



1  
00:00:00,500 --> 00:00:06,533  
[ Music ]

2  
00:00:07,033 --> 00:00:08,700  
>> Pamela Marcum: I  
think of SOFIA mostly

3  
00:00:08,700 --> 00:00:10,367  
as sort of catching light.

4  
00:00:13,300 --> 00:00:14,633  
>> Brent Cobleigh: Day  
after day we can get up

5  
00:00:14,633 --> 00:00:18,367  
and do these missions and really  
do really cutting edge astronomy

6  
00:00:18,367 --> 00:00:19,300  
in the infrared spectrum.

7  
00:00:20,500 --> 00:00:39,533  
[ Music ]

8  
00:00:40,033 --> 00:00:40,900  
SOFIA is an observatory.

9  
00:00:40,900 --> 00:00:43,100  
And like other observatories  
around the world,

10  
00:00:43,100 --> 00:00:44,533  
it can do a lot of  
different science.

11  
00:00:44,933 --> 00:00:47,133  
A lot of those observatories  
are on the tops of mountains

12

00:00:47,133 --> 00:00:49,067

around 13,000 or 14,000 feet.

13

00:00:49,067 --> 00:00:50,900

>> Michael Person: Even when we have a ground-based telescope

14

00:00:50,900 --> 00:00:53,333

in a perfect place, sometimes it doesn't get any data

15

00:00:53,333 --> 00:00:55,233

because the clouds come in.

16

00:00:55,233 --> 00:00:58,667

Being able to fly over all of that is just a tremendous asset.

17

00:00:58,667 --> 00:01:00,467

>> Pamela Marcum: What happens is in the upper atmosphere

18

00:01:00,467 --> 00:01:03,467

of the Earth, as the light comes down, you know,

19

00:01:03,467 --> 00:01:06,867

from some astronomical object,

20

00:01:06,867 --> 00:01:08,567

very little of that light is able

21

00:01:08,567 --> 00:01:10,167

to pass all the way down to the ground.

22

00:01:10,767 --> 00:01:14,067

So what SOFIA does is

it flies above the bulk

23

00:01:14,067 --> 00:01:16,500  
of that water in the atmosphere.

24

00:01:17,500 --> 00:01:20,567  
[ Music ]

25

00:01:21,067 --> 00:01:23,067  
>> Brent Cobleigh: SOFIA  
can fly at 43,000 feet,

26

00:01:23,067 --> 00:01:24,500  
more than double  
the height of all

27

00:01:24,500 --> 00:01:26,100  
of the other observatories  
in the world.

28

00:01:26,100 --> 00:01:28,800  
>> Eddie Zavala: And that is  
above 90% of the water vapor.

29

00:01:29,233 --> 00:01:32,100  
And that's a position that  
is necessary for astronomers

30

00:01:32,100 --> 00:01:33,967  
to do infrared astronomy.

31

00:01:34,500 --> 00:01:48,500  
[ Music ]

32

00:01:49,000 --> 00:01:50,000  
>> Brent Cobleigh:

33

00:01:50,000 --> 00:01:53,000  
The space-based observatories

have some really unique aspects  
to them.

34

00:01:53,000 --> 00:01:53,967

They're always in space.

35

00:01:53,967 --> 00:01:54,800

They're very cold.

36

00:01:54,800 --> 00:01:57,133

They can observe round the  
clock day in and day out.

37

00:01:57,133 --> 00:02:00,533

>> Alois Himmes: The  
spacecraft demand on low weight,

38

00:02:00,767 --> 00:02:02,833

low power consumption  
are very extreme

39

00:02:03,100 --> 00:02:06,167

so in an airborne observatory  
you have a lot of power,

40

00:02:06,167 --> 00:02:07,600

a lot of space available.

41

00:02:08,167 --> 00:02:10,333

[ Music ]

42

00:02:10,333 --> 00:02:11,467

>> Brent Cobleigh: We  
can carry instruments

43

00:02:11,467 --> 00:02:12,500

that are hundreds of pounds.

44

00:02:12,900 --> 00:02:14,733

We can give those instruments much more power

45

00:02:14,733 --> 00:02:16,933

than you can generate from solar collectors in space.

46

00:02:17,600 --> 00:02:19,733

We're not limited to the minimum weight

47

00:02:19,733 --> 00:02:20,933

that launch vehicles require

48

00:02:20,933 --> 00:02:22,567

to put something in to space.

