



1  
00:00:06,439 --> 00:00:10,577  
>> Al Bowers: So, real quick,  
how do we get here, right?

2  
00:00:10,577 --> 00:00:15,081  
So, really fundamentally.

3  
00:00:15,081 --> 00:00:16,583  
Imagination.

4  
00:00:16,583 --> 00:00:19,102  
Where do these sort  
of ideas come from?

5  
00:00:19,102 --> 00:00:21,771  
But, at the same time, when  
we're talking to students,

6  
00:00:21,771 --> 00:00:26,342  
the very important thing is,  
we try and impart knowledge.

7  
00:00:26,342 --> 00:00:30,480  
And the problem with knowledge  
is; knowledge is a box.

8  
00:00:30,480 --> 00:00:31,681  
And as long as you --

9  
00:00:31,681 --> 00:00:34,868  
if we taught you everything  
that could be known, then,

10  
00:00:34,868 --> 00:00:37,937  
there still wouldn't be anything  
new that would come out of that.

11  
00:00:37,937 --> 00:00:40,507  
And that's just not the

way things should be.

12

00:00:40,507 --> 00:00:43,143

We're -- as people,  
we're creative.

13

00:00:43,143 --> 00:00:46,646

We want to create new things,  
to create new opportunities,

14

00:00:46,646 --> 00:00:49,516

and to do things with -- hey,  
this device does this thing.

15

00:00:49,516 --> 00:00:51,701

But, if I put it  
with this thing,

16

00:00:51,701 --> 00:00:54,304

then it does something  
completely different,

17

00:00:54,304 --> 00:00:56,906

and that's where we  
really want to go.

18

00:00:56,906 --> 00:00:59,976

And Einstein understood  
this completely.

19

00:00:59,976 --> 00:01:02,212

The guy was brilliant, not  
just about particle physics.

20

00:01:02,212 --> 00:01:05,715

I mean, the man was  
brilliant about leadership,

21

00:01:05,715 --> 00:01:08,568

and about what we need to do,

22

00:01:08,568 --> 00:01:11,771  
as far as creativity,  
and imagination.

23

00:01:11,771 --> 00:01:13,540  
So, it's imagination  
versus knowledge.

24

00:01:13,540 --> 00:01:17,544  
Okay. So, one of the  
things that we have,

25

00:01:17,544 --> 00:01:20,914  
one of the things we get  
taught as engineers --

26

00:01:20,914 --> 00:01:22,198  
assumptions and concepts.

27

00:01:24,740 --> 00:01:27,693  
If you have an assumption  
or requirement, that,

28

00:01:27,700 --> 00:01:32,471  
quite literally, becomes the box  
in which your idea has to exist.

29

00:01:33,320 --> 00:01:36,690  
When people talk about  
thinking outside the box,

30

00:01:36,690 --> 00:01:39,316  
you have to go back and  
question those requirements

31

00:01:39,320 --> 00:01:41,623  
that you put together  
originally.

32

00:01:41,623 --> 00:01:43,638

And, sometimes you discover

33

00:01:43,640 --> 00:01:46,777

that something you thought was  
a requirement really isn't a

34

00:01:46,780 --> 00:01:47,914

requirement at all.

35

00:01:47,920 --> 00:01:51,490

It's an artificial thing  
that you imposed on yourself,

36

00:01:51,490 --> 00:01:53,082

and it turns out that,  
that wall doesn't exist.

37

00:01:53,082 --> 00:01:56,183

And, so, when people-and  
I never knew this

38

00:01:56,183 --> 00:01:58,549

until I actually got  
to this point, right?

39

00:01:58,549 --> 00:02:03,328

People never told me that  
thinking outside the box, okay,

40

00:02:03,328 --> 00:02:09,259

is simply a question of knowing  
which side of that wall you need

41

00:02:09,260 --> 00:02:12,497

to be in, and whether  
you can think about --

42

00:02:12,500 --> 00:02:14,502

if that's not really  
a requirement --

43

00:02:14,502 --> 00:02:16,819  
you can do those things.

44

00:02:16,820 --> 00:02:20,657  
Now, once you do those  
things, now, here's the key,

45

00:02:20,660 --> 00:02:24,497  
knowing which rule to break  
is the really important part.

46

00:02:24,500 --> 00:02:26,102  
Because, sometimes  
it's okay to break

47

00:02:26,102 --> 00:02:28,703  
that rule; sometimes it's not.

48

00:02:28,703 --> 00:02:31,135  
You have to know when  
you can do those things.

49

00:02:31,180 --> 00:02:33,066  
Okay. But, here's the problem.

50

00:02:33,066 --> 00:02:38,565  
Once you create a solution,  
once you create an idea, right?

51

00:02:38,565 --> 00:02:41,496  
We carry those things -- you  
can see that in your mind.

52

00:02:41,500 --> 00:02:44,170  
When I talk about people  
landing on the moon, okay?

53

00:02:44,170 --> 00:02:48,064

When I was your age,  
younger than you, actually,

54

00:02:48,064 --> 00:02:49,194

people walked on the moon!

55

00:02:49,200 --> 00:02:51,919

I saw it live, alright?

56

00:02:51,980 --> 00:02:53,982

It was that exciting!

57

00:02:53,982 --> 00:02:55,348

It was incredible to see!

58

00:02:55,380 --> 00:02:57,950

That these -- there were 12  
people that walked on the moon.

59

00:02:57,950 --> 00:02:59,408

You ever get that  
opportunity to go hear one

60

00:02:59,408 --> 00:03:02,503

of those guys, you  
must go do it.

61

00:03:02,503 --> 00:03:04,902

Hands down, no question.

62

00:03:04,902 --> 00:03:06,335

There's only eight of them left.

63

00:03:06,340 --> 00:03:09,426

There were 12, there are  
only eight of them left.

64

00:03:09,426 --> 00:03:11,856  
You know what I'm saying.

65  
00:03:11,860 --> 00:03:13,295  
Okay. You need to go do this.

66  
00:03:13,340 --> 00:03:17,244  
If you-even just the guys  
who went to the moon,

67  
00:03:17,244 --> 00:03:22,045  
that's just so amazing that we  
had the audacity to do that.

68  
00:03:22,060 --> 00:03:25,346  
Now, we think going to Mars --  
that would be the same thing.

69  
00:03:25,346 --> 00:03:26,942  
Not at all.

70  
00:03:26,980 --> 00:03:27,681  
Can't do it.

71  
00:03:27,681 --> 00:03:29,440  
Can't do it the same way at all.

72  
00:03:29,440 --> 00:03:34,845  
It turns out it's a hundred  
times as long to get there,

73  
00:03:34,845 --> 00:03:36,442  
and it's a thousand  
times as far.

74  
00:03:36,442 --> 00:03:39,076  
We can't do it the same way.

75  
00:03:39,080 --> 00:03:41,833

Somebody's going to have  
to solve that problem, and,

76

00:03:41,840 --> 00:03:42,874

I can guarantee you  
it's not going

77

00:03:42,880 --> 00:03:45,316

to be guys that look like me.

78

00:03:45,320 --> 00:03:46,388

It's going to be guys  
that look like you

79

00:03:46,388 --> 00:03:49,383

that are going to  
figure this out.

80

00:03:49,420 --> 00:03:54,224

Alright? So, requirements,  
assumptions, concepts,

81

00:03:54,224 --> 00:03:56,289

and ideas, and, by the way,  
once you see that idea,

82

00:03:56,320 --> 00:03:59,206

you can put it in your  
tool bag, and they call

83

00:03:59,206 --> 00:04:00,969

that experience, right?

