1
00:00:00,780 --> 00:00:03,420
[Music]

2
00:00:03,760 --> 00:00:07,920
>>An average person's access to technology increases every year.

3
00:00:07,930 --> 00:00:10,570
Maybe even every day.

4
00:00:10,570 --> 00:00:12,520
So does their use of energy.

5
00:00:12,520 --> 00:00:17,660
People around the world are driven to find faster, more efficient, and cleaner ways to

6
00:00:17,660 --> 00:00:23,840
utilize energy so that it can be accessed sustain-ably on an even greater scale.

7
00:00:23,840 --> 00:00:25,650
Some are doing it with power.

8
00:00:25,650 --> 00:00:29,210
Others are revolutionizing automobiles.

9
00:00:29,210 --> 00:00:32,000
Engineers at NASA are working on a better airplane.

10
00:00:32,000 --> 00:00:33,680
[Music/Background noise]

11
00:00:33,680 --> 00:00:37,120
>>We are looking at ways for more efficient travel.

12

00:00:37,120 --> 00:00:42,370
One way to do this is with ultra-efficient
lift wings that are built with new and lighter

13
00:00:42,370 --> 00:00:43,600
material.

14
00:00:43,600 --> 00:00:48,480
[Music/scribbling]

15
00:00:48,700 --> 00:00:53,280
However, this type of wing could have an issue
with flutter.

16
00:00:53,580 --> 00:00:58,700
[Music]

17
00:00:58,760 --> 00:01:03,260
>>Flutter is a type of unstable interaction
between a structure and the air that is moving

18
00:01:03,260 --> 00:01:04,840
around it.

19
00:01:04,840 --> 00:01:05,760
[String plucks]

20
00:01:05,760 --> 00:01:10,469
All structures vibrate at their own fundamental
frequencies, with their own harmonics.

21
00:01:10,469 --> 00:01:14,670
Simple structures, like guitar strings, have
relatively simple harmonics, which allow for

22
00:01:14,670 --> 00:01:17,880
the production of a clean, clear musical note.

23
00:01:17,880 --> 00:01:19,560

[String plucks]

24
00:01:19,740 --> 00:01:24,240
More complex structures have more complex
harmonics, but they still vibrate according

25
00:01:24,249 --> 00:01:26,130
to the same laws of physics.

26
00:01:26,130 --> 00:01:30,140
The air around these objects is a fluid, and even though you can't see it,

27
00:01:30,140 --> 00:01:33,630
it exerts a force on everything moving through
it.

28
00:01:33,630 --> 00:01:37,859
Flutter occurs when the forces from the air
interact with the structural vibrations in

29
00:01:37,859 --> 00:01:41,639
such a way that they to grow.

30
00:01:41,639 --> 00:01:46,799
Sometimes these unstable interactions can
have catastrophic consequences.

31
00:01:46,799 --> 00:01:49,969
Even very large structures
can be affected by these types of destructive

32
00:01:49,969 --> 00:01:51,140
phenomena.

33
00:01:51,140 --> 00:01:53,140
[Music/Tarmac noise]

34
00:01:53,260 --> 00:01:57,500
Flutter phenomena in modern transport aircraft

is well understood as a result of decades

35
00:01:57,509 --> 00:01:59,060
of research.

36
00:01:59,060 --> 00:02:04,100
Today's aircraft wings are built to account
for flutter by building them relatively rigid.

37
00:02:04,100 --> 00:02:08,560
The problem with rigidity is that it makes
airplanes heavier and less efficient

38
00:02:08,560 --> 00:02:11,039
than they would be with more flexible wings.

39
00:02:11,840 --> 00:02:16,420
There is an ever increasing demand for greater
speed, better fuel efficiency, and passenger

40
00:02:16,420 --> 00:02:21,170
comfort, but as we push the limits of what
is possible with current technology we must

41
00:02:21,170 --> 00:02:27,010
find ways to achieve these gains without sacrificing
the hard-won and impressive safety record

42
00:02:27,010 --> 00:02:29,800
of today's aviation industry.

43
00:02:31,240 --> 00:02:34,910
One promising technology that may make it
possible to improve both aircraft safety and

44
00:02:34,910 --> 00:02:40,920
performance is active stabilization of flutter
using advanced flight control systems.

45

00:02:40,920 --> 00:02:43,280
Current aircraft use passive means to avoid flutter.

46
00:02:43,280 --> 00:02:47,170
They carry around extra structure and limit operational speeds, basically avoiding the

47
00:02:47,170 --> 00:02:48,620
conditions where flutter occurs.

48
00:02:48,620 --> 00:02:50,860
[Music]

49
00:02:51,040 --> 00:02:52,100
Consider this wine glass.