49

00:02:22,567 --> 00:02:24,667

We can fix those instruments day after day.

50

00:02:24,667 --> 00:02:25,533

The airplane comes home.

51

00:02:25,533 --> 00:02:26,333

We can repair them.

52

00:02:26,333 --> 00:02:29,000

It's very, very challenging to ever repair anything in space.

53

00:02:29,000 --> 00:02:30,667

And it has been done very, very few times.

54

00:02:31,500 --> 00:02:37,533

[ Background Discussion ]

55

00:02:38,033 --> 00:02:40,233

>> Pamela Marcum: The  
plane provides this motion

56

00:02:40,233 --> 00:02:42,067

as the telescope  
provides this motion.

57

00:02:42,633 --> 00:02:45,767

And together you're actually  
able to track a target

58

00:02:45,767 --> 00:02:49,967

as it moves across the sky  
as it's rising and setting.

59

00:02:49,967 --> 00:02:53,100

Not only does it have to be  
aware of time and position,

60

00:02:53,333 --> 00:02:55,800

but it's also got to be  
making the right motions

61

00:02:55,800 --> 00:02:56,900

across the surfaces of the Earth

62

00:02:56,900 --> 00:03:00,367

so that combined motions  
allow us to be able to lock

63

00:03:00,367 --> 00:03:03,667

on to the object over  
periods of a couple of hours.

64

00:03:05,533 --> 00:03:08,333

One of the powerful benefits

65

00:03:08,333 --> 00:03:10,800

that SOFIA brings

us is the ability

66

00:03:10,800 --> 00:03:13,567

to go chasing these  
occultations in a way

67

00:03:13,567 --> 00:03:15,900

that no other observatory  
can do.

68

00:03:16,500 --> 00:03:18,533

[ Music ]

69

00:03:19,033 --> 00:03:21,000

>> Eddie Zavala: An occultation  
is basically a situation

70

00:03:21,000 --> 00:03:23,667

where a planet or an  
object of interest moves

71

00:03:23,667 --> 00:03:25,100

in front of a background star.

72

00:03:25,300 --> 00:03:28,533

>> Pamela Marcum: We  
observed a Pluto occultation,

73

00:03:28,533 --> 00:03:31,467

so that was where Pluto  
fell in our line of sight

74

00:03:31,467 --> 00:03:33,233

with the background  
star and made

75

00:03:33,233 --> 00:03:36,300

that star's light blink  
out very momentarily.

76

00:03:36,900 --> 00:03:38,633

>> Eddie Zavala: They modeled where that shadow is going

77

00:03:38,633 --> 00:03:42,733

to be, and we flew this airplane at roughly 500 miles an hour

78

00:03:43,200 --> 00:03:46,267

to catch a shadow that was going across the surface of the Earth

79

00:03:46,267 --> 00:03:48,200

at 53,000 miles an hour.

80

00:03:48,533 --> 00:03:51,000

>> Pamela Marcum: Simply by looking at the way

81

00:03:51,000 --> 00:03:54,167

that the background light blinked out, tells us something

82

00:03:54,167 --> 00:03:56,233

about the shape of the object,

83

00:03:56,967 --> 00:03:59,767

whether that object has an atmosphere or not,

84

00:04:00,133 --> 00:04:06,000

and even determine things like how the atmosphere's temperature

85

00:04:06,000 --> 00:04:11,267

and pressure vary from the ground all the way up to the top

86

00:04:11,267 --> 00:04:13,200

of that atmosphere  
on that object.

87

00:04:14,500 --> 00:04:16,533  
[ Music ]

88

00:04:17,033 --> 00:04:19,833  
You are limited as to what parts

89

00:04:19,833 --> 00:04:22,833  
of the sky you can  
actually observe when you're

90

00:04:22,833 --> 00:04:23,833  
in the Northern Hemisphere.

91

00:04:24,033 --> 00:04:26,733  
So deployments out  
of our home base here

92

00:04:26,733 --> 00:04:30,433  
in Palmdale gives us access  
to one half of the sphere.

93

00:04:30,433 --> 00:04:34,000  
And when we go down to New  
Zealand, we'll have access

94

00:04:34,000 --> 00:04:38,300  
to a whole new set of objects,  
a whole new part of the sky.