84

00:04:00,969 --> 00:04:05,631

That's why places that  
employ us keep guys

85

00:04:05,640 --> 00:04:06,680

that look like me around.

86

00:04:06,680 --> 00:04:10,217

Even though we're dead  
weight baggage, alright?

87

00:04:10,220 --> 00:04:11,388

Seriously!

88

00:04:11,388 --> 00:04:12,381

They talk about experience.

89

00:04:12,381 --> 00:04:14,198

"Oh, yeah, we solved this  
problem once before.

90

00:04:14,200 --> 00:04:17,570

Hang on a second," and  
you pull that out, and,

91

00:04:17,570 --> 00:04:19,462

that's not what  
we're looking for.

92

00:04:19,462 --> 00:04:22,814

We're going, "well  
why did you do that? That

93

00:04:22,820 --> 00:04:25,739

was dumb. You didn't need  
to do this part."

94

00:04:25,740 --> 00:04:27,876

That's what we're looking for.

95

00:04:27,880 --> 00:04:29,948

How to solve these  
problems, differently.

96

00:04:29,948 --> 00:04:33,594

Okay. So, one of the

things I want to talk about,

97

00:04:33,600 --> 00:04:35,168

There's an atmosphere on Mars.

98

00:04:35,168 --> 00:04:37,496

Remember, just a couple weeks ago, right?

99

00:04:37,500 --> 00:04:38,267

There's water on Mars.

100

00:04:38,267 --> 00:04:40,796

Liquid water on Mars.

101

00:04:40,800 --> 00:04:42,302

So, you have an atmosphere; you have water.

102

00:04:42,302 --> 00:04:46,404

Okay. If you have an atmosphere and water on Mars, then,

103

00:04:46,404 --> 00:04:47,918

you can fly an airplane there.

104

00:04:47,920 --> 00:04:51,891

One of the things we don't talk about a whole heck of a lot,

105

00:04:51,900 --> 00:04:55,400

is if you have water on Mars, and if you have an atmosphere

106

00:04:55,400 --> 00:04:58,603

on Mars, by the way, those are two products

107

00:04:58,603 --> 00:05:01,536

that are rocket exhaust.

108

00:05:01,540 --> 00:05:05,895

If you have rocket exhaust  
on Mars, adding energy to it,

109

00:05:05,900 --> 00:05:09,470

you can break that back down,  
turn it back into rocket fuel.

110

00:05:09,470 --> 00:05:11,962

When the astronauts leave,  
and this is not talked

111

00:05:11,962 --> 00:05:14,530

about very much, either, and  
I've been really surprised

112

00:05:14,530 --> 00:05:19,057

about this, when they leave-from  
the moon-to go to Mars.

113

00:05:19,060 --> 00:05:20,478

We're not leaving from Earth.

114

00:05:20,480 --> 00:05:23,784

We're leaving from the  
moon to go to Mars.

115

00:05:23,784 --> 00:05:27,016

Okay? When they leave from  
the moon to go to Mars,

116

00:05:27,020 --> 00:05:29,756

the amount of fuel that  
they're going to have on board

117

00:05:29,760 --> 00:05:33,564

to come back from Mars is zero.

118

00:05:33,564 --> 00:05:37,514

They're going to manufacture  
all their rocket fuel on Mars.

119

00:05:37,520 --> 00:05:41,691

By the way, nobody's invented  
that machine to do that, yet.

120

00:05:41,700 --> 00:05:42,768

We know how to do it.

121

00:05:42,768 --> 00:05:46,330

We can do it in a lab, but  
nobody's done that, yet.

122

00:05:46,330 --> 00:05:48,222

Again, the people who  
solve that problem --

123

00:05:48,222 --> 00:05:52,722

that's not me, that's  
going to be you guys.

124

00:05:52,722 --> 00:05:54,572

All you guys.

125

00:05:54,580 --> 00:05:58,851

Okay. So, we have an atmosphere.

126

00:05:58,860 --> 00:06:02,497

We could potentially make an  
airplane that could fly on Mars.

127

00:06:02,500 --> 00:06:06,304

Now, there have been people  
who have been captivated

128

00:06:06,304 --> 00:06:08,369

by this idea since the 1970s.

129

00:06:08,369 --> 00:06:11,980

I knew some of those people  
when I was an intern at NASA,

130

00:06:11,980 --> 00:06:14,282

and that was 35 years ago.

131

00:06:14,282 --> 00:06:18,251

Alright? And those  
guys are gone, now.

132

00:06:18,260 --> 00:06:22,130

But, there have been  
nine proposals

133

00:06:22,140 --> 00:06:25,544

to fly an airplane on Mars.

134

00:06:25,580 --> 00:06:27,932

I've been on eight of them.

135

00:06:27,940 --> 00:06:30,376

They still haven't flown  
an airplane on Mars.

136

00:06:30,380 --> 00:06:33,350

I want this to happen so bad.

137

00:06:33,350 --> 00:06:35,675

You have no idea.

138

00:06:35,680 --> 00:06:37,482

This excites me!

139

00:06:37,482 --> 00:06:40,181

Okay. One of the other  
problems I've been working

140

00:06:40,181 --> 00:06:44,334

on for an incredibly long  
time -- flying wings.

141

00:06:44,340 --> 00:06:46,308

This was a problem that  
I set out to solve,

142

00:06:46,308 --> 00:06:49,037

and it was done in  
my spare time.

143

00:06:49,040 --> 00:06:52,610

And a really close buddy  
of mine, he was a professor

144

00:06:52,610 --> 00:06:55,436

at a university, and he used to  
come and visit for the summer,

145

00:06:55,440 --> 00:06:57,542

and he gave me all  
this information.

146

00:06:57,542 --> 00:07:00,360

He said "you know, flying  
wings, they look just so simple,

147

00:07:00,360 --> 00:07:01,961

but they're really hard to fly,

148

00:07:01,961 --> 00:07:05,796

they don't handle  
well, and, why is that?

149

00:07:05,800 --> 00:07:09,571

You look at this thing and  
you go "this should be awesome,"

150

00:07:09,580 --> 00:07:10,940  
and it doesn't work.

151  
00:07:10,941 --> 00:07:14,043  
It doesn't work for  
the pilot very well.

152  
00:07:14,043 --> 00:07:15,875  
Why is that?

153  
00:07:15,880 --> 00:07:17,866  
What are we missing?

154  
00:07:17,866 --> 00:07:21,497  
There's something fundamental  
here that we are missing.

155  
00:07:21,500 --> 00:07:25,237  
Well, so one of the ways you  
solve this problem is you put a

156  
00:07:25,240 --> 00:07:27,509  
tail on a flying wing, so it's  
not a flying wing anymore,

157  
00:07:27,509 --> 00:07:28,134  
right?

158  
00:07:28,140 --> 00:07:29,341  
Where does that come from?

159  
00:07:29,341 --> 00:07:31,308  
It comes from these two guys,  
Wilbur and Orville Wright.

160  
00:07:31,308 --> 00:07:34,720  
Turns out their first three  
solutions to the problem,

161

00:07:34,720 --> 00:07:37,790

they didn't have a tail on  
their airplane, on the back.

162

00:07:37,790 --> 00:07:40,183

They weren't trying to  
steer with the rudder.

163

00:07:40,183 --> 00:07:43,416

They did not solve  
the problem that way.

164

00:07:43,420 --> 00:07:47,257

This, actually, was the  
thing they'd missed.

