



1  
00:00:00,600 --> 00:00:06,600  
[music playing]

2  
00:00:17,150 --> 00:00:18,840  
Welcome to the 2015  
NASA Ames Summer Series.

3  
00:00:21,030 --> 00:00:22,540  
The world around us  
contains materials

4  
00:00:23,510 --> 00:00:25,450  
that can be divided  
into solids, liquid, and gas.

5  
00:00:28,180 --> 00:00:29,780  
These descriptions  
of the state of matter

6  
00:00:30,660 --> 00:00:33,000  
are relative to the particular  
time span being observed.

7  
00:00:35,570 --> 00:00:36,570  
Given a long enough time,

8  
00:00:37,570 --> 00:00:39,030  
all matter  
exhibits fluid motion.

9  
00:00:41,480 --> 00:00:42,750  
Understanding the interactions

10  
00:00:43,780 --> 00:00:45,480  
between these different  
states of matter

11  
00:00:45,750 --> 00:00:48,000  
is important for optimization

of design and function,

12

00:00:51,000 --> 00:00:52,480

specifically when you  
talk about work

13

00:00:53,540 --> 00:00:55,390

that is done in aeronautics  
and space travels.

14

00:00:57,630 --> 00:00:59,240

Today's seminar is  
"It's a Fluid World"

15

00:01:02,150 --> 00:01:03,660

and will be presented  
by Christina Ngo.

16

00:01:05,300 --> 00:01:07,120

Christina received  
her Bachelors of Science

17

00:01:08,180 --> 00:01:09,240

in mechanical engineering

18

00:01:09,270 --> 00:01:10,630

with a concentration  
in aerospace

19

00:01:10,780 --> 00:01:13,000

from the University of  
California, San Diego in 2013,

20

00:01:16,300 --> 00:01:18,000

but prior to that,  
she was also here at Ames

21

00:01:20,840 --> 00:01:21,840

as an intern in 2009.

22

00:01:23,510 --> 00:01:25,240

So all the interns  
that are in the audience,

23

00:01:25,720 --> 00:01:26,720

think of the future.

24

00:01:29,810 --> 00:01:31,750

After doing the internship,  
she got experiences

25

00:01:34,090 --> 00:01:35,720

both in work and as an intern  
in aeronautics

26

00:01:37,420 --> 00:01:39,600

at Pratt & Whitney, at  
Hamilton Sundstrand, and SpaceX.

27

00:01:43,120 --> 00:01:44,660

And then she decided  
to come back to Ames.

28

00:01:46,480 --> 00:01:48,000

So she joined  
the Fluid Mechanics Lab

29

00:01:48,840 --> 00:01:49,840

as a research engineer

30

00:01:51,240 --> 00:01:52,720

two years ago  
as a full-time employee.

31

00:01:54,480 --> 00:01:56,420

And so please join me  
in welcoming Christina Ngo.

32

00:01:58,480 --> 00:02:01,540

[applause]

33

00:02:04,390 --> 00:02:05,390

Hello.

34

00:02:05,840 --> 00:02:06,840

My name is Christina Ngo,

35

00:02:07,570 --> 00:02:09,060

part of  
the Fluid Mechanics branch.

36

00:02:09,270 --> 00:02:10,270

[clears throat]

37

00:02:11,600 --> 00:02:13,450

Today I'll be presenting  
"It's a Fluid World."

38

00:02:15,090 --> 00:02:16,810

So about six years ago,  
like Jacob mentioned,

39

00:02:17,570 --> 00:02:19,720

I was sitting exactly where  
you are sitting as an intern

40

00:02:20,630 --> 00:02:21,720

and thought to myself, "Man,

41

00:02:22,510 --> 00:02:24,540

it would be great one day  
if I could ever be up there."

42

00:02:24,690 --> 00:02:27,270

And honestly, I never thought I  
would ever have the opportunity.

43

00:02:28,120 --> 00:02:30,390

So word of advice to all the  
interns who are out there today,

44

00:02:31,330 --> 00:02:32,810

work hard,  
ask questions, learn a lot.

45

00:02:33,750 --> 00:02:35,480

You're surrounded  
by some amazing people.

46

00:02:35,630 --> 00:02:37,360

Really take advantage  
of your internship.

47

00:02:38,060 --> 00:02:39,060

So let's begin.

48

00:02:39,570 --> 00:02:40,570

So, during this talk,

49

00:02:41,060 --> 00:02:43,090

I'm going to show you  
some of the hot research topics

50

00:02:43,180 --> 00:02:44,720

that we have that we've done  
in our branch

51

00:02:44,750 --> 00:02:45,750

currently and in the past

52

00:02:46,390 --> 00:02:50,000

as well as how the aerodynamics  
applies to the world around us.

53

00:02:52,360 --> 00:02:53,870

Here you see a lot  
of interesting photo.

54

00:02:54,630 --> 00:02:56,449

It's basically a collage  
of a lot of the research topics

55

00:02:56,450 --> 00:02:57,510

that we've done in the past,

56

00:02:58,600 --> 00:03:01,150

anywhere from space shuttles  
to rockets to even sports balls,

57

00:03:03,270 --> 00:03:04,360

next generation airplanes.

58

00:03:06,270 --> 00:03:08,180

For in our branch,  
we are investigating the flow

59

00:03:08,660 --> 00:03:10,269

around our models,  
whether that's on the surface

60

00:03:10,270 --> 00:03:11,450

or off the surface of the model.

61

00:03:12,720 --> 00:03:15,840

So how many of you have heard  
of a wind tunnel?

62

00:03:17,150 --> 00:03:18,150

[chuckles]

63

00:03:18,150 --> 00:03:19,150

Majority of you, great.

64

00:03:20,060 --> 00:03:21,870

So, for us to investigate  
all these parameters,

65

00:03:23,390 --> 00:03:24,780

characteristics  
of the flow field,

66

00:03:25,840 --> 00:03:28,060

we have to look at it sometimes  
instantaneous in time.

67

00:03:29,390 --> 00:03:31,720

So it's really difficult  
to measure these characteristics

68

00:03:32,690 --> 00:03:33,870

having, say,  
a rocket going up

69

00:03:34,270 --> 00:03:36,450

several hundred miles per hour  
through the atmosphere.

70

00:03:37,360 --> 00:03:38,720

So, instead of  
having air moving--

71

00:03:40,330 --> 00:03:41,750

having the model  
moving over the air,

72

00:03:42,360 --> 00:03:43,660

we have air moving  
over the model,

73

00:03:44,180 --> 00:03:45,480

which is why we have  
wind tunnels.

74

00:03:46,240 --> 00:03:47,630

There's several of them  
shown here.

75

00:03:48,240 --> 00:03:49,720

Top left, we have the 40x80  
wind tunnel

76

00:03:50,450 --> 00:03:52,030

and next generation  
airplanes shown.

77

00:03:52,690 --> 00:03:55,030

Top right, we're home to  
the world's largest wind tunnel.

78

00:03:55,240 --> 00:03:56,870

We have parachute testing  
right over here.

79

00:03:58,180 --> 00:03:59,479

We even have  
smaller scale wind tunnels

80

00:03:59,480 --> 00:04:01,450

like the 11 feet by 11 feet  
transonic wind tunnel

81

00:04:02,240 --> 00:04:04,360

testing a plane as well  
and sports ball aerodynamics.

82

00:04:06,030 --> 00:04:07,390

Really great things  
you need to do,

83

00:04:08,660 --> 00:04:10,719

and the majority of the research  
is done in wind tunnels

84

00:04:10,720 --> 00:04:11,780

because of this, of course.

85

00:04:15,360 --> 00:04:17,060

So I talked a little bit  
about wind tunnels

86

00:04:17,210 --> 00:04:18,750

and how we use air  
to move over our models,

87

00:04:19,720 --> 00:04:21,210

but we could actually  
use any fluid.

88

00:04:21,690 --> 00:04:23,540

Here we have a facility  
called a water channel,

89

00:04:23,720 --> 00:04:25,330

so we're moving water  
across our model.

90

00:04:26,060 --> 00:04:27,060

So how does this work?

91

00:04:27,840 --> 00:04:29,840

Well, we have an upper channel  
and a lower channel,

92

00:04:30,600 --> 00:04:32,179

and the water moves  
from the upper channel

93

00:04:32,180 --> 00:04:34,300

through our test section  
back down to a lower channel,

94

00:04:34,660 --> 00:04:35,810

gets pumped back behind here.

95

00:04:36,360 --> 00:04:37,510

That's not shown on the photo.

96

00:04:37,780 --> 00:04:39,570

We're able to put  
small scale models in here.

97

00:04:40,390 --> 00:04:42,390

Once that is done,  
we inject this fluorescent dye.

98

00:04:43,360 --> 00:04:45,840

These green lines that you see,  
that's illuminated by UV lights.

99

00:04:46,540 --> 00:04:47,540

We have a second color dye.

100

00:04:48,210 --> 00:04:49,720

It's the orange dye  
that we use to inject

101

00:04:50,030 --> 00:04:52,180

in places of interest, say,  
in the seat of a convertible

102

00:04:53,150 --> 00:04:54,630

or behind a sports ball  
right over here

103

00:04:55,300 --> 00:04:56,300

or even behind a hill.

104

00:04:56,750 --> 00:04:58,690

So it's a really great visual  
technique to start,

105

00:05:00,690 --> 00:05:01,690

instead of using

106

00:05:01,690 --> 00:05:03,329

really expensive  
computational techniques

107  
00:05:03,330 --> 00:05:05,660  
or advanced instrumentation  
before we even begin testing.

108  
00:05:08,000 --> 00:05:09,059  
But what better way  
to explain it

109  
00:05:09,060 --> 00:05:10,480  
than actually showing you  
in action?

110  
00:05:11,180 --> 00:05:12,180  
So here you go.

111  
00:05:14,120 --> 00:05:16,270  
We have the fluorescent dye  
flowing from left to right.

112  
00:05:16,750 --> 00:05:17,750  
It's the green dye,

113  
00:05:18,150 --> 00:05:20,180  
and we injected the orange dye  
in the very back here.

114  
00:05:21,720 --> 00:05:23,240  
What's in this test section  
is a hill.

115  
00:05:24,270 --> 00:05:26,420  
We call it the Fundamental Aero  
Investigates The Hill,

116  
00:05:27,210 --> 00:05:28,210  
or FAITH Hill.

117

00:05:29,540 --> 00:05:30,630

What's great about this dye,

118

00:05:31,390 --> 00:05:33,090

this feature

you can actually see exactly

119

00:05:33,300 --> 00:05:35,540

where the flow is separating

off the model right over here

120

00:05:36,600 --> 00:05:38,510

and the vortex shedding

that's coming off of it.

121

00:05:39,660 --> 00:05:41,359

Even on this hill,

it does look quite simple.

