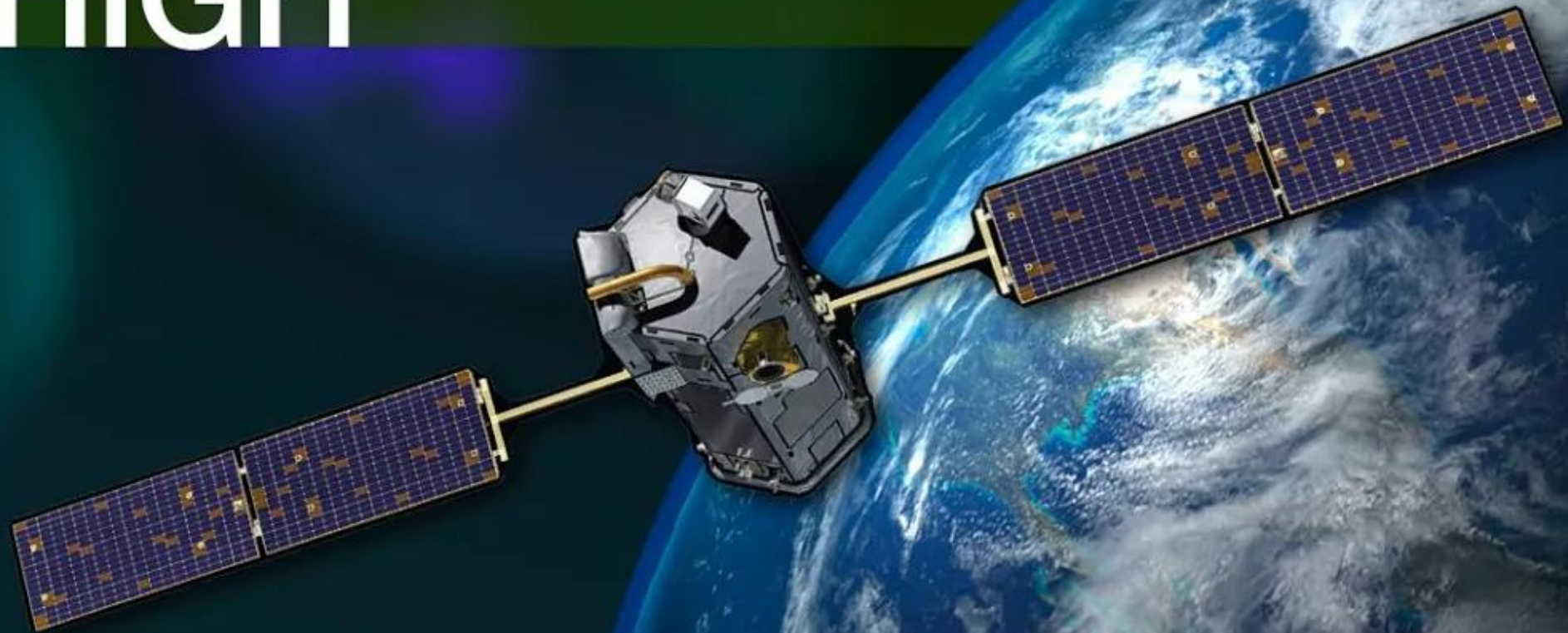


Sky HIGH



JPL and the Space Age

1
00:00:00,533 --> 00:00:04,204
(light digital intro music)

2
00:00:05,238 --> 00:00:08,241
- [Narrator] When someone
mentions NASA, what comes to mind?

3
00:00:09,542 --> 00:00:11,544
Astronauts on the moon?

4
00:00:11,544 --> 00:00:13,279
The space station?

5
00:00:13,279 --> 00:00:15,115
Rovers on Mars?

6
00:00:15,115 --> 00:00:17,917
The Voyagers now flying
through interstellar space?

7
00:00:19,386 --> 00:00:21,654
But there's no place
NASA has explored more

8
00:00:21,654 --> 00:00:22,922
than our own planet.

9
00:00:23,823 --> 00:00:26,826
NASA has a fleet of
satellites that are constantly

10
00:00:26,826 --> 00:00:29,629
collecting data to monitor
the health of the Earth.

11
00:00:31,498 --> 00:00:35,301
Using the vantage point of
space to understand our planet

12

00:00:35,301 --> 00:00:38,471

dates back to the
beginnings of the space age.

13

00:00:38,471 --> 00:00:40,874

(pondering music)

14

00:00:40,874 --> 00:00:42,942

(rocket engines firing)

15

00:00:42,942 --> 00:00:46,746

It was then, in response to
the Soviet Union Sputnik,

16

00:00:46,746 --> 00:00:48,648

that JPL built and helped launch

17

00:00:48,648 --> 00:00:51,584

the first U.S. satellite, Explorer 1.

18

00:00:54,087 --> 00:00:56,923

Inside Explorer was
this science instrument,

19

00:00:56,923 --> 00:01:00,760

a kind of Geiger counter
designed to detect cosmic rays.

20

00:01:02,896 --> 00:01:05,131

It also discovered the
presence of radiation

21

00:01:05,131 --> 00:01:06,966

surrounding the Earth.

22

00:01:06,966 --> 00:01:09,636

What turned out to be a
belt of charged particles

23

00:01:09,636 --> 00:01:11,905

held in place by Earth's magnetic field.

24

00:01:13,406 --> 00:01:16,342

They are named the Van
Allen Radiation Belts,

25

00:01:16,342 --> 00:01:19,813

for the scientist who built
Explorer's Geiger counter.

26

00:01:19,813 --> 00:01:22,348

This was the very first science discovery

27

00:01:22,348 --> 00:01:23,450

made from space.

28

00:01:24,984 --> 00:01:27,854

A major finding about our planet,

29

00:01:27,854 --> 00:01:29,722

for these belts shield the Earth,

30

00:01:29,722 --> 00:01:32,092

deflecting solar particles
that would otherwise

31

00:01:32,092 --> 00:01:35,361

shred our atmosphere,
over time destroying it

32

00:01:35,361 --> 00:01:38,064

and everything about our
planet as we know it to be.

33

00:01:40,333 --> 00:01:42,502

- More than half a century has passed

34

00:01:42,502 --> 00:01:44,871
since the time of Explorer 1.

35

00:01:44,871 --> 00:01:47,874
And today we know that our
planet is changing in ways

36

00:01:47,874 --> 00:01:49,075
we need to understand.

37

00:01:49,943 --> 00:01:53,146
I'm Mike Meacham, a systems
engineer here at JPL.

38

00:01:54,013 --> 00:01:57,283
The job of a systems engineer
is to look at the big picture

39

00:01:57,283 --> 00:01:59,552
of how all different parts of a spacecraft

40

00:01:59,552 --> 00:02:02,255
are supposed to interact as one system,

41

00:02:02,255 --> 00:02:03,823
and to make sure that they do.

42

00:02:04,757 --> 00:02:07,527
The Earth is a system
too, with many parts:

43

00:02:09,062 --> 00:02:14,033
the land, the ice caps,
the oceans, the atmosphere,

44

00:02:14,834 --> 00:02:16,002
and living things.

45

00:02:18,204 --> 00:02:20,573

I wanna discover, along with you,

46

00:02:20,573 --> 00:02:23,743

how Earth's complex climate is changing.

47

00:02:23,743 --> 00:02:27,514

In the next hour, we are going
to explore the role JPL has,

48

00:02:27,514 --> 00:02:30,517

and is today playing, as
part of NASA's larger effort

49

00:02:30,517 --> 00:02:33,920

to understand what's
happening to our atmosphere.

50

00:02:33,920 --> 00:02:36,189

But to begin, let's start our journey

51

00:02:36,189 --> 00:02:38,591

by visiting the planet
known as Earth's twin.

52

00:02:39,959 --> 00:02:43,296

(deep thoughtful music)

53

00:02:51,871 --> 00:02:56,109

- [Control Room] Five,
four, three, two, one, zero.

54

00:02:58,478 --> 00:03:00,547

Ignition.
(rocked engine whooshing)

55

00:03:00,547 --> 00:03:01,381

Lift off.

56

00:03:03,016 --> 00:03:07,220

- [Narrator] The year is 1962
and we're on our way to Venus

57

00:03:07,220 --> 00:03:10,356
on board JPL's Mariner 2 spacecraft.

58

00:03:10,356 --> 00:03:13,860
(futuristic music)

59

00:03:13,860 --> 00:03:16,429
Venus was the first
planet chosen to explore

60

00:03:16,429 --> 00:03:17,964
for a very practical reason.

61

00:03:18,965 --> 00:03:20,833
It is our nearest planetary neighbor.

62

00:03:22,235 --> 00:03:26,172
And that proximity offered
the best chance for success

63

00:03:26,172 --> 00:03:28,041
in the early days of the space age.

64

00:03:29,342 --> 00:03:32,312
(futuristic music)

65

00:03:32,312 --> 00:03:35,515
Still Mariner 2 barely made it there.

66

00:03:39,719 --> 00:03:42,622
(futuristic music)

67

00:03:45,391 --> 00:03:48,595
At the time of the mission,
JPL produced this film,

68

00:03:48,595 --> 00:03:51,130

which explored how Venus
had once been thought of

69

00:03:51,130 --> 00:03:54,133

as Earth's twin, given its similar size,

70

00:03:54,133 --> 00:03:56,469

density and cloudy atmosphere.

71

00:03:56,469 --> 00:03:59,172

- [Film Narrator] Where
does the story start?

72

00:03:59,172 --> 00:04:02,442

Historically, I suppose, it
began more than 100 years ago

73

00:04:02,442 --> 00:04:04,677

when man first viewed the clouds of Venus.

74

00:04:05,612 --> 00:04:09,315

Because of the thick clouds
it seemed logical to suppose-

75

00:04:09,315 --> 00:04:11,584

- [Narrator] There had
even been speculation

76

00:04:11,584 --> 00:04:12,852

that beneath the planet's clouds,

77

00:04:12,852 --> 00:04:15,321

there might exist a
tropical world of jungles,

78

00:04:15,321 --> 00:04:17,290

swamps and rainforests.

79

00:04:18,358 --> 00:04:20,660

But by the time of Mariner 2,

80

00:04:20,660 --> 00:04:23,296

a radically different
view of Venus was emerging

81

00:04:23,296 --> 00:04:26,065

due in part to the research
of a young scientist

82

00:04:26,065 --> 00:04:29,902

who was beginning to make a
name for himself, Carl Sagan.

83

00:04:30,870 --> 00:04:33,006

- Many theories of the Venus environment

84

00:04:33,006 --> 00:04:34,774

have been suggested.

85

00:04:34,774 --> 00:04:36,409

However, new information eliminates

86

00:04:36,409 --> 00:04:38,778

at least some of these theories.

87

00:04:38,778 --> 00:04:40,747

Measurements with radio telescopes show

88

00:04:41,581 --> 00:04:43,750

that there is a region on
Venus where temperatures

89

00:04:43,750 --> 00:04:45,952

are greater than 600 degrees Fahrenheit.

90

00:04:47,153 --> 00:04:50,123

It is just possible that
the hot region exists

91

00:04:50,123 --> 00:04:51,791
at a high altitude.

92

00:04:51,791 --> 00:04:54,694
However, it is more
likely that the hot region

93

00:04:54,694 --> 00:04:56,996
is the surface, heated
either by an enormous

94

00:04:56,996 --> 00:05:00,266
greenhouse effect or by wind friction.

95

00:05:00,266 --> 00:05:02,201
Therefore, if there is life on Venus,

96

00:05:02,201 --> 00:05:04,971
it is probably of a type
that we cannot now imagine.

97

00:05:05,805 --> 00:05:08,708
- [Film Narrator] Tantalizing,
exasperating Venus,

98

00:05:08,708 --> 00:05:11,477
a single significant
experiment can confirm

99

00:05:11,477 --> 00:05:14,113
old, or create new theories.