165

00:07:47,260 --> 00:07:48,460

When they would bank  
their airplane,

166

00:07:48,460 --> 00:07:50,411

they would create more lift.

167

00:07:50,420 --> 00:07:51,722

This was their key.

168

00:07:51,760 --> 00:07:53,795

I can prove this to you, watch.

169

00:07:53,900 --> 00:07:56,503

They would bank the  
airplane in order to turn,

170

00:07:56,503 --> 00:07:58,802

but when you create more  
lift, you create more drag.

171

00:07:58,802 --> 00:08:01,336

So, they would bank, but the  
airplane would slice the wrong

172

00:08:01,340 --> 00:08:04,276  
way, and then it would  
crash into the ground.

173

00:08:04,280 --> 00:08:10,270  
And this flyer right here, their  
1901 glider, they flew hundreds

174

00:08:10,270 --> 00:08:13,419  
of times, and Wilbur was  
so frustrated at the end

175

00:08:13,420 --> 00:08:14,722  
of that flying season, he said

176

00:08:14,722 --> 00:08:17,689  
that man would not  
fly for 50 years.

177

00:08:17,689 --> 00:08:20,783  
They went back, they did a  
bunch of wind tunnel tests,

178

00:08:20,783 --> 00:08:24,034  
and in 1902, they came  
back with an airplane,

179

00:08:24,040 --> 00:08:26,609  
a glider that had  
a vertical tail.

180

00:08:26,620 --> 00:08:27,854  
They solved this problem.

181

00:08:27,860 --> 00:08:32,865  
Their entire flying season that  
year was two weeks, 14 days.

182

00:08:32,865 --> 00:08:34,128

That was it.

183

00:08:34,128 --> 00:08:37,590

And at the end of that 14 days,  
they were done; they were ready.

184

00:08:37,590 --> 00:08:40,180

Because the next time they  
came back to Kitty Hawk,

185

00:08:40,190 --> 00:08:43,933

the following year, 1903,

186

00:08:43,940 --> 00:08:45,108

and they flew their  
airplane for the first time.

187

00:08:45,108 --> 00:08:48,937

But when they went back in  
1906, to patent their idea,

188

00:08:48,940 --> 00:08:54,546

right here, there was no engine,  
there were no propellers.

189

00:08:54,546 --> 00:08:56,776

They patented their glider.

190

00:08:56,780 --> 00:08:59,532

And the reason they patented  
their glider as the airplane,

191

00:08:59,540 --> 00:09:02,143

it was all about the control.

192

00:09:02,143 --> 00:09:03,575

Now, they had a device  
on the back

193

00:09:03,580 --> 00:09:05,482

when they would bank their  
airplane, they would turn

194

00:09:05,482 --> 00:09:08,616

that rudder, and they  
could control yaw.

195

00:09:08,620 --> 00:09:09,688

Guess what?

196

00:09:09,688 --> 00:09:12,583

We still solved that  
problem the same way, today.

197

00:09:12,620 --> 00:09:15,740

Airplanes have some direct  
method of controlling yaw

198

00:09:15,740 --> 00:09:19,443

on them, even the B-2, even  
though it doesn't have a rudder.

199

00:09:19,443 --> 00:09:21,642

I'll show you that later on.

200

00:09:22,960 --> 00:09:27,398

So, flying wings appear  
to not be possible.

201

00:09:27,400 --> 00:09:28,367

Why is that?

202

00:09:28,367 --> 00:09:31,547

So, this guy, Ludwig  
Prandtl, a brilliant man,

203

00:09:31,547 --> 00:09:34,776

should have won the

## Nobel Prize for physics

204

00:09:34,780 --> 00:09:37,650

because of his contributions  
to aeronautics.

205

00:09:37,650 --> 00:09:41,777

He figured out the tool, and his  
tool was called the Lifting

206

00:09:41,780 --> 00:09:44,216

Line. His tool predicted the  
performance of wings.

207

00:09:44,220 --> 00:09:47,440

It was the first time anybody  
could predict what the wing

208

00:09:47,440 --> 00:09:51,477

would fly like before  
you actually built it.

209

00:09:51,480 --> 00:09:52,815

You could do this with math.

210

00:09:52,820 --> 00:09:59,393

Okay? It was brilliant what he  
did, and he did that in 1918.

211

00:09:59,400 --> 00:10:02,770

And he had four really brilliant  
students working for him,

212

00:10:02,770 --> 00:10:05,713

at that time, who carried  
on his work after he retired

213

00:10:05,720 --> 00:10:07,489

from being a professor.

214

00:10:07,489 --> 00:10:09,215

But, one of the things  
he discovered,

215

00:10:09,220 --> 00:10:11,188

once you have a tool,  
you can do optimization.

216

00:10:11,188 --> 00:10:15,218

You can find out what's the  
minimum drag for this wing,

217

00:10:15,220 --> 00:10:19,924

and when you do that, by the  
way, you end up with an ellipse,

218

00:10:19,924 --> 00:10:22,740

right here, right across that.

219

00:10:22,740 --> 00:10:25,743

So, this is the standard theory.

220

00:10:25,743 --> 00:10:28,876

But, there's two ways of  
measuring the size of a wing,

221

00:10:28,880 --> 00:10:30,349

and this was the one way.

222

00:10:30,349 --> 00:10:31,841

Everybody thought  
about the wing span.

223

00:10:31,841 --> 00:10:34,476

Remember that box?

224

00:10:34,480 --> 00:10:36,549

So, that's one requirement.

225

00:10:36,549 --> 00:10:37,424

What's the wing span?

226

00:10:37,424 --> 00:10:40,523

You have to optimize  
for the wing span.

227

00:10:40,523 --> 00:10:43,590

Here's the funny thing,  
somewhere along the way,

228

00:10:43,590 --> 00:10:44,714

somebody forgot --

229

00:10:44,720 --> 00:10:51,227

oh, sometimes, you can actually  
see this on airplanes.

230

00:10:51,227 --> 00:10:54,707

See the ellipse over the wing  
from one wing tip to the other?

231

00:10:54,707 --> 00:10:55,500

Now, watch what happens here.

232

00:10:55,500 --> 00:10:58,637

Okay? You get wing tip vortices.

233

00:10:58,640 --> 00:11:00,976

And his theory predicts  
this, also.

234

00:11:01,040 --> 00:11:04,309

These things are wing tip  
vortices straining off the wing,

235

00:11:04,309 --> 00:11:05,635

and they're leaving energy

236

00:11:05,640 --> 00:11:11,629

into the-in the air behind  
the wing, and this is drag.

237

00:11:11,629 --> 00:11:15,091

Sometimes, you can see both.

238

00:11:15,100 --> 00:11:15,900

Very rare.

239

00:11:18,460 --> 00:11:22,098

Okay. This is the  
standard theory.

240

00:11:22,098 --> 00:11:23,718

This is what everybody does.

241

00:11:23,720 --> 00:11:27,407

When you get to university,  
they're going to teach you this.

242

00:11:27,407 --> 00:11:31,570

And, it's not that they're  
wrong, but there is an

243

00:11:31,570 --> 00:11:35,164

alternative, and that  
alternative looks like this.

244

00:11:35,640 --> 00:11:41,246

And you see these every day, and  
the amazing thing is if you try

245

00:11:41,246 --> 00:11:43,509

and find out in the  
scientific literature,

246

00:11:43,509 --> 00:11:47,053

how these animals turn

without vertical tail,

247

00:11:47,060 --> 00:11:49,763

you will not find that paper.

