



1  
00:00:00,790 --> 00:00:07,320

[Music]

2  
00:00:12,080 --> 00:00:09,220

[Applause]

3  
00:00:14,869 --> 00:00:12,090

hey I'm stat I'm going to talk to you

4  
00:00:19,310 --> 00:00:14,879

today about LC so one of the challenges

5  
00:00:22,640 --> 00:00:19,320

of sampling europa is using the Europa

6  
00:00:24,950 --> 00:00:22,650

Lander cameras to find the spot on the

7  
00:00:26,929 --> 00:00:24,960

surface nearby the lander that contains

8  
00:00:29,150 --> 00:00:26,939

evidence of habitability of the ocean

9  
00:00:31,970 --> 00:00:29,160

and potentially bio signatures to

10  
00:00:34,370 --> 00:00:31,980

measure from somewhere within a 2 square

11  
00:00:37,160 --> 00:00:34,380

meter workspace and do this in just a

12  
00:00:40,160 --> 00:00:37,170

couple of days within the confines of a

13  
00:00:42,110 --> 00:00:40,170

22 day mission now this sounds extremely

14

00:00:43,850 --> 00:00:42,120

challenging and it will be but we've

15

00:00:46,310 --> 00:00:43,860

actually done something related before

16

00:00:49,190 --> 00:00:46,320

and that is finding the Mars 2020

17

00:00:51,770 --> 00:00:49,200

landing site granted at a much slower

18

00:00:55,220 --> 00:00:51,780

pace but with a similar objective of

19

00:00:57,880 --> 00:00:55,230

using a spectral signature of a mineral

20

00:01:00,830 --> 00:00:57,890

to find a past habitable environment

21

00:01:04,130 --> 00:01:00,840

that has the potential to preserve bio

22

00:01:06,469 --> 00:01:04,140

signatures so we can take a lesson from

23

00:01:09,010 --> 00:01:06,479

how that was done using data from the

24

00:01:12,289 --> 00:01:09,020

Chris Amon and other instruments on MRO

25

00:01:14,569 --> 00:01:12,299

looking for carbonates or other minerals

26

00:01:17,239 --> 00:01:14,579

that with evidence potential landing

27

00:01:19,879 --> 00:01:17,249

sites in materials to sample this is

28

00:01:22,609 --> 00:01:19,889

actually the discovery image in which

29

00:01:25,370 --> 00:01:22,619

carbonates were first identified on Mars

30

00:01:27,830 --> 00:01:25,380

and you see a three color composite here

31

00:01:30,260 --> 00:01:27,840

from visible wavelengths from these data

32

00:01:33,649 --> 00:01:30,270

you can guess at the presence in

33

00:01:35,599 --> 00:01:33,659

location of carbonates or other minerals

34

00:01:37,459 --> 00:01:35,609

of interest from color and morphology

35

00:01:40,389 --> 00:01:37,469

but you can't be sure because the

36

00:01:43,010 --> 00:01:40,399

diagnostic features are in the infrared

37

00:01:46,940 --> 00:01:43,020

this is the infrared part of the same

38

00:01:49,969 --> 00:01:46,950

image using false color and here you can

39

00:01:52,699 --> 00:01:49,979

directly detect primary mafic minerals

40

00:01:54,889 --> 00:01:52,709

clays and carbonates because they have

41

00:01:58,249 --> 00:01:54,899

strong spectral signatures at these

42

00:02:02,359 --> 00:01:58,259

wavelengths and to give you the answer

43

00:02:05,749 --> 00:02:02,369

the inset at the right here that bright

44

00:02:07,699 --> 00:02:05,759

green material that's the carbonate you

45

00:02:12,980 --> 00:02:07,709

just can't see it at the visible

46

00:02:16,610 --> 00:02:12,990

wavelengths now the the attributes that

47

00:02:20,929 --> 00:02:16,620

make a material desirable to measure in

48

00:02:21,290 --> 00:02:20,939

situ also will address the other science

49

00:02:23,930 --> 00:02:21,300

goals

50

00:02:25,250 --> 00:02:23,940

of Europa Lander for example one of the

51  
00:02:27,530 --> 00:02:25,260  
indicators of an interesting material

52  
00:02:29,630 --> 00:02:27,540  
will be concentrated salts showing that

53  
00:02:32,540 --> 00:02:29,640  
you've got ocean water that salt