122

00:05:41,360 --> 00:05:42,360

It's a cosine hill.

123

00:05:42,390 --> 00:05:43,780

The flow

is actually quite complex,

124

00:05:44,420 --> 00:05:46,750

and with this hill, we use all

of our experimental technique

125

00:05:47,570 --> 00:05:49,570

to measure the forces

and pressures on the surface

126

00:05:49,690 --> 00:05:51,180

and on top of the surface

of the model

127

00:05:51,870 --> 00:05:53,720

to validate a lot  
of our computational method.

128  
00:05:55,600 --> 00:05:57,330  
Again, here you can see  
how complex the flow

129  
00:05:57,480 --> 00:05:58,480  
can actually be.

130  
00:05:59,000 --> 00:06:01,180  
See the recirculation area  
and the flow behind there,

131  
00:06:01,570 --> 00:06:02,570  
it's almost stagnant.

132  
00:06:02,660 --> 00:06:03,660  
It's barely moving.

133  
00:06:05,750 --> 00:06:06,750  
One technique that we use

134  
00:06:08,780 --> 00:06:10,150  
is fringe-imaging skin friction

135  
00:06:11,210 --> 00:06:13,120  
to measure the skin friction  
on top of our model.

136  
00:06:14,540 --> 00:06:16,450  
Here is FAITH Hill again,  
and how does this work?

137  
00:06:17,330 --> 00:06:19,030  
Well, let me explain  
skin friction first.

138  
00:06:20,330 --> 00:06:21,809

Skin friction is the force  
that parallels

139

00:06:21,810 --> 00:06:22,810  
the surface of the model.

140

00:06:23,330 --> 00:06:25,480  
So we have a model, and it has  
to be shiny for this to work.

141

00:06:26,360 --> 00:06:27,720  
We install this  
into a wind tunnel.

142

00:06:28,240 --> 00:06:30,360  
We turn on the wind tunnel  
for a certain amount of time.

143

00:06:31,450 --> 00:06:33,150  
Remember to apply oil  
of known viscosity.

144

00:06:34,450 --> 00:06:36,570  
Once the wind tunnel runs  
for a certain amount of time,

145

00:06:36,630 --> 00:06:38,240  
the oil sort of smears  
around our model.

146

00:06:40,000 --> 00:06:41,600  
Once that is done,  
we illuminate the model

147

00:06:41,780 --> 00:06:43,630  
with an extended  
monochromatic light source.

148

00:06:44,510 --> 00:06:46,660  
You get two interfering

light waves when that happens.

149

00:06:47,300 --> 00:06:49,420

First the light reflects  
off the surface of the model,

150

00:06:50,480 --> 00:06:51,999

so that's one light wave,  
and then second,

151

00:06:52,000 --> 00:06:53,720

the light reflects  
off the surface of the oil.

152

00:06:54,120 --> 00:06:55,180

That's a second light wave.

153

00:06:55,570 --> 00:06:57,600

And you get these fringe  
patterns that you see here.

154

00:06:58,870 --> 00:07:00,090

In measuring the direction

155

00:07:00,330 --> 00:07:01,659

and the space  
in the fringe pattern,

156

00:07:01,660 --> 00:07:03,660

we could actually record that  
with skin friction.

157

00:07:04,000 --> 00:07:05,540

So remember the video  
I showed you before

158

00:07:05,540 --> 00:07:07,540

where the flow starts  
separating and speeding up?

159

00:07:07,870 --> 00:07:09,180

You could see it in here  
as well.

160

00:07:09,840 --> 00:07:12,000

Starts speeding up  
and the skin friction increases,

161

00:07:12,510 --> 00:07:13,510

and once the flow's--

162

00:07:13,780 --> 00:07:15,510

it's all stagnant and slow  
in the very back,

163

00:07:16,000 --> 00:07:18,870

skin friction is actually  
really low right back here.

164

00:07:22,120 --> 00:07:23,810

Another technique  
that our branch excels at

165

00:07:25,270 --> 00:07:27,450

and spends a lot of time in  
is pressure-sensitive paint.

166

00:07:30,300 --> 00:07:32,210

So originally, normally,  
we install our models

167

00:07:33,150 --> 00:07:35,060

with discrete pressure tap,  
or pressure holes,

168

00:07:35,390 --> 00:07:37,630

like you see here in one of  
our crew exploration vehicles,

169

00:07:38,240 --> 00:07:39,240  
Orion.

170  
00:07:39,390 --> 00:07:40,870  
These tiny holes  
to measure pressure.

171  
00:07:41,840 --> 00:07:44,000  
And for us to get a nice  
contour surface pressure map,

172  
00:07:45,060 --> 00:07:46,270  
we have to extrapolate the data,

173  
00:07:47,240 --> 00:07:49,150  
which sometimes could cause  
a lot of error here.

174  
00:07:50,780 --> 00:07:52,270  
So with  
pressure-sensitive paint,

175  
00:07:52,390 --> 00:07:53,780  
you pretty much  
get a pressure tap--

176  
00:07:54,090 --> 00:07:56,210  
a pressure measurement  
at every pixel of the picture.

177  
00:07:57,030 --> 00:07:58,030  
So you get a whole map

178  
00:07:58,300 --> 00:08:00,480  
of the pressure surface  
without even extrapolating.

179  
00:08:02,180 --> 00:08:03,390  
It's a very powerful technique.

180  
00:08:04,810 --> 00:08:05,810  
Well, how does this work?

181  
00:08:06,660 --> 00:08:07,749  
This pressure-sensitive paint

182  
00:08:07,750 --> 00:08:09,240  
is first painted  
on top of the model.

183  
00:08:09,780 --> 00:08:11,060  
It's this nice pink color here.

184  
00:08:11,360 --> 00:08:12,360  
It's pretty cute here,

185  
00:08:14,030 --> 00:08:15,419  
and there's these molecules  
inside the paint

186  
00:08:15,420 --> 00:08:16,570  
that are excited by UV lights.

187  
00:08:17,810 --> 00:08:19,420  
For them to return back  
to the base state

188  
00:08:20,210 --> 00:08:21,750  
is via oxygen quenching,  
which is great,

189  
00:08:23,360 --> 00:08:25,179  
because the higher pressure  
you have on the surface,

190  
00:08:25,180 --> 00:08:26,180  
the more oxygen there is;

191

00:08:26,480 --> 00:08:27,780  
therefore they're more quenching

192  
00:08:28,030 --> 00:08:30,300  
and the less luminescence  
that's picked up by our cameras.

193  
00:08:30,600 --> 00:08:32,540  
And we can correlate this  
with pressure to give us

194  
00:08:33,030 --> 00:08:34,660  
a nice contour map  
that you see on the right.

195  
00:08:37,540 --> 00:08:39,180  
A few examples I have is  
on a space shuttle

196  
00:08:40,090 --> 00:08:41,270  
right over here going Mach 2.5.

197  
00:08:43,630 --> 00:08:44,780  
So Mach 1 is the speed of sound.

198  
00:08:45,600 --> 00:08:47,330  
Right now it's 2.5 times  
the speed of sound.

199  
00:08:48,630 --> 00:08:50,660  
On the bottom right,  
you see an F-18 going Mach 1.25.

200  
00:08:52,720 --> 00:08:54,870  
Another great advantage  
of pressure-sensitive paint

201  
00:08:55,480 --> 00:08:58,030  
is you're able to paint surfaces  
where you probably couldn't--

202

00:08:58,690 --> 00:09:00,540

an instrument, say,  
where the wing attaches

203

00:09:01,210 --> 00:09:05,180

to the body or the tip  
of the nose, right?

204

00:09:08,030 --> 00:09:09,660

Here is a video  
of changing angles of attack

205

00:09:10,000 --> 00:09:11,000

of an F-16 model.

206

00:09:11,390 --> 00:09:13,030

You can see  
how the pressure is changing.

207

00:09:14,780 --> 00:09:16,510

Say, if I'm running  
a computational method

208

00:09:16,840 --> 00:09:18,000

to see the surface pressure

209

00:09:18,480 --> 00:09:20,180

only at angles zero  
and one or two degrees,

210

00:09:21,390 --> 00:09:23,210

how would I know  
at the higher angles of attack

211

00:09:23,720 --> 00:09:25,210

to install pressure tap  
right here,

212

00:09:25,540 --> 00:09:27,180  
and that's actually  
an area of interest?

213  
00:09:27,600 --> 00:09:28,600  
You wouldn't.

214  
00:09:28,600 --> 00:09:29,839  
But with  
pressure-sensitive paint,

215  
00:09:29,840 --> 00:09:31,840  
you don't need to do that.

216  
00:09:34,660 --> 00:09:36,450  
So we talked a lot  
about pressures and forces

217  
00:09:37,330 --> 00:09:38,390  
on the surface of the model.

218  
00:09:38,630 --> 00:09:39,630  
How about off of the model?

219  
00:09:40,690 --> 00:09:42,089  
The flow field  
off the top of the model?

220  
00:09:42,090 --> 00:09:43,570  
Well, we use a lot  
of optics technique.

221  
00:09:44,690 --> 00:09:47,180  
One technique we use is particle  
image velocimetry seen here.

222  
00:09:49,510 --> 00:09:51,540  
We use a laser that's shining  
into a circular mirror

223

00:09:52,000 --> 00:09:53,150

and produces this laser sheet

224

00:09:53,240 --> 00:09:54,840

right across the model

in our wind tunnel.

225

00:09:55,030 --> 00:09:56,240

We need windows for this, right?

226

00:09:57,090 --> 00:09:58,090

Right over here.

227

00:09:58,810 --> 00:10:00,510

And using pulse LED lights

and two cameras

228

00:10:01,600 --> 00:10:04,030

and injecting, say, smoke or

known particles into the flow,

229

00:10:05,240 --> 00:10:06,630

we're able to track

these particles

230

00:10:07,390 --> 00:10:08,390

through the laser sheet.

231

00:10:08,750 --> 00:10:09,840

So we know DP,

the position,

232

00:10:10,540 --> 00:10:12,509

and the time it took for it

to move to that position;

233

00:10:12,510 --> 00:10:13,660

therefore, we know velocity.

234

00:10:14,000 --> 00:10:15,180

Three components of velocity.

235

00:10:15,720 --> 00:10:16,780

This is a very powerful tool

236

00:10:17,390 --> 00:10:19,000

to validate, say,  
computational codes

237

00:10:19,360 --> 00:10:20,630

or looking at turbulence models.

238

00:10:21,630 --> 00:10:23,030

For the aero engineers  
out there,

239

00:10:23,180 --> 00:10:24,180

you can even see bow shock

240

00:10:24,300 --> 00:10:25,840

coming off of the shuttle  
right over here

241

00:10:26,300 --> 00:10:30,270

starting this really big jump  
in velocity.

242

00:10:33,360 --> 00:10:34,360

But why stop there?

