

702
00:24:31,110 --> 00:24:28,640
now we're ready to talk about the future

703
00:24:34,230 --> 00:24:31,120
and what servicing may look like

704
00:24:36,070 --> 00:24:34,240
from here on out and to do that

705
00:24:37,190 --> 00:24:36,080
we've got the folks who actually work on

706
00:24:38,710 --> 00:24:37,200
some of these

707
00:24:41,110 --> 00:24:38,720
instruments that you're seeing in here

708
00:24:42,630 --> 00:24:41,120
and today with me i've got ben reed from

709
00:24:44,390 --> 00:24:42,640
satellite servicing thanks so much for

710
00:24:47,269 --> 00:24:44,400
being here ben of course

711
00:24:51,029 --> 00:24:47,279
so let's talk about robotic servicing

712
00:24:52,630 --> 00:24:51,039
what are the advantages of using robots

713
00:24:55,430 --> 00:24:52,640

so

714
00:24:58,950 --> 00:24:55,440
the advantages of using robots is the

715
00:25:01,029 --> 00:24:58,960
same as using robots here on the ground

716
00:25:02,549 --> 00:25:01,039
we like to use them in places the the

717
00:25:04,950 --> 00:25:02,559
traditional three that people like to

718
00:25:07,750 --> 00:25:04,960
say is dumb dirty and dangerous

719
00:25:10,630 --> 00:25:07,760
so let's focus on the dangerous

720
00:25:13,029 --> 00:25:10,640
astronauts are absolutely fabulous i i

721
00:25:14,630 --> 00:25:13,039
love the astronaut core

722
00:25:17,190 --> 00:25:14,640
unfortunately we don't have the

723
00:25:19,750 --> 00:25:17,200
technology to protect astronauts from

724
00:25:21,830 --> 00:25:19,760
radiation in

725
00:25:23,830 --> 00:25:21,840
for example polar orbit around the north

726
00:25:26,470 --> 00:25:23,840
and south pole of the earth

727
00:25:28,630 --> 00:25:26,480
radiation is worse there than it is um

728
00:25:29,990 --> 00:25:28,640
at the lower latitudes

729
00:25:31,190 --> 00:25:30,000
as a result

730
00:25:33,269 --> 00:25:31,200
we can't

731
00:25:34,710 --> 00:25:33,279
work on missions sending astronauts to

732
00:25:36,710 --> 00:25:34,720
polar orbit

733
00:25:39,350 --> 00:25:36,720
it wouldn't be good for their health so

734
00:25:41,350 --> 00:25:39,360
we're not considering it but that is a

735
00:25:43,750 --> 00:25:41,360
ripe opportunity to develop robotic

736
00:25:46,950 --> 00:25:43,760
technology because there are a lot of

737
00:25:48,630 --> 00:25:46,960
satellites in low earth orbit polar leo

738
00:25:50,870 --> 00:25:48,640

polar

739
00:25:53,750 --> 00:25:50,880
in fact one satellite that has been

740
00:25:55,590 --> 00:25:53,760
there since 1999 is a satellite called

741
00:25:57,669 --> 00:25:55,600
landsat 7 and you've been looking at

742
00:26:00,230 --> 00:25:57,679
part of it in this feed

743
00:26:01,269 --> 00:26:00,240
what you see here is a full-scale

744
00:26:04,149 --> 00:26:01,279
mock-up

745
00:26:07,029 --> 00:26:04,159
of landsat 7

746
00:26:08,870 --> 00:26:07,039
about 22 feet long

747
00:26:11,029 --> 00:26:08,880
and we're not considering sending

748
00:26:13,110 --> 00:26:11,039
astronauts to work on a satellite in

749
00:26:15,350 --> 00:26:13,120
that location because of the environment

750
00:26:17,510 --> 00:26:15,360
so that is a perfect opportunity to

751
00:26:20,390 --> 00:26:17,520
develop robotic technology to be able to

752
00:26:23,830 --> 00:26:20,400
service a satellite like landsat 7 so we

753
00:26:25,029 --> 00:26:23,840
absolutely do not view it as robots or

754
00:26:28,310 --> 00:26:25,039
astronauts

755
00:26:30,630 --> 00:26:28,320
each are unique each have capabilities

756
00:26:33,190 --> 00:26:30,640
that the other cannot duplicate we use

757
00:26:35,590 --> 00:26:33,200
them for different jobs

758
00:26:37,350 --> 00:26:35,600
awesome so here in the robotics

759
00:26:39,350 --> 00:26:37,360
operations center you've got a couple

760
00:26:40,870 --> 00:26:39,360
different of ways that you simulate

761
00:26:42,390 --> 00:26:40,880
being in space

762
00:26:45,590 --> 00:26:42,400
can you explain to our audience what

763
00:26:47,110 --> 00:26:45,600

some of those ways are sure

764
00:26:49,830 --> 00:26:47,120
so

765
00:26:51,990 --> 00:26:49,840
we have a vacuum chamber down the hall

766
00:26:53,510 --> 00:26:52,000
in this complex here at goddard space

767
00:26:55,830 --> 00:26:53,520
flight center and that's where we

768
00:26:58,230 --> 00:26:55,840
simulate the vacuum of space

769
00:27:00,630 --> 00:26:58,240
in this room we need to simulate other

770
00:27:01,909 --> 00:27:00,640
aspects of space so what is another

771
00:27:04,149 --> 00:27:01,919
aspect

772
00:27:06,390 --> 00:27:04,159
it's dark if the sun's not shining on

773
00:27:07,669 --> 00:27:06,400
you because you're on the the night side

774
00:27:10,310 --> 00:27:07,679
of earth

775
00:27:12,549 --> 00:27:10,320
space is very very very dark as you all

776
00:27:13,990 --> 00:27:12,559
know when you go outside at night so

777
00:27:15,669 --> 00:27:14,000
that is why you see all these black

778
00:27:17,110 --> 00:27:15,679
curtains everywhere is we need to

779
00:27:19,750 --> 00:27:17,120
simulate

780
00:27:21,750 --> 00:27:19,760
a a robot

781
00:27:23,909 --> 00:27:21,760
working on a satellite

782
00:27:26,070 --> 00:27:23,919
in the absence of light so we do lights

783
00:27:28,549 --> 00:27:26,080
out testing in this laboratory we kill

784
00:27:31,750 --> 00:27:28,559
all the lights and if you look at below

785
00:27:34,470 --> 00:27:31,760
the mock-up of landsat 7 these these

786
00:27:37,269 --> 00:27:34,480
lights that you see there that is the

787
00:27:39,350 --> 00:27:37,279
exact same lighting that we would use

788
00:27:43,029 --> 00:27:39,360

during a robotic surfacing mission of

789
00:27:45,830 --> 00:27:43,039
landsat 7 illuminating the work site

790
00:27:47,590 --> 00:27:45,840
just as it would be illuminated in space

791
00:27:49,190 --> 00:27:47,600
so that's one aspect of how we simulate

792
00:27:54,310 --> 00:27:49,200
space

793
00:27:56,870 --> 00:27:54,320
need to simulate so that we can be

794
00:27:58,549 --> 00:27:56,880
testing in as realistic an environment

795
00:28:01,510 --> 00:27:58,559
as possible

796
00:28:03,830 --> 00:28:01,520
is gravity now it is very difficult to

797
00:28:04,710 --> 00:28:03,840
turn off gravity in fact no one knows

798
00:28:06,630 --> 00:28:04,720
how

799
00:28:10,149 --> 00:28:06,640
but we can simulate

800
00:28:12,310 --> 00:28:10,159
no gravity by uh a robotic platform that

801
00:28:14,389 --> 00:28:12,320
can move objects around as if they were

802
00:28:16,389 --> 00:28:14,399
floating in space and let me show you

803
00:28:18,389 --> 00:28:16,399
what ours looks like

804
00:28:19,590 --> 00:28:18,399
so come with me this way aaron

805
00:28:21,029 --> 00:28:19,600
i'm with you

806
00:28:23,590 --> 00:28:21,039
all right

807
00:28:29,029 --> 00:28:26,950
first let me back up a half a step and

808
00:28:31,510 --> 00:28:29,039
point out the fact that

809
00:28:34,630 --> 00:28:31,520
every satellite in space at one point or

810
00:28:36,789 --> 00:28:34,640
another was blasted up by rocket

811
00:28:38,470 --> 00:28:36,799
so you could imagine a rocket and a

812
00:28:40,149 --> 00:28:38,480
satellite you need to attach the two

813
00:28:40,950 --> 00:28:40,159

together so the satellite doesn't fall

814