100

00:05:15,682 --> 00:05:17,216
- [Narrator] Mariner 2 and the missions

101

00:05:17,216 --> 00:05:19,319

that followed did just that,

102

00:05:19,319 --> 00:05:22,388

turning Venus into the poster
child for global warming.

103

00:05:25,758 --> 00:05:29,028

Earth's twin? More like Earth's evil twin.

104

00:05:31,864 --> 00:05:34,267

That label was further reinforced

105

00:05:34,267 --> 00:05:38,004

when JPL's Magellan spacecraft
used radar to penetrate

106

00:05:38,004 --> 00:05:41,874

through the clouds and first
saw the surface of Venus,

107

00:05:41,874 --> 00:05:45,712

a tortured land landscape
full of ancient volcanoes,

108

00:05:45,712 --> 00:05:48,081

more than any other planet
in the solar system.

109

00:05:48,981 --> 00:05:51,217

Some may still be active.

110

00:05:51,217 --> 00:05:54,987

(light dramatic music)

111

00:05:54,987 --> 00:05:56,255

But a billion years ago,

112

00:05:56,255 --> 00:05:58,257

Venus may have had an Earth-like climate

113

00:05:58,257 --> 00:05:59,892
with oceans of water.

114

00:06:01,961 --> 00:06:05,064
Yet, over time, something
went catastrophically wrong.

115

00:06:06,733 --> 00:06:09,736
(volcanoes exploding)

116

00:06:09,736 --> 00:06:13,072
Volcanoes may have played a
role in creating this hellscape

117

00:06:13,072 --> 00:06:18,010
that is today's Venus, but
the primary cause may be

118

00:06:18,010 --> 00:06:23,015
the result of the sun's
solar wind, charged particles

119

00:06:23,015 --> 00:06:25,385
that are constantly
streaming off our star.

120

00:06:26,753 --> 00:06:29,722
The effect of this endless
bombardment of radiation,

121

00:06:29,722 --> 00:06:34,727
weakened Venus' magnetic
field, making it unstable,

122

00:06:34,861 --> 00:06:37,130
and leaving the planet to fend for itself.

123

00:06:39,866 --> 00:06:42,969

It may be as simple as
Venus wasn't able to handle

124
00:06:42,969 --> 00:06:43,803
all this heat.

125
00:06:47,240 --> 00:06:50,276
As temperatures rose the oceans evaporated

126
00:06:50,276 --> 00:06:51,978
turning into water vapor.

127
00:06:53,146 --> 00:06:56,349
Then carbon dioxide also
built up in the atmosphere

128
00:06:56,349 --> 00:06:59,018
resulting in a runaway greenhouse effect.

129
00:07:01,421 --> 00:07:03,823
- With Venus being a little
bit closer to the sun

130
00:07:03,823 --> 00:07:06,859
basically meant that it
never really had a chance.

131
00:07:06,859 --> 00:07:10,496
So over time that carbon dioxide
and water vapor built up,

132
00:07:10,496 --> 00:07:13,433
it was impossible for any
water to stay on the surface

133
00:07:13,433 --> 00:07:16,002
as a liquid, it all
stayed in the atmosphere.

134

00:07:16,002 --> 00:07:19,138

That produced a massive
greenhouse atmosphere

135

00:07:19,138 --> 00:07:21,307

that produced a tremendous
amount of warming,

136

00:07:21,307 --> 00:07:24,410

probably warming even greater
than what we're seeing today

137

00:07:24,410 --> 00:07:27,246

with surface temperatures
around 950 Fahrenheit.

138

00:07:31,451 --> 00:07:34,420

- [Narrator] Our next closest
planetary neighbor is Mars.

139

00:07:36,689 --> 00:07:38,691

Like Venus, the red planet

140

00:07:38,691 --> 00:07:40,560

shares similar features with Earth.

141

00:07:41,627 --> 00:07:45,264

Mars has polar caps, seasons,
and a rotational rate

142

00:07:45,264 --> 00:07:47,133

nearly identical to our planet.

143

00:07:48,167 --> 00:07:52,004

But any hopes that Mars might
have been more earthlike

144

00:07:52,004 --> 00:07:55,575

were squashed after the
first fly-by of the planet

145

00:07:55,575 --> 00:07:57,243
by JPL's Mariner 4.

146

00:07:59,946 --> 00:08:03,182
A handful of grainy black and
white images from the mission

147

00:08:03,182 --> 00:08:06,752
was all that was needed to see
that Mars is a barren world.

148

00:08:10,423 --> 00:08:14,160
Just like Venus, scientists
believe that ancient Mars

149

00:08:14,160 --> 00:08:15,895
was more like today's Earth,

150

00:08:17,897 --> 00:08:21,634
it was warmer and wetter, wet
enough to have had oceans.

151

00:08:22,902 --> 00:08:26,572
But about 4 billion years ago,
Mars lost its magnetic field

152

00:08:26,572 --> 00:08:28,474
that served as a planetary shield.

153

00:08:29,876 --> 00:08:32,478
And without the shield,
the Martian atmosphere was,

154

00:08:32,478 --> 00:08:36,182
like Venus, left at the mercy
of the sun's solar wind.

155

00:08:37,383 --> 00:08:40,520

(light dramatic music)

156

00:08:40,520 --> 00:08:43,789

- And as it cooled, the interior froze up.

157

00:08:43,789 --> 00:08:46,626

And when that happened,
the dynamo that generated

158

00:08:46,626 --> 00:08:49,395

its magnetic field froze up as well,

159

00:08:49,395 --> 00:08:51,397

and that was the end of it for Mars.

160

00:08:53,966 --> 00:08:56,435

- [Narrator] It took
about 500 million years,

161

00:08:56,435 --> 00:08:58,304

but eventually the solar wind

162

00:08:58,304 --> 00:09:00,006

shredded the Martian atmosphere.

163

00:09:01,207 --> 00:09:04,544

And as it disappeared, the
exposed oceans evaporated

164

00:09:06,479 --> 00:09:09,181

and the planet cooled
down into the frozen world

165

00:09:09,181 --> 00:09:10,816

it is today.

166

00:09:10,816 --> 00:09:13,586

(daunting music)

167
00:09:20,092 --> 00:09:22,762
(forlorn music)

168
00:09:26,766 --> 00:09:29,735
- So long ago, Mars
and Venus were not just

169
00:09:29,735 --> 00:09:32,939
our nearest neighbors, they
were our close cousins.

170
00:09:32,939 --> 00:09:35,074
Today, Mars is in deep freeze

171
00:09:35,074 --> 00:09:38,544
and Venus is a furnace, sobering
examples of how a planet

172
00:09:38,544 --> 00:09:40,880
might flip from paradise to hell.

173
00:09:43,549 --> 00:09:45,985
- [Narrator] Are we just
lucky that Earth resides

174
00:09:45,985 --> 00:09:49,789
in a Goldilocks zone, where
it's not too hot, not too cold,

175
00:09:49,789 --> 00:09:51,624
but just right?

176
00:09:51,624 --> 00:09:53,659
That's part of the explanation,

177
00:09:54,827 --> 00:09:57,597
but there's also the delicate
and intricate balance

178

00:09:57,597 --> 00:10:00,433

of interactions taking place
throughout our planet's

179

00:10:00,433 --> 00:10:04,070

system of water, ice, land, atmosphere,

180

00:10:04,070 --> 00:10:05,438

and all living things.

181

00:10:07,273 --> 00:10:10,276

The more we learn about
these interactions,

182

00:10:10,276 --> 00:10:12,044

the more we are understanding

183

00:10:12,044 --> 00:10:14,413

how fragile the Earth is to change.

184

00:10:16,115 --> 00:10:18,351

- Our planet is warming

185

00:10:18,351 --> 00:10:21,420

And the major causes of
that are greenhouse gases

186

00:10:21,420 --> 00:10:24,423

like carbon dioxide, or CO₂ for short.

187

00:10:25,992 --> 00:10:29,061

Carbon dioxide is a chemical
compound comprised of

188

00:10:29,061 --> 00:10:31,764

one part carbon and two parts oxygen.

189

00:10:31,764 --> 00:10:33,866

The oxygen, not a problem.

190

00:10:33,866 --> 00:10:36,268

The carbon, everywhere you
look you're going find it,

191

00:10:36,268 --> 00:10:38,504

it's the basic building block of life.

192

00:10:38,504 --> 00:10:41,474

It's in the animals, the
fish, the plant, the trees,

193

00:10:41,474 --> 00:10:42,808

and in me and you.

194

00:10:46,379 --> 00:10:48,814

- [Narrator] Nature has
an elegant but simple way

195

00:10:48,814 --> 00:10:49,982

of using carbon.

196

00:10:51,217 --> 00:10:54,820

It travels from the atmosphere
into organisms in the Earth,

197

00:10:56,255 --> 00:10:59,492

and then back into the
atmosphere over and over again.

198

00:11:01,794 --> 00:11:04,764

This process is called the carbon cycle.

199

00:11:09,168 --> 00:11:12,271

It has helped to keep our
climate in balance for at least

200

00:11:12,271 --> 00:11:15,241

the last 100,000 years, if not millions.

201

00:11:18,778 --> 00:11:20,479

As part of this cycle,

202

00:11:20,479 --> 00:11:24,283

carbon from decaying organisms
can end up in the ground

203

00:11:24,283 --> 00:11:28,921

where it can be transformed
into coal, oil and natural gas.

204

00:11:28,921 --> 00:11:31,657

(train horn blowing)

205

00:11:31,657 --> 00:11:34,393

Which we started using as
fuels to power machines

206

00:11:34,393 --> 00:11:35,995

over 200 years ago,

207

00:11:37,630 --> 00:11:40,366

and that changed the
natural order of things

208

00:11:40,366 --> 00:11:44,403

as more and more carbon in
the form of CO₂ is ending up

209

00:11:44,403 --> 00:11:47,840

in the atmosphere where it
soaks up and re-emits heat.

210

00:11:54,714 --> 00:11:58,751

Have you ever wondered why
carbon dioxide and other gases

211

00:11:58,751 --> 00:12:01,120
are called greenhouse gases?

212

00:12:01,120 --> 00:12:02,755
It's an analogy, of course,

213

00:12:03,756 --> 00:12:06,192
a greenhouse works by letting in light,

214

00:12:06,192 --> 00:12:09,729
which heats up objects
inside a structure like this,

215

00:12:09,729 --> 00:12:10,963
keeping plants warm.

216

00:12:11,964 --> 00:12:14,200
- But if light can get
in through this glass,

217

00:12:14,200 --> 00:12:16,802
why can't the heat escape back out?

218

00:12:16,802 --> 00:12:20,806
The answer is that light
and heat are not the same.

219

00:12:20,806 --> 00:12:23,476
The light that we see coming
off the sun is just a sliver

220

00:12:23,476 --> 00:12:25,444
of the electromagnetic spectrum,

221

00:12:25,444 --> 00:12:28,080
energy that ranges from
very long wavelength

222

00:12:28,080 --> 00:12:32,218

like radio waves, to shorter wavelengths like X-rays.

223

00:12:32,218 --> 00:12:34,720

The wavelength that we can pick up with our eyes

224

00:12:34,720 --> 00:12:37,256

is a relatively shorter wavelength of radiation

225

00:12:37,256 --> 00:12:39,158

that can penetrate through this glass.

226

00:12:40,593 --> 00:12:44,230

- [Narrator] Heat in the form of infrared radiation

227

00:12:44,230 --> 00:12:46,699

has longer wavelengths and it can't travel

228

00:12:46,699 --> 00:12:48,601

through the glass as easily.