243

00:10:34,720 --> 00:10:36,120

How about we take  
a multiple image

244

00:10:36,420 --> 00:10:38,330

to get a nice video  
that varies in space and time?

245

00:10:40,150 --> 00:10:42,060

So here on the top  
is the still image of a cylinder

246

00:10:43,390 --> 00:10:44,870

with smoke injected  
into a flow field.

247

00:10:45,300 --> 00:10:46,450

You get this vortex shedding.

248

00:10:47,390 --> 00:10:48,810

Same thing as down here  
but using PIV.

249

00:10:50,480 --> 00:10:51,750

We have a cylinder  
right up here,

250

00:10:52,630 --> 00:10:54,690

and you see the vortex shedding  
moving back and forth

251

00:10:55,000 --> 00:10:56,000

right over here.

252

00:10:56,450 --> 00:11:00,750

It's two out of the three  
components of velocity plotted.

253

00:11:04,450 --> 00:11:06,600

Another imaging technique  
we use is called Schlieren.

254

00:11:08,360 --> 00:11:09,870

So usually we use air  
in our wind tunnel,

255

00:11:11,240 --> 00:11:12,660

and once  
you start approaching, say,

256  
00:11:12,840 --> 00:11:15,210  
the speed of sound, Mach 1,  
air starts getting compressed.

257  
00:11:16,120 --> 00:11:18,390  
When air starts getting  
compressed, the density changes.

258  
00:11:18,750 --> 00:11:20,750  
So using LED light source  
and high-speed cameras,

259  
00:11:22,090 --> 00:11:23,480  
we can measure  
the refractive index

260  
00:11:24,270 --> 00:11:25,540  
of how the light  
is reflected off

261  
00:11:26,570 --> 00:11:29,060  
through the density gradient  
and take this really nice image.

262  
00:11:30,720 --> 00:11:32,000  
Right here we have a rigid model

263  
00:11:32,150 --> 00:11:34,210  
of a Mars Science Lab parachute  
going about Mach 2.5,

264  
00:11:36,330 --> 00:11:38,660  
where it's extremely evident  
where the density is changing

265  
00:11:38,780 --> 00:11:39,780  
is around shocks.

266

00:11:40,600 --> 00:11:42,420

And you can see a nice bow shock  
right over here

267

00:11:42,510 --> 00:11:45,660

dancing around  
in front of our model.

268

00:11:48,300 --> 00:11:49,690

Okay.

269

00:11:50,690 --> 00:11:51,690

On with imaging.

270

00:11:52,360 --> 00:11:54,480

So one test that we've done  
is to look at just the plumes

271

00:11:57,240 --> 00:11:58,240

and take a nice image

272

00:11:58,780 --> 00:12:00,420

and see the details  
of what's going on.

273

00:12:01,030 --> 00:12:03,090

Normally, we have a picture  
like this on the top left.

274

00:12:03,570 --> 00:12:05,750

It's really saturated, and a lot  
of the details are lost.

275

00:12:06,630 --> 00:12:08,360

How about, what if  
we had different cameras

276

00:12:10,150 --> 00:12:12,150

around the same location  
with different filters?

277

00:12:12,150 --> 00:12:13,780

We're able to superimpose  
these filters--

278

00:12:14,150 --> 00:12:15,150

these photos together,

279

00:12:15,600 --> 00:12:17,780

each having a little bit of--  
the last photo didn't have,

280

00:12:19,420 --> 00:12:21,660

little bit of pieces of areas  
that we couldn't get before,

281

00:12:24,030 --> 00:12:25,149

and superimpose them together

282

00:12:25,150 --> 00:12:28,360

to get a really nice photo  
like this here.

283

00:12:31,810 --> 00:12:33,630

So we used this technique  
at a shuttle launch.

284

00:12:34,210 --> 00:12:35,210

What better way to use it?

285

00:12:36,060 --> 00:12:38,210

Right here we have the 2011  
last, final shuttle launch.

286

00:12:39,810 --> 00:12:41,000

On the left is a normal photo.

287

00:12:41,870 --> 00:12:43,060  
Keep in mind the right photo,

288

00:12:43,720 --> 00:12:45,510  
we used five cameras  
with different filters

289

00:12:45,600 --> 00:12:46,600  
and one IR camera,

290

00:12:47,210 --> 00:12:49,150  
or infrared camera,  
that measures temperature.

291

00:12:50,870 --> 00:12:52,030  
So this part right over here

292

00:12:53,720 --> 00:12:55,209  
you could see  
with the different filters,

293

00:12:55,210 --> 00:12:56,210  
but with this part

294

00:12:56,300 --> 00:12:57,600  
on the shuttle  
that's coming off,

295

00:12:58,150 --> 00:13:00,120  
none of the filters  
would actually pick that up.

296

00:13:00,240 --> 00:13:02,360  
That is because we had an  
IR camera on this part as well.

297

00:13:04,090 --> 00:13:05,419  
The second thing  
that's also really great--

298

00:13:05,420 --> 00:13:07,179

looking at debris

that's coming off of the model

299

00:13:07,180 --> 00:13:08,720

that we couldn't see

in normal pictures.

300

00:13:10,420 --> 00:13:11,570

But using the same technique,

301

00:13:12,510 --> 00:13:14,660

we are actually able to produce

really nice videos too,

302

00:13:15,150 --> 00:13:16,210

and I'll show you right now.

303

00:13:19,120 --> 00:13:22,120

[rocket engines firing]

304

00:13:29,570 --> 00:13:31,180

(Christina)

You can see all the details

305

00:13:31,240 --> 00:13:33,300

that we never could have seen

without this technique

306

00:13:36,390 --> 00:13:38,240

and even little debris

that might be coming off

307

00:13:39,120 --> 00:13:41,180

we could definitely detect

in this better than this.

308

00:13:41,780 --> 00:13:43,780

[man speaks indistinctly]

on video]

309

00:13:47,180 --> 00:13:49,330

Pretty amazing.

310

00:13:51,870 --> 00:13:54,210

So one big project that we've  
done in the last couple years

311

00:13:55,840 --> 00:13:57,750

was the crew exploration  
vehicle launch abort.

312

00:13:59,060 --> 00:14:00,510

So in this scenario,  
it only happens

313

00:14:00,780 --> 00:14:03,270

during an emergency abort where  
we have to take our astronauts

314

00:14:03,600 --> 00:14:05,090

off the rocket  
and back home safely.

315

00:14:06,120 --> 00:14:07,270

And many aerodynamic aspects

316

00:14:08,660 --> 00:14:10,480

that we need to consider  
during this mission.

317

00:14:12,510 --> 00:14:13,510

Here we have Orion capsule

318

00:14:14,660 --> 00:14:16,360

painted with  
pressure-sensitive paint,

319

00:14:17,480 --> 00:14:19,600  
and we have a simulation  
of a rocket right behind here.

320  
00:14:21,180 --> 00:14:22,810  
So we separate the capsule  
from the rocket,

321  
00:14:24,330 --> 00:14:26,209  
and we could look at  
to see the density gradients

322  
00:14:26,210 --> 00:14:28,030  
and the shocks  
and the aerodynamic variation

323  
00:14:28,690 --> 00:14:29,690  
during that separation.

324  
00:14:30,480 --> 00:14:32,840  
Secondly, we're concerned about  
the abort motors right here

325  
00:14:34,270 --> 00:14:36,600  
using high-pressure air to  
simulate an abort motor exhaust

326  
00:14:36,690 --> 00:14:38,390  
impinging onto the surface  
of the rocket,

327  
00:14:39,270 --> 00:14:41,750  
whether that be forces, moments,  
pressures, or even acoustics.

328  
00:14:44,420 --> 00:14:46,420  
On the right, you have a bunch  
of Schlieren photos.

329  
00:14:47,450 --> 00:14:49,630

You could see the density  
gradients are right over here.

330  
00:14:49,690 --> 00:14:51,720  
They're usually shocks  
and a nice shock in the front

331  
00:14:52,540 --> 00:14:53,540  
of the model over here

332  
00:14:54,330 --> 00:14:55,480  
and a second shock right here.

333  
00:14:57,480 --> 00:14:58,480  
So why is this important?

334  
00:14:59,030 --> 00:15:00,450  
Well,  
where do the astronauts sit?

335  
00:15:00,780 --> 00:15:01,780  
They sit right here,

336  
00:15:02,600 --> 00:15:04,000  
so we need to understand  
very well

337  
00:15:04,690 --> 00:15:07,840  
what is happening  
during this process.

338  
00:15:10,480 --> 00:15:12,270  
Here's a Schlieren photo  
of the separation,

339  
00:15:13,210 --> 00:15:14,840  
and you can see  
the rapid changes in density

340

00:15:16,630 --> 00:15:18,810  
and how dynamic the environment  
is during this portion.

341  
00:15:20,780 --> 00:15:23,000  
So the crew capsule is removing  
itself from the rocket

342  
00:15:23,540 --> 00:15:24,540  
at about 10 Gs.

343  
00:15:25,120 --> 00:15:27,060  
That's incredibly fast  
and incredibly dynamic,

344  
00:15:27,300 --> 00:15:28,390  
and a lot of force is going on.

345  
00:15:32,000 --> 00:15:33,420  
Here is a second video  
of impingement

346  
00:15:34,870 --> 00:15:36,870  
using high-pressure air  
to simulate the exhaust.

347  
00:15:37,540 --> 00:15:39,390  
One interesting feature  
to point on this photo

348  
00:15:39,480 --> 00:15:41,480  
is you could see these  
multiple shocks coming off,

349  
00:15:41,660 --> 00:15:42,660  
converging into one,

350  
00:15:43,720 --> 00:15:45,180  
as well as  
the exhaust interaction

351

00:15:45,300 --> 00:15:46,300  
with the second shock,

352

00:15:46,570 --> 00:15:48,360  
you see a crossover  
coming over here as well.

353

00:15:50,600 --> 00:15:52,210  
And we talked a little  
about acoustics,

354

00:15:52,420 --> 00:15:54,330  
but how do you look  
at acoustics data using this?

355

00:15:55,720 --> 00:15:57,180  
Well, we have  
a whole research team

356

00:15:58,360 --> 00:15:59,510  
dedicated to aeroacoustics.

357

00:16:01,750 --> 00:16:02,750  
On the top right,

358

00:16:03,120 --> 00:16:04,750  
you have a 26% scale  
of a 777 wing right here.

359

00:16:07,630 --> 00:16:09,540  
And right here,  
you have these acoustics array.

360

00:16:10,810 --> 00:16:13,360  
There's usually several dozen  
to a couple hundred microphones

361

00:16:14,300 --> 00:16:16,300

in a predetermined pattern  
measuring this noise.

362

00:16:17,330 --> 00:16:19,570

With this technique, we're able  
to measure the magnitude

363

00:16:20,540 --> 00:16:21,690

and the location of the noise,

364

00:16:23,060 --> 00:16:24,360

so I would call it  
a sound picture.