248

00:11:49,763 --> 00:11:52,696

That paper does not exist.

249

00:11:52,700 --> 00:11:58,906

Now, if you could solve the  
flying wing problem, possibly,

250

00:11:58,906 --> 00:12:03,955

you would solve this problem.

251

00:12:03,960 --> 00:12:06,897

Let me tell you a story.

252

00:12:06,940 --> 00:12:11,244

Right here, notice, see  
that joint right there?

253

00:12:11,244 --> 00:12:14,009

That joint right  
there is a knuckle.

254

00:12:14,040 --> 00:12:18,895

Alright? So, when you have  
a knuckle those are fingers

255

00:12:18,900 --> 00:12:21,503

outboard of that point.

256

00:12:21,503 --> 00:12:26,471

And, in fact, from here on  
out that's a feather, right?

257

00:12:26,480 --> 00:12:28,583

So, let's stop and think about

a feather for a minute.

258

00:12:28,583 --> 00:12:32,116

Okay? How much load can you  
carry on the end of a feather?

259

00:12:32,120 --> 00:12:34,940

Nothing. Right?

260

00:12:34,940 --> 00:12:37,042

I just got done telling you

261

00:12:37,042 --> 00:12:39,542

that you should have an  
ellipse that goes on there.

262

00:12:39,542 --> 00:12:41,976

So, that means that 20 to  
30 percent of the weight

263

00:12:41,980 --> 00:12:44,716

of the bird should  
rest on this feather.

264

00:12:44,720 --> 00:12:46,500

That doesn't happen.

265

00:12:46,500 --> 00:12:47,298

Birds don't do that.

266

00:12:47,300 --> 00:12:48,467

This animal, Wandering  
Albatross,

267

00:12:48,467 --> 00:12:51,213

flies around the world  
five times every year

268

00:12:51,220 --> 00:12:56,726

when it leaves its nest, and  
then it comes back every year,

269

00:12:56,726 --> 00:12:57,854  
and then it goes and does this.

270

00:12:57,860 --> 00:12:59,528  
By the way, the oldest  
living bird

271

00:12:59,528 --> 00:13:01,422  
in the wild right  
now is an Albatross.

272

00:13:01,422 --> 00:13:02,755  
Her name is Wisdom.

273

00:13:02,760 --> 00:13:05,529  
She's 63 years old.

274

00:13:05,529 --> 00:13:09,041  
Okay? Five times around  
the world every year.

275

00:13:09,041 --> 00:13:12,443  
Stop and think about that.

276

00:13:12,443 --> 00:13:17,879  
Carrying 20 percent of  
her weight on her fingers.

277

00:13:17,880 --> 00:13:21,583  
Doesn't make sense;  
doesn't work.

278

00:13:21,583 --> 00:13:25,334  
So, remember that guy, Prandtl?

279

00:13:25,340 --> 00:13:30,178

He wondered about this  
problem, and he looks at this

280  
00:13:30,180 --> 00:13:33,450  
and he goes "that can't be  
right.

281  
00:13:33,480 --> 00:13:35,240  
What if we measured the  
wing in a different way,

282  
00:13:35,240 --> 00:13:37,273  
instead of just the wing span,

283  
00:13:37,280 --> 00:13:40,583  
what if we measured  
the weight of the wing?

284  
00:13:40,583 --> 00:13:42,299  
Let's hold the weight  
of the wing,

285  
00:13:42,300 --> 00:13:44,168  
and not constrain  
the wing span."

286  
00:13:44,168 --> 00:13:45,128  
Now, what happens?

287  
00:13:45,128 --> 00:13:46,708  
Here's our old friend  
the ellipse, right?

288  
00:13:47,760 --> 00:13:52,400  
Right here, curve A,  
and stops right here.

289  
00:13:52,400 --> 00:13:56,804  
But if you make it the same  
weight, exact same weight,

290

00:13:56,804 --> 00:14:00,220  
not one ounce more  
for structure, okay?

291

00:14:00,220 --> 00:14:03,724  
And you get the same lift,

292

00:14:03,760 --> 00:14:05,261  
what's the minimum  
drag solution?

293

00:14:05,261 --> 00:14:06,328  
And it looks like this.

294

00:14:06,328 --> 00:14:09,857  
And this is curve C that  
goes all the way out here,

295

00:14:09,900 --> 00:14:12,002  
and goes to zero at the tip.

296

00:14:12,002 --> 00:14:14,842  
You notice how it tapers  
to nothing at the tip?

297

00:14:15,600 --> 00:14:19,480  
It tapers to nothing at the tip,  
and all the sudden you can carry

298

00:14:19,480 --> 00:14:22,950  
that load on your tip, because  
you don't have any load.

299

00:14:23,330 --> 00:14:27,391  
But, there's something funny  
about the drag and the thing

300

00:14:27,400 --> 00:14:32,588

that causes that vortex at  
the tip is called downwash.

301

00:14:32,588 --> 00:14:35,483

Alright? Here's the elliptical  
downwash, it's straight,

302

00:14:35,483 --> 00:14:38,083

and then you step off the  
curve, and there's a downwash,

303

00:14:38,120 --> 00:14:41,290

right here, and it  
causes a vortex.

304

00:14:41,600 --> 00:14:45,437

Alright? But here's what happens  
when you use the other curve.

305

00:14:45,440 --> 00:14:50,028

The curve C, it's this long,  
sweeping curve that's down,

306

00:14:50,028 --> 00:14:54,624

crosses over, and then it  
becomes upwash at the tip.

307

00:14:54,624 --> 00:14:55,922

In other words, it's  
not drag at the tip,

308

00:14:55,922 --> 00:14:58,789

it's thrust at the tip.

309

00:14:58,789 --> 00:15:00,815

Now, if it's thrust at the  
tip, and you create more lift,

310

00:15:00,820 --> 00:15:02,856

you create more thrust,

and you roll,

311

00:15:02,860 --> 00:15:04,845

and you yaw the  
correct direction,

312

00:15:04,880 --> 00:15:07,016

and you don't need  
a vertical tail.

313

00:15:07,020 --> 00:15:09,122

Now, the guy who came  
up with this idea,

314

00:15:09,122 --> 00:15:11,522

this paper, was written in 1933.

315

00:15:11,522 --> 00:15:13,555

The man's name is Ludwig  
Prandtl.

316

00:15:13,600 --> 00:15:18,105

The most brilliant man on  
the planet in this area,

317

00:15:18,105 --> 00:15:22,087

and he missed that last part.

318

00:15:23,460 --> 00:15:26,060

He never made that connection  
that there would be thrust

319

00:15:26,060 --> 00:15:35,060

there on the wing tips, and this  
paper laid there until 2007.

320

00:15:37,140 --> 00:15:42,153

And then I read the paper.

321

00:15:42,157 --> 00:15:47,337

Now, I want you to understand, Prandtl is up here.

322

00:15:47,340 --> 00:15:51,411

Okay? I'm way down here on the floor.

323

00:15:51,420 --> 00:15:53,720

Okay? I am not that smart a guy.

324

00:15:53,720 --> 00:15:55,105

Believe me.

325

00:15:56,780 --> 00:16:00,283

Sometimes, it's just making the right connection.

326

00:16:00,283 --> 00:16:05,152

Anybody can make the right connection.

327

00:16:05,160 --> 00:16:07,796

Alright. So, there were two other guys that stumbled

328

00:16:07,800 --> 00:16:09,535

into this exact same thing.

329

00:16:09,540 --> 00:16:12,259

Each of them were working on a different piece of the puzzle.

