



1
00:00:08,046 --> 00:00:10,176
What does flight mean to you?

2
00:00:10,176 --> 00:00:11,776
Immediately, we think of birds.

3
00:00:11,776 --> 00:00:13,586
Winged beings, high above.

4
00:00:13,586 --> 00:00:16,346
But to think of ourselves
flying,

5
00:00:16,346 --> 00:00:19,296
we think of an airplane
- tube, tail, wings.

6
00:00:19,296 --> 00:00:23,286
Everyone knows that's how you
fly, that's what we're used to -

7
00:00:23,286 --> 00:00:25,306
following the same basic model
the Wright brothers used.

8
00:00:25,306 --> 00:00:29,836
After a century of innovation,
we are still limiting ourselves

9
00:00:29,836 --> 00:00:31,886
to the Wright's assumptions
about manned flight.

10
00:00:31,886 --> 00:00:35,446
As said by Sir Ken Robinson:
"If you're not prepared

11
00:00:35,446 --> 00:00:37,946
to be wrong you will never come

up with anything original".

12

00:00:37,946 --> 00:00:42,946

As engineers, we take that to
heart and we believe it's time

13

00:00:42,946 --> 00:00:44,996

to push the boundaries
of aviation.

14

00:00:44,996 --> 00:00:46,896

We believe in making
the impossible possible

15

00:00:47,046 --> 00:00:48,566

and are captivated by the idea

16

00:00:48,756 --> 00:00:50,856

of enabling the future
to exist today.

17

00:00:50,856 --> 00:00:54,926

Since 1946, the Dryden Flight
Research Center has been the

18

00:00:54,976 --> 00:00:57,456

premier facility for
atmospheric flight testing.

19

00:00:57,636 --> 00:01:01,146

For over 60 years, the
most advanced aircraft

20

00:01:01,146 --> 00:01:03,216

of the day have flown here.

21

00:01:03,216 --> 00:01:06,366

So much expertise,
knowledge, innovation.

22

00:01:07,186 --> 00:01:09,296

Surely the basics of
flight are well understood.

23

00:01:10,336 --> 00:01:12,626

But what if we missed something?

24

00:01:12,626 --> 00:01:14,596

In the late 1800's
people were thinking

25

00:01:14,596 --> 00:01:15,656

about heavier than air flight.

26

00:01:15,976 --> 00:01:17,866

Balloons weren't cutting it.

27

00:01:17,866 --> 00:01:19,476

They understood the need
for a force pushing you

28

00:01:19,476 --> 00:01:21,666

up that would overcome
gravity pulling you down.

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00:01:21,666 --> 00:01:24,666

See, when an airplane is
in steady level flight,

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00:01:24,666 --> 00:01:27,846

it experiences four
major forces: lift,

31

00:01:28,136 --> 00:01:30,866

weight, thrust and drag.

32

00:01:30,866 --> 00:01:32,906

Weight constantly tries
to pull the airplane down,

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00:01:32,906 --> 00:01:35,766
and the airplane must produce
lift to stay in the air.

34

00:01:35,766 --> 00:01:38,236
Thrust provides enough
force to overcome drag.

35

00:01:38,236 --> 00:01:39,956
Now, drag is more complex.

36

00:01:40,076 --> 00:01:44,046
There are three main types
of drag: viscous, pressure

37

00:01:44,046 --> 00:01:46,146
and induced drag - all acting

38

00:01:46,146 --> 00:01:48,506
to slow the airplane
from flying forward.

39

00:01:48,506 --> 00:01:49,966
Aircraft designers
are most concerned

40

00:01:49,966 --> 00:01:52,766
with induced drag,
a byproduct of lift.

41

00:01:52,856 --> 00:01:55,176
Lift is generated by producing
high pressure underneath the

42

00:01:55,176 --> 00:01:57,616
wing, and a low pressure above.

43

00:01:57,616 --> 00:02:00,186

But pressure acts in all directions, not just up or down.

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00:02:00,186 --> 00:02:03,386

Thus, while the plane is in flight, air will 'leak'

45

00:02:03,386 --> 00:02:06,216

from beneath the wing and curl around the tip.

46

00:02:06,506 --> 00:02:09,366

This spins the air as it moves around the wing.

47

00:02:10,026 --> 00:02:12,546

This is called a wing tip vortex, and it looks

48

00:02:12,546 --> 00:02:15,576

like a small tornado coming off the end of the wing.

49

00:02:15,576 --> 00:02:16,306

This isn't good.

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00:02:16,306 --> 00:02:19,686

Making these takes a lot of waste energy; and if you think

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00:02:19,686 --> 00:02:23,706

of the air as water, it's like making big splashes in a pool.

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00:02:23,706 --> 00:02:25,466

Now, however you design your wing,

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00:02:25,466 --> 00:02:28,136

to get more lift you need a

bigger difference in pressure.

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00:02:28,456 --> 00:02:31,196

The more lift produced, the more induced drag there will be

55

00:02:31,606 --> 00:02:34,626

because more air will leak and curl around the wingtips.