365

00:16:24,870 --> 00:16:27,330

Once that picture is taken,  
you can superimpose this picture

366

00:16:27,390 --> 00:16:28,870

on the surface  
of the model, say, here.

367

00:16:30,840 --> 00:16:32,089

Right now you can see  
a lot of the noise

368

00:16:32,090 --> 00:16:33,630

coming from the leading edge,  
the slats,

369

00:16:34,210 --> 00:16:36,210

and from the trailing edge,  
the flaps, right here.

370

00:16:37,810 --> 00:16:39,870

Nowadays, engines  
are getting quieter and quieter,

371

00:16:40,390 --> 00:16:42,570

so we need to reduce the noise

of the plane itself as well.

372

00:16:43,780 --> 00:16:45,569

I always thought,  
when a plane was flying over,

373

00:16:45,570 --> 00:16:46,840

it was all  
from the engine noise,

374

00:16:47,810 --> 00:16:48,810

but it really isn't.

375

00:16:50,180 --> 00:16:51,660

A huge amount of noise  
also comes from,

376

00:16:52,000 --> 00:16:53,000

like, the landing gear.

377

00:16:53,570 --> 00:16:55,090

Basically anything  
with a sharp edge

378

00:16:55,210 --> 00:16:56,210

produces a lot of noise.

379

00:16:57,750 --> 00:16:59,060

On the bottom right  
right here,

380

00:16:59,480 --> 00:17:01,330

it's something  
called an anechoic chamber.

381

00:17:02,360 --> 00:17:03,720

It's what we use  
to build our arrays

382

00:17:04,780 --> 00:17:06,060  
and do some sound experiments.

383

00:17:08,210 --> 00:17:09,630  
So what this chamber does  
is the walls

384

00:17:10,210 --> 00:17:12,210  
are built up with these wedges  
that absorbs noise.

385

00:17:14,510 --> 00:17:15,720  
So, if you're testing something

386

00:17:16,030 --> 00:17:17,449  
and you want to know  
exactly where a noise source

387

00:17:17,450 --> 00:17:19,270  
is coming from,  
you don't have the reflection

388

00:17:20,750 --> 00:17:22,660  
off the walls coming off  
and messing up your data

389

00:17:22,810 --> 00:17:23,810  
or giving you errors.

390

00:17:24,450 --> 00:17:25,510  
So that's what's done here.

391

00:17:26,360 --> 00:17:27,540  
The majority of any experiment

392

00:17:28,420 --> 00:17:30,330  
that goes up on  
the International Space Station

393

00:17:30,630 --> 00:17:32,090

needs a sound  
qualification test,

394

00:17:32,810 --> 00:17:36,060

and that's usually done here  
in an anechoic chamber.

395

00:17:38,750 --> 00:17:40,660

Here is an example  
of our microphones in action.

396

00:17:42,060 --> 00:17:43,570

We have the launch abort mode  
full scale

397

00:17:44,270 --> 00:17:46,000

that was tested in Utah  
several years back,

398

00:17:46,810 --> 00:17:49,150

and here are the microphones  
that's measuring magnitude

399

00:17:49,390 --> 00:17:50,390

in this case.

400

00:17:52,810 --> 00:17:54,600

But a better visualization  
of this is seeing

401

00:17:55,570 --> 00:17:57,390

the launch abort motors  
actually turning on,

402

00:17:58,810 --> 00:18:00,180

so I have a video  
for you as well.

403

00:18:01,480 --> 00:18:04,660

[rocket engine firing]

404

00:18:13,420 --> 00:18:15,480

(Christina)

Imagine how loud  
it really actually is

405

00:18:16,180 --> 00:18:17,240

and sitting right above it,

406

00:18:18,840 --> 00:18:20,330

right under it  
could be detrimental

407

00:18:21,210 --> 00:18:24,570

if you don't understand  
the characteristics of this.

408

00:18:26,210 --> 00:18:27,210

But...

409

00:18:27,390 --> 00:18:29,030

So back in 2013,  
we went one step further.

410

00:18:30,660 --> 00:18:32,780

We tested this at a real launch  
for the very first time.

411

00:18:34,150 --> 00:18:35,450

So here is  
the microphone arrays,

412

00:18:36,810 --> 00:18:38,420

and to give you a scale  
of how big this is,

413

00:18:38,540 --> 00:18:39,540

about 10 feet by 10 feet.

414  
00:18:40,240 --> 00:18:41,240  
It's huge.

415  
00:18:41,540 --> 00:18:43,360  
Several hundred microphones  
are installed,

416  
00:18:44,870 --> 00:18:47,090  
and honestly, we just get  
one chance to take this data.

417  
00:18:47,690 --> 00:18:49,389  
We couldn't stop them,  
be like, "Oh, excuse me.

418  
00:18:49,390 --> 00:18:51,120  
Could you launch that rocket  
one more time?

419  
00:18:51,270 --> 00:18:52,360  
I didn't get the right data."

420  
00:18:52,720 --> 00:18:54,000  
So a lot of engineering and work

421  
00:18:54,720 --> 00:18:56,660  
went into making sure  
it was structurally sound,

422  
00:18:56,720 --> 00:18:58,300  
we were able to get  
the frequency right

423  
00:18:58,450 --> 00:19:00,540  
and all the data correctly  
during this experiment.

424  
00:19:03,150 --> 00:19:05,060  
Here I'll show you a video

of what it looked like.

425

00:19:05,420 --> 00:19:06,570

The sound image is on the left,

426

00:19:07,150 --> 00:19:09,270

and the camera that's really  
close to it is on the right

427

00:19:09,570 --> 00:19:10,720

to better see what's going on.

428

00:19:11,780 --> 00:19:14,030

You can see a lot of noise  
coming from the nozzle itself.

429

00:19:16,120 --> 00:19:17,839

There is actually a duct  
that goes under the launch pad

430

00:19:17,840 --> 00:19:18,840

that comes out at the exit.

431

00:19:20,090 --> 00:19:22,029

And once it shows it again,  
you can see a lot of noise

432

00:19:22,030 --> 00:19:23,720

actually coming  
out of the exit duct as well.

433

00:19:26,510 --> 00:19:27,870

We have  
a water suppressant system

434

00:19:28,750 --> 00:19:30,270

that actually  
suppresses the noise.

435

00:19:31,330 --> 00:19:32,720

Have any of you seen  
a launch before?

436

00:19:34,720 --> 00:19:35,720

Probably majority of you?

437

00:19:35,870 --> 00:19:37,510

Okay, so, if you ever  
see the water system

438

00:19:38,810 --> 00:19:40,510

that's getting blown  
onto the launch pad,

439

00:19:40,630 --> 00:19:42,450

I always thought  
it was to cool the launch pad,

440

00:19:42,840 --> 00:19:44,360

but it's actually  
to suppress noise.

441

00:19:45,390 --> 00:19:47,450

And because of this test,  
it changed the whole system

442

00:19:48,750 --> 00:19:50,750

of how launches were done  
in the future after this.

443

00:19:52,150 --> 00:19:53,450

It had to be initiated  
a lot sooner

444

00:19:54,810 --> 00:19:57,150

to suppress the noise.

445

00:20:00,450 --> 00:20:01,450

On to more rockets.

446

00:20:02,630 --> 00:20:04,570

We have a huge group  
in partnership with Stanford

447

00:20:07,210 --> 00:20:09,030

working on  
liquefying hybrid rocket motors.

448

00:20:10,750 --> 00:20:12,030

We've done 41 tests here at Ames

449

00:20:12,660 --> 00:20:14,120

and over 500 ground tests  
overall.

450

00:20:14,870 --> 00:20:16,450

A lot of effort  
and work went into this.

451

00:20:17,420 --> 00:20:18,600

And here's some few advantages

452

00:20:19,660 --> 00:20:21,120

of this liquefying  
hybrid rocket.

453

00:20:22,390 --> 00:20:23,780

First it uses  
a paraffin solid fuel,

454

00:20:25,330 --> 00:20:26,330

than the normal HTPB fuel.

455

00:20:28,870 --> 00:20:30,060

It burns three times faster.

456

00:20:30,390 --> 00:20:31,390

What does that give us?

457

00:20:31,660 --> 00:20:33,480

Well, it gives us  
a more simple system to burn.

458

00:20:35,000 --> 00:20:36,810

Here, that's what the fuel  
normally looks like.

459

00:20:38,000 --> 00:20:40,120

You have multiple ports  
for it to burn evenly through.

460

00:20:41,630 --> 00:20:43,150

Because it burns  
three times faster,

461

00:20:43,480 --> 00:20:45,180

we don't need  
the multiple ports anymore.

462

00:20:45,270 --> 00:20:47,300

We have one port where it  
could burn evenly through.

463

00:20:48,420 --> 00:20:50,450

And with multiple ports,  
if it doesn't burn evenly,

464

00:20:51,240 --> 00:20:52,600

it could cause  
structural damage,

465

00:20:54,090 --> 00:20:55,600

and it makes rockets  
a little less safe.

466

00:20:57,270 --> 00:20:58,480

But with this,  
it's a lot safer,

467

00:20:58,570 --> 00:21:00,150  
and it's environmentally  
friendly.

468

00:21:01,150 --> 00:21:03,300  
Right here, and on the right,  
we have a Peregrine rocket

469

00:21:05,660 --> 00:21:07,840  
that we hope to test roughly  
one year from now at Wallops.

470

00:21:10,450 --> 00:21:12,510  
In 2014, we conducted tests  
that shows that this fuel

471

00:21:14,150 --> 00:21:15,690  
is both viable  
and stable and efficient,

472

00:21:17,330 --> 00:21:19,360  
and it's able to fly in a flight  
with configuration.

473

00:21:20,720 --> 00:21:22,780  
I also want to emphasize  
the advantage of this rocket

474

00:21:24,300 --> 00:21:25,300  
where it has the advantage

475

00:21:26,270 --> 00:21:27,870  
of both a solid-  
and liquid-state rocket.

476

00:21:28,780 --> 00:21:30,690  
With a solid state,  
you get a really high thrust,

477  
00:21:31,270 --> 00:21:32,270  
but it's on and off.

478  
00:21:32,690 --> 00:21:34,810  
You light it up, it lights,  
it burns, and then it's off.

479  
00:21:36,450 --> 00:21:38,390  
With the liquid fuel,  
you're able to throttle it.

480  
00:21:38,840 --> 00:21:40,480  
This hybrid rocket,  
it's able to do both.

481  
00:21:41,270 --> 00:21:43,660  
You have a liquid-state fuel,  
and you have a solid-state fuel,

482  
00:21:44,750 --> 00:21:45,810  
and it's really efficient,

483  
00:21:50,240 --> 00:21:52,240  
so...

484  
00:21:53,840 --> 00:21:54,840  
Here you go.