330

00:16:12,260 --> 00:16:15,630

Horten figured out that he would have thrust at the tips,

331

00:16:15,630 --> 00:16:17,756

he was actually trying to create them with his airplane.

332

00:16:17,820 --> 00:16:21,056

By the way, Prandtl  
gave up in 1933.

333

00:16:21,060 --> 00:16:22,462

He never did anything  
with that paper again.

334

00:16:22,462 --> 00:16:24,995

Horten gave up in 1950.

335

00:16:25,000 --> 00:16:27,720

He never built another airplane  
again to try and prove this.

336

00:16:27,720 --> 00:16:30,289

And, by the way, R.T.  
Jones -- Robert T. Jones --

337

00:16:30,289 --> 00:16:31,681

who was the chief scientist

338

00:16:31,681 --> 00:16:35,050

at a place called The Ames  
Aeronautical Laboratory,

339

00:16:35,050 --> 00:16:38,377

up in San Francisco  
Bay area, I actually got

340

00:16:38,380 --> 00:16:43,352

to meet Dr. Jones;  
the real Dr. Jones.

341

00:16:43,360 --> 00:16:47,047

And, he really was impressive.

342

00:16:47,047 --> 00:16:50,977

Incredibly smart guy --  
incredibly smart guy.

343  
00:16:50,980 --> 00:16:53,416  
He did that exact same  
thing in 1950, and again,

344  
00:16:53,420 --> 00:16:55,522  
he never did anything with it

345  
00:16:57,300 --> 00:17:00,580  
after that, either, and all  
these papers laid there until

346  
00:17:00,580 --> 00:17:02,883  
2007. I'm reading all three of  
these papers, I go

347  
00:17:02,883 --> 00:17:06,684  
"wait a second, I've heard  
something like this before."

348  
00:17:06,684 --> 00:17:10,344  
And, I was the one that  
put the pieces together.

349  
00:17:10,344 --> 00:17:11,541  
So, here's what happens.

350  
00:17:13,340 --> 00:17:15,820  
I calculated the answer, and  
I go "that can't be right."

351  
00:17:15,820 --> 00:17:17,560  
I had been trained as a pilot.

352  
00:17:17,560 --> 00:17:18,876  
I knew what the rudder  
pedals were for.

353

00:17:18,880 --> 00:17:20,982

I knew what a rudder was.

354

00:17:20,982 --> 00:17:21,981

Adverse yaw is a fact of life.

355

00:17:21,981 --> 00:17:23,448

You just can't escape that.

356

00:17:23,448 --> 00:17:26,820

And, I had an intern  
working with me, at the time.

357

00:17:26,820 --> 00:17:28,022

Mike Allen.

358

00:17:28,022 --> 00:17:29,955

Mike said, "of course  
it's right.

359

00:17:29,960 --> 00:17:31,795

You calculated those numbers.

360

00:17:31,800 --> 00:17:33,435

Give me those numbers".

361

00:17:33,440 --> 00:17:34,574

And he went away  
for the weekend,

362

00:17:34,580 --> 00:17:34,964

and he built this airplane.

363

00:17:34,964 --> 00:17:36,195

Guess what?

364

00:17:36,200 --> 00:17:40,337

This thing flew exactly like

a bird -- exactly like a bird.

365

00:17:40,340 --> 00:17:44,544

And, this had that exact same curve in it that produces

366

00:17:44,580 --> 00:17:47,283

that lift distribution

that I showed you earlier.

367

00:17:47,283 --> 00:17:53,763

Mike built the very first one.

368

00:17:53,763 --> 00:17:54,460

So, this is what it looks like.

369

00:17:54,460 --> 00:17:55,595

Remember, I was talking

370

00:17:55,600 --> 00:17:58,100

about the flow off the trailing edge, right? Downwash?

371

00:17:58,100 --> 00:17:59,080

Here it is.

372

00:17:59,080 --> 00:18:02,920

Here it's down, and then it crosses over and it becomes up.

373

00:18:02,920 --> 00:18:04,922

And, if you look carefully right here, look at this;

374

00:18:04,922 --> 00:18:07,940

down and up, down and up.

375

00:18:07,940 --> 00:18:10,776

In fact, that looks just like

it might be a vortex, huh?

376

00:18:10,780 --> 00:18:12,749

The vortex wouldn't  
be at the tip.

377

00:18:12,749 --> 00:18:17,277

In fact, if you released  
the wake, is what we say

378

00:18:17,280 --> 00:18:18,248

as an engineer, you've got

379

00:18:18,248 --> 00:18:21,010

to have some fancy  
term for it, right?

380

00:18:21,010 --> 00:18:25,421

So, we release the wake, then  
we end up with the vortices.

381

00:18:25,421 --> 00:18:27,021

You can see that.

382

00:18:27,021 --> 00:18:30,457

Now, if you could actually  
see this on the airplane,

383

00:18:30,460 --> 00:18:34,898

then you might be able to  
see where the vortices were.

384

00:18:35,540 --> 00:18:37,800

The vortices are not  
at the wing tips.

385

00:18:37,800 --> 00:18:39,800

By the way, one of  
the hardest things

386

00:18:39,800 --> 00:18:42,780

to stop doing is saying  
wing tip vortices.

387

00:18:42,788 --> 00:18:47,685

I still say it, so if you  
catch me, call me on it.

388

00:18:47,685 --> 00:18:50,480

Okay? But, these  
are wing vortices,

389

00:18:50,480 --> 00:18:52,840

they're not wing tip vortices.

390

00:18:52,880 --> 00:18:55,149

But that means there's  
upwash at the tip,

391

00:18:55,149 --> 00:18:56,942

and there's thrust out there.

392

00:18:56,942 --> 00:18:58,758

And, oh, by the way, if  
birds really did this,

393

00:18:58,800 --> 00:19:01,770

then when birds flew in  
formation, they would fly

394

00:19:01,770 --> 00:19:04,529

with those vortices  
aligned, and they would fly

395

00:19:04,529 --> 00:19:06,589

with their wing tips overlapped.

396

00:19:09,260 --> 00:19:16,720

Okay? Now, you start looking

at this stuff and you go,

397

00:19:16,720 --> 00:19:20,120

"Well maybe there's scientific papers on this stuff."

398

00:19:20,120 --> 00:19:21,788

Sure enough, there is.

399

00:19:21,788 --> 00:19:22,948

This is Jeff Spedding.

400

00:19:22,948 --> 00:19:25,709

The man got his Ph. D. in Bristol, England.

401

00:19:25,760 --> 00:19:29,564

He is now a Professor of Aeronautics down at USC.

402

00:19:29,564 --> 00:19:31,912

In fact, unfortunately, I have to lecture

403

00:19:31,920 --> 00:19:34,523

to his class this afternoon.

404

00:19:34,523 --> 00:19:35,955

So, I can't stick around for lunch.

405

00:19:35,960 --> 00:19:39,697

So, while you guys are enjoying lunch, I'm going to be driving,

406

00:19:39,700 --> 00:19:42,436

which might be challenging today, actually,

407

00:19:42,440 --> 00:19:44,809  
and I have to talk to the class,

408

00:19:44,840 --> 00:19:49,228  
and to their professor  
who did this data.

409

00:19:49,228 --> 00:19:51,622  
But, "it's elliptical, the  
vortices have to come from the

410

00:19:51,622 --> 00:19:54,990  
wing tips!" So, he draws curves  
on his data, in order to try

411

00:19:54,990 --> 00:19:58,584  
and force the vortices to  
come from the wing tips.