00:28:43,830 --> 00:28:40,960
off

815
00:28:46,389 --> 00:28:43,840
during during launch and the how they're

816
00:28:49,110 --> 00:28:46,399
attached to each other is done with

817
00:28:50,789 --> 00:28:49,120
what's called a a marmon ring and so

818
00:28:51,750 --> 00:28:50,799
what we have here

819
00:28:52,710 --> 00:28:51,760
is

820
00:28:55,830 --> 00:28:52,720
the

821
00:28:59,669 --> 00:28:55,840
lower end of a satellite and here

822
00:29:02,310 --> 00:28:59,679
is the marmon ring so this big ring here

823
00:29:04,710 --> 00:29:02,320
is the marmon ring we have this

824
00:29:07,590 --> 00:29:04,720
satellite mock-up on this hydraulic

825
00:29:11,190 --> 00:29:07,600
stewart platform that we call a hexapod

826
00:29:13,510 --> 00:29:11,200
six struts hex a pod

827
00:29:15,590 --> 00:29:13,520
we have a robot in front of it and the

828
00:29:18,070 --> 00:29:15,600
robot would reach out and touch it and

829
00:29:21,110 --> 00:29:18,080
it needs to react it needs to bounce off

830
00:29:21,909 --> 00:29:21,120
and float away as if it were in space

831
00:29:22,630 --> 00:29:21,919
so

832
00:29:24,710 --> 00:29:22,640
we

833
00:29:27,909 --> 00:29:24,720
have developed a very sophisticated

834
00:29:29,430 --> 00:29:27,919
technique to simulate space contact

835
00:29:31,510 --> 00:29:29,440
dynamics

836
00:29:34,389 --> 00:29:31,520
to put a satellite in motion and so i'm

837
00:29:36,470 --> 00:29:34,399
going to shout across to a fabulous

838
00:29:39,350 --> 00:29:36,480

engineer brian gregory and he is going

839
00:29:51,669 --> 00:29:39,360
to put this satellite into motion take

840
00:29:51,679 --> 00:30:03,909
so

841
00:30:09,909 --> 00:30:06,710
it's not often that you get to see space

842
00:30:11,750 --> 00:30:09,919
simulated in greenbelt maryland but it

843
00:30:13,430 --> 00:30:11,760
actually is a common occurrence that

844
00:30:17,269 --> 00:30:13,440
right here at goddard space flight

845
00:30:19,510 --> 00:30:17,279
center we simulate space on the ground

846
00:30:22,789 --> 00:30:19,520
in our robotics lab

847
00:30:24,549 --> 00:30:22,799
very cool that's awesome i can't imagine

848
00:30:27,909 --> 00:30:24,559
that out in space now

849
00:30:30,310 --> 00:30:27,919
black in the that's right lights um so

850
00:30:33,029 --> 00:30:30,320
humans obviously in this facility have

851
00:30:35,350 --> 00:30:33,039
developed this types of technology so

852
00:30:38,149 --> 00:30:35,360
the human and the technology and you

853
00:30:40,230 --> 00:30:38,159
know you see the horror films you know

854
00:30:43,909 --> 00:30:40,240
human versus robot but really when they

855
00:30:45,350 --> 00:30:43,919
come together they create amazing things

856
00:30:47,750 --> 00:30:45,360
can you tell us a little bit about that

857
00:30:49,110 --> 00:30:47,760
interaction between humans and robotics

858
00:30:50,549 --> 00:30:49,120
and how it makes such a successful

859
00:30:53,830 --> 00:30:50,559
product oh

860
00:30:57,110 --> 00:30:53,840
that's an excellent observation

861
00:31:00,149 --> 00:30:57,120
so going back to the hubble missions

862
00:31:02,549 --> 00:31:00,159
in every hubble servicing mission

863
00:31:03,590 --> 00:31:02,559

we had humans and robots working

864
00:31:04,950 --> 00:31:03,600
together

865
00:31:05,990 --> 00:31:04,960
we have

866
00:31:08,710 --> 00:31:06,000
trained

867
00:31:11,669 --> 00:31:08,720
incredibly brilliant fantastically

868
00:31:13,590 --> 00:31:11,679
dexterous astronauts working in the

869
00:31:15,590 --> 00:31:13,600
shuttle payload bay

870
00:31:18,070 --> 00:31:15,600
with

871
00:31:19,830 --> 00:31:18,080
a robotic arm the shuttle had a robotic

872
00:31:20,710 --> 00:31:19,840
arm in the payload bay

873
00:31:24,870 --> 00:31:20,720
and

874
00:31:29,190 --> 00:31:26,870
maneuvering the objects around that they

875
00:31:31,430 --> 00:31:29,200
replaced inside hubble

876
00:31:34,389 --> 00:31:31,440
today as we think about robots going

877
00:31:38,789 --> 00:31:34,399
into for example leopold to work on mid

878
00:31:43,110 --> 00:31:40,789
we are going to keep the astronauts or

879
00:31:45,190 --> 00:31:43,120
the humans on the ground and they will

880
00:31:47,430 --> 00:31:45,200
remotely control the robot

881
00:31:50,870 --> 00:31:47,440
from the safety of planet earth with the

882
00:31:52,549 --> 00:31:50,880
robotic arms being in space and i can

883
00:31:58,549 --> 00:31:52,559
show you that in the back of the lab so

884
00:32:02,870 --> 00:32:00,549
and and while we're walking i will point

885
00:32:05,190 --> 00:32:02,880
out as we walk across the lab you can

886
00:32:08,310 --> 00:32:05,200
see on international space station which

887
00:32:10,310 --> 00:32:08,320
is what these video feeds are of

888
00:32:12,870 --> 00:32:10,320

robotic arms on international space

889
00:32:15,430 --> 00:32:12,880
station so nasa has a long history

890
00:32:17,350 --> 00:32:15,440
robotic arms on the shuttle robotic arms

891
00:32:18,789 --> 00:32:17,360
on space station robotic arms on the

892
00:32:20,310 --> 00:32:18,799
surface of mars

893
00:32:22,310 --> 00:32:20,320
and i'm going to show you the latest

894
00:32:26,630 --> 00:32:22,320
generation of robotic arm right behind

895
00:32:30,630 --> 00:32:29,190
that's getting close getting close

896
00:32:32,070 --> 00:32:30,640
all right

897
00:32:34,710 --> 00:32:32,080
so here we are

898
00:32:37,669 --> 00:32:34,720
in the next part of our our tour

899
00:32:40,710 --> 00:32:37,679
um with our space arm

900
00:32:42,789 --> 00:32:40,720
and our two robotic arm operators go

901
00:32:44,950 --> 00:32:42,799
easily and charlie bolden who you've

902
00:32:47,830 --> 00:32:44,960
already met

903
00:32:50,070 --> 00:32:47,840
so this robotic arm is

904
00:32:53,590 --> 00:32:50,080
flight like so what does that mean it

905
00:32:55,909 --> 00:32:53,600
has got similar materials finish

906
00:32:58,389 --> 00:32:55,919
electronics that can all withstand the

907
00:33:00,710 --> 00:32:58,399
rigors of space so this flight like

908
00:33:02,950 --> 00:33:00,720
robotic arm joe and charlie are going to

909
00:33:04,630 --> 00:33:02,960
go ahead and put it into motion

910
00:33:07,029 --> 00:33:04,640
um

911
00:33:08,470 --> 00:33:07,039
it's a 7 degree of freedom arm and what

912
00:33:11,029 --> 00:33:08,480
the heck does that mean

913
00:33:12,710 --> 00:33:11,039

what that means is the shoulder

914
00:33:16,070 --> 00:33:12,720
elbow and wrist

915
00:33:17,509 --> 00:33:16,080
have seven articulating joints so three

916
00:33:19,269 --> 00:33:17,519
at the shoulder you see it's doing a

917
00:33:21,110 --> 00:33:19,279
shoulder roll right now

918
00:33:23,269 --> 00:33:21,120
it's got two at the elbow

919
00:33:25,990 --> 00:33:23,279
and two at the wrist so three plus two

920
00:33:27,909 --> 00:33:26,000
plus two yes that's nasa arithmetic for

921
00:33:30,870 --> 00:33:27,919
you that is seven

922
00:33:33,509 --> 00:33:30,880
and you see they are changing the lo the

923
00:33:36,310 --> 00:33:33,519
orientation of the end effector

924
00:33:38,870 --> 00:33:36,320
to point right at us so with two

925
00:33:41,029 --> 00:33:38,880
different hand controllers

926
00:33:43,990 --> 00:33:41,039
astronaut retired marine corps general