485  
00:21:55,090 --> 00:21:58,090  
[rocket engine firing]

486  
00:22:13,750 --> 00:22:14,750  
Beautiful.

487  
00:22:15,360 --> 00:22:16,360  
Very complete.

488  
00:22:16,540 --> 00:22:17,540

This was a ground test.

489

00:22:17,720 --> 00:22:18,870

It was parallel to the ground,

490

00:22:20,570 --> 00:22:22,030

but it's usually  
pointed upwards,

491

00:22:22,510 --> 00:22:23,510

so we could go up.

492

00:22:24,570 --> 00:22:25,570

[laughter]

493

00:22:27,480 --> 00:22:29,210

So we talked a lot  
about going up into space.

494

00:22:30,630 --> 00:22:32,120

What about coming back down  
to space

495

00:22:32,150 --> 00:22:33,360

or even other planetary bodies?

496

00:22:34,690 --> 00:22:36,180

Coming back down,  
it's really fast,

497

00:22:36,600 --> 00:22:38,779

and it's really harsh, and it's  
a really hot environment.

498

00:22:38,780 --> 00:22:40,390

So we use something  
called a heat shield

499

00:22:40,600 --> 00:22:41,600

to protect our vehicle,

500

00:22:41,750 --> 00:22:43,480

our instrumentation,  
and our astronauts.

501

00:22:44,660 --> 00:22:47,000

And to simulate that, we have  
a facility called the Arc Jet

502

00:22:48,000 --> 00:22:49,630

to test these  
thermal protection systems.

503

00:22:50,750 --> 00:22:52,120

Right now you have  
a heat shield,

504

00:22:53,270 --> 00:22:55,060

and it's being put  
into the arc jet right now.

505

00:22:57,090 --> 00:22:58,360

So typically,  
for us to quantify

506

00:22:59,300 --> 00:23:01,810

how well it worked, we measure  
the heat shield material before,

507

00:23:03,300 --> 00:23:05,329

and once that's done, we measure  
the heat shield after,

508

00:23:05,330 --> 00:23:07,030

and that's  
how much material has ablated.

509

00:23:07,330 --> 00:23:09,270

The material has to ablate

to dissipate the heat.

510

00:23:12,540 --> 00:23:14,600

In the Fluid Mechanics Lab,  
we developed a better way

511

00:23:14,810 --> 00:23:16,450

to do this to actually see  
what's going on

512

00:23:17,270 --> 00:23:18,630

between the beginning  
and the end.

513

00:23:21,690 --> 00:23:23,840

We call this photogrammetric  
recession measurement.

514

00:23:24,720 --> 00:23:26,120

It uses the same technique  
as PIV,

515

00:23:27,270 --> 00:23:28,660

but instead of  
tracking molecules,

516

00:23:29,210 --> 00:23:31,390

you're actually tracking  
the surface of the heat shield

517

00:23:31,690 --> 00:23:32,690

being ablated away.

518

00:23:33,360 --> 00:23:34,750

Right now we have PICA  
in the arc jet.

519

00:23:38,090 --> 00:23:40,420

And one great use of this is,  
what if the ablation was uneven?

520

00:23:42,420 --> 00:23:44,690

Like, how would you know that  
measuring it before and after

521

00:23:44,690 --> 00:23:46,359

and when it actually  
started becoming uneven?

522

00:23:46,360 --> 00:23:48,510

With this technique, you're able  
to see it in real time.

523

00:23:50,570 --> 00:23:53,120

And it's actually extremely hard  
to put any sort of instruments

524

00:23:53,450 --> 00:23:55,300

that would survive  
in this kind of conditions,

525

00:23:56,060 --> 00:23:57,750

and a lot of engineering  
also went into this.

526

00:23:59,810 --> 00:24:03,810

The surface right here  
is brighter than the sun, so...

527

00:24:08,660 --> 00:24:10,180

Like I mentioned  
from the beginning,

528

00:24:10,840 --> 00:24:11,840

coming back into space,

529

00:24:12,360 --> 00:24:14,600

NASA Ames is also home to  
the world's largest wind tunnel.

530  
00:24:16,750 --> 00:24:18,030  
It could fit a full-scale F-18,

531  
00:24:20,090 --> 00:24:21,270  
even a full-scale semi-truck.

532  
00:24:22,360 --> 00:24:24,420  
But what better way to use it  
than to test parachutes?

533  
00:24:25,570 --> 00:24:27,420  
On the left--this was done  
earlier this year--

534  
00:24:28,060 --> 00:24:29,450  
it's two  
out of the three parachutes

535  
00:24:29,780 --> 00:24:31,060  
that would be deployed on Orion

536  
00:24:31,570 --> 00:24:32,720  
when it comes back onto Earth.

537  
00:24:34,720 --> 00:24:37,090  
On the very right, you have  
the Mars Science Lab parachute.

538  
00:24:38,150 --> 00:24:39,660  
It's the largest  
supersonic parachute

539  
00:24:40,060 --> 00:24:41,780  
ever successfully designed  
right over here.

540  
00:24:44,180 --> 00:24:46,510  
And what's incredible about  
this parachute in particular,

541

00:24:47,000 --> 00:24:48,180  
it's moving--it's taking MSL,

542

00:24:49,150 --> 00:24:50,750  
or "Curiosity,"  
onto the Mars atmosphere

543

00:24:51,330 --> 00:24:53,060  
but when it's approaching  
the atmosphere,

544

00:24:54,060 --> 00:24:55,810  
it's going about...  
over 1,000 miles per hour,

545

00:24:57,000 --> 00:24:58,060  
and it's the size of a Prius.

546

00:24:58,480 --> 00:25:00,870  
And we have to slow this Prius  
down to about 200 miles per hour

547

00:25:01,600 --> 00:25:02,600  
with just one parachute.

548

00:25:04,000 --> 00:25:05,000  
Pretty incredible.

549

00:25:05,570 --> 00:25:08,030  
I recommend YouTubing "Seven  
Minutes of Terror" on YouTube.

550

00:25:08,480 --> 00:25:10,510  
It also shows you the other  
complicated techniques

551

00:25:10,720 --> 00:25:11,720  
with zero margin of error

552

00:25:12,720 --> 00:25:15,570

how to make this mission  
successful.

553

00:25:18,420 --> 00:25:19,600

Here we had a high-speed camera

554

00:25:20,150 --> 00:25:21,540

capture  
the successful deployment

555

00:25:22,150 --> 00:25:23,510

of the Mars Science Lab  
parachute.

556

00:25:24,330 --> 00:25:25,420

Of course, it's slowed down.

557

00:25:25,720 --> 00:25:27,300

We had some problems  
in the beginning,

558

00:25:28,300 --> 00:25:30,300

but at the end, we were able  
to solve those problems

559

00:25:30,330 --> 00:25:31,690

and have  
a successful deployment.

560

00:25:32,330 --> 00:25:34,840

But did this work?

561

00:25:36,630 --> 00:25:37,630

Here's proof.

562

00:25:37,750 --> 00:25:38,750

I took it with my iPhone.

563

00:25:39,150 --> 00:25:40,150

[laughter]

564

00:25:41,090 --> 00:25:43,210

So this is "Curiosity" landing  
on Mars August 5, 2012,

565

00:25:45,480 --> 00:25:48,030

and everything went flawlessly,  
and the mission was a success.

566

00:25:50,390 --> 00:25:52,240

Okay, so I talked a lot  
about supersonic speeds

567

00:25:53,630 --> 00:25:54,840

and breaking the sound barrier,

568

00:25:55,270 --> 00:25:57,210

but how does it look like  
to the naked eye on Earth?

569

00:25:59,180 --> 00:26:00,240

Well, I got a photo.

570

00:26:00,660 --> 00:26:02,060

This is an F-18  
flying about Mach 1

571

00:26:03,540 --> 00:26:04,600

over the San Francisco Bay.

572

00:26:04,870 --> 00:26:06,150

It's about 40 feet above water.

573

00:26:07,150 --> 00:26:08,150

It's a very daring pilot,

574

00:26:08,750 --> 00:26:10,480

and you can see the shocks  
coming off of here

575

00:26:10,570 --> 00:26:11,570

or even the canopy.

576

00:26:12,630 --> 00:26:14,360

When shocks occur,  
it's usually a change--

577

00:26:14,810 --> 00:26:16,390

it's a change  
of pressure and density.

578

00:26:16,690 --> 00:26:18,150

So that's what  
you're seeing here.

579

00:26:18,330 --> 00:26:21,450

I'll call it  
a real-life Schlieren photo.

580

00:26:23,540 --> 00:26:24,600

But what does it sound like?

581

00:26:25,660 --> 00:26:26,660

Well...

582

00:26:26,660 --> 00:26:29,660

[loud boom]

583

00:26:32,870 --> 00:26:33,870

[roaring]

584

00:26:35,360 --> 00:26:36,360

[crowd exclaiming]

585

00:26:36,840 --> 00:26:37,840  
[roaring]

586  
00:26:39,600 --> 00:26:41,600  
(woman)  
Whoo-hoo-hoo-hoo-hoo!

587  
00:26:43,870 --> 00:26:44,870  
[loud boom]

588  
00:26:47,720 --> 00:26:49,630  
(man)  
Sound travels  
at about 760 miles per hour

589  
00:26:51,660 --> 00:26:52,660  
or 340 meters per second.

590  
00:26:54,270 --> 00:26:56,330  
That's about 661 knots  
on an average day at sea level.

591  
00:26:58,510 --> 00:27:00,060  
And sometimes  
you can almost see it.

592  
00:27:01,840 --> 00:27:03,119  
(Christina)  
That's how it sounds like.

593  
00:27:03,120 --> 00:27:04,120  
[laughs]

594  
00:27:04,540 --> 00:27:06,780  
Keep in mind you're also hearing  
a lot of the engine noises

595  
00:27:07,150 --> 00:27:08,150  
that are coming off of it,

596  
00:27:08,660 --> 00:27:10,149  
but I definitely don't want  
one of these planes

597  
00:27:10,150 --> 00:27:11,420  
flying over my house  
at 3:00 a.m.

598  
00:27:14,480 --> 00:27:16,210  
So NASA actually  
has a supersonics program

599  
00:27:17,570 --> 00:27:19,359  
in partnership with a lot  
of commercial companies

600  
00:27:19,360 --> 00:27:21,180  
such as Lockheed or Boeing  
and other entities

601  
00:27:22,000 --> 00:27:24,030  
where we're trying  
to reduce the sound signature--

602  
00:27:24,390 --> 00:27:26,510  
boom signature so it could fly  
over land efficiently.

603  
00:27:28,750 --> 00:27:30,810  
These are several of the designs  
that they have here.

604  
00:27:31,270 --> 00:27:32,630  
And this is  
for commercial planes.