412

00:19:58,584 --> 00:20:01,316  
If he'd just drawn  
straight lines,

413

00:20:01,360 --> 00:20:03,896  
he would have had  
the right answer.

414

00:20:03,900 --> 00:20:05,151  
But he didn't.

415

00:20:05,160 --> 00:20:08,380  
And, by the way, other people  
have seen this exact same thing

416

00:20:08,380 --> 00:20:09,340  
with birds.

417

00:20:09,340 --> 00:20:11,008  
Upwash at the wing tips.

418

00:20:11,008 --> 00:20:14,904

Okay? If you take everybody's data that's ever done this,

419

00:20:14,904 --> 00:20:17,670

the formation flight of birds, where birds like to fly,

420

00:20:17,670 --> 00:20:20,663

four different papers.

421

00:20:20,663 --> 00:20:23,512

You take all these and you normalize them for the number

422

00:20:23,520 --> 00:20:25,656

of samples, and for their wing span,

423

00:20:25,660 --> 00:20:29,063

and overlay everybody's data, you get these curves,

424

00:20:29,063 --> 00:20:31,763

and you can clearly see where the birds like to fly.

425

00:20:31,763 --> 00:20:34,963

Right here, where this orange column is.

426

00:20:34,963 --> 00:20:37,596

Alright? And this blue line, right here,

427

00:20:37,600 --> 00:20:42,922

this blue line is PRANDTL on the inside, and this part out here,

428

00:20:42,922 --> 00:20:45,189

my interns  
and I calculated that,

429

00:20:47,080 --> 00:20:52,600

and our data exactly  
matches what the birds did.

430

00:20:52,601 --> 00:20:55,404

Why don't birds have  
a tip stall problem?

431

00:20:55,404 --> 00:20:56,564

This is a really big deal.

432

00:20:56,564 --> 00:20:58,044

Everyone always asks  
me this question.

433

00:20:58,044 --> 00:20:59,900

It's like the second  
or third question

434

00:20:59,900 --> 00:21:02,528

out of an aerodynamicist's mind.

435

00:21:02,528 --> 00:21:05,423

Because flying wings  
have this problem.

436

00:21:05,423 --> 00:21:06,955

They have a huge  
problem with tip stall.

437

00:21:07,000 --> 00:21:09,636

Why don't birds have  
a tip stall problem?

438

00:21:09,640 --> 00:21:11,208

It's because their

lift coefficient goes

439

00:21:11,208 --> 00:21:13,386  
to zero at the tip.

440

00:21:13,386 --> 00:21:16,616  
Oh, by the way, the maximum  
lift coefficient is in here,

441

00:21:16,620 --> 00:21:20,725  
about 20 to 30 percent of  
the way from the center line.

442

00:21:20,725 --> 00:21:24,523  
Okay? And, so, if a bird flew  
by you very, very slowly,

443

00:21:24,523 --> 00:21:28,841  
and it was right near stall,  
then you might be able

444

00:21:28,880 --> 00:21:31,983  
to see the feathers ruffle at  
that 20 to 30 percent of the way

445

00:21:31,983 --> 00:21:34,850  
out from the tip, because  
the wing is starting

446

00:21:34,850 --> 00:21:39,078  
to stall right there  
for the bird.

447

00:21:39,080 --> 00:21:40,881  
All these things  
led us to believe

448

00:21:40,881 --> 00:21:42,982  
that we had the exact answer

449

00:21:42,982 --> 00:21:45,016

that the birds have  
been using all along,

450

00:21:45,020 --> 00:21:48,940

and they haven't  
been telling us.

451

00:21:50,140 --> 00:21:52,776

So, we built the airplane,  
and we actually got the data

452

00:21:52,780 --> 00:21:54,520

and predicted what it should be.

453

00:21:54,520 --> 00:21:56,800

That's the black line.

454

00:21:56,800 --> 00:21:59,770

That black line was  
calculated by Mike Allen and I,

455

00:21:59,770 --> 00:22:04,414

and then my interns in 2011, and  
2012, produced the scatter data,

456

00:22:04,420 --> 00:22:09,692

here, that you see, that  
almost matches the black line.

457

00:22:12,000 --> 00:22:15,940

And that term, by the  
way, is called Cnda.

458

00:22:15,940 --> 00:22:17,942

Alright? And that's  
coefficient

459

00:22:17,942 --> 00:22:24,664

of yawing moment due to  
aileron deflection, Cnda.

460

00:22:24,664 --> 00:22:27,329

And we predicted that, and  
it's coming up very, very close.

461

00:22:27,329 --> 00:22:31,891

We had, this last summer, we  
got 58 more points that we've put

462

00:22:31,900 --> 00:22:36,521

on this scatter plot, and that  
was done by, again, my interns.

463

00:22:36,521 --> 00:22:40,659

So, we've built several  
different aircraft.

464

00:22:40,659 --> 00:22:43,095

We've done, in fact,  
only nine aircraft

465

00:22:43,095 --> 00:22:44,730

like this have ever been built.

466

00:22:44,730 --> 00:22:46,750

The tenth one is being  
built right now,

467

00:22:46,750 --> 00:22:49,843

and two of our interns,  
actually, three of them,

468

00:22:49,843 --> 00:22:52,526

are working on doing  
an inertia swing

469

00:22:52,526 --> 00:22:54,689

on that probably next week.

470

00:22:55,460 --> 00:22:58,180

And, that would be the  
tenth airplane that's ever

471

00:22:58,180 --> 00:22:58,820

done this.

472

00:22:58,820 --> 00:23:03,625

By the way, ten, ever, in  
the history of aviation,

473

00:23:03,625 --> 00:23:07,223

and eight of those,  
came out of our lab.

474

00:23:08,880 --> 00:23:11,490

I know the guys who  
did the other two.

475

00:23:11,490 --> 00:23:14,760

They're buddies of mine, too.

476

00:23:14,760 --> 00:23:18,280

So, your options; you  
can either drag a tail

477

00:23:18,280 --> 00:23:20,520

around with you all  
the time, okay,

478

00:23:20,520 --> 00:23:21,921

which is the way  
everybody else does it,

479

00:23:21,921 --> 00:23:25,240

or you can manipulate drag at  
the wing tips to control yaw.

480

00:23:25,240 --> 00:23:29,411

See how the B-2 has to fly  
with its wing tip rudders,

481

00:23:29,420 --> 00:23:32,256

those drag things open?

482

00:23:32,260 --> 00:23:33,261

Go look at that.

483

00:23:33,261 --> 00:23:34,494

Go see if you can find a  
picture of those closed.

484

00:23:34,500 --> 00:23:36,769

There's one, actually,  
but it was photoshopped.

485

00:23:36,769 --> 00:23:39,296

You can tell because  
there's another photo

486

00:23:39,300 --> 00:23:40,969

of it exactly the  
same with them open,

487

00:23:40,969 --> 00:23:43,212

and you're going-and the  
clouds are exactly the same

488

00:23:43,220 --> 00:23:47,324

in the background,  
and you're going "No."

489

00:23:47,324 --> 00:23:52,492

Or, you can manipulate thrust  
at the wing tips to control yaw.

490

00:23:55,920 --> 00:23:59,955

By the way, I think vertebrate

flight has been doing this

491

00:23:59,955 --> 00:24:02,057  
for a really long time.

492

00:24:02,057 --> 00:24:04,292  
Pterosaur bones, right?

493

00:24:04,292 --> 00:24:06,061  
Look at those bones  
out there at the tip.