95

00:04:39,500 --> 00:04:45,567  
[ Music ]

96

00:04:46,067 --> 00:04:50,900  
Infrared astronomy allows  
you to peer into the core

97

00:04:50,900 --> 00:04:55,333  
of really cold gas clouds where  
the stars are starting to form,

98

00:04:55,600 --> 00:04:59,733  
planets, comets, dust  
particles...to look

99

00:04:59,733 --> 00:05:02,967  
at star formation  
in extreme regions.

100

00:05:02,967 --> 00:05:05,667  
These things, because of  
their cold temperatures,

101

00:05:05,900 --> 00:05:08,967  
happen to radiate  
most of their energy

102

00:05:09,233 --> 00:05:12,867  
at these infrared  
wavelengths that SOFIA studies.

103

00:05:13,500 --> 00:05:15,867  
[ Music ]

104

00:05:16,367 --> 00:05:19,267  
SOFIA actually has several  
different instruments.

105

00:05:19,567 --> 00:05:21,100  
>> Brent Cobleigh: The  
science instruments receive the

106

00:05:21,100 --> 00:05:24,400  
electromagnetic spectrum, the  
light, through the telescope.

107

00:05:24,400 --> 00:05:25,833

>> Alois Himmes:  
Instruments mean cameras

108  
00:05:25,833 --> 00:05:28,267  
or photometers or spectrometers.

109  
00:05:28,833 --> 00:05:30,767  
The telescope without  
instruments is totally useless.

110  
00:05:30,767 --> 00:05:33,233  
>> Brent Cobleigh: We have  
a whole team whose job is

111  
00:05:33,233 --> 00:05:36,200  
to prepare the instruments  
and do a very precise movement,

112  
00:05:36,200 --> 00:05:38,000  
a choreographed movement,

113  
00:05:38,000 --> 00:05:41,167  
of one instrument off the  
airplane, another one on.

114  
00:05:41,167 --> 00:05:44,200  
>> Pamela Marcum: Some  
of them make pictures

115  
00:05:44,200 --> 00:05:46,733  
that will look a lot like  
something that would have come

116  
00:05:46,733 --> 00:05:48,733  
out of a digital  
camera, but of course

117  
00:05:48,733 --> 00:05:49,567  
at a different wavelength.

118

00:05:50,467 --> 00:05:52,800

Others will not look  
like a picture at all.

119

00:05:53,500 --> 00:06:13,533

[ Music ]

120

00:06:14,033 --> 00:06:15,133

>> Brent Cobleigh: One of the  
biggest challenges, of course,

121

00:06:15,133 --> 00:06:17,033

is we're putting a large hole  
in the side of the airplane.

122

00:06:17,033 --> 00:06:20,367

>> Alois Himmes: The telescope  
in total is 17 metric tons.

123

00:06:21,400 --> 00:06:24,533

And there's an additional  
3 tons distributed

124

00:06:24,533 --> 00:06:26,667

in electronic racks  
all over the aircraft.

125

00:06:27,500 --> 00:06:31,533

[ Music ]

126

00:06:32,033 --> 00:06:34,267

>>Eddie Zavala: The telescope  
as a certain level of precision.

127

00:06:34,267 --> 00:06:37,167

The instruments require a  
certain level of precision

128

00:06:37,167 --> 00:06:39,167

and accuracy in order  
to conduct the science.

129

00:06:39,600 --> 00:06:42,733

And the engineering challenge  
of providing that stability

130

00:06:42,733 --> 00:06:44,100

on an airplane that is flying

131

00:06:44,533 --> 00:06:47,433

and encountering turbulence  
is a significant challenge.

132

00:06:48,000 --> 00:06:49,700

>> Brent Cobleigh: We had  
major structural modifications

133

00:06:49,700 --> 00:06:50,367

that had to happen.

134

00:06:50,367 --> 00:06:53,300

We had to add an additional  
bulkhead just forward

135

00:06:53,300 --> 00:06:55,800

of the telescope so that we  
can maintain a pressure area

136

00:06:55,800 --> 00:06:56,600

where people can work.

137

00:06:57,100 --> 00:06:58,600

And then the aft area is vented

138

00:06:58,600 --> 00:07:00,100

to the outside as  
we open the door.