229

00:12:48,601 --> 00:12:51,137

The result, the greenhouse warms up.

230

00:12:52,571 --> 00:12:55,641

- CO₂ in the atmosphere works in a similar way.

231

00:12:55,641 --> 00:12:58,344

It slows the heat escaping out into space,

232

00:12:58,344 --> 00:13:00,546

and the result, the Earth warms up.

233

00:13:01,413 --> 00:13:05,050

Across the globe, humans

output about 40 billion tons

234

00:13:05,050 --> 00:13:08,287

of CO2 into the atmosphere every year.

235

00:13:08,287 --> 00:13:10,556

But let's turn that

number into something more

236

00:13:10,556 --> 00:13:11,390

down to Earth.

237

00:13:12,424 --> 00:13:14,260

(car engine whirring)

238

00:13:14,260 --> 00:13:16,128

- [Narrator] Let's say the average car

239

00:13:16,128 --> 00:13:18,430

weighs about two tons.

240

00:13:18,430 --> 00:13:23,369

So we, the world, by burning

fossil fuels in various ways

241

00:13:23,369 --> 00:13:27,006

are putting the equivalent

mass of 20 billion cars

242

00:13:27,006 --> 00:13:29,308

into the atmosphere every year

243

00:13:31,243 --> 00:13:33,612

and the lifetime of CO2 in the atmosphere,

244

00:13:33,612 --> 00:13:34,780

hundreds of years,

245

00:13:38,117 --> 00:13:40,419
With nearly every passing year,

246

00:13:40,419 --> 00:13:42,555
the level of CO₂ is rising.

247

00:13:43,622 --> 00:13:47,393
In 1950, the record for
the highest amount of CO₂

248

00:13:47,393 --> 00:13:51,397
that had stood for 800,000
years was shattered.

249

00:13:52,598 --> 00:13:55,367
Since then the spike has soared,

250

00:13:56,569 --> 00:13:59,205
and now the Earth is heating
up at the fastest rate

251

00:13:59,205 --> 00:14:02,141
of any known time in the
history of our planet.

252

00:14:03,142 --> 00:14:05,511
The last time CO₂ was this high

253

00:14:05,511 --> 00:14:08,047
was nearly 4 million years ago,

254

00:14:09,114 --> 00:14:13,018
a time when sea level was
78 feet higher than today,

255

00:14:13,018 --> 00:14:16,055
and the Arctic was covered with forests.

256

00:14:16,055 --> 00:14:18,791

(dramatic music)

257

00:14:22,928 --> 00:14:26,031

(light upbeat music)

258

00:14:29,768 --> 00:14:32,705

The importance of CO2 and
other greenhouse gases

259

00:14:32,705 --> 00:14:35,507

was not lost on scientists at JPL.

260

00:14:37,443 --> 00:14:39,378

One of them was Moustafa Chahine,

261

00:14:40,512 --> 00:14:42,915

a native of Lebanon who
moved to the United States

262

00:14:42,915 --> 00:14:44,049

to attend college.

263

00:14:46,552 --> 00:14:50,856

In 1958 while pursuing
his PhD at UC Berkeley,

264

00:14:50,856 --> 00:14:54,593

he saw on the news, the iconic
image of JPL's Explorer 1

265

00:14:54,593 --> 00:14:55,794

being held aloft.

266

00:14:57,496 --> 00:15:00,466

That moment inspired him
to pursue a space career,

267

00:15:00,466 --> 00:15:02,067

which took him to JPL.

268

00:15:06,005 --> 00:15:08,173

Mus, as everyone called him,

269

00:15:08,173 --> 00:15:10,743

was non assuming as he was brilliant.

270

00:15:11,844 --> 00:15:14,680

He served as JPL's chief scientist,

271

00:15:14,680 --> 00:15:18,083

and it was largely his idea
to create an organization

272

00:15:18,083 --> 00:15:19,285

to harbor and nurture

273

00:15:19,285 --> 00:15:21,487

the lab's growing number of scientists.

274

00:15:22,755 --> 00:15:24,590

- [Announcer] For outstanding
performance and leadership

275

00:15:24,590 --> 00:15:28,327

in developing the JPL Earth
and Space Sciences Division

276

00:15:28,327 --> 00:15:31,397

and enhancing the science
programs of JPL and NASA.

277

00:15:32,531 --> 00:15:35,634

(audience clapping)

278

00:15:38,771 --> 00:15:42,675

- [Narrator] Muse's motto
was, "Always make progress."

279

00:15:42,675 --> 00:15:45,878

And for three decades Mous
was fixated on finding a way

280

00:15:45,878 --> 00:15:49,148

to study Earth's atmosphere
from the vantage of space.

281

00:15:50,849 --> 00:15:52,117

- A value of satellite data

282

00:15:52,117 --> 00:15:54,687

is that it gives you global coverage.

283

00:15:54,687 --> 00:15:59,124

Now we can get global coverage
with the same accuracy

284

00:15:59,124 --> 00:16:00,492

as balloon-borne instrument.

285

00:16:03,262 --> 00:16:04,096

- [Narrator] Mouse's ambition

286

00:16:04,096 --> 00:16:06,098

was to build a science
instrument that would help

287

00:16:06,098 --> 00:16:07,733

to understand climate change.

288

00:16:08,701 --> 00:16:11,203

But that proved to be a
hard sell politically.

289

00:16:12,438 --> 00:16:16,041

So he stressed how the same
instrument could also be used

290

00:16:16,041 --> 00:16:17,943
to improve weather forecasting.

291

00:16:19,244 --> 00:16:22,781
- The mission is to
understand the relationship

292

00:16:22,781 --> 00:16:24,683
between weather and climate.

293

00:16:24,683 --> 00:16:27,720
For example, are the weather anomalies,

294

00:16:27,720 --> 00:16:31,056
which we are seeing today,
hurricanes, et cetera,

295

00:16:31,056 --> 00:16:33,025
are they related to climate change?

296

00:16:38,564 --> 00:16:41,166
- [Narrator] And for that
idea he found takers.

297

00:16:42,267 --> 00:16:45,904
Mous's instrument called the
Atmospheric Infrared Sounder,

298

00:16:45,904 --> 00:16:50,042
or AIRS, was one of
six science instruments

299

00:16:50,042 --> 00:16:53,612
that won a spot to fly
aboard NASA's Aqua satellite.

300

00:16:53,612 --> 00:16:57,516
- [Control Room] Four, three, two, one.

301
00:16:57,516 --> 00:17:02,521
(spectators cheering)
(engines firing)

302
00:17:14,733 --> 00:17:17,403
- [Narrator] AIRS was designed
to detect infrared energy

303
00:17:17,403 --> 00:17:20,839
over a range of more than
2,000 wavelength bands.

304
00:17:22,174 --> 00:17:24,510
And from those bands it was hoped,

305
00:17:24,510 --> 00:17:27,046
for AIRS was officially an experiment,

306
00:17:28,180 --> 00:17:30,749
that it would be possible
to create 3D maps

307
00:17:30,749 --> 00:17:33,185
of atmospheric temperatures
and water vapor.

308
00:17:34,186 --> 00:17:37,322
But before any of these
measurements could be put to work

309
00:17:37,322 --> 00:17:39,658
all of the raw data of zeros and ones

310
00:17:39,658 --> 00:17:42,494
first had to be calibrated and validated.

311
00:17:44,730 --> 00:17:47,099
- Once you have those numbers
that you think represent

312

00:17:47,099 --> 00:17:50,736

reality, you have to confirm
that they are reality.

313

00:17:50,736 --> 00:17:53,105

This is one thing I did for
the first five or so years

314

00:17:53,105 --> 00:17:55,808

of the mission, pretty much daily,

315

00:17:55,808 --> 00:17:57,443

including a lot of weekends,

316

00:17:57,443 --> 00:17:58,744

just looked at what AIRS said

317

00:17:58,744 --> 00:18:00,946

and what say a weather balloon said.

318

00:18:02,915 --> 00:18:04,516

Or what AIRS said and what an aircraft

319

00:18:04,516 --> 00:18:06,285

that flew underneath AIRS said.

320

00:18:08,587 --> 00:18:11,256

And with several years of
hard work, we concluded

321

00:18:11,256 --> 00:18:14,226

we weren't crazy; that the
numbers that we reported

322

00:18:14,226 --> 00:18:17,696

from the instrument were actually
representative of reality.

323

00:18:18,897 --> 00:18:22,501

- [Narrator] And soon AIRS
began delivering on its promise.

324

00:18:22,501 --> 00:18:26,105

Its measurements were helping
to improve weather forecasts.

325

00:18:27,906 --> 00:18:30,209

- That was said to be enough

326

00:18:30,209 --> 00:18:32,344

to pay for the instrument itself.

327

00:18:32,344 --> 00:18:35,814

So forecast really was
a major accomplishment,

328

00:18:35,814 --> 00:18:37,816

but NASA's not a forecast center.

329

00:18:39,585 --> 00:18:43,222

- [Narrator] And Mous always
trying to make progress,

330

00:18:43,222 --> 00:18:46,692

next, wanted to explore how
AIRS might be put to use

331

00:18:46,692 --> 00:18:49,027

to better understand climate change.

332

00:18:53,899 --> 00:18:57,002

(light upbeat music)

333

00:18:59,238 --> 00:19:01,440

- As part of AIRS original purpose

334

00:19:01,440 --> 00:19:03,709
of improving weather forecasting,

335

00:19:03,709 --> 00:19:06,411
the instrument had already
gathered a wealth of data

336

00:19:06,411 --> 00:19:10,048
about water vapor,
which is H₂O in the form

337

00:19:10,048 --> 00:19:11,783
of an invisible gas.

338

00:19:11,783 --> 00:19:13,285
We know it best as humidity.

339

00:19:15,120 --> 00:19:17,089
(light futuristic music)

340

00:19:17,089 --> 00:19:20,092
- [Narrator] Water vapor
is also a greenhouse gas,

341

00:19:21,860 --> 00:19:22,995
and there's more water vapor

342

00:19:22,995 --> 00:19:25,564
than all other greenhouse gases combined.

343

00:19:26,532 --> 00:19:29,935
But through the ages, the
warmth provided by water vapor

344

00:19:29,935 --> 00:19:31,436
has been a good thing.

345

00:19:31,436 --> 00:19:34,773
Without it our planet would

be just a frozen ice cube.

346

00:19:36,875 --> 00:19:40,512

Water vapor is part of nature's
normal recycling of water

347

00:19:40,512 --> 00:19:44,917

from the Earth's surface
into the atmosphere

348

00:19:44,917 --> 00:19:46,919

and then back again to the surface,

349

00:19:48,387 --> 00:19:51,423

And this recycling goes on constantly,

350

00:19:51,423 --> 00:19:53,125

but on different time scales.

351

00:19:55,027 --> 00:19:58,030

A piece of ice in the
Arctic can remain a solid

352

00:19:58,030 --> 00:19:59,598

for millions of years.

353

00:20:00,899 --> 00:20:03,869

A drop of water in the
ocean, thousands of years.

354

00:20:05,637 --> 00:20:08,574

That same drop of water
in the form of water vapor

355

00:20:08,574 --> 00:20:12,244

in the atmosphere, on
average, just nine days.

356

00:20:14,079 --> 00:20:16,448

The amount of water
vapor in the atmosphere

357

00:20:16,448 --> 00:20:19,184
is directly related to temperature:

358

00:20:19,184 --> 00:20:22,487
the warmer it is the
more water evaporates,

359

00:20:22,487 --> 00:20:23,822
becoming water vapor.

360

00:20:25,023 --> 00:20:28,894
And more water vapor results
in warmer temperatures.

361

00:20:31,430 --> 00:20:32,831
- So you've got your cycle.