927
00:33:45,590 --> 00:33:44,000
charlie bolden is controlling this seven

928
00:33:48,389 --> 00:33:45,600
degree of freedom arm

929
00:33:49,430 --> 00:33:48,399
pointing it right at the camera so it is

930
00:33:51,909 --> 00:33:49,440
with

931
00:33:54,549 --> 00:33:51,919
it's at this very robotic control

932
00:33:57,190 --> 00:33:54,559
station that we will be

933
00:33:59,669 --> 00:33:57,200
manipulating robots in the future to

934
00:34:01,029 --> 00:33:59,679
perform servicing operations like

935
00:34:01,990 --> 00:34:01,039
refueling

936
00:34:07,590 --> 00:34:02,000
on

937
00:34:09,829 --> 00:34:07,600
extending their life getting more value

938
00:34:12,629 --> 00:34:09,839

out of the taxpayers investments

939
00:34:14,389 --> 00:34:12,639
with this technology that is amazing

940
00:34:16,790 --> 00:34:14,399
thank you so much for showing us your

941
00:34:18,550 --> 00:34:16,800
toys and thanks charlie for volunteering

942
00:34:20,629 --> 00:34:18,560
to play um

943
00:34:23,109 --> 00:34:20,639
we've got a bunch of questions

944
00:34:24,950 --> 00:34:23,119
and thanks joe

945
00:34:26,629 --> 00:34:24,960
skilled and natural over here thank you

946
00:34:27,510 --> 00:34:26,639
for teaching charlie everything he knows

947
00:34:31,109 --> 00:34:27,520
about

948
00:34:34,790 --> 00:34:32,790
um so like i said before we've got

949
00:34:35,990 --> 00:34:34,800
questions coming in from social media

950
00:34:38,149 --> 00:34:36,000
and um

951
00:34:39,990 --> 00:34:38,159
i've got some for both of our friends

952
00:34:42,149 --> 00:34:40,000
over here so

953
00:34:44,710 --> 00:34:42,159
uh let's start with ben so what other

954
00:34:46,869 --> 00:34:44,720
satellites are designed to be serviced

955
00:34:48,710 --> 00:34:46,879
in space by robots uh that's an

956
00:34:49,430 --> 00:34:48,720
excellent question

957
00:34:51,829 --> 00:34:49,440
so

958
00:34:53,190 --> 00:34:51,839
designed to be serviced there's really

959
00:34:54,710 --> 00:34:53,200
only two

960
00:34:57,190 --> 00:34:54,720
hubble and the international space

961
00:34:58,790 --> 00:34:57,200
station both designed with human

962
00:34:59,990 --> 00:34:58,800
servicing in mind

963
00:35:02,230 --> 00:35:00,000

um

964
00:35:04,630 --> 00:35:02,240
so those are very notable satellites if

965
00:35:06,470 --> 00:35:04,640
we went to the local grocery store and

966
00:35:08,310 --> 00:35:06,480
asked the average shopper namely two

967
00:35:09,990 --> 00:35:08,320
satellites probably those would be the

968
00:35:11,510 --> 00:35:10,000
two that they would say hubble and the

969
00:35:13,670 --> 00:35:11,520
iss

970
00:35:15,990 --> 00:35:13,680
but there is a thousand eight hundred

971
00:35:18,150 --> 00:35:16,000
other satellites operating in space as

972
00:35:20,230 --> 00:35:18,160
we speak right now today a thousand

973
00:35:21,430 --> 00:35:20,240
eight hundred thereabouts

974
00:35:25,190 --> 00:35:21,440
two of which were designed to be

975
00:35:27,349 --> 00:35:25,200
serviced so a technique a capability

976
00:35:29,190 --> 00:35:27,359
that we are actively working on

977
00:35:31,349 --> 00:35:29,200
with the hardware here in this lab is

978
00:35:33,670 --> 00:35:31,359
the ability to service a satellite that

979
00:35:35,349 --> 00:35:33,680
wasn't designed with servicing in mind

980
00:35:37,510 --> 00:35:35,359
the 99

981
00:35:40,630 --> 00:35:37,520
not just the one percent that's very

982
00:35:43,910 --> 00:35:40,640
much within our uh active uh

983
00:35:46,150 --> 00:35:43,920
program design here is to work on

984
00:35:49,190 --> 00:35:46,160
technologies and capabilities for the

985
00:35:50,310 --> 00:35:49,200
many not just the few okay and charlie i

986
00:35:52,069 --> 00:35:50,320
know i left you out of the question

987
00:35:53,910 --> 00:35:52,079
thing earlier but we've got a bunch of

988
00:35:55,750 --> 00:35:53,920

them that have come in for you now so

989
00:35:57,829 --> 00:35:55,760
from instagram we have someone asking

990
00:36:00,069 --> 00:35:57,839
how long hubble is projected to be in

991
00:36:02,470 --> 00:36:00,079
service that's a good question and i you

992
00:36:03,670 --> 00:36:02,480
know you ask me i would say i think

993
00:36:05,829 --> 00:36:03,680
we're i don't know what we're talking

994
00:36:08,310 --> 00:36:05,839
about now in terms of the finite end of

995
00:36:09,270 --> 00:36:08,320
it but hubble's in great shape

996
00:36:10,950 --> 00:36:09,280
you know

997
00:36:12,470 --> 00:36:10,960
every time we have a problem it takes

998
00:36:13,829 --> 00:36:12,480
itself into safe mode until we can

999
00:36:15,510 --> 00:36:13,839
figure out what's wrong and then we

1000
00:36:17,430 --> 00:36:15,520
bring it back out again i don't think

1001
00:36:18,950 --> 00:36:17,440
anybody would venture i will not venture

1002
00:36:21,510 --> 00:36:18,960
to take a guess

1003
00:36:24,230 --> 00:36:21,520
as to when hubble's life will be over

1004
00:36:26,630 --> 00:36:24,240
the the final decision will probably be

1005
00:36:29,190 --> 00:36:26,640
be made by the budget guys i hate to say

1006
00:36:31,990 --> 00:36:29,200
because once we have james webb uh in

1007
00:36:34,470 --> 00:36:32,000
place and operating it was intended to

1008
00:36:36,470 --> 00:36:34,480
be the replacement for hubble my guess

1009
00:36:39,349 --> 00:36:36,480
is you're going to see the the budget

1010
00:36:41,589 --> 00:36:39,359
guys and the s the astrophysicist and

1011
00:36:43,670 --> 00:36:41,599
the astronomers go at it because hubble

1012
00:36:46,870 --> 00:36:43,680
will continue to give us data that we

1013
00:36:49,589 --> 00:36:46,880

can use to feed into indus telescopes

1014
00:36:51,349 --> 00:36:49,599
like james webb uh to make them even

1015
00:36:53,109 --> 00:36:51,359
more efficient so i would say hubble's

1016
00:36:54,790 --> 00:36:53,119
got a lot more life than we're probably

1017
00:36:55,910 --> 00:36:54,800
going to give it to be quite honest and

1018
00:36:57,430 --> 00:36:55,920
you mentioned something really

1019
00:36:58,390 --> 00:36:57,440
interesting so there are things that we

1020
00:37:00,470 --> 00:36:58,400
can do

1021
00:37:02,790 --> 00:37:00,480
from the ground not

1022
00:37:06,150 --> 00:37:02,800
with astronauts or

1023
00:37:08,630 --> 00:37:06,160
with robots to extend the life of hubble

1024
00:37:10,310 --> 00:37:08,640
what is that well i wasn't i wasn't

1025
00:37:12,710 --> 00:37:10,320
saying we could do anything to extend

1026
00:37:15,430 --> 00:37:12,720
the life of hubble but

1027
00:37:17,670 --> 00:37:15,440
what i was saying before was the way we

1028
00:37:18,550 --> 00:37:17,680
left it after the final servicing

1029
00:37:20,390 --> 00:37:18,560
mission

1030
00:37:22,550 --> 00:37:20,400
it was in much better shape than it was

1031
00:37:24,230 --> 00:37:22,560
designed to be when it was built so it's

1032
00:37:26,150 --> 00:37:24,240
a much more capable

1033
00:37:28,150 --> 00:37:26,160
observatory today than anybody ever

1034
00:37:28,870 --> 00:37:28,160
imagined it would be and that's why i

1035
00:37:30,230 --> 00:37:28,880
think

1036
00:37:32,630 --> 00:37:30,240
there's probably somebody in this

1037
00:37:35,430 --> 00:37:32,640