54  
00:02:34,130 --> 00:02:32,550  
chemistry also illuminates the chemistry

55  
00:02:36,560 --> 00:02:34,140  
of the ocean and its potential

56  
00:02:40,940 --> 00:02:36,570  
habitability and the spectral signatures

57  
00:02:43,580 --> 00:02:40,950  
to look for or 1.3 to 2.6 microns the

58  
00:02:45,890 --> 00:02:43,590  
ideal material to sample has the least

59  
00:02:47,990 --> 00:02:45,900  
radiation damage of the material of the

60  
00:02:51,800 --> 00:02:48,000  
site leaving complex organic molecules

61  
00:02:55,550 --> 00:02:51,810  
intact and this this signature of that

62  
00:02:59,630 --> 00:02:55,560  
could be fresh Amorphous ice or ice that

63  
00:03:01,400 --> 00:02:59,640

has crystallized but not older ice whose

64

00:03:03,890 --> 00:03:01,410

outer rims have been damaged by

65

00:03:06,430 --> 00:03:03,900

radiation finding this desirable

66

00:03:08,780 --> 00:03:06,440

material also is an indication of

67

00:03:13,100 --> 00:03:08,790

geologically young ice emplacement and

68

00:03:14,870 --> 00:03:13,110

the spectral signatures of the interior

69

00:03:17,950 --> 00:03:14,880

and the rims of the grains would be at

70

00:03:21,920 --> 00:03:17,960

one point six five and 3.1 microns

71

00:03:23,840 --> 00:03:21,930

finally organic compounds would be the

72

00:03:26,240 --> 00:03:23,850

indication of a potential biotic

73

00:03:29,180 --> 00:03:26,250

material and those are evident from

74

00:03:34,130 --> 00:03:29,190

absorption features at 3.2 to 3.4

75

00:03:35,690 --> 00:03:34,140

microns now I will try to convince you

76  
00:03:37,729 --> 00:03:35,700  
that the Europa Lander should be

77  
00:03:40,390 --> 00:03:37,739  
surveying its landing site in its

78  
00:03:43,940 --> 00:03:40,400  
workspace in the infrared this iconic

79  
00:03:46,430 --> 00:03:43,950  
Galileo false-color visible image shows

80  
00:03:49,160 --> 00:03:46,440  
Europa a 1.6 kilometers per pixel and

81  
00:03:51,680 --> 00:03:49,170  
this clearly a spectrally heterogeneous

82  
00:03:53,479 --> 00:03:51,690  
surface let's zoom down to just the

83  
00:03:55,010 --> 00:03:53,489  
three pixel scale in this image and

84  
00:03:57,680 --> 00:03:55,020  
you've got the highest resolution

85  
00:04:00,140 --> 00:03:57,690  
Galileo image that you've taken and what

86  
00:04:02,180 --> 00:04:00,150  
you see is the heterogeneity extends

87  
00:04:05,540 --> 00:04:02,190  
down to the smallest resolvable skills

88  
00:04:07,430 --> 00:04:05,550

and the contrasts are even larger if we

89

00:04:10,670 --> 00:04:07,440

zoom down to one pixel in this image

90

00:04:13,040 --> 00:04:10,680

that's the Europa Landrus landing site

91

00:04:15,170 --> 00:04:13,050

and the workspace is within that it may

92

00:04:18,320 --> 00:04:15,180

very well present a variety of materials

93

00:04:20,720 --> 00:04:18,330

however I our spectral variations are

94

00:04:22,730 --> 00:04:20,730

only known a very low resolution not

95

00:04:25,070 --> 00:04:22,740

like the visible resolution you see here

96

00:04:29,180 --> 00:04:25,080

and the use of visible color as a proxy

97

00:04:31,580 --> 00:04:29,190

to find them is really unknown so LC

98

00:04:33,530 --> 00:04:31,590

addresses these issues by taking landed

99

00:04:36,170 --> 00:04:33,540

imaging into the infrared

100

00:04:38,840 --> 00:04:36,180

it actually has three sensors there are

101  
00:04:41,990 --> 00:04:38,850  
dual stereo imagers a right eye that

102  
00:04:43,280 --> 00:04:42,000  
covers point four to 1.8 microns and the

103  
00:04:45,680 --> 00:04:43,290  
left eye that covers point eight to

104  
00:04:49,370 --> 00:04:45,690  
three point six microns each eye has a

105  
00:04:51,800 --> 00:04:49,380  
15 degree field of view and 375 micro