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00:02:34,736 --> 00:02:39,866

In 1925, Ludwig Prandtl derived the first way to minimize drag.

57

00:02:40,396 --> 00:02:42,706

His solution was the elliptical span load.

58

00:02:42,706 --> 00:02:47,026

So a wing doesn't produce all of its lift in one place, rather,

59

00:02:47,266 --> 00:02:50,056

it produces a little bit of lift everywhere.

60

00:02:50,056 --> 00:02:52,746

And Prandtl came up with how much lift should be produced

61

00:02:52,746 --> 00:02:54,956

at a particular location along the wing,

62

00:02:55,376 --> 00:02:58,726

and visually his solution was a quarter of an ellipse,

63

00:02:59,276 --> 00:03:02,176

where the most lift was at the

root of the wing and tapered

64

00:03:02,206 --> 00:03:03,756
to zero at the wingtips.

65

00:03:04,006 --> 00:03:07,936
More than 85 years later, this
is still the solution we use

66

00:03:08,116 --> 00:03:09,006
when designing aircraft.

67

00:03:10,006 --> 00:03:12,226
When the Wright brothers
first flew their 1901 glider,

68

00:03:12,576 --> 00:03:13,986
they could not get
the airplane to turn.

69

00:03:14,586 --> 00:03:16,646
Every time they rolled their
aircraft in one direction,

70

00:03:16,886 --> 00:03:19,576
it would turn in the
opposite direction and crash.

71

00:03:19,916 --> 00:03:23,026
As they rolled the airplane,
one wing generated more lift,

72

00:03:23,656 --> 00:03:27,206
but also more induced drag,
forcing the nose to turn,

73

00:03:27,586 --> 00:03:30,006
or yaw, in the opposite
direction.

74

00:03:30,316 --> 00:03:31,756

We call this adverse yaw.

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00:03:31,796 --> 00:03:35,176

To solve this, the Wrights put
a rudder on their airplane,

76

00:03:35,236 --> 00:03:37,286

which would angle
more drag on the tail

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00:03:37,286 --> 00:03:40,646

that would directly oppose
the induced drag on the wings,

78

00:03:40,646 --> 00:03:42,816

forcing their airplane
to yaw the correct way.

79

00:03:42,816 --> 00:03:45,266

Controlled flight was solved!

80

00:03:45,266 --> 00:03:47,176

Or was it?

81

00:03:47,176 --> 00:03:51,036

After publishing his paper in
1925, Prandtl continued thinking

82

00:03:51,036 --> 00:03:52,526

about minimizing drag.

83

00:03:52,526 --> 00:03:55,206

He knew about adverse yaw
and how the Wrights accounted

84

00:03:55,206 --> 00:03:58,666

for it, but to overcome
drag with drag?

85

00:03:58,666 --> 00:04:00,146

He thought back to the
inspiration for flight.

86

00:04:00,146 --> 00:04:03,106

He wondered why he'd never
seen a bird with a rudder.

87

00:04:03,106 --> 00:04:04,896

How did they do it?

88

00:04:04,896 --> 00:04:08,496

The Aeronautics Academies
of 2012 and 2013

89

00:04:08,496 --> 00:04:11,246

at NASA Dryden wondered
the very same thing.

90

00:04:11,246 --> 00:04:14,996

In 1932 Prandtl published
another paper on induced drag.

91

00:04:14,996 --> 00:04:17,896

By considering the
strength of a wing rather

92

00:04:17,896 --> 00:04:18,896

than just the wingspan,

93

00:04:19,136 --> 00:04:21,426

he derived a new
bell-shaped lift distribution

94

00:04:21,626 --> 00:04:24,526

that would produce
11% less induced drag.

95

00:04:24,896 --> 00:04:28,316

At the same time, two teenagers,
Walter and Reimar Horten,

96

00:04:28,636 --> 00:04:31,686

began designing all wing
gliders, no tail at all.

97

00:04:31,716 --> 00:04:34,906

To get Prandtl's bell shaped
lift distribution they added

98

00:04:34,936 --> 00:04:35,996

twist to their wing design.

99

00:04:37,006 --> 00:04:38,926

They discovered as they
turned their glider,

100

00:04:39,126 --> 00:04:41,786

the nose FOLLOWED the
roll of the vehicle,

101

00:04:41,786 --> 00:04:43,826

they didn't need a rudder.

102

00:04:43,826 --> 00:04:46,206

To explain their solution,
I have to explain the work

103

00:04:46,206 --> 00:04:49,956

of Dick Whitcomb and his
devices known as "winglets."

104

00:04:49,956 --> 00:04:52,236

You've all seen them-
little tips that point

105

00:04:52,236 --> 00:04:53,696

up on Southwest jetliners.

106

00:04:54,356 --> 00:04:57,506

These small vertical sections
are actually the wings,

107

00:04:57,506 --> 00:04:58,206

just pointing up.