605  
00:27:33,090 --> 00:27:35,150  
So one of you, you and I  
could fly in one of these planes

606  
00:27:35,450 --> 00:27:36,450  
in the next 15, 20 years.

607  
00:27:36,720 --> 00:27:37,720  
How amazing would that be?

608  
00:27:38,660 --> 00:27:40,270  
And so instead of going  
to New York, say,

609  
00:27:40,660 --> 00:27:42,480  
in, like, 5 hours,  
you're there in 2 1/2 hours.

610  
00:27:43,210 --> 00:27:44,689  
I'll definitely go to New York  
a lot more often

611  
00:27:44,690 --> 00:27:45,690  
if I had the money.

612  
00:27:46,450 --> 00:27:47,450  
Right here.

613  
00:27:49,240 --> 00:27:51,060  
And to point out,  
back here is a pressure rail,

614  
00:27:53,330 --> 00:27:55,780  
and that's what we're using to  
measure the sonic boom signature

615  
00:27:56,300 --> 00:27:57,300  
coming off of the plane.

616  
00:27:58,000 --> 00:27:59,480  
And the pointy nose  
and the wing itself

617  
00:28:01,240 --> 00:28:02,750  
all reduces the noise  
of that boom, boom

618  
00:28:04,150 --> 00:28:05,780  
that you hear  
when it's flying over as well.

619  
00:28:08,300 --> 00:28:09,300  
Okay.

620  
00:28:09,510 --> 00:28:10,690  
So what about subsonic planes?

621  
00:28:11,810 --> 00:28:14,150  
What have we done for those  
instead of supersonic planes?

622  
00:28:15,150 --> 00:28:16,239  
Well, we've actually done  
a lot of work

623  
00:28:16,240 --> 00:28:17,420  
to make planes more efficient,

624  
00:28:17,660 --> 00:28:20,090  
part of the environmentally  
responsible aviation program

625  
00:28:20,720 --> 00:28:21,720  
here at Ames.

626  
00:28:23,270 --> 00:28:24,269  
One technique  
that we've developed

627  
00:28:24,270 --> 00:28:25,330  
is called the sweeping jet.

628

00:28:26,090 --> 00:28:28,150

Right now what you're seeing  
is the 40x80 wind tunnel

629

00:28:28,840 --> 00:28:30,660

with a full-sized  
Boeing 757 tail installed.

630

00:28:33,090 --> 00:28:34,810

So these sweeping jets  
right here that you see

631

00:28:36,330 --> 00:28:37,840

has no moving parts,  
and about 30 of them

632

00:28:38,510 --> 00:28:41,060

are installed on these hinges,  
which provides us flow control.

633

00:28:42,840 --> 00:28:45,330

Because these are installed,  
it provides 20% more side force,

634

00:28:47,720 --> 00:28:48,720

which results in--

635

00:28:50,240 --> 00:28:51,630

we don't need tails  
that big anymore

636

00:28:52,600 --> 00:28:53,600

for the plane to fly.

637

00:28:54,060 --> 00:28:55,660

So we could reduce the size  
tremendously,

638

00:28:57,090 --> 00:28:58,450

therefore reducing  
mass and drag,

639  
00:29:00,300 --> 00:29:01,720  
and giving us  
a more efficient plane.

640  
00:29:03,330 --> 00:29:04,390  
This was a successful test,

641  
00:29:04,870 --> 00:29:06,870  
and they actually tested it  
in flight in April 2015

642  
00:29:08,480 --> 00:29:09,840  
on an ecoDemonstrator  
right here,

643  
00:29:11,240 --> 00:29:12,750  
and that was also  
a successful mission.

644  
00:29:14,060 --> 00:29:15,600  
I suspect to be  
seeing these flow control

645  
00:29:17,870 --> 00:29:20,120  
on all future planes.

646  
00:29:22,870 --> 00:29:25,030  
Here's one test that's going on  
right now as we speak.

647  
00:29:26,330 --> 00:29:28,360  
I was actually walking  
next to the plane yesterday,

648  
00:29:28,690 --> 00:29:30,420  
putting it  
into the wind tunnel right here.

649

00:29:31,090 --> 00:29:32,300

It's the hybrid wing body plane.

650

00:29:33,120 --> 00:29:35,150

It's a plane that's

both designed by NASA and Boeing

651

00:29:36,630 --> 00:29:37,630

right here.

652

00:29:37,630 --> 00:29:39,000

So environmentally responsible

653

00:29:39,120 --> 00:29:40,510

doesn't just mean

fuel efficiency.

654

00:29:41,540 --> 00:29:42,840

It also means

reducing the noise.

655

00:29:44,030 --> 00:29:45,120

So we have the engines on top.

656

00:29:46,120 --> 00:29:47,390

They're typically on the bottom,

657

00:29:47,480 --> 00:29:49,390

and this kind of shields

the noise off the ground

658

00:29:50,720 --> 00:29:51,720

right over here.

659

00:29:52,600 --> 00:29:54,540

And this nice blended wing body

gives us actually

660  
00:29:56,240 --> 00:29:58,090  
a lot more efficiency  
and higher cruise speed.

661  
00:29:59,750 --> 00:30:00,750  
You can see over here.

662  
00:30:01,330 --> 00:30:02,840  
And back  
to the air aeroacoustics team,

663  
00:30:03,420 --> 00:30:05,540  
we also installed several  
acoustics array right here

664  
00:30:06,210 --> 00:30:07,210  
to measure the sound.

665  
00:30:09,390 --> 00:30:10,390  
Pretty great.

666  
00:30:13,330 --> 00:30:14,420  
This here is a special plane.

667  
00:30:15,570 --> 00:30:17,060  
It's a design  
that's commonly used.

668  
00:30:18,750 --> 00:30:19,750  
It's nonproprietary,

669  
00:30:21,030 --> 00:30:22,300  
and it's used  
all over the world.

670  
00:30:23,060 --> 00:30:25,210  
So this plane, you could use  
your computational method

671  
00:30:26,210 --> 00:30:28,480  
or your experimental method  
that you developed in your lab

672  
00:30:28,630 --> 00:30:30,090  
or install  
different wind tunnels

673  
00:30:30,120 --> 00:30:31,120  
and go back to the database

674  
00:30:31,570 --> 00:30:33,360  
that everyone can use  
and validate your data

675  
00:30:33,690 --> 00:30:35,270  
or check if it's right  
or even close by.

676  
00:30:35,780 --> 00:30:36,780  
It's really useful,

677  
00:30:37,000 --> 00:30:38,119  
especially if you're not  
part of NASA,

678  
00:30:38,120 --> 00:30:40,120  
you really want to check  
your computational code.

679  
00:30:40,150 --> 00:30:41,150  
How do you do that?

680  
00:30:41,270 --> 00:30:42,810  
Well, you run it  
on the same model, right?

681  
00:30:43,540 --> 00:30:44,540  
Angle check there.

682

00:30:45,540 --> 00:30:46,749

We've even done  
some work ourselves

683

00:30:46,750 --> 00:30:48,720

in the Fluid Mechanics Lab.

684

00:30:51,090 --> 00:30:52,090

Right over here.

685

00:30:52,180 --> 00:30:53,390

So this is  
a semi-span CRM model

686

00:30:55,240 --> 00:30:56,600

tested in  
our low-speed test cell.

687

00:30:58,060 --> 00:31:00,360

And these blue streaks are  
actually oil that was applied.

688

00:31:01,630 --> 00:31:02,689

We turned on the wind tunnel,

689

00:31:02,690 --> 00:31:04,180

and we were able to see  
the flow field

690

00:31:04,480 --> 00:31:05,540

on the surface of the model,

691

00:31:06,390 --> 00:31:08,390

give us this nice visual effect  
of what's going on.

692

00:31:09,690 --> 00:31:10,690

On the left and on the right

693

00:31:11,540 --> 00:31:13,060

we're measuring  
wing-tip vortices.

694

00:31:13,450 --> 00:31:15,510

On the left, we use a covert  
probe or a four-hole probe

695

00:31:16,660 --> 00:31:18,240

that measures pressure  
along a plane.

696

00:31:20,510 --> 00:31:21,749

And on the right,  
in the same plane,

697

00:31:21,750 --> 00:31:23,570

we used PIV to  
measure velocities right here.

698

00:31:27,330 --> 00:31:28,330

So why is it important

699

00:31:28,450 --> 00:31:30,180

that we understand  
the wing-tip vortices?

700

00:31:30,240 --> 00:31:32,090

Well, have you ever  
sat on a plane and wondered,

701

00:31:33,780 --> 00:31:35,329

"The other plane's  
already taken off.

702

00:31:35,330 --> 00:31:37,390

Why am I still sitting here?  
Why haven't we taken off?

703

00:31:37,600 --> 00:31:39,240

I can't wait to go home  
for Thanksgiving.

704

00:31:39,330 --> 00:31:40,600

My food's getting cold,"  
right?

705

00:31:42,000 --> 00:31:44,030

Well, actually, wing-tip  
vortices can be so strong

706

00:31:45,060 --> 00:31:47,210

that, if we're flying way  
too closely on the next plane,

707

00:31:48,810 --> 00:31:50,540

it could flip another plane  
over behind it.

708

00:31:52,780 --> 00:31:54,240

Which leads me  
to our next project.

709

00:31:55,060 --> 00:31:57,300

Here we study wing-tip vortices  
and how to alleviate them

710

00:31:58,420 --> 00:32:00,330

using vortices  
coming off the tail right here.

711

00:32:02,330 --> 00:32:04,030

So if one vortice's  
coming off the wing tip

712

00:32:04,480 --> 00:32:05,480

going one direction,

713

00:32:06,000 --> 00:32:08,059  
what if we had another vortice  
going in a different direction,

714

00:32:08,060 --> 00:32:09,060  
coming off the tail,

715

00:32:09,300 --> 00:32:11,000  
and basically cancelling  
each other out?

716

00:32:12,450 --> 00:32:14,180  
This did work,  
but the plane configuration

717

00:32:15,480 --> 00:32:17,390  
is just not a viable  
plane configuration to fly.

718

00:32:18,090 --> 00:32:19,270  
But we did prove that it worked.

719

00:32:20,000 --> 00:32:21,840  
On the bottom right,  
the red shows one direction.

720

00:32:23,330 --> 00:32:25,389  
The blue shows a different  
direction of the vortices.

721

00:32:25,390 --> 00:32:27,120  
These are two vortices  
coming from the wing

722

00:32:27,630 --> 00:32:29,210  
and two vortices  
coming from the tail.

723

00:32:30,030 --> 00:32:32,600  
Let me show you how it worked.

724

00:32:40,120 --> 00:32:41,630

If we could find a way  
to get this to work,

725

00:32:42,630 --> 00:32:47,270

we could reduce airline traffic  
by an incredible amount.

726

00:32:51,180 --> 00:32:52,570

So we talked a lot  
about spacecrafts

727

00:32:52,840 --> 00:32:54,150

and aircrafts and air vehicles.