362

00:20:34,533 --> 00:20:39,504
When you change the state of
water from vapor to liquid,

363

00:20:40,472 --> 00:20:44,109
this change releases
enormous amount of energy

364

00:20:44,109 --> 00:20:45,244
into the atmosphere.

365

00:20:47,946 --> 00:20:49,848
The understanding it is critical

366

00:20:49,848 --> 00:20:51,750
to understanding our climate change.

367

00:20:52,884 --> 00:20:54,853
This is why it is important.

368

00:21:00,759 --> 00:21:01,893

- [Narrator] At any one time,

369

00:21:01,893 --> 00:21:06,131

the atmosphere contains over
37 million billion gallons

370

00:21:06,131 --> 00:21:08,500

of water vapor, which contains

371

00:21:08,500 --> 00:21:10,168

an astonishing amount of energy.

372

00:21:13,005 --> 00:21:16,775

And all this water vapor
doesn't disappear into thin air.

373

00:21:16,775 --> 00:21:21,780

It is constantly transforming
back into water, ice and snow,

374

00:21:22,814 --> 00:21:24,316

which rains down on us.

375

00:21:26,885 --> 00:21:28,720

(water whooshing)

376

00:21:28,720 --> 00:21:31,923

Often in the form of storms
that are becoming more frequent

377

00:21:32,891 --> 00:21:34,026

and more severe.

378

00:21:38,563 --> 00:21:42,801

But water vapor is not the
driver of global warming.

379

00:21:42,801 --> 00:21:46,204

The main catalyst is carbon dioxide, CO₂.

380

00:21:48,674 --> 00:21:51,243

And Mous wanted to tease
out of the AIRS data,

381

00:21:51,243 --> 00:21:54,680

the signature of CO₂ and
other greenhouse gases,

382

00:21:54,680 --> 00:21:56,982

which he nicknamed, The Culprit.

383

00:21:58,684 --> 00:22:00,652

But detecting CO₂ from the data

384

00:22:00,652 --> 00:22:03,722

proved an enormously difficult task,

385

00:22:03,722 --> 00:22:07,292

what his team liken to
unscrambling a scrambled egg.

386

00:22:09,728 --> 00:22:13,632

- So the problem here is
looking at a set of data

387

00:22:13,632 --> 00:22:15,934

with the information you want,

388

00:22:15,934 --> 00:22:19,738

but the noise is so high
that what you are looking for

389

00:22:19,738 --> 00:22:21,073

is within the noise;

390

00:22:22,708 --> 00:22:25,377
the unscrambling of a scrambled egg.

391
00:22:26,611 --> 00:22:30,982
That difficulty was thought
of as insurmountable.

392
00:22:35,387 --> 00:22:38,423
- [Narrator] But just four
years after the launch of AIRS,

393
00:22:38,423 --> 00:22:40,726
the insurmountable was surmounted.

394
00:22:41,993 --> 00:22:46,365
The Culprit, Mous declared,
had been coaxed out of hiding.

395
00:22:46,365 --> 00:22:48,967
- We've done it, now we
are looking at climate.

396
00:22:50,702 --> 00:22:52,871
- [Narrator] This is the
first global map showing

397
00:22:52,871 --> 00:22:55,640
the distribution of carbon
dioxide around the world

398
00:22:55,640 --> 00:22:57,008
as seen from Earth orbit.

399
00:22:58,343 --> 00:23:02,214
It clearly shows a distinct
pattern of high carbon dioxide

400
00:23:02,214 --> 00:23:03,915
in the Northern Hemisphere,

401
00:23:03,915 --> 00:23:05,684
which was consistent with predictions

402
00:23:05,684 --> 00:23:07,185
made by climate modelers.

403
00:23:10,422 --> 00:23:14,659
Methane, another greenhouse
gas, is seen here

404
00:23:14,659 --> 00:23:15,494
having a global

405
00:23:15,494 --> 00:23:18,830
distribution similar to that of CO₂.

406
00:23:20,799 --> 00:23:24,603
Here, carbon monoxide, which
is not a greenhouse gas

407
00:23:24,603 --> 00:23:27,439
can be seen being created
by the burning of forests

408
00:23:27,439 --> 00:23:28,407
in the Amazon.

409
00:23:29,841 --> 00:23:32,577
The gas then makes its
way across the Atlantic.

410
00:23:33,412 --> 00:23:35,947
Fires in Africa can also be seen.

411
00:23:38,650 --> 00:23:41,386
This animation is composed
of nearly six years

412

00:23:41,386 --> 00:23:44,289
of AIRS's first observations.

413

00:23:44,289 --> 00:23:46,992
The overlaying of the up and down curves

414

00:23:46,992 --> 00:23:49,795
are CO₂ measurements made from the ground

415

00:23:49,795 --> 00:23:51,763
that correspond to the seasons.

416

00:23:52,697 --> 00:23:55,200
It is a way of showing
how the Earth breathes.

417

00:23:56,034 --> 00:23:59,204
Note, the steady March of CO₂ upwards.

418

00:24:00,939 --> 00:24:03,074
The map continues to be updated,

419

00:24:03,074 --> 00:24:06,244
all showing a constant increase of CO₂.

420

00:24:10,916 --> 00:24:14,119
20 years after being
launched, the AIRS instrument

421

00:24:14,119 --> 00:24:17,289
onboard NASA's Aqua
satellite is still operating

422

00:24:18,490 --> 00:24:21,593
eying from Earth orbit,
not only greenhouse gases,

423

00:24:21,593 --> 00:24:26,598
but hurricanes, dust storms,

wildfires, volcanoes,

424

00:24:28,667 --> 00:24:31,136

and, of course, helping weather forecasts.

425

00:24:32,871 --> 00:24:34,706

It was a kind of progress Mous

426

00:24:34,706 --> 00:24:36,508

had always hoped to accomplish.

427

00:24:42,314 --> 00:24:47,319

- It is like having worked for an idea.

428

00:24:47,819 --> 00:24:51,923

And I had doubts, my colleagues had doubt,

429

00:24:51,923 --> 00:24:55,527

but 30 years later, the idea works,

430

00:24:55,527 --> 00:24:59,998

and this is the great sense of happiness,

431

00:24:59,998 --> 00:25:05,003

of satisfaction I get and my
colleagues get out of the AIRS,

432

00:25:05,570 --> 00:25:10,575

that a concept that we worked
on for 30 years worked,

433

00:25:11,643 --> 00:25:14,045

and worked very well.

434

00:25:14,045 --> 00:25:15,213

This is great.

435

00:25:16,314 --> 00:25:19,217

(thoughtful music)

436

00:25:28,894 --> 00:25:31,997

(light upbeat music)

437

00:25:36,468 --> 00:25:38,670

- [Narrator] The
pioneering success of AIRS

438

00:25:38,670 --> 00:25:42,207

helped to create a pathway
for CO2 hunters that followed.

439

00:25:43,275 --> 00:25:46,611

Here at JPL, a handful
of scientists plotted out

440

00:25:46,611 --> 00:25:51,283

a new mission, the Orbiting
Carbon Observatory or OCO.

441

00:25:53,218 --> 00:25:56,588

It was envisioned as an
instrument to fly on a spacecraft

442

00:25:56,588 --> 00:25:59,658

devoted solely to
measuring carbon dioxide.

443

00:25:59,658 --> 00:26:02,727

(light upbeat music)

444

00:26:05,497 --> 00:26:08,466

- The goal was to learn
where CO2 was being created,

445

00:26:08,466 --> 00:26:09,901

what are known as sources,

446

00:26:09,901 --> 00:26:12,837
and where it was being absorbed, sinks.

447
00:26:12,837 --> 00:26:15,740
It was already understood
that half of the CO2

448
00:26:15,740 --> 00:26:18,176
was being absorbed into the atmosphere,

449
00:26:18,176 --> 00:26:21,012
leaving the other half going
into sinks in the oceans,

450
00:26:21,012 --> 00:26:23,415
forests and the land.

451
00:26:23,415 --> 00:26:26,451
Exactly where and how much were unknown,

452
00:26:26,451 --> 00:26:29,154
but OCO intended to find the answers,

453
00:26:29,154 --> 00:26:31,089
adding a new dimension of data on top

454
00:26:31,089 --> 00:26:32,457
of what AIRS was providing.

455
00:26:33,892 --> 00:26:37,762
- AIRS measures CO2 at high
altitudes in the atmosphere,

456
00:26:37,762 --> 00:26:40,165
about halfway between where
we're sitting on the ground here

457
00:26:40,165 --> 00:26:41,733
and where airplanes fly.

458

00:26:41,733 --> 00:26:45,270

And so it was a useful measurement
for studying the impact

459

00:26:45,270 --> 00:26:47,439

of carbon dioxide on greenhouse effects,

460

00:26:47,439 --> 00:26:50,675

but it wasn't useful for
actually tracking the sources

461

00:26:50,675 --> 00:26:53,044

that were emitting carbon
dioxide into the air

462

00:26:53,044 --> 00:26:56,381

and the natural sinks that are
absorbing it at the surface.

463

00:26:56,381 --> 00:26:58,883

For that we needed to
use reflected sunlight

464

00:26:58,883 --> 00:27:01,419

rather than thermal energy
to make this measurement,

465

00:27:01,419 --> 00:27:04,089

and we can essentially count
all the molecules from the top

466

00:27:04,089 --> 00:27:06,524

of the atmosphere down to the
surface and back to space.

467

00:27:06,524 --> 00:27:08,293

That measurement's much, much better

468

00:27:08,293 --> 00:27:11,296
for tracking CO2 sources and sinks.

469
00:27:11,296 --> 00:27:13,732
(light upbeat music)

470
00:27:13,732 --> 00:27:15,667
- [Narrator] In 2002, the mission

471
00:27:15,667 --> 00:27:17,469
was given the go ahead by NASA.

472
00:27:18,303 --> 00:27:21,272
By then scientists everywhere
were realizing that

473
00:27:21,272 --> 00:27:24,209
climate change wasn't something
far off in the future,

474
00:27:25,543 --> 00:27:27,779
it was going to impact
their children's lives

475
00:27:27,779 --> 00:27:31,483
if not their own, which made
the work of the OCO team

476
00:27:31,483 --> 00:27:32,517
even more urgent.

477
00:27:33,952 --> 00:27:37,155
- The original Orbiting
Carbon Observatory mission

478
00:27:37,155 --> 00:27:40,191
was a long, difficult project.

479
00:27:41,359 --> 00:27:46,364

It took nine years of
effort, 1,000 work years,

480
00:27:47,932 --> 00:27:51,302
a lot of trials and tribulations
to get to the launch site.

481
00:27:54,406 --> 00:27:59,411
So on February 24th, 2009,
we were finally there.

482
00:28:00,679 --> 00:28:03,748
(anticipatory music)

483
00:28:06,551 --> 00:28:08,319
- [Control Room] Step
130, verify (indistinct).

484
00:28:11,823 --> 00:28:13,491
Copy, check 130 complete.

485
00:28:13,491 --> 00:28:15,727
Check, 131 RCSE, send range data,

486
00:28:15,727 --> 00:28:17,595
solar signal and verify.

487
00:28:17,595 --> 00:28:21,132
- It was indeed a beautiful evening.

488
00:28:21,132 --> 00:28:24,269
You can clearly see the stars in the sky.

489
00:28:24,269 --> 00:28:26,337
There was very little wind.

490
00:28:26,337 --> 00:28:28,106
So it was a perfect night.

491

00:28:28,106 --> 00:28:30,175

The air was just filled with excitement.

492

00:28:30,175 --> 00:28:32,444

- [Control Room] RCSE step 132.

493

00:28:33,278 --> 00:28:35,780

- So we went through the manuals and made

494

00:28:35,780 --> 00:28:37,649

of all our final checks.