building who who will venture a guess

1038
00:37:37,510 --> 00:37:35,440

that as to hubble's lifetime i'm not one

1039
00:37:39,990 --> 00:37:37,520
of them because it's not the same

1040
00:37:42,950 --> 00:37:40,000
observatory that you know we designed

1041
00:37:44,550 --> 00:37:42,960
and built back in the 70s 80s and 90s so

1042
00:37:46,950 --> 00:37:44,560
i think it has more capability than we

1043
00:37:48,069 --> 00:37:46,960
can imagine ben you may know well there

1044
00:37:52,550 --> 00:37:48,079
is a

1045
00:37:57,030 --> 00:37:55,270
a phrase we use with uh all complex

1046
00:37:58,790 --> 00:37:57,040
equipment hubble being one infant

1047
00:38:03,030 --> 00:37:58,800
mortality

1048
00:38:06,710 --> 00:38:03,040
of different ways solar ray had some

1049
00:38:08,550 --> 00:38:06,720
issues gyros had some issues

1050
00:38:10,470 --> 00:38:08,560
the optics of course we discovered it

1051
00:38:13,750 --> 00:38:10,480
had some unique features with the optics

1052
00:38:14,630 --> 00:38:13,760
that weren't exactly by design

1053
00:38:18,150 --> 00:38:14,640
hubble

1054
00:38:19,589 --> 00:38:18,160
one of the few exceptions where we have

1055
00:38:22,150 --> 00:38:19,599
through servicing missions and through

1056
00:38:24,230 --> 00:38:22,160
smart engineers on the ground overcome

1057
00:38:26,150 --> 00:38:24,240
though that infant mortality and now it

1058
00:38:28,390 --> 00:38:26,160
is it's going like gangbusters i have to

1059
00:38:30,310 --> 00:38:28,400
agree 100 with charlie

1060
00:38:32,630 --> 00:38:30,320
it is far more powerful than the day it

1061
00:38:35,910 --> 00:38:32,640
launched in fact i believe the the

1062
00:38:37,510 --> 00:38:35,920
number is four orders of magnitude

1063
00:38:39,910 --> 00:38:37,520

more powerful than the day at launch

1064
00:38:41,910 --> 00:38:39,920
because moore's law advances technology

1065
00:38:43,829 --> 00:38:41,920
here on the ground no different but the

1066
00:38:46,550 --> 00:38:43,839
cameras that were put in by these very

1067
00:38:48,470 --> 00:38:46,560
capable astronauts so it's far better

1068
00:38:49,589 --> 00:38:48,480
than the day it was launched and knock

1069
00:38:50,950 --> 00:38:49,599
on wood

1070
00:38:52,950 --> 00:38:50,960
we're going to keep the the science

1071
00:38:55,030 --> 00:38:52,960
discoveries coming

1072
00:38:57,750 --> 00:38:55,040
i've got one more specific question um

1073
00:38:59,589 --> 00:38:57,760
for ben so are there applications for

1074
00:39:02,630 --> 00:38:59,599
these technologies like you know the

1075
00:39:03,670 --> 00:39:02,640
robotic arm beyond satellite servicing

1076
00:39:06,630 --> 00:39:03,680
sure

1077
00:39:09,109 --> 00:39:06,640
we want to discover our place

1078
00:39:12,470 --> 00:39:09,119
in the universe and one way to do that

1079
00:39:18,950 --> 00:39:16,069
go to planetary bodies comets asteroids

1080
00:39:19,750 --> 00:39:18,960
surface of the moon the surface of mars

1081
00:39:21,430 --> 00:39:19,760
and

1082
00:39:23,510 --> 00:39:21,440
collect samples

1083
00:39:26,150 --> 00:39:23,520
collecting samples and analyzing them

1084
00:39:28,470 --> 00:39:26,160
when we are there as mars curiosity

1085
00:39:30,870 --> 00:39:28,480
rover is doing we flew the chemistry lab

1086
00:39:32,630 --> 00:39:30,880
to the surface of mars that required a

1087
00:39:34,870 --> 00:39:32,640
lot of work and that was

1088
00:39:36,630 --> 00:39:34,880

an incredible achievement but just think

1089
00:39:39,190 --> 00:39:36,640
what we could do if we could bring a

1090
00:39:41,430 --> 00:39:39,200
sample back from the surface of mars or

1091
00:39:43,750 --> 00:39:41,440
an asteroid or a comet back to earth you

1092
00:39:44,950 --> 00:39:43,760
know like like a big sample not a few

1093
00:39:46,710 --> 00:39:44,960
grains

1094
00:39:48,310 --> 00:39:46,720
which we've already done from from a

1095
00:39:50,710 --> 00:39:48,320
comet

1096
00:39:51,750 --> 00:39:50,720
so the ability to have advanced robotics

1097
00:39:52,630 --> 00:39:51,760
to have

1098
00:39:54,870 --> 00:39:52,640
these

1099
00:39:57,349 --> 00:39:54,880
tremendous capabilities that engineers

1100
00:39:59,910 --> 00:39:57,359
like joe are helping us develop and use

1101
00:40:01,589 --> 00:39:59,920
those for other exploration missions to

1102
00:40:04,309 --> 00:40:01,599
help support astronauts going further

1103
00:40:07,270 --> 00:40:04,319
into the solar system we are absolutely

1104
00:40:08,470 --> 00:40:07,280
focusing on that as part of our

1105
00:40:09,349 --> 00:40:08,480
mission set

1106
00:40:11,190 --> 00:40:09,359
not

1107
00:40:13,109 --> 00:40:11,200
just satellites even though that's a

1108
00:40:14,870 --> 00:40:13,119
broad thing to say

1109
00:40:17,349 --> 00:40:14,880
we're we're looking at the the entire

1110
00:40:18,790 --> 00:40:17,359
spectrum here a good example of what ben

1111
00:40:20,710 --> 00:40:18,800
was just talking about is we have a

1112
00:40:22,630 --> 00:40:20,720
mission that just accomplished one of

1113
00:40:24,230 --> 00:40:22,640

its major milestones and it's got it got

1114
00:40:26,069 --> 00:40:24,240
kind of lost because it came right on

1115
00:40:28,710 --> 00:40:26,079
the heels of insights land yeah it's

1116
00:40:31,030 --> 00:40:28,720
called osiris-rex that is now orbiting

1117
00:40:32,630 --> 00:40:31,040
bennu an asteroid and that's exactly

1118
00:40:34,309 --> 00:40:32,640
what ben was talking about it's no

1119
00:40:36,790 --> 00:40:34,319
humans involved whatsoever it's

1120
00:40:39,510 --> 00:40:36,800
surveying to find a place that it can

1121
00:40:40,870 --> 00:40:39,520
land so to speak go down get a sample

1122
00:40:43,589 --> 00:40:40,880
and then bring it back and for the first

1123
00:40:46,309 --> 00:40:43,599
time we'll actually have a sample of

1124
00:40:47,910 --> 00:40:46,319
soil if you will from an asteroid that's

1125
00:40:49,510 --> 00:40:47,920
going to help us understand more about

1126
00:40:51,589 --> 00:40:49,520
our solar system and more about our own

1127
00:40:53,349 --> 00:40:51,599
planet earth since it all started from

1128
00:40:54,950 --> 00:40:53,359
the same place so you know the stuff

1129
00:40:57,430 --> 00:40:54,960
that joe and the guys here are doing

1130
00:41:00,390 --> 00:40:57,440
with um with the satellites that they're

1131
00:41:02,390 --> 00:41:00,400
working on right now it's i i would not

1132
00:41:04,950 --> 00:41:02,400
even venture to say what what it is that

1133
00:41:07,829 --> 00:41:04,960
we cannot do with satellites and and

1134
00:41:09,349 --> 00:41:07,839
robotic space spacecraft i love that so

1135
00:41:11,510 --> 00:41:09,359
i know that the astronauts kind of

1136
00:41:12,309 --> 00:41:11,520
answered it from their perspective but

1137
00:41:16,950 --> 00:41:12,319
from

1138
00:41:18,790 --> 00:41:16,960

hubble did you incorporate into the

1139
00:41:21,190 --> 00:41:18,800
servicing technology that you're working

1140
00:41:22,870 --> 00:41:21,200
on right now oh that's a great question

1141
00:41:24,630 --> 00:41:22,880
i'll give you

1142
00:41:30,230 --> 00:41:24,640
the general answer and then a specific

1143
00:41:35,670 --> 00:41:33,109
hubble has been in orbit for many years

1144
00:41:37,109 --> 00:41:35,680