139

00:07:00,700 --> 00:07:02,100

>> Alois: Himmes: The  
telescope is operated

140

00:07:02,500 --> 00:07:03,900

when the large door is open,

141

00:07:03,900 --> 00:07:06,133

so the environment  
is not very benign.

142

00:07:06,433 --> 00:07:08,100

>> Eddie: Zavala: The  
telescope is something

143

00:07:08,100 --> 00:07:09,433

that is designed to free-float.

144

00:07:10,033 --> 00:07:11,833

It floats on a spherical  
bearing.

145

00:07:12,233 --> 00:07:15,367

And that allows the telescope  
to be somewhat isolated

146

00:07:15,367 --> 00:07:16,600

from the movement  
of the aircraft.

147

00:07:17,867 --> 00:07:20,733

Inside SOFIA it's like  
flying on any other airliner.

148

00:07:21,500 --> 00:07:27,533

[ Music ]

149

00:07:28,033 --> 00:07:29,833

>> Jim Less: We're planning  
for about a 10-hour mission,

150  
00:07:29,833 --> 00:07:31,667  
hopefully about eight  
and a half hours' worth

151  
00:07:31,667 --> 00:07:32,933  
of science out of that.

152  
00:07:32,933 --> 00:07:34,300  
>> Brent Cobleigh: We  
do preflight checks

153  
00:07:34,300 --> 00:07:36,833  
on all the airplane systems and  
all the observatory systems.

154  
00:07:37,300 --> 00:07:38,333  
Fuel up the airplane.

155  
00:07:38,567 --> 00:07:40,600  
We go into a crew brief  
in the late afternoons

156  
00:07:40,600 --> 00:07:42,033  
where the entire team  
that is going to fly

157  
00:07:42,033 --> 00:07:44,167  
on the airplane gets together  
and talks about the objectives

158  
00:07:44,167 --> 00:07:47,267  
for the flight, status of  
all the systems, the weather,

159  
00:07:47,267 --> 00:07:48,600  
and the mission plan ahead.

160  
00:07:49,133 --> 00:07:51,567

The team goes out and does their preflight checks

161  
00:07:51,567 --> 00:07:54,633  
on the airplane, start engines, we take off, climb to altitude,

162  
00:07:54,633 --> 00:07:56,333  
and do whatever mission is planned for that night.

163  
00:07:56,333 --> 00:07:57,733  
Usually it's about a 10-hour flight.

164  
00:07:58,133 --> 00:08:00,367  
>> Pamela Marcum: We know before we even get

165  
00:08:00,367 --> 00:08:03,433  
on the plane what objects are going to be looked at,

166  
00:08:03,800 --> 00:08:05,500  
at exactly what time

167  
00:08:05,500 --> 00:08:07,300  
in the flight they're going to be looked at.

168  
00:08:07,300 --> 00:08:10,067  
It's all sort of planned out and choreographed

169  
00:08:10,800 --> 00:08:13,533  
like a complicated dance routine.

170  
00:08:14,500 --> 00:08:19,533  
[ Music ]

171

00:08:20,033 --> 00:08:21,167  
>> Eddie Zavala: SOFIA  
is a unique blend

172

00:08:21,167 --> 00:08:24,367  
of aeronautical capabilities,  
science engineering in the form

173

00:08:24,367 --> 00:08:25,867  
of a state of the art telescope,

174

00:08:26,100 --> 00:08:28,533  
and then cutting edge  
science instruments.

175

00:08:28,533 --> 00:08:29,567  
>> Brent Cobleigh:  
We have the U.S.

176

00:08:29,567 --> 00:08:32,933  
/German partnership, which is  
80% U.S. and 20% German.

177

00:08:32,933 --> 00:08:35,600  
>> Alois Himmes: We are  
responsible for developing

178

00:08:35,600 --> 00:08:38,167  
and delivering and  
support the integration

179

00:08:38,167 --> 00:08:40,633  
of SOFIA's infrared telescope.

180

00:08:40,633 --> 00:08:42,633  
>> Eddie Zavala: On board  
there's probably about 20

181

00:08:42,933 --> 00:08:46,000  
to 30 personnel along  
with USRA personnel,

182

00:08:46,000 --> 00:08:48,833  
our science support  
personnel, the mission ops.