494

00:24:06,061 --> 00:24:07,601  
Hundred and twenty eight million  
years they've been doing the

495

00:24:07,601 --> 00:24:09,635  
same solution.

496

00:24:09,640 --> 00:24:12,943  
How much of a load can  
you carry on that bone?

497

00:24:13,460 --> 00:24:20,317  
Nothing. So, there's  
huge efficiency gains.

498

00:24:20,320 --> 00:24:22,522  
What if you could make  
this work on Mars?

499

00:24:23,520 --> 00:24:25,720  
This is very, very stable.

500

00:24:25,730 --> 00:24:26,765  
It flies very naturally.

501

00:24:26,765 --> 00:24:27,732  
You're going to see some of that.

502

00:24:27,732 --> 00:24:31,169

You're going to hear  
some of that later on.

503

00:24:31,169 --> 00:24:34,089

We can make this work on Mars.

504

00:24:34,089 --> 00:24:36,929

So, the mission would  
be something like this;

505

00:24:36,929 --> 00:24:39,823

we're going to go on  
a large Mars rover,

506

00:24:39,823 --> 00:24:43,324

and they always carry a little  
bit of ballast with them.

507

00:24:43,324 --> 00:24:48,775

We want to send a CubeSat,  
a three year CubeSat.

508

00:24:48,780 --> 00:24:50,980

About like this, okay?

509

00:24:50,980 --> 00:24:54,960

And, inside would be  
an airplane, rolled up.

510

00:24:54,960 --> 00:24:57,400

And, after it would  
descend on a parachute.

511

00:24:57,400 --> 00:24:59,600

And, by the way, you would  
deploy the parachute before you

512

00:24:59,600 --> 00:25:00,801  
enter the atmosphere.

513  
00:25:00,801 --> 00:25:05,136  
This is a huge innovation  
that's only just been started --

514  
00:25:05,136 --> 00:25:07,436  
experimented with  
up at NASA Ames.

515  
00:25:07,440 --> 00:25:10,980  
Started in March of this year,  
they actually deployed a CubeSat

516  
00:25:10,980 --> 00:25:12,815  
from space off the  
International Space Station.

517  
00:25:12,820 --> 00:25:15,960  
In fact, that's what that photo  
is up there, the second one,

518  
00:25:15,960 --> 00:25:18,662  
and that -- they put  
a parachute on there,

519  
00:25:18,662 --> 00:25:20,028  
and the thing came back  
in the Earth's atmosphere,

520  
00:25:20,028 --> 00:25:23,073  
didn't burn up, no heat  
shield, doesn't need it,

521  
00:25:23,080 --> 00:25:25,783  
uses a parachute, instead.

522  
00:25:25,783 --> 00:25:30,618  
It's a brilliant idea,

and after you do that,

523

00:25:30,620 --> 00:25:32,722

the second on the  
parachute, they

524

00:25:32,760 --> 00:25:37,065

deploy this thing from CubeSat.

525

00:25:37,065 --> 00:25:38,328

And it would unroll.

526

00:25:38,328 --> 00:25:42,574

And, you have a two foot wide  
airplane that weighed two pounds

527

00:25:42,580 --> 00:25:43,881

in the Martian atmosphere.

528

00:25:46,180 --> 00:25:47,960

Here on Earth, it  
would weigh two pounds.

529

00:25:47,963 --> 00:25:50,365

In Mars, it only weighs  
three-quarters of a pound.

530

00:25:50,365 --> 00:25:52,225

Different gravity, okay?

531

00:25:52,225 --> 00:25:53,721

Very thin atmosphere.

532

00:25:53,721 --> 00:25:55,872

It would glide at  
six-tenths Mach number,

533

00:25:55,880 --> 00:25:57,460

about 400 miles per hour

534

00:25:57,460 --> 00:25:59,695

for five minutes before it  
would collide with the ground.

535

00:25:59,700 --> 00:26:03,771

It would take photos, and if  
we could get this to deploy

536

00:26:03,780 --> 00:26:10,835

over a landing site, where  
the humans are going to land,

537

00:26:10,835 --> 00:26:17,192

we could see rocks down to  
about an inch with the video.

538

00:26:17,192 --> 00:26:18,860

I want that to happen.

539

00:26:18,860 --> 00:26:21,630

When this thing crashes on Mars,  
I want there to be a little,

540

00:26:21,630 --> 00:26:25,470

tiny chip on there with  
the name of every student

541

00:26:25,470 --> 00:26:31,150

that has ever worked  
on it to go with us.

542

00:26:33,240 --> 00:26:36,544

And then, finally, sometime  
later it would transmit the

543

00:26:36,544 --> 00:26:38,508

data and pictures back.

544

00:26:39,160 --> 00:26:42,340

This is our pilot,  
that's his personality,

545

00:26:42,340 --> 00:26:45,320

trying to get the band back  
together.

546

00:26:45,320 --> 00:26:47,255

These are my interns,  
these are all the names

547

00:26:47,260 --> 00:26:50,363

that I've got so far.

548

00:26:50,363 --> 00:26:51,495

This is an advertisement.

549

00:26:52,820 --> 00:26:55,020

I want you to come work with me.

550

00:26:55,020 --> 00:26:57,423

If you're a student, I  
want you to come work

551

00:26:57,423 --> 00:26:58,387

with me for the summer.

552

00:26:58,387 --> 00:27:02,701

Okay? We have limited  
slots, we really do.

553

00:27:02,701 --> 00:27:04,869

But I would love to take  
every student who wanted

554

00:27:04,869 --> 00:27:07,696

to come work on this with us.

555

00:27:07,700 --> 00:27:12,739

And it's the most awesome  
thing to actually go out and,

556

00:27:12,740 --> 00:27:16,443

I know you guys sometimes  
think, you know, we get to hang

557

00:27:16,443 --> 00:27:18,409

out with the chief -- one of  
the chief scientists at NASA.

558

00:27:18,409 --> 00:27:19,718

Yeah, that's true, right?

559

00:27:19,720 --> 00:27:23,824

But what happens is I have  
to run like a crazy man just

560

00:27:23,824 --> 00:27:27,691

to keep up with you  
all summer long.

561

00:27:27,700 --> 00:27:30,302

So, I don't take  
summer vacations.

562

00:27:30,302 --> 00:27:32,836

Oh, by the way, we pay.

563

00:27:32,840 --> 00:27:34,876

You'll hear about that  
here in a little bit.

564

00:27:34,880 --> 00:27:38,800

Come work with us.

565

00:27:38,800 --> 00:27:41,803

And, by the way, a couple of  
years ago, the students showed

566

00:27:41,803 --> 00:27:44,002  
up with cans of paint --  
that's always a bad thing.

567

00:27:44,002 --> 00:27:45,569  
They vandalized my  
parking space.

568

00:27:47,720 --> 00:27:50,435  
I hope they never change it.

569

00:27:50,435 --> 00:27:53,621  
>> This is clearly all about  
the aerodynamics, much more

570

00:27:53,621 --> 00:27:56,091  
about just making  
the wing shape work.

571

00:27:56,091 --> 00:27:59,071  
Has there been -- has  
anyone considered the idea

572

00:27:59,080 --> 00:28:00,580  
of what it would actually  
take to put an engine on one

573

00:28:00,580 --> 00:28:01,381  
of these, or is that  
not the focus

574

00:28:01,381 --> 00:28:03,481  
of your research at this time?