when we got to hubble there were items

1145
00:41:38,870 --> 00:41:37,119
on it that weren't exactly like they

1146
00:41:39,829 --> 00:41:38,880
were when we left it especially on the

1147
00:41:42,550 --> 00:41:39,839
outside

1148
00:41:44,950 --> 00:41:42,560
space is an incredibly harsh environment

1149
00:41:46,470 --> 00:41:44,960
radiation micro meteoroids orbital

1150
00:41:48,390 --> 00:41:46,480
debris

1151
00:41:50,870 --> 00:41:48,400
solar thermal cycling

1152
00:41:53,270 --> 00:41:50,880
it takes its toll on the outside of the

1153
00:41:57,030 --> 00:41:53,280
telescope every telescope or every

1154
00:41:59,750 --> 00:41:57,040
satellite faces these these challenges

1155
00:42:01,990 --> 00:41:59,760
so what we did with hubble we designed

1156
00:42:04,470 --> 00:42:02,000
our tools and our techniques and train

1157
00:42:06,630 --> 00:42:04,480
the astronauts to accommodate a wide

1158
00:42:08,150 --> 00:42:06,640
range of conditions when you arrive

1159
00:42:10,470 --> 00:42:08,160
and one thing we

1160
00:42:12,309 --> 00:42:10,480
technique we used was if you're not sure

1161
00:42:13,829 --> 00:42:12,319
the condition of a component what it's

1162
00:42:15,030 --> 00:42:13,839
going to be bring up your own

1163
00:42:16,550 --> 00:42:15,040

replacement

1164
00:42:17,750 --> 00:42:16,560
that way you can be sure that what you

1165
00:42:21,030 --> 00:42:17,760
leave behind

1166
00:42:23,670 --> 00:42:21,040
is pristine or will work properly

1167
00:42:25,670 --> 00:42:23,680
so robotic servicing we are going to be

1168
00:42:28,069 --> 00:42:25,680
going to a

1169
00:42:32,710 --> 00:42:28,079
22 year old satellite so it'll be old

1170
00:42:34,790 --> 00:42:32,720
enough to drink when we go to refuel it

1171
00:42:37,270 --> 00:42:34,800
it has blanketing on the outside that

1172
00:42:39,430 --> 00:42:37,280
shiny gold blanketing you saw earlier

1173
00:42:41,910 --> 00:42:39,440
we don't know if we're going to mess up

1174
00:42:43,990 --> 00:42:41,920
the blanketing when we robotically cut a

1175
00:42:46,470 --> 00:42:44,000
hole in it to get access to the fueling

1176
00:42:48,550 --> 00:42:46,480
valve so what are we going to do we are

1177
00:42:50,470 --> 00:42:48,560
going to bring up our own thermal cover

1178
00:42:52,230 --> 00:42:50,480
in case that blanket gets mangled and

1179
00:42:54,630 --> 00:42:52,240
quite frankly we are learning by doing

1180
00:42:56,390 --> 00:42:54,640
we might make a mistake

1181
00:42:59,270 --> 00:42:56,400
by bringing our own thermal cover a

1182
00:43:01,270 --> 00:42:59,280
five-sided top hat so to speak

1183
00:43:03,670 --> 00:43:01,280
we will be sure we can leave the telus

1184
00:43:05,270 --> 00:43:03,680
the uh that satellite in a stable

1185
00:43:07,750 --> 00:43:05,280
configuration thermally stable

1186
00:43:09,589 --> 00:43:07,760
configuration with with our own thermal

1187
00:43:11,349 --> 00:43:09,599
cover so there's an example of what we

1188
00:43:13,430 --> 00:43:11,359

learned with hubble was if you can't

1189
00:43:15,589 --> 00:43:13,440
trust it bring your own we're going to

1190
00:43:17,109 --> 00:43:15,599
do that with robots as well and so

1191
00:43:20,710 --> 00:43:17,119
unfortunately we've only got time for

1192
00:43:22,230 --> 00:43:20,720
one more question um how are humans also

1193
00:43:24,069 --> 00:43:22,240
involved in the robotic servicing that

1194
00:43:27,270 --> 00:43:24,079
we're seeing here in this lab what is

1195
00:43:30,230 --> 00:43:27,280
the human component here human judgment

1196
00:43:32,470 --> 00:43:30,240
human dexterity human skill

1197
00:43:34,390 --> 00:43:32,480
you get it guys like joe here running

1198
00:43:36,230 --> 00:43:34,400
those hand controllers right he is going

1199
00:43:37,030 --> 00:43:36,240
to be doing that with video coming back

1200
00:43:39,030 --> 00:43:37,040
down

1201
00:43:40,950 --> 00:43:39,040
from our tools all of our robotic tools

1202
00:43:43,270 --> 00:43:40,960
have cameras on them so joe is going to

1203
00:43:45,829 --> 00:43:43,280
be using those camera views coming back

1204
00:43:47,589 --> 00:43:45,839
on his screens here and deciding how

1205
00:43:48,630 --> 00:43:47,599
much to move the joystick in what

1206
00:43:51,510 --> 00:43:48,640
direction

1207
00:43:52,870 --> 00:43:51,520
so robots are not smart they are not

1208
00:43:55,589 --> 00:43:52,880
smart at all

1209
00:43:58,230 --> 00:43:55,599
guys like joe are smart they've got

1210
00:43:59,829 --> 00:43:58,240
judgment they've got experience and that

1211
00:44:01,589 --> 00:43:59,839
is how we are going to make sure that

1212
00:44:03,349 --> 00:44:01,599
the best qualities of humans and the

1213
00:44:05,270 --> 00:44:03,359

best qualities of robots are married

1214
00:44:06,710 --> 00:44:05,280
together in these future missions now

1215
00:44:07,910 --> 00:44:06,720
you just made it really hard for joe to

1216
00:44:09,510 --> 00:44:07,920
get around the lab the rest of the

1217
00:44:11,030 --> 00:44:09,520
afternoon

1218
00:44:12,790 --> 00:44:11,040
everybody will get out of your way joe

1219
00:44:14,630 --> 00:44:12,800
get out of my way

1220
00:44:16,630 --> 00:44:14,640
everything for joe

1221
00:44:18,630 --> 00:44:16,640
thank you all so much for being here and

1222
00:44:20,870 --> 00:44:18,640
for answering all these questions and

1223
00:44:23,349 --> 00:44:20,880
for giving us this wonderful demo and

1224
00:44:25,589 --> 00:44:23,359
the space to host this show

1225
00:44:27,670 --> 00:44:25,599
we're very grateful but the party's not

1226
00:44:29,990 --> 00:44:27,680
over yet we've got two more live shows

1227
00:44:31,670 --> 00:44:30,000
tomorrow with astronauts we've got two

1228
00:44:33,430 --> 00:44:31,680
astronauts from servicing mission one

1229
00:44:34,710 --> 00:44:33,440
talking about their experience on the

1230
00:44:36,710 --> 00:44:34,720
first ever

1231
00:44:39,430 --> 00:44:36,720
human servicing mission to hubble how

1232
00:44:40,710 --> 00:44:39,440
did that go find out tomorrow

1233
00:44:43,349 --> 00:44:40,720
on facebook

1234
00:44:45,190 --> 00:44:43,359
our facebook specifically and then

1235
00:44:47,910 --> 00:44:45,200
we also have a show in the afternoon of

1236
00:44:49,750 --> 00:44:47,920
astronauts from all the five servicing

1237
00:44:51,670 --> 00:44:49,760
missions plus we got charlie will be

1238
00:44:52,790 --> 00:44:51,680

with us too so

1239
00:44:54,470 --> 00:44:52,800
you're going to want to tune in you're

1240
00:44:56,069 --> 00:44:54,480
going to want to send in your questions

1241
00:44:57,589 --> 00:44:56,079
and we will see you then but in the

1242
00:45:00,390 --> 00:44:57,599
meantime if you want more hubble you can

1243
00:45:02,230 --> 00:45:00,400
always find us on nasa.gov hubble or on

1244
00:45:09,510 --> 00:45:02,240
social media at nasa hubble thank you

1245
00:45:12,230 --> 00:45:11,270
five four

1246
00:45:13,109 --> 00:45:12,240
three

1247
00:45:15,990 --> 00:45:13,119
two

1248
00:45:17,829 --> 00:45:16,000
one and liftoff of the space shuttle

1249
00:45:21,830 --> 00:45:17,839
discovery with the hubble space

1250
00:45:32,580 --> 00:45:21,840
telescope our window on the universe

1251
00:46:45,510 --> 00:46:20,630
[Music]