183

00:08:49,167 --> 00:08:50,733  
>> Brent Cobleigh: We also  
have multiple NASA centers,

184

00:08:50,733 --> 00:08:53,400  
NASA Ames, primarily  
responsible for the science,

185

00:08:53,400 --> 00:08:55,133  
and NASA Dryden (Armstrong)  
responsible for the aircraft

186

00:08:55,133 --> 00:08:56,133  
operations.

187

00:08:56,167 --> 00:08:59,133  
It takes that total group  
of expertise together

188

00:08:59,167 --> 00:09:01,800  
that makes SOFIA an  
operational telescope.

189

00:09:01,867 --> 00:09:02,767  
>> Cris DeWolf: Sometimes  
I think

190

00:09:02,767 --> 00:09:04,267  
that my kids think  
science is done

191

00:09:04,267 --> 00:09:06,133

by some person sitting in a lab

192

00:09:06,133 --> 00:09:08,733

or up on a mountain with a  
telescope all by themselves.

193

00:09:09,033 --> 00:09:10,500

Having them see that it is  
really

194

00:09:10,500 --> 00:09:12,167

such a team effort I  
think is important.

195

00:09:13,500 --> 00:09:17,900

[ Music ]

196

00:09:18,400 --> 00:09:19,300

>> Alois Himmes:  
Using instruments

197

00:09:19,500 --> 00:09:20,567

from Germany doesn't mean

198

00:09:20,567 --> 00:09:22,500

that they can only  
be used by Germans.

199

00:09:22,500 --> 00:09:27,867

So those instruments can be  
used also by U.S. institutions,

200

00:09:27,867 --> 00:09:28,767

by other institutions.

201

00:09:29,100 --> 00:09:31,367

>> Eddie Zavala: This facility  
is not being built for NASA.

202

00:09:31,367 --> 00:09:34,300

We are providing it for  
the science community,

203

00:09:35,033 --> 00:09:37,900

for future scientists,  
and for educators.

204

00:09:38,433 --> 00:09:40,933

Through those teachers, they're  
our airborne astronomy

205

00:09:40,967 --> 00:09:44,967

ambassadors program, and they'll  
be able to extend a lot of what

206

00:09:45,000 --> 00:09:48,500

we learn  
on SOFIA into the classroom.

207

00:09:48,500 --> 00:10:06,833

[ Music ]

208

00:10:07,333 --> 00:10:11,133

>> Pamela Marcum: SOFIA's  
science is drive by the demands

209

00:10:11,367 --> 00:10:13,833

and the imagination  
of the community.

210

00:10:14,133 --> 00:10:15,200

>> Brent Cobleigh: The  
thing I get satisfaction

211

00:10:15,200 --> 00:10:18,133

over is seeing the teams  
succeed themselves and whether

212

00:10:18,133 --> 00:10:20,533

that be technicians  
installing electrical components

213  
00:10:20,533 --> 00:10:23,233  
or scientists getting the  
data that they receive

214  
00:10:23,233 --> 00:10:25,267  
or a teacher getting a  
good experience on board

215  
00:10:25,633 --> 00:10:27,200  
to take back to their  
classrooms.

216  
00:10:27,200 --> 00:10:29,000  
>> Pamela Marcum: So  
SOFIA is considered

217  
00:10:29,000 --> 00:10:32,267  
to be an international  
resource to be used

218  
00:10:32,267 --> 00:10:34,833  
by the global community  
of astronomers.

219  
00:10:35,533 --> 00:10:37,733  
>> Eddie Zavala: We hope  
to truly inspire students,

220  
00:10:38,033 --> 00:10:42,167  
scientists, engineers,  
mechanics, pilots so anyone

221  
00:10:42,367 --> 00:10:44,133  
in a grade school  
classroom right now,

222  
00:10:44,333 --> 00:10:45,767

depending on what  
their interest is,

223

00:10:46,233 --> 00:10:48,167

they can see themselves  
operating SOFIA

224

00:10:48,167 --> 00:10:49,567

in the next 10 to 15 years.

225

00:10:49,933 --> 00:10:53,000

>> Pamela Marcum: There are a  
lot of open science questions

226

00:10:53,000 --> 00:10:56,067

that have been open for, quite  
frankly, a very long time.

227

00:10:56,433 --> 00:11:01,700

Creativity and inquiry is what's  
going to lead SOFIA to discovery

228

00:11:02,067 --> 00:11:04,233

and to answering a lot  
of outstanding questions