495

00:28:37,649 --> 00:28:40,919

And I gave the go ahead saying that,

496

00:28:40,919 --> 00:28:42,353

yeah, OCO is ready to launch.

497

00:28:43,488 --> 00:28:46,357

I remember the countdown
being given, you know.

498

00:28:46,357 --> 00:28:48,359

10, 9, 8-

499

00:28:48,359 --> 00:28:52,030

- [Control Room] Seven, six, five, four,

500

00:28:52,030 --> 00:28:56,434

three, two, one, zero.

- Three, two, one.

501

00:28:56,434 --> 00:29:01,139

- [Control Room] And lift off
of the Taurus rocket with OCO

502

00:29:01,139 --> 00:29:04,409

tracking a greenhouse gas in seek of clues

503

00:29:04,409 --> 00:29:05,410
to global warming.

504

00:29:06,945 --> 00:29:09,547
- [Ralph] All of your
senses are heightened,

505

00:29:09,547 --> 00:29:11,750
your emotions are running on overdrive.

506

00:29:11,750 --> 00:29:13,618
All of those years work

507

00:29:13,618 --> 00:29:17,055
is finally leading up to this culmination.

508

00:29:17,055 --> 00:29:18,823
We could hear the rumbling, you know,

509

00:29:18,823 --> 00:29:20,391
inside of the control room.

510

00:29:22,861 --> 00:29:25,396
We're not just glued to our chairs,

511

00:29:25,396 --> 00:29:27,332
but also glued to the monitors.

512

00:29:27,332 --> 00:29:30,535
- [Rick] Zero TVA
initialized, pressure nominal.

513

00:29:30,535 --> 00:29:34,672
Stage one ignition in
approximately five seconds.

514

00:29:34,672 --> 00:29:36,107

- [Ralph] It was a beautiful launch.

515

00:29:36,107 --> 00:29:38,143

- [Rick] Vent cover jettison,

516

00:29:38,143 --> 00:29:39,911

stage zero burnout, stage one ignition,

517

00:29:39,911 --> 00:29:41,146

stage zero separation,

518

00:29:42,113 --> 00:29:44,182

vehicle altitude nominal,

power bus is nominal.

519

00:29:44,182 --> 00:29:47,118

Stage one burn will last

approximately 70 seconds.

520

00:29:47,118 --> 00:29:49,487

- [Ralph] You couldn't have

asked for anything better.

521

00:29:50,421 --> 00:29:52,423

- Because the sky was so clear

522

00:29:52,423 --> 00:29:54,893

we could actually see

the rocket go all the way

523

00:29:54,893 --> 00:29:58,863

to the horizon, just with our naked eyes,

524

00:29:58,863 --> 00:30:01,032

and we got some beautiful

pictures of that.

525

00:30:02,634 --> 00:30:06,671

Everything went perfectly up until

526

00:30:06,671 --> 00:30:09,474

3 minutes and 50 seconds after the launch.

527

00:30:10,508 --> 00:30:12,610

- [Rick] Fairing separation,

528

00:30:12,610 --> 00:30:13,545

vehicle altitude nominal

529

00:30:13,545 --> 00:30:15,914

following jettison and payload fairing,

530

00:30:15,914 --> 00:30:17,081

proper load shedding.

531

00:30:17,081 --> 00:30:19,717

- We were listening
intently on our headsets

532

00:30:21,452 --> 00:30:23,621

and then I heard some chatter.

533

00:30:25,023 --> 00:30:26,291

- [Rick] Approximately 130 miles.

534

00:30:26,291 --> 00:30:27,992

Vehicle is, what's that?

535

00:30:36,467 --> 00:30:39,771

- But I was also looking at
the screen and the animation

536

00:30:39,771 --> 00:30:42,207

was still showing everything was fine,

537

00:30:43,408 --> 00:30:44,642

but my eyes were telling me one thing,

538

00:30:44,642 --> 00:30:46,778

but I was hearing something different.

539

00:30:46,778 --> 00:30:50,114

(rocket engines firing)

540

00:30:51,182 --> 00:30:54,986

- I was in the control center,
standing at the screen,

541

00:30:54,986 --> 00:30:56,821

watching the numbers go by.

542

00:30:56,821 --> 00:30:58,323

And I knew that to make orbit,

543

00:30:58,323 --> 00:31:00,358

I had to go seven kilometers per second

544

00:31:01,759 --> 00:31:04,262

And every calculation
I could do in my mind

545

00:31:04,262 --> 00:31:06,030

at two o'clock in the
morning was telling me

546

00:31:06,030 --> 00:31:07,799

those numbers weren't adding up.

547

00:31:07,799 --> 00:31:12,103

So I turned around to the
main engineer for the rocket

548

00:31:12,103 --> 00:31:16,875

and I kind of went like this
and he goes, "I'm sorry."

549

00:31:18,409 --> 00:31:20,245

- [Rick] You know on that,

550

00:31:20,245 --> 00:31:23,047

it appears we've had a contingency with the OCO mission.

551

00:31:24,616 --> 00:31:26,384

Please enact the emission mishap

552

00:31:26,384 --> 00:31:28,553

preparedness and contingency plan.

553

00:31:28,553 --> 00:31:30,455

Begin with notification data empowerment

554

00:31:30,455 --> 00:31:32,624

and mishap response tasks.

555

00:31:32,624 --> 00:31:33,758

Do not leave your station.

556

00:31:33,758 --> 00:31:36,561

Do not attempt to call out and release information to anyone

557

00:31:36,561 --> 00:31:38,930

or speculate on the cause of the contingency.

558

00:31:40,632 --> 00:31:42,166

- [Ralph] It was devastating.

559

00:31:43,234 --> 00:31:45,770

Everything seemed so surreal.

560

00:31:45,770 --> 00:31:49,173

We kept looking at this

plume from the second stage

561

00:31:49,173 --> 00:31:50,775
and we're hearing all this chatter

562

00:31:50,775 --> 00:31:54,178
on the engineering net and
it just didn't make sense.

563

00:31:55,113 --> 00:31:59,918
It was just this sense
of disbelief and shock.

564

00:32:00,885 --> 00:32:05,857
(daunting music)
(rocket firing)

565

00:32:30,581 --> 00:32:33,751
- NASA's Orbiting Carbon
Observatory satellite

566

00:32:33,751 --> 00:32:38,756
failed to reach orbit after
its 1:55 and 31 second

567

00:32:38,990 --> 00:32:41,159
launch time lift off from Vandenberg-

568

00:32:41,159 --> 00:32:42,593
- [Narrator] It only took a few hours

569

00:32:42,593 --> 00:32:44,329
to determine what had happened.

570

00:32:44,329 --> 00:32:47,465
- Preliminary indications
are that the fairing

571

00:32:47,465 --> 00:32:50,735

on the Taurus XL launch
vehicle failed to separate.

572

00:32:50,735 --> 00:32:53,104

The fairing is a clamshell structure

573

00:32:53,104 --> 00:32:55,206

that encapsulates the
satellite as it travels

574

00:32:55,206 --> 00:32:56,341

through the atmosphere.

575

00:32:59,911 --> 00:33:02,380

- The fairing, the
pointy end on the rocket

576

00:33:02,380 --> 00:33:04,282

was supposed to open up.

577

00:33:04,282 --> 00:33:05,416

That didn't happen.

578

00:33:05,416 --> 00:33:08,119

The mechanism that was supposed to open

579

00:33:08,119 --> 00:33:10,855

the fairing failed, malfunctioned.

580

00:33:11,723 --> 00:33:13,725

And so the fairing stayed on the rocket.

581

00:33:15,927 --> 00:33:17,495

- [Narrator] Instead of reaching orbit,

582

00:33:17,495 --> 00:33:20,832

the spacecraft still
encased in the fairing,

583

00:33:20,832 --> 00:33:23,868

reentered the atmosphere
and fell back to Earth.

584

00:33:26,404 --> 00:33:30,575

- You, it was like losing
somebody you've loved, you know,

585

00:33:30,575 --> 00:33:33,544

it was that emotional for all of us.

586

00:33:35,013 --> 00:33:38,583

But I would say 24 hours later,

587

00:33:38,583 --> 00:33:42,787

you know, those emotions
turned into a resolve.

588

00:33:47,925 --> 00:33:50,862

- [Narrator] But along with
resolve to re-fly the mission

589

00:33:50,862 --> 00:33:52,296

required new funding.

590

00:33:57,535 --> 00:34:02,540

- This was not an easy time to try

591

00:34:02,540 --> 00:34:05,710

to go back and re-fly a
mission that you had just lost.

592

00:34:06,577 --> 00:34:10,314

We had just dropped a
quarter of a billion dollars

593

00:34:10,314 --> 00:34:11,449

in the Indian Ocean.

594

00:34:13,251 --> 00:34:17,288

We were gonna go to Congress,
the White House and say,

595

00:34:17,288 --> 00:34:19,957

"Can I have some more
money to do it again?"

596

00:34:20,792 --> 00:34:22,960

This is hard to do at any time,

597

00:34:22,960 --> 00:34:27,832

but it was especially hard
to do in February of 2009

598

00:34:28,933 --> 00:34:33,071

because we were in the depth
of the greatest recession

599

00:34:33,071 --> 00:34:34,572

since the Great Depression.

600

00:34:38,676 --> 00:34:41,112

- [Narrator] It took a
year to get the NASA funds

601

00:34:41,112 --> 00:34:44,682

to rebuild the mission,
which was named OCO-2.

602

00:34:45,917 --> 00:34:47,985

But the funding ended up being delayed,

603

00:34:49,020 --> 00:34:52,056

keeping the team intact while marking time

604

00:34:52,056 --> 00:34:53,424

became a new challenge.

605

00:34:54,692 --> 00:34:56,494

- [Rick] Seven, six-

606

00:34:56,494 --> 00:34:57,462

- [Narrator] Then NASA suffered

607

00:34:57,462 --> 00:34:59,664

the loss of another spacecraft,

608

00:34:59,664 --> 00:35:02,300

the Goddard Space Flight
Center's Glory mission,

609

00:35:02,300 --> 00:35:06,237

like OCO, was launched
from the same launch site

610

00:35:06,237 --> 00:35:08,106

on the same type of rocket.

611

00:35:08,106 --> 00:35:09,941

- [Control Room] We were
at T plus 300 seconds.

612

00:35:09,941 --> 00:35:13,611

The vehicle speed air is
indicating under performance.

613

00:35:13,611 --> 00:35:16,380

- [Narrator] And met the same
fate for the same reason.

614

00:35:17,849 --> 00:35:19,250

- [Control Room] Which is expected

615

00:35:19,250 --> 00:35:22,520

due to a fairing not separating.

616

00:35:22,520 --> 00:35:25,223

- [Narrator] The loss of
Glory caused further delays

617

00:35:25,223 --> 00:35:26,491

for the launch of OCO-2.

618

00:35:27,592 --> 00:35:30,528

- [Control Room] Do not leave
your stations until released.

619

00:35:30,528 --> 00:35:34,031

Do not attempt to call out and
release information to anyone

620

00:35:34,031 --> 00:35:35,500

or speculate on the cause-

621

00:35:35,500 --> 00:35:38,336

- [Narrator] Years passed
before the cause of the Glory

622

00:35:38,336 --> 00:35:41,739

and OCO fairing failures was tracked down.

623

00:35:41,739 --> 00:35:45,409

But in 2019, the U.S.
Department of Justice

624

00:35:45,409 --> 00:35:48,880

announced that a manufacturer
whose materials had been used

625

00:35:48,880 --> 00:35:51,415

in the fairing release
mechanism had agreed to a fine

626

00:35:51,415 --> 00:35:56,420

of \$46 million to resolve
criminal charges and civil claims

627

00:35:56,787 --> 00:35:59,724

related to falsifying test certifications.