575

00:28:03,481 --> 00:28:04,949  
>> Al Bowers: Right at the  
moment, we're not talking

576

00:28:04,949 --> 00:28:07,302  
about doing an engine.

577

00:28:07,302 --> 00:28:09,888  
A lot of other people have  
considered putting engines,

578

00:28:09,888 --> 00:28:13,258  
the airplanes get  
very big, very fast.

579

00:28:13,258 --> 00:28:15,258  
One of the last ones  
that put an engine

580

00:28:15,260 --> 00:28:19,197  
on was ARIES, NASA Langley did.

581

00:28:19,197 --> 00:28:22,267  
And it ended up being  
bigger than a Cessna.

582

00:28:22,267 --> 00:28:24,536  
The airplanes get  
very big, very fast.

583

00:28:24,536 --> 00:28:26,037  
The idea that we're trying

584

00:28:26,037 --> 00:28:30,125  
to pursue is do the incredibly  
simplest thing, you know,

585

00:28:30,125 --> 00:28:33,661  
that a dummy could  
do, and do that first,

586

00:28:33,661 --> 00:28:36,164  
and, at least get there.

587

00:28:36,164 --> 00:28:39,144

Because if you ride  
along it's balanced,

588

00:28:39,144 --> 00:28:41,436

that's what we want to do.

589

00:28:41,436 --> 00:28:42,921

Good question.

590

00:28:42,921 --> 00:28:49,094

>> Is there any research to  
replicate the atmosphere on Mars

591

00:28:49,094 --> 00:28:52,530

to see how the glider  
would react?

592

00:28:52,530 --> 00:28:55,467

>> Al Bowers: So, you'd need  
a pretty big pressure chamber

593

00:28:55,467 --> 00:29:06,960

to do that -- but, okay, so  
there's an Avenger's movie

594

00:29:06,960 --> 00:29:13,560

that starts out inside a huge  
pressure chamber at NASA Glenn.

595

00:29:13,560 --> 00:29:15,537

In fact, the base of  
the pressure chamber is

596

00:29:15,537 --> 00:29:19,477

about twice the size  
of this room.

597

00:29:19,480 --> 00:29:23,394

And that could be done, and  
I have not thought of that,

598

00:29:23,394 --> 00:29:26,331  
that's why I have students.

599

00:29:26,331 --> 00:29:28,633  
What are you doing next summer?

600

00:29:29,540 --> 00:29:32,460  
You might have to spend your  
entire ten weeks next summer

601

00:29:32,470 --> 00:29:34,756  
at NASA Glenn, trying to work

602

00:29:34,756 --> 00:29:36,224  
with those guys trying  
to figure this out.

603

00:29:36,224 --> 00:29:38,126  
I would love to have  
that happen.

604

00:29:38,126 --> 00:29:38,827  
That's a great idea.

605

00:29:38,827 --> 00:29:39,461  
I like that.

606

00:29:39,461 --> 00:29:41,596  
Somebody write that down.

607

00:29:41,596 --> 00:29:43,131  
One of my interns,  
write that down.

608

00:29:43,131 --> 00:29:47,435  
Okay. How about a couple from online?

609

00:29:47,435 --> 00:29:51,189

>> One that we have online is  
"where will the landing of the

610

00:29:51,189 --> 00:29:53,391

plane be since Mars is rocky?"

611

00:29:53,391 --> 00:29:54,759

>> Al Bowers: Yeah, Mars --

612

00:29:54,759 --> 00:29:57,061

where will the landing  
of the airplane be?

613

00:29:57,061 --> 00:29:58,596

We're going to collide  
with the ground.

614

00:29:58,596 --> 00:30:02,066

I mean, there's just --  
it's 400 miles an hour.

615

00:30:02,066 --> 00:30:06,306

I mean, you might be able to  
slow it down to like 250,

616

00:30:06,306 --> 00:30:08,802

but it's going to  
be challenging.

617

00:30:08,802 --> 00:30:14,005

So, we're just going to overfly  
a particular landing point, and,

618

00:30:14,005 --> 00:30:17,740

for people, and we're just  
going to crash into the ground

619

00:30:17,740 --> 00:30:19,834  
where we crash into the ground.

620  
00:30:19,834 --> 00:30:21,236  
One of the places we have talked

621  
00:30:21,236 --> 00:30:28,393  
about going was the big  
grand canyon that's on Mars,

622  
00:30:28,393 --> 00:30:32,230  
Valles Marineris and  
actually fly down the canyon.

623  
00:30:32,230 --> 00:30:36,267  
It turns out it would  
take four CubeSats to map

624  
00:30:36,267 --> 00:30:38,970  
out that entire canyon.

625  
00:30:38,970 --> 00:30:42,290  
We talked about that for a  
science mission, but it sounds

626  
00:30:42,290 --> 00:30:45,960  
like they've already got that  
predialled with the water flowing

627  
00:30:45,960 --> 00:30:49,964  
down the -- one of the sites  
they found water was actually

628  
00:30:49,964 --> 00:30:51,900  
in the bottom of the canyon.

629  
00:30:51,900 --> 00:30:54,168  
>> Someone's asking  
for more clarification

630

00:30:54,168 --> 00:30:56,654

on how the plane will fly  
in the Mars' atmosphere?

631

00:30:56,654 --> 00:30:59,357

>> Al Bowers: So, we would  
design it to do some autonomy.

632

00:30:59,357 --> 00:31:03,361

And, in fact, you're going to  
hear a little bit about that.

633

00:31:03,361 --> 00:31:06,231

And, it's actually  
very, very simple.

634

00:31:06,231 --> 00:31:07,565

The airplane is incredibly  
stable.

635

00:31:07,565 --> 00:31:10,468

We would design it for a  
particular glide point,

636

00:31:10,468 --> 00:31:14,289

a design point for crews, and  
it would spend most of its time

637

00:31:14,289 --> 00:31:15,890

at that same glide point.

638

00:31:15,890 --> 00:31:16,824

It would have very  
weak guidance.

639

00:31:16,824 --> 00:31:19,994

We want to prove that  
on three missions,

640

00:31:19,994 --> 00:31:23,164  
and we're brainstorming  
this quite literally.

641  
00:31:23,164 --> 00:31:26,701  
We were putting this together,  
David Berger, a project manager

642  
00:31:26,701 --> 00:31:30,989  
and I, and we want to try  
and get two launches off

643  
00:31:30,989 --> 00:31:32,690  
of high altitude balloons.

644  
00:31:32,690 --> 00:31:36,261  
The first one, it would  
be already pre-deployed,

645  
00:31:36,261 --> 00:31:39,731  
and just hanging nose  
down, and it would fly away

646  
00:31:39,731 --> 00:31:41,966  
from about 100,000 feet.

647  
00:31:41,966 --> 00:31:44,502  
The second one, we would  
actually hang it in a CubeSat,

648  
00:31:44,502 --> 00:31:51,426  
and deploy it again, from a  
CubeSat, at 112,000 feet, or so.

649  
00:31:51,426 --> 00:31:56,130  
And that would simulate  
the atmosphere of Mars.

650  
00:31:56,130 --> 00:31:59,033  
The last one, we actually

want to put the CubeSat

651

00:31:59,033 --> 00:32:02,837

on a sounding rocket, and  
reenter the Earth's atmosphere

652

00:32:02,837 --> 00:32:06,691

at around 450,000 feet on  
the end of the parachute

653

00:32:06,691 --> 00:32:11,195

and do the entire deployment  
sequence at about 115,000 feet

654

00:32:11,195 --> 00:32:14,699

and have the glider fly back  
and land at its take off point.