50
00:02:52,100 --> 00:02:55,040
[Ding]

51
00:02:55,140 --> 00:03:00,080
The structure of the wine glass resonates, or vibrates, at a characteristic frequency.

52
00:03:00,090 --> 00:03:04,420
If we excite those frequencies with enough energy, the structure of the wine glass will

53
00:03:04,420 --> 00:03:05,650
break.

54
00:03:05,650 --> 00:03:08,380
Now think about the airplane structure like the wine glass.

55
00:03:08,380 --> 00:03:12,620
It vibrates at few characteristic frequencies, and if we fly fast enough, like turning up

56

00:03:12,620 --> 00:03:17,080
the volume, and we are exciting those wing
frequencies the wing can break similar the

57
00:03:17,080 --> 00:03:18,220
wine glass.

58
00:03:18,220 --> 00:03:22,300
By building the wings stiff, and flying slower
we prevent the wings from being destroyed

59
00:03:22,300 --> 00:03:24,290
by flutter.

60
00:03:24,290 --> 00:03:28,950
However, as we try to fly faster with lighter
weight more flexible wings we can no longer

61
00:03:28,950 --> 00:03:30,350
just avoid flutter.

62
00:03:30,350 --> 00:03:33,980
We have to improve our prediction and analysis
tools and come up with clever innovative solutions

63
00:03:33,980 --> 00:03:36,820
to the flutter problem.

64
00:03:37,860 --> 00:03:41,360
One promising solution to the problems we
encounter with flutter as wings become lighter

65
00:03:41,360 --> 00:03:46,160
weight and we fly faster is to take an active
role in suppressing those structural vibrations

66
00:03:46,160 --> 00:03:51,290
with the control system. We can utilize advanced
sensors, software, actuators, and computers

67
00:03:51,290 --> 00:03:55,340
to sense the wing vibrations and proactively
manage flutter.

68
00:03:55,980 --> 00:03:57,490
This is what we're trying to accomplish with
X-56.

69
00:03:57,490 --> 00:04:02,569
We are preparing to flight test control systems
that actively suppress flutter, and investigating

70
00:04:02,569 --> 00:04:06,600
advanced sensors, such as these fiber optic
strain sensors that may give us a more detailed

71
00:04:06,600 --> 00:04:09,130
picture of the motion within the aircraft
structure.

72
00:04:09,130 --> 00:04:12,480
But to actively control something you have
to understand how it works.

73
00:04:12,480 --> 00:04:17,540
We are developing more detailed and accurate
math and physics models of aircraft and validating

74
00:04:17,540 --> 00:04:21,129
those models with as much test data as we
can get our hands on.

75
00:04:21,129 --> 00:04:24,789
It's essential that we understand exactly
how our aircraft moves.

76
00:04:24,789 --> 00:04:26,090
How loads affect wing bending,

77

00:04:26,090 --> 00:04:29,050
how forces and moments from various sources affect aircraft motion,

78
00:04:29,050 --> 00:04:33,460
And at what frequencies does the X-56 structure vibrate?

79
00:04:33,500 --> 00:04:35,900
[Music]

80
00:04:35,980 --> 00:04:40,330
By answering these questions, the team can model how the X-56 will behave in flight.

81
00:04:40,330 --> 00:04:44,529
We can make predictions about flutter-induced instability, and we can create controls to

82
00:04:44,529 --> 00:04:47,029
respond to these dynamics.

83
00:04:47,029 --> 00:04:50,650
And by predicting how the aircraft will behave in flight and how it may flutter, the team

84
00:04:50,650 --> 00:04:55,400
can begin to develop accurate control strategies and software.

85
00:04:55,400 --> 00:05:03,280
[Music/Background noise]

86
00:05:11,160 --> 00:05:15,180
Once the control software is written and the airplane is once again ready to fly, flight

87
00:05:15,180 --> 00:05:19,419
tests will attempt to purposefully put X-56 into flutter conditions to investigate the

88
00:05:19,419 --> 00:05:21,949
performance of the active control system.

89
00:05:21,949 --> 00:05:25,749
Can these control systems actively suppress
flutter?

90
00:05:25,749 --> 00:05:28,249
But before that, there still is much to be
done.

91
00:05:28,249 --> 00:05:32,279
The active controls must be tested on the
ground, the control room must be prepared,

92
00:05:32,279 --> 00:05:35,139
and communication equipment tested and validated.

93
00:05:35,139 --> 00:05:39,030
And Active Controls are not the only way to
suppress flutter.

94
00:05:39,030 --> 00:05:43,020
NASA engineers and their partners are working
on a multitude of methods to deal with it,