1252
00:46:48,150 --> 00:46:45,520
trouble isn't just a satellite

1253
00:46:49,910 --> 00:46:48,160
it's uh about humanity's quest for

1254
00:46:51,750 --> 00:46:49,920
knowledge the only way of finding the

1255
00:46:54,069 --> 00:46:51,760
limits of the possible

1256
00:46:55,589 --> 00:46:54,079
is by going beyond them into the

1257
00:46:57,430 --> 00:46:55,599
impossible

1258
00:47:00,309 --> 00:46:57,440
i want to wish hubble its own set of

1259
00:47:09,589 --> 00:47:00,319
adventures that it may unlock further

1260
00:47:13,910 --> 00:47:11,270
hubble's space telescope imaging

1261
00:47:15,670 --> 00:47:13,920
spectrograph or stis has capabilities

1262
00:47:17,190 --> 00:47:15,680
like searching for black holes and

1263
00:47:18,950 --> 00:47:17,200

looking at the atmospheres of planets

1264
00:47:21,510 --> 00:47:18,960
orbiting other stars

1265
00:47:22,790 --> 00:47:21,520
after stis had a power failure in 2004

1266
00:47:24,710 --> 00:47:22,800
the hubble team was tasked with

1267
00:47:26,390 --> 00:47:24,720
replacing stis's damaged electronics

1268
00:47:27,750 --> 00:47:26,400
boards on the final servicing mission in

1269
00:47:29,750 --> 00:47:27,760
2009

1270
00:47:36,829 --> 00:47:29,760
which would turn out to be a memorable

1271
00:47:42,069 --> 00:47:39,589
involved so for about two years i spent

1272
00:47:43,829 --> 00:47:42,079
almost every day with the eva team the

1273
00:47:45,910 --> 00:47:43,839
four crew members we practiced that

1274
00:47:47,510 --> 00:47:45,920
repair many many times and we practice

1275
00:47:50,150 --> 00:47:47,520
it in the water start to finish in the

1276
00:47:51,829 --> 00:47:50,160
pool many times we spent hours and days

1277
00:47:53,910 --> 00:47:51,839
and weeks and months going through what

1278
00:47:56,069 --> 00:47:53,920
if this bolt fails what if the cable

1279
00:47:57,349 --> 00:47:56,079
doesn't mate so i felt that we had

1280
00:47:59,190 --> 00:47:57,359
covered you know as much as we could

1281
00:48:06,549 --> 00:47:59,200
have thought of going into this

1282
00:48:11,109 --> 00:48:09,349
so we came in to work here at the space

1283
00:48:14,150 --> 00:48:11,119
telescope operations control center at

1284
00:48:15,910 --> 00:48:14,160
goddard our mechanical response team was

1285
00:48:17,990 --> 00:48:15,920
was watching the eva in a conference

1286
00:48:20,390 --> 00:48:18,000
room in building 29 i was located down

1287
00:48:22,230 --> 00:48:20,400
at johnson space center along with a

1288
00:48:24,069 --> 00:48:22,240

servicing mission manager the day

1289
00:48:26,150 --> 00:48:24,079
started out really well you know i was i

1290
00:48:27,589 --> 00:48:26,160
was trying to make it a perfect day no

1291
00:48:28,950 --> 00:48:27,599
problems so they get to the section

1292
00:48:30,870 --> 00:48:28,960
where they have to remove the handrail

1293
00:48:32,150 --> 00:48:30,880
on stairs and you have to remove this

1294
00:48:34,069 --> 00:48:32,160
handrail that was designed actually to

1295
00:48:35,270 --> 00:48:34,079
help remove and install the entire

1296
00:48:37,670 --> 00:48:35,280
instrument

1297
00:48:40,150 --> 00:48:37,680
in order to access the electronics board

1298
00:48:42,790 --> 00:48:40,160
underneath and we watched mike massimino

1299
00:48:44,470 --> 00:48:42,800
attempt to do a rather simple task all

1300
00:48:46,549 --> 00:48:44,480
you had to do was remove four screws

1301
00:48:48,630 --> 00:48:46,559
from a hand rail so the two screws at

1302
00:48:50,150 --> 00:48:48,640
the top of the handrail came off fine

1303
00:48:51,670 --> 00:48:50,160
the one on the bottom left comes out

1304
00:48:52,790 --> 00:48:51,680
fine i go to the bottom right we could

1305
00:48:54,630 --> 00:48:52,800
see

1306
00:48:56,630 --> 00:48:54,640
the pistol grip tool

1307
00:48:59,030 --> 00:48:56,640
spinning in the bolt head

1308
00:49:00,829 --> 00:48:59,040
and the bolt wasn't coming out

1309
00:49:04,069 --> 00:49:00,839
we don't want to strip the

1310
00:49:05,109 --> 00:49:04,079
thing oh my god um that was the first

1311
00:49:07,829 --> 00:49:05,119
thing you know it's what are we going to

1312
00:49:09,910 --> 00:49:07,839
do because this is a a show stopper

1313
00:49:12,309 --> 00:49:09,920

right here for a while probably about an

1314
00:49:14,390 --> 00:49:12,319
hour or so we were trying different bits

1315
00:49:16,630 --> 00:49:14,400
on the end of the power tool and we were

1316
00:49:17,829 --> 00:49:16,640
trying all kinds of things

1317
00:49:19,910 --> 00:49:17,839
you know the one thing that crossed my

1318
00:49:21,190 --> 00:49:19,920
mind was what would you do what would

1319
00:49:22,390 --> 00:49:21,200
you do at home you know what would you

1320
00:49:24,069 --> 00:49:22,400
do in your garage you know and i was

1321
00:49:25,430 --> 00:49:24,079
thinking back to my garage you know and

1322
00:49:27,030 --> 00:49:25,440
sometimes what would i do you know and i

1323
00:49:28,309 --> 00:49:27,040
just kind of you know use the brute

1324
00:49:30,230 --> 00:49:28,319
force you know so i thought you know

1325
00:49:31,829 --> 00:49:30,240
what about just trying to break it it

1326
00:49:32,790 --> 00:49:31,839
didn't even occur to a lot of us just

1327
00:49:34,549 --> 00:49:32,800
because it's something that you're not

1328
00:49:35,750 --> 00:49:34,559
really ever trained to do or think of so

1329
00:49:37,510 --> 00:49:35,760
one of the things i did was i called

1330
00:49:39,589 --> 00:49:37,520
back to james cooper back here at

1331
00:49:41,510 --> 00:49:39,599
goddard james cooper called us on the

1332
00:49:42,790 --> 00:49:41,520
speaker phone and said hey guys we

1333
00:49:44,549 --> 00:49:42,800
you're watching this right and he said

1334
00:49:47,589 --> 00:49:44,559
yeah yeah of course we found out we did

1335
00:49:49,349 --> 00:49:47,599
have a mock-up of this disc front panel

1336
00:49:52,309 --> 00:49:49,359
with the handrail on it we came up with

1337
00:49:54,549 --> 00:49:52,319
a quick plan bill mitchell said i've got

1338
00:49:56,390 --> 00:49:54,559

two handrails inside the clean room and

1339
00:49:58,630 --> 00:49:56,400
ken dickinson and i came up with a plan

1340
00:50:00,710 --> 00:49:58,640
for how to rig up the test so we

1341
00:50:02,230 --> 00:50:00,720
scattered into the building to get all

1342
00:50:04,470 --> 00:50:02,240
the materials we were going to need well

1343
00:50:06,790 --> 00:50:04,480
it was a sunday nobody was around

1344