728

00:32:54,540 --> 00:32:55,540

We don't just do just that.

729

00:32:56,390 --> 00:32:58,390

In the last 15 years,  
we've also studied truck drag

730

00:32:59,270 --> 00:33:01,120

and wondering:  
why is truck drag important?

731

00:33:01,810 --> 00:33:03,270

Well, trucks consume 13%  
of the oil

732

00:33:04,750 --> 00:33:05,810

we use in the United States,

733

00:33:06,660 --> 00:33:08,060

and over 60% of that fuel  
on a truck

734

00:33:08,630 --> 00:33:10,000

is to overcome aerodynamic drag.

735

00:33:10,810 --> 00:33:13,180

That's a huge amount of fuel  
overcoming aerodynamic drag.

736

00:33:14,240 --> 00:33:16,240

So if we could even make it  
to 5%, 10%, 15% less drag,

737

00:33:18,330 --> 00:33:20,450

imagine how much fuel savings  
we could have in the U.S.

738

00:33:21,690 --> 00:33:23,270

So here we have  
a side and base extender

739

00:33:25,120 --> 00:33:26,120

to cover up the gap.

740

00:33:26,540 --> 00:33:27,540

That also reduces drag.

741

00:33:28,150 --> 00:33:29,750

Another thing  
we tried is lowboy trailer,

742

00:33:30,600 --> 00:33:31,600

or we called it side flaps.

743

00:33:32,720 --> 00:33:34,420

Here it could reduce the drag  
by about 10%.

744

00:33:35,510 --> 00:33:37,300

And if you want to add  
the trailer base flaps,

745

00:33:38,330 --> 00:33:40,060

it could reduce drag  
by 15% right over here.

746

00:33:41,570 --> 00:33:43,720

You could see a lot of this  
being implemented out there.

747

00:33:44,210 --> 00:33:45,210

If you drive on Highway 5

748

00:33:46,000 --> 00:33:47,510

or even on 101,  
a lot of trucks have this.

749

00:33:49,360 --> 00:33:51,420

Most of them already have  
the side and base extenders

750

00:33:51,840 --> 00:33:54,240

covering the gap for you.

751

00:33:59,300 --> 00:34:00,360

On to the fun part.

752

00:34:02,000 --> 00:34:03,000

So NASA's mission

753

00:34:03,240 --> 00:34:05,150

is to inspire the next  
generation of explorers.

754

00:34:05,840 --> 00:34:07,030

So the next couple of slides,

755

00:34:07,180 --> 00:34:08,659

I'm gonna show you  
student-based projects

756

00:34:08,660 --> 00:34:10,390  
that we've done  
in the Fluid Mechanics Lab.

757  
00:34:13,570 --> 00:34:15,030  
Here we have  
a fruit fly experiment

758  
00:34:15,780 --> 00:34:17,180  
that was done  
over three summers,

759  
00:34:17,390 --> 00:34:19,300  
and it was pretty much solely  
an intern project.

760  
00:34:20,750 --> 00:34:22,030  
It was used to track and analyze

761  
00:34:22,420 --> 00:34:24,480  
how fruit flies flew  
in micro-gravity environment.

762  
00:34:25,120 --> 00:34:27,480  
But the biggest challenge was  
fitting this whole experiment

763  
00:34:27,540 --> 00:34:28,540  
in a 4-inch by 6-inch box.

764  
00:34:30,300 --> 00:34:31,300  
You can see here.

765  
00:34:32,390 --> 00:34:33,390  
Pretty great.

766  
00:34:34,390 --> 00:34:36,210  
This experiment flew up  
to the ISS last summer

767  
00:34:36,450 --> 00:34:38,720  
on a SpaceX rocket.

768  
00:34:43,060 --> 00:34:45,060  
Here we've done a lot  
of sports ball aerodynamics,

769  
00:34:46,030 --> 00:34:47,540  
student-based  
educational programs.

770  
00:34:48,570 --> 00:34:50,810  
On the top left, you see a  
tennis ball that's not spinning,

771  
00:34:52,090 --> 00:34:53,630  
and we're injecting smoke  
into the flow.

772  
00:34:54,300 --> 00:34:55,720  
You see  
a very symmetric flow pattern

773  
00:34:56,810 --> 00:34:58,270  
on top and on the bottom  
of the ball.

774  
00:35:00,720 --> 00:35:02,090  
And here we have  
a spinning ball.

775  
00:35:03,390 --> 00:35:04,390  
It's spinning this way.

776  
00:35:04,540 --> 00:35:06,150  
So you have the weight  
going further out

777  
00:35:06,330 --> 00:35:07,840

and the separation  
going further down,

778

00:35:08,570 --> 00:35:09,780

so this causes a downward force.

779

00:35:11,600 --> 00:35:12,600

Oh.

780

00:35:12,600 --> 00:35:13,660

It's probably easier to see

781

00:35:13,660 --> 00:35:15,150

if I show you a video  
of it happening.

782

00:35:16,030 --> 00:35:17,030

Here it's a baseball.

783

00:35:17,090 --> 00:35:18,090

Again, symmetric flow

784

00:35:18,240 --> 00:35:20,030

both on the top  
and on the bottom of this ball.

785

00:35:21,150 --> 00:35:23,510

And once it starts spinning, you  
can see how the flow changes.

786

00:35:24,420 --> 00:35:26,270

The wake starts coming  
right off further down,

787

00:35:27,750 --> 00:35:29,570

and you have the separation  
going further up,

788

00:35:30,210 --> 00:35:31,210

causing a sideways force.

789

00:35:31,870 --> 00:35:33,120

That's how a curveball works,

790

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

upward force.

791

00:35:38,300 --> 00:35:39,300

So, fun fact, a tennis ball

792

00:35:40,300 --> 00:35:42,210

has the highest drag

out of all the sports balls.

793

00:35:44,060 --> 00:35:45,060

Why is that?

794

00:35:45,360 --> 00:35:47,000

It's 'cause it has

the roughest surface.

795

00:35:48,000 --> 00:35:49,000

So we tested that as well.

796

00:35:50,060 --> 00:35:52,240

We have the same tennis ball

tested at different speeds.

797

00:35:53,510 --> 00:35:54,510

First is at low speed.

798

00:35:54,720 --> 00:35:56,389

You can see the filaments

kind of sticking out

799

00:35:56,390 --> 00:35:57,780

kind of like hair on your arm,

right?

800

00:35:59,210 --> 00:36:00,630

A really rough surface,  
high drag.

801

00:36:01,600 --> 00:36:03,300

We tested that same ball  
at higher speeds,

802

00:36:03,750 --> 00:36:05,360

but now all the filaments  
are laid down.

803

00:36:07,570 --> 00:36:10,180

Smoother ball, less drag.

804

00:36:14,630 --> 00:36:16,210

How many of you have seen  
the World Cup?

805

00:36:18,600 --> 00:36:19,600

A lot of you.

806

00:36:20,330 --> 00:36:21,480

So the last couple World Cups,

807

00:36:21,600 --> 00:36:23,750

there have been a lot of  
controversy on the soccer ball.

808

00:36:24,270 --> 00:36:26,300

Every World Cup, they have  
a new soccer ball design.

809

00:36:26,750 --> 00:36:28,120

It's not just  
for the looks of it.

810

00:36:28,690 --> 00:36:30,630

The aerodynamics  
are actually quite different,

811  
00:36:30,750 --> 00:36:32,660  
and that's because  
of the roughness of the ball.

812  
00:36:33,450 --> 00:36:35,600  
The roughness is determined  
by the length of the seams,

813  
00:36:37,030 --> 00:36:38,030  
how deep the seams are,

814  
00:36:38,420 --> 00:36:40,120  
and the pimples  
on the surface of the ball.

815  
00:36:42,750 --> 00:36:44,360  
This last year,  
it was the Brazuca ball.

816  
00:36:45,090 --> 00:36:47,000  
It was a lot rougher  
than the previous World Cup,

817  
00:36:49,240 --> 00:36:51,030  
and therefore,  
changing the aerodynamics.

818  
00:36:51,510 --> 00:36:53,449  
The goalies and the players  
are actually a lot happier

819  
00:36:53,450 --> 00:36:55,600  
with this ball, and we had  
no complaints this last year.

820  
00:36:58,450 --> 00:37:00,750  
I would recommend Googling

or YouTubing Brazuca or NASA.

821

00:37:03,510 --> 00:37:04,869

There's a lot  
of great articles about it,

822

00:37:04,870 --> 00:37:06,480

a lot of great videos  
to show you the work

823

00:37:06,660 --> 00:37:07,810

that we put into our research,

824

00:37:08,450 --> 00:37:09,720

and a lot  
of the student projects

825

00:37:09,720 --> 00:37:12,060

to get students excited  
about aerodynamics with sports.

826

00:37:14,180 --> 00:37:15,180

So it's really great.

827

00:37:18,060 --> 00:37:20,120

And lastly, how many of you  
have seen "MythBusters?"

828

00:37:21,750 --> 00:37:22,750

A lot of you.

829

00:37:23,060 --> 00:37:24,750

We have a few stars  
in the audience right now.

830

00:37:26,540 --> 00:37:28,390

So anytime "Mythbusters" has  
an aero problem,

831

00:37:29,480 --> 00:37:30,480  
who do they come to?

832  
00:37:30,570 --> 00:37:32,090  
They come  
to the Fluid Mechanics Lab.

833  
00:37:32,540 --> 00:37:33,749  
They've been here several times.

834  
00:37:33,750 --> 00:37:35,450  
When I was an intern,  
they were here twice.

835  
00:37:35,780 --> 00:37:36,780  
It was pretty cool.

836  
00:37:38,390 --> 00:37:39,540  
And they test all their myths.

837  
00:37:40,060 --> 00:37:41,780  
One of my favorite myths  
is the golf ball myth.

838  
00:37:42,720 --> 00:37:44,420  
So say you have a golf ball  
and it's dimpled

839  
00:37:46,060 --> 00:37:48,210  
and have the same exact ball  
that's completely smooth.

840  
00:37:48,510 --> 00:37:50,029  
If I hit it  
with the same amount of force,

841  
00:37:50,030 --> 00:37:51,210  
the golf ball goes twice as far,

842

00:37:52,090 --> 00:37:54,540  
and that's because of the dimple  
on the golf ball reducing drag.

843  
00:37:55,570 --> 00:37:57,210  
So will that same idea  
work on, say, a car?

844  
00:37:59,600 --> 00:38:01,690  
If I dimpled my car,  
would I get twice the efficiency

845  
00:38:02,870 --> 00:38:03,870  
on my gas usage?

846  
00:38:05,570 --> 00:38:07,270  
Well, we had actually  
high school interns

847  
00:38:08,030 --> 00:38:09,030  
test that out here as well,

848  
00:38:11,150 --> 00:38:12,150  
and as a matter of fact,

849  
00:38:13,600 --> 00:38:15,000  
you actually  
don't get less drag.