628

00:36:01,225 --> 00:36:03,961

(daunting music)

629

00:36:08,499 --> 00:36:11,602

(anticipatory music)

630

00:36:28,953 --> 00:36:33,024

Five years after the loss
of the first OCO spacecraft,

631

00:36:33,024 --> 00:36:35,526

the second Orbiting Carbon Observatory

632

00:36:35,526 --> 00:36:37,094

was sitting on the launchpad.

633

00:36:39,897 --> 00:36:42,600

- [Control Room] At T minus 1
hour 38 minutes eight seconds

634

00:36:42,600 --> 00:36:45,369

and counting, this is
Delta Launch Control.

635

00:36:45,369 --> 00:36:49,874

- We knew we had built an
OCO-2 that was gonna work,

636

00:36:49,874 --> 00:36:52,076

and I felt a lot of excitement.

637

00:36:52,076 --> 00:36:54,111

It was a beautiful launch,

638

00:36:54,111 --> 00:36:56,113
but it was a one that we didn't see.

639
00:36:58,082 --> 00:37:00,518
- [Narrator] On this night,
Vandenberg Air Force Base

640
00:37:00,518 --> 00:37:03,921
was fogged in, not that
anyone had really cared,

641
00:37:03,921 --> 00:37:06,490
for OCO-2 would be
treated to a perfect ride.

642
00:37:06,490 --> 00:37:08,593
- [Control Room] Two, engine start.

643
00:37:08,593 --> 00:37:09,827
One, zero

644
00:37:09,827 --> 00:37:13,931
Lift off of the Delta II rocket with OCO-2

645
00:37:13,931 --> 00:37:17,835
tracking of greenhouse gas,
seek of clues to climate change.

646
00:37:21,539 --> 00:37:24,041
- So I remember one of
my colleagues saying,

647
00:37:24,041 --> 00:37:28,145
"Hey, wow, that was one of the
best launches I never saw."

648
00:37:29,313 --> 00:37:31,515
- [Control Room] Good chamber
pressure in the three solids,

649

00:37:31,515 --> 00:37:36,087

good symmetrical burn, 22
seconds in, still looking good.

650

00:37:38,422 --> 00:37:40,524

Good chamber pressure on the second stage.

651

00:37:43,561 --> 00:37:46,264

Standing by for fairing jettison.

652

00:37:46,264 --> 00:37:49,166

(futuristic music)

653

00:37:51,469 --> 00:37:53,504

And we have fairing jettison.

654

00:37:54,872 --> 00:37:57,875

(futuristic music)

655

00:38:03,481 --> 00:38:07,852

Standing by for SECO-1 standing by.

656

00:38:11,255 --> 00:38:12,423

And we have SECO.

657

00:38:15,893 --> 00:38:18,562

- I mentioned to a lot of you
that we wanted an opportunity

658

00:38:18,562 --> 00:38:20,698

to finally complete some
unfinished business, you know,

659

00:38:20,698 --> 00:38:23,134

with the loss of the original OCO mission,

660

00:38:23,134 --> 00:38:26,304

and we've taken the first

step in that direction.

661

00:38:27,571 --> 00:38:31,008

Solar rays did deploy and
we are power positive.

662

00:38:37,248 --> 00:38:40,051

- [Narrator] And now OCO-2
was circling the Earth

663

00:38:40,051 --> 00:38:42,687

14 1/2 times every day,

664

00:38:45,489 --> 00:38:48,959

and completing a full mapping
of the Earth every 16 days

665

00:38:51,295 --> 00:38:53,297

making millions of individual measurements

666

00:38:53,297 --> 00:38:56,400

that now had to be
translated into usable data.

667

00:38:58,369 --> 00:39:01,706

But OCO-2's challenges were not over.

668

00:39:01,706 --> 00:39:04,175

After calibrating the instrument,

669

00:39:04,175 --> 00:39:06,043

scientists thought something was wrong.

670

00:39:09,413 --> 00:39:11,282

- There was a problem when we recognized

671

00:39:11,282 --> 00:39:14,085

that the light signals of
glint data over the ocean

672

00:39:14,085 --> 00:39:16,587

were not nearly what we
thought they should be.

673

00:39:16,587 --> 00:39:19,123

On the land that data
was looking really good,

674

00:39:20,358 --> 00:39:21,959

but when you look over the ocean,

675

00:39:21,959 --> 00:39:25,196

you're looking at where
the bright sunlint is.

676

00:39:25,196 --> 00:39:27,264

We were starting to analyze that data,

677

00:39:27,264 --> 00:39:28,799

the retrievals weren't looking good,

678

00:39:28,799 --> 00:39:31,836

and then one of our guys had
plotted this as a function

679

00:39:31,836 --> 00:39:34,238

of the angle of the sun, and he said,

680

00:39:34,238 --> 00:39:36,640

"There's a certain pattern
I expect I'm gonna see

681

00:39:36,640 --> 00:39:38,809

"and I'm not seeing that pattern.

682

00:39:38,809 --> 00:39:40,945

"I know this idea is kind of crazy,

683

00:39:40,945 --> 00:39:44,382

"but this data sorta looks
to me like you're measuring

684

00:39:44,382 --> 00:39:47,852

"with the wrong sensitivity
to polarization."

685

00:39:47,852 --> 00:39:50,154

And just to clarify what polarization is,

686

00:39:50,154 --> 00:39:52,823

we probably all have a pair of sunglasses,

687

00:39:52,823 --> 00:39:54,825

and if you have polarized sunglasses,

688

00:39:54,825 --> 00:39:57,695

when you look at a piece of
water, right, it doesn't,

689

00:39:57,695 --> 00:39:59,663

it's not super glary.

690

00:39:59,663 --> 00:40:02,066

And if you turn your sunglasses 90 degrees

691

00:40:02,066 --> 00:40:04,935

you would actually see
the glary light again.

692

00:40:04,935 --> 00:40:07,972

So it's very different
at this 90 degrees off,

693

00:40:07,972 --> 00:40:10,541

especially over water reflections.

694

00:40:10,541 --> 00:40:13,544

So he's like, "I think we've
got our sunglasses on sideways.

695

00:40:13,544 --> 00:40:15,379

"We're looking at the wrong polarization."

696

00:40:15,379 --> 00:40:18,115

And we're like, "Are you serious, Chris?"

697

00:40:18,115 --> 00:40:19,617

We're both like, "Are you serious?"

698

00:40:19,617 --> 00:40:22,153

And we're like, "uh-oh."

699

00:40:23,454 --> 00:40:27,124

(light upbeat music)

700

00:40:27,124 --> 00:40:29,894

- [Narrator] The problem
was traced back to an error

701

00:40:29,894 --> 00:40:32,396

in the design of the science instrument,

702

00:40:32,396 --> 00:40:36,000

a flaw that could not be fixed
with spacecraft in orbit.

703

00:40:36,967 --> 00:40:40,271

- This is where the engineering
team again saved our bacon,

704

00:40:40,271 --> 00:40:42,072

and they found that, in fact,

705

00:40:42,072 --> 00:40:46,944

we could just fly our

spacecraft a little bit angled.

706

00:40:46,944 --> 00:40:49,713

It was not such an angle that
the sunlight wasn't enough,

707

00:40:49,713 --> 00:40:51,982

so the solar panel still got enough light,

708

00:40:51,982 --> 00:40:54,852

it wasn't 90 degrees to
get that full sensitivity,

709

00:40:54,852 --> 00:40:57,021

but it was 1/3 of the way there

710

00:40:57,021 --> 00:40:59,557

and it actually increased
the signal enough.

711

00:41:01,559 --> 00:41:03,527

In the end, right, I can
make it all sound like,

712

00:41:03,527 --> 00:41:05,963

"Oh, simple solution,
rotate your spacecraft."

713

00:41:05,963 --> 00:41:07,898

There was a lot of angst between,

714

00:41:07,898 --> 00:41:09,867

"I think our sensitivity's different,"

715

00:41:09,867 --> 00:41:13,204

and "Here we go with our
little rotated spacecraft."

716

00:41:13,204 --> 00:41:14,038

But yeah.

717

00:41:14,038 --> 00:41:16,507

Wow, that was quite a start of a mission.

718

00:41:19,443 --> 00:41:21,412

- [Narrator] Then a new problem arose.

719

00:41:23,214 --> 00:41:26,083

Following the loss of the Glory mission,

720

00:41:26,083 --> 00:41:29,153

OCO-2's launch was delayed
for more than a year,

721

00:41:29,153 --> 00:41:32,122

forcing the spacecraft
to be put into storage.

722

00:41:32,122 --> 00:41:34,225

And that had unforeseen consequences.

723

00:41:36,260 --> 00:41:40,664

- While we were in storage,
unknown to us, the focal planes,

724

00:41:40,664 --> 00:41:43,033

the detectors that detect the light,

725

00:41:43,033 --> 00:41:47,071

the infrared light, were slowly
pulling themselves apart.

726

00:41:48,272 --> 00:41:50,774

Because they were at room
temperature and they wanted to be

727

00:41:50,774 --> 00:41:52,776

really, really cold,

728

00:41:52,776 --> 00:41:55,613

halfway between room
temperature and absolute zero.

729

00:41:55,613 --> 00:41:58,616

And so when we flew the mission,

730

00:41:58,616 --> 00:42:02,186

many of the detector
pixels across our infrared

731

00:42:02,186 --> 00:42:04,355

focal planes had gone bad.

732

00:42:05,990 --> 00:42:07,992

So it's just another challenge,

733

00:42:07,992 --> 00:42:09,727

we still had plenty of pixels that worked.

734

00:42:09,727 --> 00:42:12,096

The question is, how do
we work around the ones

735

00:42:12,096 --> 00:42:13,564

that went bad?

736

00:42:13,564 --> 00:42:15,699

We calibrated a whole set of data.

737

00:42:15,699 --> 00:42:17,468

We ran it through computers.

738

00:42:17,468 --> 00:42:19,603

It took months and months of processing,

739

00:42:19,603 --> 00:42:22,540

and the products that
came out weren't good.

740

00:42:24,475 --> 00:42:26,677

- The scientists were forced
to scrub through their data

741

00:42:26,677 --> 00:42:27,845

a second time.

742

00:42:27,845 --> 00:42:30,247

And remember OCO-2 was beaming back

743

00:42:30,247 --> 00:42:32,182

about a million individual measurements,

744

00:42:32,182 --> 00:42:35,553

or soundings as they are
called, every single day.

745

00:42:35,553 --> 00:42:38,489

That's 24 soundings a second.

746

00:42:38,489 --> 00:42:41,825

And most of them like those,
taken at night over clouds,

747

00:42:41,825 --> 00:42:44,962

and those bad pixels are of no use,

748

00:42:44,962 --> 00:42:46,730

they have to be filtered out.

749

00:42:46,730 --> 00:42:48,165

So by the end of every day,

750

00:42:48,165 --> 00:42:52,369

the team has about
85,000 usable soundings,

751

00:42:52,369 --> 00:42:54,405

yet, even with a really fast computer,

752

00:42:54,405 --> 00:42:58,008

it takes about five minutes of
computation time per sounding

753

00:42:58,008 --> 00:42:59,977

to derive any useful information.

754

00:43:01,245 --> 00:43:03,247

And to do this, thousands of computers

755

00:43:03,247 --> 00:43:05,382

have to be lashed together.

756

00:43:05,382 --> 00:43:08,419

And the CO₂ that scientists
are seeking to find in the data

757

00:43:08,419 --> 00:43:12,256

is absolutely minuscule,
about 400 parts per million.

758

00:43:13,357 --> 00:43:17,394

Which means detecting 400
CO₂ molecules residing

759

00:43:17,394 --> 00:43:20,364

in the midst of a million other molecules,

760

00:43:20,364 --> 00:43:23,100

it's enough to bring even a
supercomputer to its knees.