00:50:08,870 --> 00:50:06,800
so i i'm literally running through the

1345
00:50:11,030 --> 00:50:08,880
halls and i run to where the techs would

1346
00:50:12,710 --> 00:50:11,040
be and i find a guy gene mccalliker who

1347
00:50:14,470 --> 00:50:12,720
would happen to be in the building

1348
00:50:15,750 --> 00:50:14,480
working on another project so he said

1349
00:50:17,910 --> 00:50:15,760
what do you mean

1350
00:50:19,510 --> 00:50:17,920
he seemed to pick up on my body language

1351
00:50:21,990 --> 00:50:19,520
before i even asked my question but i

1352
00:50:24,710 --> 00:50:22,000
told him i need a torque wrench and

1353
00:50:27,030 --> 00:50:24,720
i need a digital fish skill he takes off

1354
00:50:29,190 --> 00:50:27,040
to go get it i go to 190. ken

1355
00:50:31,349 --> 00:50:29,200
dickinson's already in there and within

1356
00:50:33,109 --> 00:50:31,359
minutes bill mitchell comes

1357
00:50:35,750 --> 00:50:33,119
busting through the door carrying the

1358
00:50:37,670 --> 00:50:35,760
handrail still in his bunny suit and his

1359
00:50:39,910 --> 00:50:37,680
clean room garment we get the handrail

1360
00:50:41,750 --> 00:50:39,920
all set up everything's ready to go we

1361
00:50:43,589 --> 00:50:41,760
text a couple pictures back and forth

1362
00:50:45,589 --> 00:50:43,599
james gives us the green light

1363
00:50:47,109 --> 00:50:45,599

and gene stands up on the table and

1364
00:50:48,950 --> 00:50:47,119
starts pulling the handrail and right

1365
00:50:50,230 --> 00:50:48,960
when he got to 60 pounds

1366
00:50:51,910 --> 00:50:50,240
it snapped

1367
00:50:53,670 --> 00:50:51,920
actually the bolt went flying once we'd

1368
00:50:55,910 --> 00:50:53,680
done that test then

1369
00:50:57,030 --> 00:50:55,920
i got on our communication loops and

1370
00:50:59,670 --> 00:50:57,040
called it to

1371
00:51:01,190 --> 00:50:59,680
jim corbo so ultimately you know james

1372
00:51:03,510 --> 00:51:01,200
came back and said you know take about

1373
00:51:05,510 --> 00:51:03,520
60 pounds of force for them to break it

1374
00:51:07,109 --> 00:51:05,520
off so goddard had done this test fed

1375
00:51:08,230 --> 00:51:07,119
the information to us we talked to the

1376
00:51:11,109 --> 00:51:08,240
flight director about it to get him

1377
00:51:13,589 --> 00:51:11,119
comfortable okay mass you copy that 60

1378
00:51:15,589 --> 00:51:13,599
pounds linear at the top of the handrail

1379
00:51:17,750 --> 00:51:15,599
to bust off that bottom bolt i think

1380
00:51:19,510 --> 00:51:17,760
you've got that in you that control i

1381
00:51:21,190 --> 00:51:19,520
knew i could do that what if he pulls it

1382
00:51:23,030 --> 00:51:21,200
off and there's debris what if he pulls

1383
00:51:24,710 --> 00:51:23,040
off the handrail and there's a sharp

1384
00:51:26,069 --> 00:51:24,720
edge what if he it takes a lot of force

1385
00:51:28,069 --> 00:51:26,079
and it comes back and hits him mike

1386
00:51:29,670 --> 00:51:28,079
massimino was able to

1387
00:51:31,750 --> 00:51:29,680
put some tape over the head of the bolt

1388
00:51:34,150 --> 00:51:31,760

to contain debris that that might go

1389
00:51:36,230 --> 00:51:34,160
flying and so i taped it as best i could

1390
00:51:38,069 --> 00:51:36,240
and wayne was with me helping me to take

1391
00:51:41,109 --> 00:51:38,079
that thing and then better we don't have

1392
00:51:45,430 --> 00:51:41,119
video right now but we're ready okay man

1393
00:51:50,390 --> 00:51:47,109
what's up

1394
00:51:51,910 --> 00:51:50,400
disposal back please

1395
00:51:53,990 --> 00:51:51,920
everyone erupted in

1396
00:51:55,829 --> 00:51:54,000
tears uh because when he pulled it off

1397
00:51:57,829 --> 00:51:55,839
he didn't see any debris um and he knew

1398
00:51:59,030 --> 00:51:57,839
not to touch the potential sharp edges

1399
00:52:01,510 --> 00:51:59,040
and then we could just put that fastener

1400
00:52:03,349 --> 00:52:01,520
capture plate on and complete this task

1401
00:52:05,670 --> 00:52:03,359
the rest of the repair went fairly well

1402
00:52:08,950 --> 00:52:05,680
so this i mean it was fine actually and

1403
00:52:10,710 --> 00:52:08,960
uh it's this is working that one or two

1404
00:52:12,950 --> 00:52:10,720
hours that i worked on breaking the

1405
00:52:16,069 --> 00:52:12,960
handrail that task that very well could

1406
00:52:19,670 --> 00:52:16,079
go down as a highlight of my career so

1407
00:52:27,930 --> 00:52:19,680
the goddard team did did a great job and

1408
00:52:34,770 --> 00:52:31,750
[Music]

1409
00:52:37,910 --> 00:52:34,780
we are all explorers

1410
00:52:43,109 --> 00:52:37,920
[Music]

1411
00:52:49,630 --> 00:52:47,349
we explore the depths of our oceans

1412
00:52:52,549 --> 00:52:49,640
our planet's inner regions

1413
00:52:57,910 --> 00:52:52,559

[Music]

1414
00:53:07,589 --> 00:53:00,760
we never stop exploring

1415
00:53:11,349 --> 00:53:09,750
galileo opened our eyes to the heavens

1416
00:53:12,829 --> 00:53:11,359
with his use of a newly invented

1417
00:53:14,549 --> 00:53:12,839
instrument the

1418
00:53:16,790 --> 00:53:14,559
telescope

1419
00:53:18,220 --> 00:53:16,800
he started an exploration renaissance of

1420
00:53:19,829 --> 00:53:18,230
the sky

1421
00:53:22,710 --> 00:53:19,839
[Music]

1422
00:53:27,430 --> 00:53:22,720
that would take us to the moon

1423
00:53:31,670 --> 00:53:29,589
for over a quarter century the hubble

1424
00:53:35,460 --> 00:53:31,680
space telescope has been unlocking the

1425
00:53:39,910 --> 00:53:37,750
[Music]

1426
00:53:47,270 --> 00:53:39,920
allowing us to explore the edges of

1427
00:53:47,280 --> 00:53:50,110
from nebulas

1428
00:53:55,990 --> 00:53:51,589
[Music]

1429
00:53:56,000 --> 00:53:59,670
from newborn stars

1430
00:54:03,829 --> 00:54:01,340
to planet formation

1431
00:54:07,670 --> 00:54:03,839
[Music]

1432
00:54:07,680 --> 00:54:11,750
to our own planets

1433
00:54:15,990 --> 00:54:13,320
and from dark matter

1434
00:54:22,390 --> 00:54:16,000
[Music]

1435
00:54:25,990 --> 00:54:23,910
hubble has allowed us to see the

1436
00:54:29,010 --> 00:54:26,000
breathtaking details of the universe

1437
00:54:33,750 --> 00:54:31,430
[Music]

1438
00:54:36,470 --> 00:54:33,760

we salute the thousands of men and women

1439
00:54:38,549 --> 00:54:36,480
from around the world and in space

1440
00:54:42,870 --> 00:54:38,559
that have given humanity this incredible

1441
00:54:46,630 --> 00:54:44,450
while we celebrate its past

1442
00:54:52,950 --> 00:54:46,640
[Music]