850  
00:38:16,150 --> 00:38:17,150  
It actually makes it worse

851  
00:38:18,000 --> 00:38:20,120  
from our experiment that  
we've done with the interns.

852  
00:38:20,480 --> 00:38:22,000  
And right here,  
when they first came,

853  
00:38:23,630 --> 00:38:25,450  
I think this was  
actually when I was an intern.

854  
00:38:25,750 --> 00:38:27,120  
They got to visit.  
I couldn't go.

855  
00:38:27,750 --> 00:38:30,120  
They got to visit "Mythbusters"  
<font color = #FFFFFF>up in San Francisco, so...</font>

856  
00:38:32,180 --> 00:38:33,180  
pretty cool.

857  
00:38:34,450 --> 00:38:35,450  
All right, questions?

858  
00:38:37,480 --> 00:38:38,480  
[applause]

859  
00:38:38,870 --> 00:38:39,870  
Thank you.

860  
00:38:41,240 --> 00:38:44,090  
[Christina laughs]

861  
00:38:52,180 --> 00:38:54,570  
No questions?  
Okay.

862  
00:39:00,720 --> 00:39:02,120  
Well, that makes it  
easier for me.

863  
00:39:02,480 --> 00:39:04,330  
We'll have the center microphone  
in the aisle,

864  
00:39:04,750 --> 00:39:06,870  
so please filter around  
and ask your questions there.

865  
00:39:09,420 --> 00:39:10,420  
I don't bite.  
I promise.

866  
00:39:12,090 --> 00:39:13,090  
Maybe a little.

867  
00:39:14,360 --> 00:39:15,360  
You have a question here?

868  
00:39:17,840 --> 00:39:18,840  
(woman)  
Yeah, the PIV,

869  
00:39:19,750 --> 00:39:21,060  
what is the code  
that you use...

870  
00:39:21,870 --> 00:39:23,030  
[continues indistinctly]

871  
00:39:24,270 --> 00:39:26,060  
(man)  
Could you go to the mic  
and ask please?

872  
00:39:28,030 --> 00:39:29,180  
(woman)  
Yeah, my question is

873  
00:39:30,210 --> 00:39:31,810  
about the particle imaging  
velocimetry,

874  
00:39:32,450 --> 00:39:34,570

if you just happened to know  
what code you use for that.

875

00:39:36,630 --> 00:39:38,360

And beautiful, excellent talk.

Thank you.

876

00:39:39,780 --> 00:39:41,840

(Christina)

Thank you.

Is JT in the audience today?

877

00:39:44,090 --> 00:39:45,090

Laura Kushner?

878

00:39:45,540 --> 00:39:47,870

(woman)

We tend to use LaVision,  
just a commercial package

879

00:39:47,870 --> 00:39:48,870

that is available.

880

00:39:51,240 --> 00:39:52,240

We also use...

881

00:39:52,600 --> 00:39:53,660

[continues indistinctly]

882

00:39:56,810 --> 00:39:58,540

(man)

If you don't mind  
repeating please?

883

00:39:59,060 --> 00:40:00,120

(woman)

Sure, no worries.

884

00:40:00,360 --> 00:40:02,390

We tend to use LaVision,

which is a software package

885

00:40:03,060 --> 00:40:04,330  
that is commercially available.

886

00:40:06,090 --> 00:40:07,450  
Sometimes we do use  
in-house codes

887

00:40:08,150 --> 00:40:10,420  
that we've written in-house  
if there's something special

888

00:40:10,750 --> 00:40:12,060  
that we want to do  
with the data.

889

00:40:13,420 --> 00:40:14,780  
(woman)  
Oh, and one last question.

890

00:40:15,450 --> 00:40:16,510  
Don't work in aeronautics.

891

00:40:17,360 --> 00:40:18,840  
I like the SC picture  
of the fruit flies

892

00:40:19,750 --> 00:40:21,330  
because that's the branch  
that I'm in,

893

00:40:21,600 --> 00:40:22,600  
the space biology branch.

894

00:40:24,300 --> 00:40:25,839  
But I've just been told  
that the new winglets

895

00:40:25,840 --> 00:40:27,630

you see on aircraft  
are a recent innovation,

896

00:40:29,750 --> 00:40:32,330

and I wondered if anyone could  
address the aerodynamics aspects

897

00:40:33,240 --> 00:40:34,720

of these little winglet  
innovations.

898

00:40:35,480 --> 00:40:37,000

The winglets,  
the one that goes on...

899

00:40:37,870 --> 00:40:40,389

(Christina)  
The little tips at the end  
of the wings that now go up

900

00:40:40,390 --> 00:40:42,420

that, I think, are  
a relatively recent innovation.

901

00:40:44,210 --> 00:40:45,810

- Okay, Don?  
- I'll talk to that if you want.

902

00:40:46,840 --> 00:40:48,150

- Go ahead.  
- So I'm Don Durston.

903

00:40:48,510 --> 00:40:50,000

I'm in the same branch  
as Christina.

904

00:40:50,000 --> 00:40:51,000

I'm lucky to work with her.

905

00:40:51,870 --> 00:40:53,270

She's a rising star  
in our branch.

906

00:40:53,660 --> 00:40:55,360

Winglets have been around  
for a long time,

907

00:40:55,660 --> 00:40:56,870

several decades--what's that?

908

00:40:58,690 --> 00:40:59,750

[man speaks indistinctly]

909

00:41:00,180 --> 00:41:01,450

(Don)  
Okay, stand up here, okay.

910

00:41:04,600 --> 00:41:05,839

So just in case  
they're recording this,

911

00:41:05,840 --> 00:41:06,840

I'm Don Durston.

912

00:41:07,090 --> 00:41:08,449

I work in the same branch  
as Christina.

913

00:41:08,450 --> 00:41:09,600

I'm an aerodynamicist there.

914

00:41:10,330 --> 00:41:12,030

Winglets have been around  
for a long time,

915

00:41:12,210 --> 00:41:13,630

probably a couple  
of decades or more.

916

00:41:15,600 --> 00:41:17,269

They've been tested  
on various aircraft,

917

00:41:17,270 --> 00:41:18,660

but there's been  
a lot more emphasis

918

00:41:19,420 --> 00:41:21,120

on trying to optimize them  
in their shapes

919

00:41:22,120 --> 00:41:23,840

so that they really  
do improve the efficiency

920

00:41:25,090 --> 00:41:26,780

of any kind of aircraft  
that they put them on.

921

00:41:27,660 --> 00:41:29,690

You're seeing a lot  
of airliners now with winglets.

922

00:41:30,540 --> 00:41:32,690

Southwest Airlines has put  
winglets on all their 737s,

923

00:41:34,270 --> 00:41:36,300

and I'm seeing them  
more and more on other aircraft.

924

00:41:36,840 --> 00:41:38,000

Basically what they do is--

925

00:41:39,600 --> 00:41:40,780

their basic mechanism  
is that

926

00:41:41,000 --> 00:41:42,840  
they give an effective  
span increase to the wing.

927  
00:41:45,030 --> 00:41:46,659  
Anytime you can increase  
the span a little bit,

928  
00:41:46,660 --> 00:41:48,180  
you're increasing  
the aspect ratio.

929  
00:41:48,720 --> 00:41:50,120  
That's lower drag configuration.

930  
00:41:52,600 --> 00:41:54,750  
The winglets also do help  
to distribute the wake vortex

931  
00:41:57,030 --> 00:41:58,840  
or the wing-tip vortices  
that come off the tips,

932  
00:41:59,750 --> 00:42:02,030  
and they do help to make those  
just a little bit weaker,

933  
00:42:02,390 --> 00:42:04,750  
and thus, you're reducing the  
induced drag just a little bit.

934  
00:42:05,540 --> 00:42:07,570  
So it's kind of a complicated  
aerodynamic problem.

935  
00:42:10,450 --> 00:42:12,630  
But with careful shaping  
and integration into the wings

936  
00:42:13,390 --> 00:42:15,720

of current aircraft, they  
are finding substantial savings

937

00:42:17,510 --> 00:42:18,690  
in fuel and the drag reduction,

938

00:42:20,390 --> 00:42:21,870  
so they were quite  
a great innovation.

939

00:42:23,540 --> 00:42:25,000  
And they look cool,  
as my boss says.

940

00:42:26,180 --> 00:42:27,690  
Thanks.

941

00:42:30,030 --> 00:42:31,870  
(man)  
I noticed that you use  
a lot of scale models

942

00:42:33,180 --> 00:42:34,180  
in these wind tunnels,

943

00:42:34,660 --> 00:42:36,779  
obviously 'cause you can't  
fit everything in there at once.

944

00:42:36,780 --> 00:42:38,810  
But at what point does  
the scaling sort of interfere

945

00:42:39,660 --> 00:42:41,149  
with the veracity  
of the measurement

946

00:42:41,150 --> 00:42:42,330  
that you're going to be taking?

947

00:42:43,030 --> 00:42:45,719

(Christina)

So there's this special number  
called the Reynolds number,

948

00:42:45,720 --> 00:42:47,450

and it's rho times  
the dimensional length,

949

00:42:50,360 --> 00:42:52,300

the size of it, divided  
by dynamic viscosity,  $\mu$ .

950

00:42:54,780 --> 00:42:56,690

So, if we're able to match  
this Reynolds number,

951

00:42:56,840 --> 00:42:59,180

you actually get the same  
flow field around these models,

952

00:43:00,390 --> 00:43:01,870

and we're able  
to have smaller scales.

953

00:43:03,180 --> 00:43:04,570

Can you imagine  
trying to test, say,

954

00:43:05,660 --> 00:43:06,660

a live, real-scale 737

955

00:43:08,000 --> 00:43:09,480

and how much energy  
it would take for us

956

00:43:09,630 --> 00:43:11,030

and even to fit  
into a wind tunnel?

957

00:43:12,480 --> 00:43:14,600

Which is why we go down  
to smaller scales to test these.

958

00:43:15,780 --> 00:43:17,719

A lot of the time, we actually  
don't test in full scales

959

00:43:17,720 --> 00:43:19,300

in wind tunnels  
'cause they don't fit.

960

00:43:19,660 --> 00:43:21,480

But all our validation's done  
in small scale,

961

00:43:22,060 --> 00:43:23,600

and then we go  
into flight configuration

962

00:43:23,780 --> 00:43:24,780

for the final test.

963

00:43:25,420 --> 00:43:28,180

That was a good question.  
Thank you.

964

00:43:30,390 --> 00:43:31,839

(woman)  
If there's  
no further questions,

965

00:43:31,840 --> 00:43:33,660

please join me again  
in thanking our speaker.

966

00:43:35,000 --> 00:43:38,000

[applause]