106  
00:04:54,140 --> 00:04:51,810  
Radian pixels twenty spectral filters

107  
00:04:57,080 --> 00:04:54,150  
between the two eyes are in four groups

108  
00:04:59,750 --> 00:04:57,090  
one group matches the spectral filters

109  
00:05:02,450 --> 00:04:59,760  
on the ice imaging system on Europa

110  
00:05:04,490 --> 00:05:02,460  
clipper to extrapolate color variation

111  
00:05:07,670 --> 00:05:04,500  
CC from orbit to the landing site a

112  
00:05:10,610 --> 00:05:07,680  
second group discriminates Isis and

113  
00:05:12,860 --> 00:05:10,620

hydrated salts a third distinguishes

114

00:05:14,570 --> 00:05:12,870

crystalline and amorphous isip both the

115

00:05:16,820 --> 00:05:14,580

scales of the grain rims and the green

116

00:05:19,460 --> 00:05:16,830

interiors and a fourth group of filters

117

00:05:21,620 --> 00:05:19,470

detects organic materials the third

118

00:05:23,240 --> 00:05:21,630

sensor is a point spectrometer with a

119

00:05:25,280 --> 00:05:23,250

two milliradian field of view that

120

00:05:27,290 --> 00:05:25,290

samples the surface of better than ten

121

00:05:29,360 --> 00:05:27,300

the inter meters per channel and that

122

00:05:31,700 --> 00:05:29,370

will characterize any heterogeneity that

123

00:05:34,460 --> 00:05:31,710

you identify in the images at much

124

00:05:36,380 --> 00:05:34,470

higher spectral resolution allowing you

125

00:05:40,220 --> 00:05:36,390

to identify a range of minerals and

126

00:05:42,800 --> 00:05:40,230

organic compounds this CAD rendering of

127

00:05:46,040 --> 00:05:42,810

the exterior of the instrument concept

128

00:05:49,130 --> 00:05:46,050

shows the outer surface that acts as a

129

00:05:51,740 --> 00:05:49,140

radiator to passively cool the optics in

130

00:05:55,160 --> 00:05:51,750

the focal plane using the surroundings

131

00:05:56,990 --> 00:05:55,170

to a working temperature of 115 Kelvin

132

00:05:58,910 --> 00:05:57,000

and you can note the cyclops design

133

00:06:01,130 --> 00:05:58,920

where the two eyes are the stereo

134

00:06:02,360 --> 00:06:01,140

imagers and then that little eye in the

135

00:06:04,280 --> 00:06:02,370

middle of the forehead is a point

136

00:06:06,460 --> 00:06:04,290

spectrometer if you take away the

137

00:06:11,540 --> 00:06:06,470

housing you can see the innards of the

138

00:06:13,610 --> 00:06:11,550

instrument and fold mirrors bend the

139

00:06:15,680 --> 00:06:13,620

field of view of both cameras through a

140

00:06:18,680 --> 00:06:15,690

pair of miniaturized filter wheels on

141

00:06:20,900 --> 00:06:18,690

both eyes and mirrors reflect the light

142

00:06:24,170 --> 00:06:20,910

onto a different parts of a single

143

00:06:26,030 --> 00:06:24,180

detector that is shielded by a radiation

144

00:06:28,660 --> 00:06:26,040

shield to minimize the noise from the

145

00:06:31,790 --> 00:06:28,670

radiation and the point spectrometer

146

00:06:34,400 --> 00:06:31,800

folds its light around the radiation

147

00:06:39,140 --> 00:06:34,410

shield and uses another unused part of

148

00:06:40,970 --> 00:06:39,150

the same focal plane array here's the

149

00:06:42,470 --> 00:06:40,980

optical design of the two eyes

150

00:06:43,940 --> 00:06:42,480

they're subtly different because of the

151  
00:06:46,550 --> 00:06:43,950  
different materials and wavelength

152  
00:06:48,770 --> 00:06:46,560  
ranges but each eye has

153  
00:06:51,770 --> 00:06:48,780  
adjustable focus so you can focus nearer

154  
00:06:55,790 --> 00:06:51,780  
or further and on board a technique

155  
00:06:56,930 --> 00:06:55,800  
called Z stacking is performed to create

156  
00:07:01,010 --> 00:06:56,940  
a best focused

157  
00:07:02,720 --> 00:07:01,020  