1443
00:55:07,470 --> 00:54:55,510
the hubble space telescope

1444
00:55:13,190 --> 00:55:11,670
[Music]

1445
00:55:15,510 --> 00:55:13,200
engineers at the goddard space flight

1446
00:55:18,390 --> 00:55:15,520
center discovered that there was a very

1447
00:55:20,309 --> 00:55:18,400
small fault in the power control unit

1448
00:55:22,309 --> 00:55:20,319
you know it's the heart of hubble it all

1449
00:55:24,150 --> 00:55:22,319
the power runs through that box to

1450
00:55:26,470 --> 00:55:24,160
change out the pcu you actually have to

1451
00:55:28,470 --> 00:55:26,480
turn off the telescope this is something

1452
00:55:30,069 --> 00:55:28,480
we've never ever done is turn the

1453
00:55:32,870 --> 00:55:30,079
telescope completely off because when

1454
00:55:34,390 --> 00:55:32,880
you turn all of the power off of hubble

1455
00:55:36,390 --> 00:55:34,400
it starts getting cold

1456
00:55:37,430 --> 00:55:36,400
you know space is a cruel environment

1457
00:55:40,069 --> 00:55:37,440
and so

1458
00:55:41,829 --> 00:55:40,079
the temperature control telescope is

1459
00:55:43,510 --> 00:55:41,839
very important i was brought on to

1460
00:55:45,190 --> 00:55:43,520
develop a command procedure which we

1461
00:55:47,030 --> 00:55:45,200
called the super proc which would turn

1462
00:55:49,190 --> 00:55:47,040
the telescope off as quickly as we

1463
00:55:51,349 --> 00:55:49,200

possibly could for months we analyzed

1464
00:55:53,750 --> 00:55:51,359
different scenarios we thought through

1465
00:55:55,990 --> 00:55:53,760
everything that could possibly go wrong

1466
00:56:00,390 --> 00:55:56,000
you know we felt confident we had a ream

1467
00:56:04,069 --> 00:56:02,150
i arrived late at night for the start of

1468
00:56:06,549 --> 00:56:04,079
the orbit shift so the team was very

1469
00:56:08,470 --> 00:56:06,559
prepared and very focused on on what we

1470
00:56:10,549 --> 00:56:08,480
had to do that night you know everything

1471
00:56:12,309 --> 00:56:10,559
was pretty calm everything was you know

1472
00:56:13,910 --> 00:56:12,319
you're nervous but everything was going

1473
00:56:15,349 --> 00:56:13,920
according to plan

1474
00:56:16,789 --> 00:56:15,359
john is getting into the suit he's

1475
00:56:18,309 --> 00:56:16,799
getting into the air lock they're going

1476
00:56:19,910 --> 00:56:18,319
through all their checklists and we're

1477
00:56:21,670 --> 00:56:19,920
sending commands and commands and it's

1478
00:56:24,710 --> 00:56:21,680
like a we're starting down a roller

1479
00:56:26,789 --> 00:56:24,720
coaster ride the goal was always to have

1480
00:56:28,829 --> 00:56:26,799
the work site ready to go with whatever

1481
00:56:31,270 --> 00:56:28,839
power needed to be removed for safety

1482
00:56:33,510 --> 00:56:31,280
considerations just when the crew got to

1483
00:56:35,670 --> 00:56:33,520
the work site

1484
00:56:37,910 --> 00:56:35,680
all of a sudden we hear

1485
00:56:38,950 --> 00:56:37,920
over the loops we hear john say i have a

1486
00:56:41,430 --> 00:56:38,960
leak

1487
00:56:43,430 --> 00:56:41,440
what does that mean

1488
00:56:44,789 --> 00:56:43,440

a water leak in a suit you know that's

1489
00:56:47,030 --> 00:56:44,799
that's not good

1490
00:56:48,950 --> 00:56:47,040
then al comes on the loops and tells us

1491
00:56:50,470 --> 00:56:48,960
stop doing the commanding we need to

1492
00:56:52,870 --> 00:56:50,480
figure out what we're going to do from

1493
00:56:55,510 --> 00:56:52,880
this point we immediately did was

1494
00:56:57,990 --> 00:56:55,520
started to assess what components we had

1495
00:56:59,670 --> 00:56:58,000
already powered off and i said you know

1496
00:57:01,990 --> 00:56:59,680
these things don't have a lot of margin

1497
00:57:03,750 --> 00:57:02,000
you know we're we're up to the line our

1498
00:57:05,510 --> 00:57:03,760
thermal engineers would tell us well

1499
00:57:07,750 --> 00:57:05,520
given the condition and the current

1500
00:57:08,870 --> 00:57:07,760
temperatures we've got a certain amount

1501
00:57:10,789 --> 00:57:08,880
of time

1502
00:57:12,789 --> 00:57:10,799
i said okay turn on this turn on this

1503
00:57:14,950 --> 00:57:12,799
instrument turn on these you know

1504
00:57:16,549 --> 00:57:14,960
general bus heaters at the same time the

1505
00:57:18,470 --> 00:57:16,559
astronauts are frantically working to

1506
00:57:21,829 --> 00:57:18,480
change out john's suit to get him back

1507
00:57:23,510 --> 00:57:21,839
ready the next thing we hear is okay

1508
00:57:24,950 --> 00:57:23,520
we've got it fixed you know who got into

1509
00:57:27,190 --> 00:57:24,960
a different suit and things you know

1510
00:57:28,950 --> 00:57:27,200
were working well we turned right back

1511
00:57:31,030 --> 00:57:28,960
around and started shutting things back

1512
00:57:33,030 --> 00:57:31,040
off and so we were right back on that

1513
00:57:34,630 --> 00:57:33,040

roller coaster of powering down again it

1514
00:57:36,069 --> 00:57:34,640
was a relief to me we're back on track

1515
00:57:38,390 --> 00:57:36,079
you know we're back to you know the

1516
00:57:40,390 --> 00:57:38,400
original plan luckily we had everything

1517
00:57:42,309 --> 00:57:40,400
reconfigured in time so about the time

1518
00:57:44,069 --> 00:57:42,319
by the time john got to the door and was

1519
00:57:46,309 --> 00:57:44,079
ready to start working on the pcu we

1520
00:57:49,349 --> 00:57:46,319
were able to send the super proc the

1521
00:57:52,470 --> 00:57:49,359
telescope is powered down

1522
00:57:55,190 --> 00:57:52,480
god tell those super people

1523
00:57:55,200 --> 00:57:58,870
the telescope was completely off

1524
00:58:02,069 --> 00:58:00,549
it's an engineer's lifeblood to sit

1525
00:58:03,589 --> 00:58:02,079
there and watch the television to watch

1526
00:58:05,349 --> 00:58:03,599
the temperatures watch the voltages

1527
00:58:06,630 --> 00:58:05,359
watch the power make sure everything is

1528
00:58:08,710 --> 00:58:06,640
safe while they're working on the

1529
00:58:10,630 --> 00:58:08,720
telescope we had none of that all we

1530
00:58:13,109 --> 00:58:10,640
could do was sit back and watch john

1531
00:58:15,030 --> 00:58:13,119
perform what was the most amazing eva of

1532
00:58:27,510 --> 00:58:15,040
all times it was like watching poetry in

1533
00:58:32,309 --> 00:58:30,150
before we knew it it was time to power

1534
00:58:35,030 --> 00:58:32,319
things back on they give us the call

1535
00:58:36,630 --> 00:58:35,040
down to say go for the pcu aliveness

1536
00:58:38,549 --> 00:58:36,640
test this is where we actually can send

1537
00:58:39,630 --> 00:58:38,559
the commands to turn the telescope back

1538
00:58:42,230 --> 00:58:39,640

on

1539
00:58:44,230 --> 00:58:42,240
[Music]

1540
00:58:46,630 --> 00:58:44,240
all of a sudden this flood of telemetry

1541
00:58:48,069 --> 00:58:46,640
starts coming in from the telescope

1542
00:58:50,710 --> 00:58:48,079
power was running through it the

1543
00:58:53,589 --> 00:58:50,720
batteries were charging um

1544
00:58:55,589 --> 00:58:53,599
and for me the temperatures were looking

1545
00:58:57,910 --> 00:58:55,599
in a safe you know range everyone's