761

00:43:24,768 --> 00:43:26,637

It all points to the fact that we're now

762

00:43:26,637 --> 00:43:28,172

in a different space age,

763

00:43:28,172 --> 00:43:31,875

coping with these massive data sets is now as much or more

764

00:43:31,875 --> 00:43:34,078

of a challenge as creating the rockets

765

00:43:34,078 --> 00:43:37,047

and science instruments that are now being flown.

766

00:43:37,047 --> 00:43:40,117

And to the dismay of the OCO-2 team, their measurements

767

00:43:40,117 --> 00:43:41,318

still weren't adding up.

768

00:43:43,053 --> 00:43:46,223

- So there was an early version of our OCO-2 data,

769

00:43:46,223 --> 00:43:49,927

that we don't even like to talk about amongst our team.

770

00:43:49,927 --> 00:43:53,430

A math calculation got put in the wrong order,

771

00:43:54,298 --> 00:43:56,333

and the subset of data we were testing with,

772

00:43:56,333 --> 00:43:58,435

this error was not obvious.

773

00:43:58,435 --> 00:44:01,071

But once we gave it to
the data processing team

774

00:44:01,071 --> 00:44:03,741

and they started running
through a year of data,

775

00:44:03,741 --> 00:44:06,477

you built up a time series
and you could really see,

776

00:44:06,477 --> 00:44:09,680

"Oh, something is not
right in this data set."

777

00:44:09,680 --> 00:44:11,649

You don't imagine some of these things

778

00:44:11,649 --> 00:44:14,718

that could be happening, and
so you've not imagined it,

779

00:44:14,718 --> 00:44:17,121

you didn't test for, it
and you didn't see it,

780

00:44:17,121 --> 00:44:17,955

and there you go,

781

00:44:17,955 --> 00:44:19,156

it shows up, and then you're like,

782

00:44:19,156 --> 00:44:21,258

"Oh, completely missed that one."

783

00:44:22,926 --> 00:44:25,596

In hindsight, I've gone

through this process

784

00:44:25,596 --> 00:44:28,899

so many times over, I'm like,
oh, that's par for the course,

785

00:44:28,899 --> 00:44:32,603

but it was my first time with
delivering a big data set

786

00:44:32,603 --> 00:44:34,605

being one of the key responsible members,

787

00:44:34,605 --> 00:44:35,439

and I was just like,

788

00:44:35,439 --> 00:44:37,307

"Holy cow, I can't believe we did that."

789

00:44:40,544 --> 00:44:43,947

- The team, which had
been working 24-hour days,

790

00:44:43,947 --> 00:44:46,550

regrouped, came up with
a different solution,

791

00:44:46,550 --> 00:44:49,219

and that solution worked extremely well,

792

00:44:49,219 --> 00:44:51,321

and then we were able
to reprocess that data

793

00:44:51,321 --> 00:44:55,092

to derive CO2 values that
have, basically, led the world

794

00:44:55,092 --> 00:44:56,560

in precision and accuracy.

795

00:44:58,629 --> 00:45:01,432

- [Narrator] But surprises
with the OCO's data results,

796

00:45:01,432 --> 00:45:06,170

what scientists called end
products kept on coming.

797

00:45:06,170 --> 00:45:09,039

The biggest of them came
from mother Earth herself.

798

00:45:09,907 --> 00:45:12,376

- By the spring of 2015,

799

00:45:12,376 --> 00:45:15,979

just as we're starting to get
a useful product out of it,

800

00:45:15,979 --> 00:45:18,582

we started realizing the
product was not looking

801

00:45:18,582 --> 00:45:20,184

quite like what we expected.

802

00:45:22,119 --> 00:45:24,655

We expected a product that showed us

803

00:45:24,655 --> 00:45:28,859

that tropical rainforest
were the lungs of the planet,

804

00:45:28,859 --> 00:45:32,463

then we expected them to be
where the CO2 was being pulled

805

00:45:32,463 --> 00:45:35,065

out of the atmosphere
by those marvelous trees

806

00:45:35,065 --> 00:45:37,167

and plants all the way across the tropics.

807

00:45:38,068 --> 00:45:39,570

We weren't seeing that.

808

00:45:39,570 --> 00:45:43,207

We saw that the Amazon is
actually emitting carbon dioxide

809

00:45:43,207 --> 00:45:45,809

into the air, not absorbing it.

810

00:45:45,809 --> 00:45:49,446

(water whooshing)

811

00:45:49,446 --> 00:45:50,514

- [Narrator] The Amazon,

812

00:45:50,514 --> 00:45:53,050

the largest rainforest in the world,

813

00:45:53,050 --> 00:45:55,919

has been known to be a
major absorber of CO₂.

814

00:45:57,354 --> 00:46:00,023

So what had caused such a profound shift?

815

00:46:03,026 --> 00:46:06,330

- We thought, "Oh my gosh,
biomass burning, fires,

816

00:46:06,330 --> 00:46:08,499

"wildfires are burning in the tropics

817

00:46:08,499 --> 00:46:10,801

"and that's adding carbon
dioxide to the air."

818

00:46:12,302 --> 00:46:14,605

And that turned out being a tiny piece

819

00:46:14,605 --> 00:46:16,140

of what was actually happening.

820

00:46:18,075 --> 00:46:21,612

- [Narrator] What else was
happening was an intense El Nino,

821

00:46:21,612 --> 00:46:25,149

a climate pattern that causes
an unusual warming of waters

822

00:46:25,149 --> 00:46:25,983

in the Pacific.

823

00:46:27,251 --> 00:46:30,087

And this El Nino was
also warming the Amazon.

824

00:46:31,221 --> 00:46:34,258

(daunting music)

825

00:46:34,258 --> 00:46:35,459

(upbeat music)

826

00:46:35,459 --> 00:46:37,761

- They had been going
through years of drought

827

00:46:38,662 --> 00:46:43,066

and the extra drought and heat
associated with the El Nino

828

00:46:43,066 --> 00:46:45,502

just basically shut the trees down:

829

00:46:45,502 --> 00:46:47,571

they stopped photosynthesizing,

830

00:46:47,571 --> 00:46:49,873

they stopped even trying to grow.

831

00:46:49,873 --> 00:46:53,043

And because of that, they
stopped absorbing carbon dioxide

832

00:46:53,043 --> 00:46:54,178

like they usually do.

833

00:46:55,212 --> 00:46:56,680

But that was just the Amazon.

834

00:46:58,015 --> 00:47:00,017

In Africa, they had plenty of rain,

835

00:47:01,185 --> 00:47:03,253

but it was incredibly hot,

836

00:47:03,253 --> 00:47:05,756

the hottest temperatures they had seen.

837

00:47:05,756 --> 00:47:07,491

Plants actually absorb

838

00:47:07,491 --> 00:47:09,193

carbon dioxide through photosynthesis,

839

00:47:09,193 --> 00:47:11,995

but they release carbon
dioxide through respiration.

840

00:47:11,995 --> 00:47:13,697

And because of the higher temperatures,

841

00:47:13,697 --> 00:47:17,067

the respiration was
outstripping the photosynthesis.

842

00:47:18,235 --> 00:47:20,270

Then we had Southeast Asia:

843

00:47:21,138 --> 00:47:25,609

and in Southeast Asia,
Indonesia, it was fire.

844

00:47:26,443 --> 00:47:28,345

The fires were burning out of control.

845

00:47:29,980 --> 00:47:32,616

So we got to watch all
of this happen with OCO-2

846

00:47:33,483 --> 00:47:37,354

and make detailed measurements
of how the land biosphere,

847

00:47:37,354 --> 00:47:39,890

these trees were interacting
with the atmosphere.

848

00:47:41,291 --> 00:47:44,061

- [Narrator] With all of these
tropical forests emitting

849

00:47:44,061 --> 00:47:46,730

rather than absorbing CO₂,

850

00:47:46,730 --> 00:47:49,032

it would seem that the

amount of carbon dioxide

851

00:47:49,032 --> 00:47:51,568

in the atmosphere would skyrocket,

852

00:47:51,568 --> 00:47:52,870

but that had not happened.

853

00:47:53,904 --> 00:47:57,574

Instead, for some reason,
CO2 was being absorbed

854

00:47:57,574 --> 00:48:00,177

someplace else, but where?

855

00:48:02,012 --> 00:48:04,848

- Well, it turns out that
most of it looks like

856

00:48:04,848 --> 00:48:09,152

it's going into Northern
Hemisphere forest.

857

00:48:09,152 --> 00:48:11,021

(dramatic music)

858

00:48:11,021 --> 00:48:16,026

So the forest across Europe, across Asia,

859

00:48:16,560 --> 00:48:18,195

across North America.

860

00:48:19,930 --> 00:48:22,099

So we're still tracking that down

861

00:48:22,099 --> 00:48:25,502

because it's not going into
those forests uniformly.

862

00:48:25,502 --> 00:48:28,472

Some of those forests are burning down,

863

00:48:28,472 --> 00:48:31,208

you hear about the giant
fires across Alaska

864

00:48:31,208 --> 00:48:32,409

or across Siberia.

865

00:48:33,343 --> 00:48:34,645

(fire crackling)

866

00:48:34,645 --> 00:48:36,747

That's emitting carbon dioxide,

867

00:48:36,747 --> 00:48:40,317

but yet the forest
around them are growing.

868

00:48:40,317 --> 00:48:42,386

And why are they growing?

869

00:48:42,386 --> 00:48:44,121

Well, climate change.

870

00:48:44,121 --> 00:48:46,223

(birds chirping)

871

00:48:46,223 --> 00:48:49,026

As the climate has become warmer,

872

00:48:49,026 --> 00:48:51,795

the growing seasons have become longer.

873

00:48:51,795 --> 00:48:54,331

The number of trees and
the size of the trees

874

00:48:54,331 --> 00:48:55,365
has been increasing.

875

00:48:56,633 --> 00:48:59,636
So a lot of things are
happening with climate change

876

00:48:59,636 --> 00:49:01,872
that are changing where
the sinks are going.

877

00:49:02,940 --> 00:49:05,876
It could have been that when we originally

878

00:49:05,876 --> 00:49:09,613
wanted to launch OCO, back in 2009,

879

00:49:09,613 --> 00:49:13,483
that the tropical forests
actually were absorbing CO₂.

880

00:49:14,718 --> 00:49:15,786
They're not now.

881

00:49:17,387 --> 00:49:20,223
(birds squawking)

882

00:49:21,858 --> 00:49:24,428
- [Narrator] Scientists
do not know how long

883

00:49:24,428 --> 00:49:27,564
the Northern forests will
be able to carry the burden

884

00:49:27,564 --> 00:49:29,066
of absorbing CO₂.

885

00:49:32,002 --> 00:49:34,871

But we do know more about
the health of forests,

886

00:49:34,871 --> 00:49:36,306

thanks to OCO-2.

887

00:49:37,407 --> 00:49:39,343

That's because scientists have been able

888

00:49:39,343 --> 00:49:42,446

to tease out of the data
the fluorescence of plants.

889

00:49:44,081 --> 00:49:47,484

This faint glowing,
invisible to the naked eye,

890

00:49:47,484 --> 00:49:50,921

is a natural part of the
healthy photosynthesis process.

891

00:49:51,888 --> 00:49:54,791

The kind of energy being
emitted can tell us much

892

00:49:54,791 --> 00:49:58,295

about the condition of forests,
plants, and even crops.

893

00:49:59,629 --> 00:50:04,101

This bonus science was one
reason why a third OCO instrument

894

00:50:04,101 --> 00:50:07,371

was built out of leftover spare parts.

895

00:50:07,371 --> 00:50:10,907

But OCO-3 is not a carbon copy of OCO-2.