merged image this shows a flattened

158  
00:07:04,520 --> 00:07:02,730  
version of the optical design of the

159  
00:07:06,800 --> 00:07:04,530  
spectrometer it uses what's called an

160  
00:07:10,370 --> 00:07:06,810  
off-night design in a small cast green

161  
00:07:14,210 --> 00:07:10,380  
telescope and note these little light

162  
00:07:16,940 --> 00:07:14,220  
bulb icons a field filling optic in all

163  
00:07:20,000 --> 00:07:16,950

three sensors has a rear surface that is

164

00:07:22,760 --> 00:07:20,010

partially silvered and will diffusely

165

00:07:25,310 --> 00:07:22,770

transmitted light from a closed loop

166

00:07:28,219 --> 00:07:25,320

control calibration source enabling a

167

00:07:30,969 --> 00:07:28,229

landed radiometric calibration to be

168

00:07:33,200 --> 00:07:30,979

done on the data that are collected

169

00:07:35,930 --> 00:07:33,210

here's the block diagram of the

170

00:07:39,590 --> 00:07:35,940

instrument the sensor containing all

171

00:07:42,560 --> 00:07:39,600

three sensors is located on the

172

00:07:44,420 --> 00:07:42,570

high-gain antenna there is motors to

173

00:07:46,879 --> 00:07:44,430

control the filter wheels in each eye as

174

00:07:49,790 --> 00:07:46,889

well as the adjustable focus and then

175

00:07:52,070 --> 00:07:49,800

the data processing unit is located in

176

00:07:54,440 --> 00:07:52,080

the Landorus radiation vault there are

177

00:07:58,219 --> 00:07:54,450

three cards a digital card contains

178

00:08:00,740 --> 00:07:58,229

processors and memory to process data on

179

00:08:03,500 --> 00:08:00,750

board to squeeze down the data volume an

180

00:08:05,870 --> 00:08:03,510

interface card communicates with the

181

00:08:08,710 --> 00:08:05,880

spacecraft and also drives the motors

182

00:08:11,090 --> 00:08:08,720

the calibration lamps in a heater and

183

00:08:15,310 --> 00:08:11,100

the third card provides power to

184

00:08:20,150 --> 00:08:15,320

everything else so this graph shows how

185

00:08:22,279 --> 00:08:20,160

the spectrometer will detect different

186

00:08:25,640 --> 00:08:22,289

materials on the surface you see here in

187

00:08:28,029 --> 00:08:25,650

yellow and light blue Europa IC and na

188

00:08:31,060 --> 00:08:28,039

nice materials and in green and orange

189

00:08:34,310 --> 00:08:31,070

mineral analogs to the nice materials

190

00:08:36,290 --> 00:08:34,320

the black lines are simulated spectra as

191

00:08:39,130 --> 00:08:36,300

sampled through the points spectrometer

192

00:08:41,839 --> 00:08:39,140

so they're nearly laboratory quality and

193

00:08:46,340 --> 00:08:41,849

the region of interest is here around

194

00:08:48,440 --> 00:08:46,350

1.4 to 1.5 microns and this shows the

195

00:08:51,470 --> 00:08:48,450

same data resembled into the band passes

196

00:08:54,320 --> 00:08:51,480

of the cameras the minimum reflectance

197

00:08:56,990 --> 00:08:54,330

in ice is at one wavelength and the

198

00:08:59,120 --> 00:08:57,000

minimum reflectance in hydrated salts is

199

00:09:01,790 --> 00:08:59,130

a different filter so

200

00:09:03,980 --> 00:09:01,800

it's easy to distinguish concentrated

201  
00:09:06,380 --> 00:09:03,990  
salts from the background ice and in

202  
00:09:08,960 --> 00:09:06,390  
addition there's a filter of 1.25

203  
00:09:11,090 --> 00:09:08,970  
microns that measures the depth of a

204  
00:09:13,400 --> 00:09:11,100  
band that's first sensitive dyes grain

205  
00:09:16,180 --> 00:09:13,410  
size allowing one to map out differences

206  
00:09:21,280 --> 00:09:16,190  
in surface texture at the landing site

207  
00:09:25,990 --> 00:09:21,290  
this is a 2.8 to 3.6 micron region again

208  
00:09:29,990 --> 00:09:26,000  
Europa materials on the bottom plot