108

00:04:58,206 --> 00:04:59,906

They are also sticking straight

109

00:04:59,906 --> 00:05:03,166

into the vortices we were
talking about before.

110

00:05:03,166 --> 00:05:07,046

They're making lift, same as the
main wing, only now the force

111

00:05:07,046 --> 00:05:10,266

of the lift is pointing, or
pushing as you can imagine,

112

00:05:10,266 --> 00:05:12,546

inward and a little bit forward.

113

00:05:12,546 --> 00:05:15,516

This means we're actually
getting a little bit

114

00:05:15,516 --> 00:05:16,606

of extra push forward.

115

00:05:16,606 --> 00:05:20,676

Normally it's only our
engines that push us forward.

116

00:05:20,676 --> 00:05:24,516

This works because the vortices

start at the tip and curl

117

00:05:24,516 --> 00:05:27,646

into our winglet; but if you
folded them out horizontally

118

00:05:27,646 --> 00:05:29,676

and kept the start of the
vortex in the same place,

119

00:05:30,056 --> 00:05:30,976

they would still work.

120

00:05:31,466 --> 00:05:33,096

You would have flat winglets,

121

00:05:33,156 --> 00:05:35,816

and Prandtl had figured
this out, only accidentally.

122

00:05:36,656 --> 00:05:37,946

The bell shaped distribution

123

00:05:37,946 --> 00:05:40,086

of lift he derived
caused inboard vortices

124

00:05:40,356 --> 00:05:42,216

and the Hortens were
seeing this.

125

00:05:42,526 --> 00:05:45,136

But wait, you still have
to account for adverse yaw.

126

00:05:45,586 --> 00:05:47,426

The Horten aircraft will
increase induced drag

127

00:05:47,426 --> 00:05:49,386
as it rolls, and
yaw the wrong way.

128
00:05:50,266 --> 00:05:53,106
Wrong! The Horten wing
actually uses adverse yaw

129
00:05:53,106 --> 00:05:53,996
to its advantage.

130
00:05:54,486 --> 00:05:58,476
When it rolls the lift on one
wing is increased, and yes,

131
00:05:58,476 --> 00:06:01,086
so does the induced drag,
bigger vortices remember?

132
00:06:01,716 --> 00:06:04,426
But now those vortices are
hitting our flat winglet

133
00:06:04,776 --> 00:06:07,856
and stronger vortices give
the winglet more push forward.

134
00:06:08,376 --> 00:06:10,986
The new thrust we are getting
overcomes any induced drag

135
00:06:11,316 --> 00:06:12,576
and we yaw the correct way!

136
00:06:12,976 --> 00:06:15,406
The past two aeronautics
academies

137
00:06:15,446 --> 00:06:18,716
at NASA Dryden have built a

prototype dubbed the Primary

138

00:06:18,756 --> 00:06:21,406

Research Aerodynamic
Design to Lower Drag

139

00:06:21,406 --> 00:06:22,716

or the PRANDTL-D for short.

140

00:06:23,546 --> 00:06:25,966

No data was initially
collected until we were able

141

00:06:25,966 --> 00:06:26,976

to instrument the vehicle

142

00:06:27,216 --> 00:06:29,166

and record turning
rates and accelerations.

143

00:06:29,816 --> 00:06:32,416

What we found was better than
we could have ever possibly

144

00:06:32,416 --> 00:06:32,886

hoped for.

145

00:06:33,206 --> 00:06:35,486

Roll and yaw occurred
in the same direction,

146

00:06:35,676 --> 00:06:38,816

and by definition, we
were seeing proverse yaw.

147

00:06:38,926 --> 00:06:41,966

We had demonstrated the
fundamental principal

148

00:06:42,046 --> 00:06:45,836
in a design that claims a 60%
increase in aircraft efficiency.

149
00:06:45,836 --> 00:06:49,356
We had found a viable
aircraft for the future.

150
00:06:49,356 --> 00:06:53,376
We'd all come from different
schools and backgrounds -

151
00:06:53,376 --> 00:06:56,026
brought together here by
the love of freedom obtained

152
00:06:56,026 --> 00:06:58,386
by flight, along
with speed, power,

153
00:06:58,556 --> 00:06:59,866
new frontiers, and knowledge.

154
00:06:59,866 --> 00:07:03,426
NASA Dryden, though our
work on the PRANDTL project,

155
00:07:03,426 --> 00:07:04,776
gave us the ideal environment

156
00:07:04,866 --> 00:07:06,596
to combine both the
tangible elements

157
00:07:06,596 --> 00:07:09,846
of aircraft flight testing
with theory learned at school.

158
00:07:10,116 --> 00:07:13,496
We weren't just witnessing a

breakthrough in aerodynamics,

159

00:07:13,496 --> 00:07:14,406

we were contributing to it.

160

00:07:14,406 --> 00:07:18,646

We had challenged assumptions,
conventions, and paradigms.

161

00:07:18,646 --> 00:07:21,466

This was our first step.