896

00:50:12,576 --> 00:50:14,678

Instead of flying on a spacecraft,

897

00:50:14,678 --> 00:50:16,079

it was designed to be installed

898

00:50:16,079 --> 00:50:19,883

on the International

Space Station in 2019.

899

00:50:19,883 --> 00:50:23,920

(light dramatic music)

900

00:50:23,920 --> 00:50:25,822

OCO-3 can be thought of as a kind of

901

00:50:25,822 --> 00:50:29,826

point and shoot camera,

which gives scientists

902

00:50:29,826 --> 00:50:33,397

more flexibility and zeroing

in on areas of interest.

903

00:50:35,232 --> 00:50:38,168

And among those targets are large cities.

904

00:50:40,203 --> 00:50:42,706

Urban areas account for more than 70%

905

00:50:42,706 --> 00:50:45,542

of all greenhouse

emissions caused by humans.

906

00:50:47,377 --> 00:50:50,047

These are scenes of Los Angeles,

907

00:50:50,047 --> 00:50:52,883

which has the fifth largest
urban carbon footprint

908

00:50:52,883 --> 00:50:53,717

in the world.

909

00:50:55,452 --> 00:50:58,355

It's one of the many urban
areas around the globe

910

00:50:58,355 --> 00:51:01,258

that OCO-3 has set its sight on.

911

00:51:01,258 --> 00:51:04,528

(light dramatic music)

912

00:51:05,362 --> 00:51:08,732

With a single pass over
the Los Angeles Basin,

913

00:51:08,732 --> 00:51:12,936

OCO-3 can take snapshots that
can reveal tiny differences

914

00:51:12,936 --> 00:51:16,106

in levels of CO₂ throughout the area.

915

00:51:16,106 --> 00:51:19,242

The highest readings
in, yellow on this map,

916

00:51:19,242 --> 00:51:21,711

are on the west side of downtown LA,

917

00:51:21,711 --> 00:51:24,848

a densely populated area
with congested freeways

918

00:51:24,848 --> 00:51:26,650
and CO2-emitting industries.

919
00:51:28,318 --> 00:51:31,855
The amount of CO2 being
emitted there is about twice

920
00:51:31,855 --> 00:51:33,657
the global average.

921
00:51:33,657 --> 00:51:36,726
(light dramatic music)

922
00:51:36,726 --> 00:51:40,530
- Los Angeles has an ambitious
plan to become carbon neutral

923
00:51:40,530 --> 00:51:42,199
by the year 2050.

924
00:51:42,199 --> 00:51:44,367
That will be no easy task.

925
00:51:44,367 --> 00:51:47,471
But having the ability
to track CO2 emissions

926
00:51:47,471 --> 00:51:50,273
from the ground, the air and from space

927
00:51:50,273 --> 00:51:53,443
will be crucial in
understanding the path forward,

928
00:51:53,443 --> 00:51:56,146
for there's a lot of unfinished
business ahead of us.

929
00:51:59,816 --> 00:52:02,252

- [Narrator] We've not
touched upon ozone yet,

930

00:52:02,252 --> 00:52:05,288

and here there's an
encouraging story from the past

931

00:52:05,288 --> 00:52:07,224

that can help to guide how we choose

932

00:52:07,224 --> 00:52:09,559

to confront climate
change in the days ahead.

933

00:52:11,561 --> 00:52:13,864

At the beginning of our journey we saw

934

00:52:13,864 --> 00:52:16,800

that JPL's Explorer 1 mission discovered

935

00:52:16,800 --> 00:52:19,636

the Van Allen radiation
belts that protect our planet

936

00:52:19,636 --> 00:52:21,505

from harmful solar radiation.

937

00:52:24,407 --> 00:52:28,512

And it turns out our planet
has a second line of defense,

938

00:52:28,512 --> 00:52:31,314

the ozone layer in the upper atmosphere

939

00:52:31,314 --> 00:52:35,285

that acts as a sunscreen,
blocking ultraviolet rays

940

00:52:35,285 --> 00:52:37,587

that would otherwise sterilize the Earth

941

00:52:37,587 --> 00:52:39,523

and damage all living things.

942

00:52:42,292 --> 00:52:45,562

But back in 1985, the surprising results

943

00:52:45,562 --> 00:52:48,298

of a British expedition to the Antarctic

944

00:52:48,298 --> 00:52:49,499

landed like a bombshell.

945

00:52:49,499 --> 00:52:51,301

(daunting music)

946

00:52:51,301 --> 00:52:55,071

The discovery of a dramatic
drop in the amount of ozone gas

947

00:52:55,071 --> 00:52:58,074

at the Southern Pole,
what came to be known as

948

00:52:58,074 --> 00:52:59,876

the ozone hole.

949

00:52:59,876 --> 00:53:02,612

(daunting music)

950

00:53:03,613 --> 00:53:06,550

This discovery raised
all kinds of questions.

951

00:53:07,584 --> 00:53:10,287

Was the hole an aberration?

952

00:53:10,287 --> 00:53:12,923
Why was it only at the South Pole?

953
00:53:12,923 --> 00:53:14,057
Was it spreading?

954
00:53:15,692 --> 00:53:17,861
And if so, how long would it be

955
00:53:17,861 --> 00:53:20,463
before the hole reached populated areas?

956
00:53:22,933 --> 00:53:26,002
An urgent concern was
knowing what was causing

957
00:53:26,002 --> 00:53:27,971
the ozone depletion.

958
00:53:27,971 --> 00:53:32,876
Theories abounded: might
there be a natural explanation

959
00:53:32,876 --> 00:53:34,778
or was it human caused?

960
00:53:38,148 --> 00:53:41,184
The United States rushed
a scientific expedition

961
00:53:41,184 --> 00:53:43,486
to the Antarctic the very next year.

962
00:53:46,122 --> 00:53:49,926
The team included JPL scientists
who deployed on the ground,

963
00:53:49,926 --> 00:53:52,262
a science instrument originally designed

964

00:53:52,262 --> 00:53:54,564

for high altitude balloon observations.

965

00:53:55,899 --> 00:53:58,635

Their results and those
of other measurements

966

00:53:58,635 --> 00:54:01,771

made on the expedition
pointed to a human cause

967

00:54:01,771 --> 00:54:04,808

for the hole, a class of chemicals called

968

00:54:04,808 --> 00:54:07,911

chlorofluorocarbons or CFCs,

969

00:54:10,046 --> 00:54:11,982

that were being used in everyday products

970

00:54:11,982 --> 00:54:14,184

like hairsprays and air conditioners.

971

00:54:16,319 --> 00:54:19,022

In the years that
followed, many more types

972

00:54:19,022 --> 00:54:21,057

of ozone measurements were made,

973

00:54:21,057 --> 00:54:24,094

many of them by JPL
teams who used balloons,

974

00:54:24,094 --> 00:54:27,130

aircraft, satellites and the space shuttle

975

00:54:27,130 --> 00:54:29,266
as platforms for their instruments.

976

00:54:32,369 --> 00:54:35,071
Early on many nations of the world,

977

00:54:35,071 --> 00:54:38,041
alarmed by the news that
CFCs were destroying

978

00:54:38,041 --> 00:54:41,911
the ozone layer, quickly
agreed to address the problem

979

00:54:41,911 --> 00:54:43,913
by signing the Montreal Protocol.

980

00:54:46,750 --> 00:54:49,586
This international agreement
called for reducing

981

00:54:49,586 --> 00:54:53,390
CFC emissions by half and later
called for a complete ban.

982

00:54:54,424 --> 00:54:57,427
It is the only U.N. treaty
that has ever been ratified

983

00:54:57,427 --> 00:54:59,262
by every country on Earth.

984

00:55:02,065 --> 00:55:04,367
And today the ozone hole is healing.

985

00:55:06,336 --> 00:55:09,806
Based on current projections,
a half century from now,

986

00:55:09,806 --> 00:55:11,841
ozone in the atmosphere will return

987
00:55:11,841 --> 00:55:13,410
to healthy levels once again,

988
00:55:16,880 --> 00:55:19,783
- What's being done to
tackle ozone is a model,

989
00:55:19,783 --> 00:55:22,552
a roadmap, for addressing
the greenhouse gases

990
00:55:22,552 --> 00:55:24,321
that are warming up our planet.

991
00:55:24,321 --> 00:55:27,557
But make no mistake, this
will be a much harder

992
00:55:27,557 --> 00:55:30,994
and longer road for the
world to travel than ozone.

993
00:55:30,994 --> 00:55:33,463
Remember early on when we
met that young scientist

994
00:55:33,463 --> 00:55:36,032
who shared his findings
about what greenhouse gases

995
00:55:36,032 --> 00:55:37,867
had done to Venus?

996
00:55:37,867 --> 00:55:42,272
Two decades later, in 1985,
Carl Sagan would again address

997

00:55:42,272 --> 00:55:44,341

the impact of greenhouse gases,

998

00:55:44,341 --> 00:55:46,910

but this time it would
be about our planet.

999

00:55:48,144 --> 00:55:51,314

His words are as true for
us today as they were then.

1000

00:55:55,785 --> 00:55:58,955

- [Carl] We have a kind of
handwriting on the wall.

1001

00:55:58,955 --> 00:56:03,893

The power of human beings to
affect and control and change

1002

00:56:03,893 --> 00:56:07,130

the environment is growing
as our technology grows.

1003

00:56:09,032 --> 00:56:11,968

And at present time, we
clearly have reached the stage

1004

00:56:11,968 --> 00:56:16,473

where we are capable, both
intentionally and inadvertently,

1005

00:56:16,473 --> 00:56:20,610

to make significant changes
in the global climate

1006

00:56:20,610 --> 00:56:22,145

and in the global ecosystem.

1007

00:56:23,580 --> 00:56:27,917

Because the effects occupy
more than a human generation,

1008

00:56:27,917 --> 00:56:31,888

there is a tendency to say
that they are not our problem.

1009

00:56:33,156 --> 00:56:35,191

Of course, then they're
are nobody's problem.

1010

00:56:36,393 --> 00:56:40,563

We are passing on extremely
grave problems for our children

1011

00:56:41,598 --> 00:56:43,266

when the time to solve the problems,

1012

00:56:43,266 --> 00:56:45,301

if they can be solved at all, is now.

1013

00:56:49,272 --> 00:56:51,207

It is also a global problem.

1014

00:56:52,175 --> 00:56:56,546

The nations to deal with this
problem have to make a change

1015

00:56:56,546 --> 00:57:00,350

from their traditional
concern about themselves

1016

00:57:00,350 --> 00:57:02,952

and not about the planet and the species,

1017

00:57:02,952 --> 00:57:05,822

a change from the traditional
short term objectives

1018

00:57:05,822 --> 00:57:07,557
to longer term objectives.

1019
00:57:09,292 --> 00:57:11,795
I think that what is
essential for this problem

1020
00:57:11,795 --> 00:57:13,396
is a global consciousness,

1021
00:57:14,798 --> 00:57:18,535
a view that transcends our
exclusive identifications

1022
00:57:18,535 --> 00:57:20,737
with the generational
and political groupings

1023
00:57:20,737 --> 00:57:23,373
into which, by accident,
we have been born.

1024
00:57:27,644 --> 00:57:30,280
The solution to these problems
requires a perspective

1025
00:57:30,280 --> 00:57:33,316
that embraces the planet and the future

1026
00:57:33,316 --> 00:57:36,653
because we are all in
this greenhouse together.

1027
00:57:43,159 --> 00:57:45,829
- We are all on this planet together,

1028
00:57:45,829 --> 00:57:49,399
and the path forward will take
all of us working together.

1029

00:57:49,399 --> 00:57:50,700

I'm Mike Meacham.

1030

00:57:50,700 --> 00:57:53,736

Thanks for watching and for
taking care of the good Earth.