209  
00:09:33,020 --> 00:09:30,000  
aromatic and aliphatic organics in pink

210  
00:09:36,050 --> 00:09:33,030  
and green primitive meteoritic material

211  
00:09:39,170 --> 00:09:36,060  
that contains both in black and in the

212  
00:09:42,200 --> 00:09:39,180  
bottom crystalline ice note the ice ax

213  
00:09:45,680 --> 00:09:42,210

is fully crystalline has this pronounced

214

00:09:47,900 --> 00:09:45,690

reflectance peak at 3.1 microns that's

215

00:09:50,930 --> 00:09:47,910

lacking in highly radiation damaged ice

216

00:09:53,570 --> 00:09:50,940

these are those this the right graph is

217

00:09:56,050 --> 00:09:53,580

those data resampled into the camera ban

218

00:09:58,580 --> 00:09:56,060

passes which could easily distinguish

219

00:10:01,060 --> 00:09:58,590

concentrations of organic material as

220

00:10:03,710 --> 00:10:01,070

well as the currents of crystalline ice

221

00:10:05,720 --> 00:10:03,720

now the data processing unit is

222

00:10:07,880 --> 00:10:05,730

essential to the operation of the

223

00:10:10,340 --> 00:10:07,890

instrument it mitigates the radiation

224

00:10:12,410 --> 00:10:10,350

noise in the data and helps to control

225

00:10:14,690 --> 00:10:12,420

the data volume the mitigation of

226

00:10:16,370 --> 00:10:14,700

radiation noise uses is it a technique

227

00:10:19,880 --> 00:10:16,380

that's been developed for the maies

228

00:10:21,680 --> 00:10:19,890

imager on Europa clipper for every frame

229

00:10:24,290 --> 00:10:21,690

position there's actually multiple

230

00:10:26,120 --> 00:10:24,300

integrations you throw out a subset of

231

00:10:28,160 --> 00:10:26,130

the highest values which have the

232

00:10:30,890 --> 00:10:28,170

radiation noise and you co add the rest

233

00:10:33,170 --> 00:10:30,900

to improve signal-to-noise to squeeze

234

00:10:36,380 --> 00:10:33,180

down the data volume for 16 of the 20

235

00:10:38,000 --> 00:10:36,390

filters we use a technique that we we

236

00:10:40,040 --> 00:10:38,010

pioneered on chrism called summary

237

00:10:42,260 --> 00:10:40,050

products where you take many wavelengths

238

00:10:44,540 --> 00:10:42,270

of light and reduce them down to a few

239

00:10:46,580 --> 00:10:44,550

parameterised variables that show

240

00:10:48,620 --> 00:10:46,590

spectral variations these will be

241

00:10:50,660 --> 00:10:48,630

created on board by calibrating the

242

00:10:53,630 --> 00:10:50,670

images using the calibration data that

243

00:10:55,700 --> 00:10:53,640

you've taken rescaling the pixels scale

244

00:10:57,830 --> 00:10:55,710

of each image to the common stereo

245

00:11:00,830 --> 00:10:57,840

filter to both eyes and then performing

246

00:11:03,830 --> 00:11:00,840

band math compressing and down linking

247

00:11:06,230 --> 00:11:03,840

the summary products the calibrated data

248

00:11:09,110 --> 00:11:06,240

will reside on board and from the ground

249

00:11:11,960 --> 00:11:09,120

can be interrogated for the 20 channel

250

00:11:13,369 --> 00:11:11,970

spectra to provide more detail on

251  
00:11:15,319 --> 00:11:13,379  
whatever of interest shows up in the

252  
00:11:17,569 --> 00:11:15,329  
summary products and the spectrometer

253  
00:11:21,470 --> 00:11:17,579  
can target target regions of interest

254  
00:11:24,110 --> 00:11:21,480  
for further information LC is fully

255  
00:11:26,710 --> 00:11:24,120  
capable of addressing Europa Landers

256  
00:11:31,699 --> 00:11:26,720  
science questions about habitability and

257  
00:11:33,879 --> 00:11:31,709  
geology including exogenic and energetic

258  
00:11:36,650 --> 00:11:33,889  
materials deposited on the surface

259  
00:11:39,740 --> 00:11:36,660  
tectonic features on the surface and

260  
00:11:42,650 --> 00:11:39,750  
radiation processing using a series of

261  
00:11:46,759 --> 00:11:42,660  
eight different imaging campaigns

262  
00:11:50,329 --> 00:11:46,769  
including stereo and change detection

263  
00:11:53,449 --> 00:11:50,339

mosaics of the landing site spectral

264

00:11:56,090 --> 00:11:53,459

images of the workspace and at different

265

00:12:00,290 --> 00:11:56,100

nested resolutions and higher quality

266

00:12:02,600 --> 00:12:00,300

spectral information a coverage of the

267

00:12:03,829 --> 00:12:02,610

trench as it's dug and the sites of the

268

00:12:07,699 --> 00:12:03,839

samples that are collected

269

00:12:10,179 --> 00:12:07,709

so in summary LC merges the traditional

270

00:12:12,530 --> 00:12:10,189

capabilities of landed imaging system

271

00:12:15,230 --> 00:12:12,540

high-resolution stereo change detection

272

00:12:17,420 --> 00:12:15,240

and color mapping with new capabilities

273

00:12:19,869 --> 00:12:17,430

are enabled by its coverage in the

274

00:12:22,129 --> 00:12:19,879

shortwave infrared mapping of

275

00:12:24,290 --> 00:12:22,139

compositions detection and

276

00:12:26,920 --> 00:12:24,300

discriminating minerals from ice in the

277

00:12:29,720 --> 00:12:26,930

background detecting organics and

278

00:12:31,819 --> 00:12:29,730

determining crystal of variations and

279

00:12:33,740 --> 00:12:31,829

ice crystallinity that point you towards

280

00:12:36,439 --> 00:12:33,750

the freshest material to collect for

281

00:12:38,060 --> 00:12:36,449

onboard analysis thank you and I'm happy

282

00:12:51,630 --> 00:12:38,070

to take any questions

283

00:12:57,190 --> 00:12:53,770

you have the radiation damage for the

284

00:12:59,620 --> 00:12:57,200

spacecraft so what that does is most of

285

00:13:01,870 --> 00:12:59,630

your mission you want to be harvesting

286

00:13:04,750 --> 00:13:01,880

samples and analyzing them on board so

287

00:13:07,990 --> 00:13:04,760

it puts the onus on the context cameras

288

00:13:10,300 --> 00:13:08,000

to find that spot fast and that's why

289

00:13:12,640 --> 00:13:10,310

the onboard spectral capabilities and

290

00:13:14,890 --> 00:13:12,650

our word processing minimizes the

291

00:13:16,840 --> 00:13:14,900

back-and-forth between the ground and

292

00:13:22,630 --> 00:13:16,850

spacecraft to do that while you've got

293

00:13:25,840 --> 00:13:22,640

still three weeks of lander life because

294

00:13:28,480 --> 00:13:25,850

the radiation in as explained by Cynthia

295

00:13:30,280 --> 00:13:28,490

in the previous presentation because the

296

00:13:33,370 --> 00:13:30,290

radiation will kill the lander in about

297

00:13:35,470 --> 00:13:33,380

a month well then it could survive for

298

00:13:38,530 --> 00:13:35,480

up to three months which is about the

299

00:13:42,910 --> 00:13:38,540

the radiation lifetime of the lander but

300

00:13:46,120 --> 00:13:42,920

in terms of getting through the baseline

301  
00:13:47,710 --> 00:13:46,130  
mission of three samples we can do that

302  
00:13:49,930 --> 00:13:47,720  
in seven days then there's an additional

303  
00:13:52,330 --> 00:13:49,940  
seven days of margin and an additional

304  
00:13:55,320 --> 00:13:52,340  
seven days on top of that which puts you

305  
00:13:57,970 --> 00:13:55,330  
at the twenty two days which is also a

306  
00:14:01,600 --> 00:13:57,980  
multiple of three point five five days

307  
00:14:01,990 --> 00:14:01,610  
which is Europa's a diurnal cycle around

308  
00:14:05,260 --> 00:14:02,000  
Jupiter

309  
00:14:08,320 --> 00:14:05,270  
so the 22 days is our nominal mission

310  
00:14:10,210 --> 00:14:08,330  
with plenty of margin but then using up

311  
00:14:12,550 --> 00:14:10,220  
our mass margin and allocating that to