WEBVTT

1
00:00:00.040 --> 00:00:00.873
Schedule, uh,

2
00:00:00.940 --> 00:00:04.320
Stu just informed me that there are some power bars set up and back if anybody

3
00:00:04.320 --> 00:00:07.560
needs to plug in to charge up, uh, one of your electronic devices.

4
00:00:07.620 --> 00:00:10.200
So that's available back there. Um,

5
00:00:10.220 --> 00:00:14.440
the next presentation we have for this afternoon is gonna be Dave Staples from

6
00:00:14.440 --> 00:00:17.720
Textron Aviation, and Dave is a senior engineering specialist there,

7
00:00:18.340 --> 00:00:21.870
has two degrees from Wichita State. Uh, first of all,

8
00:00:21.890 --> 00:00:24.990
I'd like to say I really like the first name, good job. And, uh,

9
00:00:26.350 --> 00:00:30.350
I crossed paths with Dave. Uh, he worked at Learjet when I was at Cessna,

10
00:00:30.350 --> 00:00:32.590
but he came over to Cessna while I was still there. And,

11
00:00:32.610 --> 00:00:36.550
and I can tell you from multiple programs being in the cockpit, it was, uh,

12
00:00:36.760 --> 00:00:40.190
super comforting to have somebody as knowledgeable and, uh,

13

00:00:40.250 --> 00:00:43.950
the expertise that he provides to TM when we're doing envelope expansion. So,

14
00:00:43.970 --> 00:00:47.470
uh, been there, had him on the ground to, to back us up and, uh,

15
00:00:47.730 --> 00:00:50.230
all I can say it was, uh, gave everybody a warm fuzzy.

16
00:00:50.370 --> 00:00:53.470
So I appreciate your efforts there. And without further ado,

17
00:00:53.860 --> 00:00:56.710
Dave Staples on the Cessna Model 4 0 8 Sky Perry.

18
00:00:56.850 --> 00:00:59.870
Thanks a lot. Excellent. Okay.

19
00:01:02.910 --> 00:01:07.350
I wanna first, uh, thank, uh, Stu for inviting Gonzalo and I to fill in for, uh,

20
00:01:07.350 --> 00:01:10.510
an open spot. Uh, Gonzalo couldn't make it today,

21
00:01:11.130 --> 00:01:12.590
so I dropped all of his slides.

22
00:01:14.390 --> 00:01:17.290
We have a pretty good 45 minute presentation,

23
00:01:17.290 --> 00:01:22.090
so we'll see if we can do it in 20. Let me find my clicker here. Okay,

24
00:01:23.030 --> 00:01:26.810
so what is the Sky Courier? Uh, the Model 4 0 8, if you're not familiar with it,

25
00:01:27.670 --> 00:01:32.370
uh, this spelt beauty is a 2000 horsepower box car with long skinny wings.

26
00:01:33.590 --> 00:01:38.050
The chief design queues are extreme simplicity for really high mission rates,

27
00:01:38.160 --> 00:01:42.480
high availability, it's manual everything, cable driven, everything.

28
00:01:43.620 --> 00:01:48.070
Uh, so we've got the, uh, the,

29
00:01:48.090 --> 00:01:51.910
the power of a bearcat and the drag of a crop duster.

30
00:01:53.930 --> 00:01:57.100
Just a brief overview of the process that we go through.

31
00:01:57.100 --> 00:02:00.980
What we're trying to do is get to where we can do a safe and successful flight

32
00:02:00.980 --> 00:02:03.900
flutter test. How does that start? It starts way early.

33
00:02:04.120 --> 00:02:08.140
We start designing an analytical model as soon as design data are available to

34
00:02:08.140 --> 00:02:11.060
us, and we update that model as the design data mature.

35
00:02:11.110 --> 00:02:16.060
Eventually we get to the point where we have hardware that we can test, uh,

36
00:02:16.060 --> 00:02:19.260
ground test, ground vibration test to validate that model.

37
00:02:19.260 --> 00:02:21.820
Eventually we get to the certification,

38

00:02:21.820 --> 00:02:23.620
ground vibration test of the whole airplane.

39
00:02:24.210 --> 00:02:27.660
What we're trying to get to is a safe flight flutter test,

40
00:02:27.710 --> 00:02:32.130
which meets the rags with a specially configured airplane, specially configured,

41
00:02:32.470 --> 00:02:37.410
uh, instrumentation package and so on. Um, there are six, not three, uh,

42
00:02:37.410 --> 00:02:41.690
certification reports. Two test plans, ground and air, two results reports,

43
00:02:41.690 --> 00:02:45.530
ground and air, a massive analysis document,

44
00:02:46.150 --> 00:02:50.530
and then a dry as dust stack of, uh, compliance statements,

45
00:02:50.530 --> 00:02:53.330
which I don't recommend unless you need sleep.

46
00:02:55.950 --> 00:03:00.080
So what's interesting about the 4 0 8 to us, um,

47
00:03:02.760 --> 00:03:07.180
the last time sess did a turbo prop airplane was in the eighties with the Model

48
00:03:07.240 --> 00:03:09.340
2 0 8 and the Beachcraft guys,

49
00:03:09.400 --> 00:03:12.620
of course have lots of King air experience and the T six,

50
00:03:12.880 --> 00:03:15.740
but the King Air was new, super King Air in 1972.

51
00:03:16.440 --> 00:03:19.380
And that even the T six experience as a new airplane was what,

52
00:03:19.690 --> 00:03:20.523
back in the nineties.

53
00:03:21.040 --> 00:03:25.580
So the people working on this project really didn't have new experience in this

54
00:03:25.580 --> 00:03:29.140
design space. Furthermore, this guy has strut braced. Okay?

55
00:03:29.160 --> 00:03:31.700
So that has not been a thing in either company for, again,

56
00:03:31.740 --> 00:03:36.340
a very long time wire struts, uh, important to us, well,

57
00:03:36.340 --> 00:03:37.660
because they're dynamic elements too.

58
00:03:38.480 --> 00:03:40.740
New airframe features and turbo prop engines,

59
00:03:40.970 --> 00:03:44.660
that means we gotta do something in the regulatory space called whirl flutter.

60
00:03:44.660 --> 00:03:45.780
We'll talk more about that in a bit.

61
00:03:46.120 --> 00:03:50.730
We had to get good at that cuz it's really important to the 4 0 8. Uh,

62
00:03:51.050 --> 00:03:54.810
I didn't really realize how much vibration is produced by propeller engines

63
00:03:54.810 --> 00:03:57.890
until I tele started telemetry. The 4 0 8.

64
00:03:58.540 --> 00:04:02.930
Those vibration signatures are in our data, our, our plots of, uh,

65
00:04:02.930 --> 00:04:05.340
time data all the time. Um,

66
00:04:06.980 --> 00:04:09.620
the shaft imbalance frequency,

67
00:04:09.620 --> 00:04:14.380
which is basically propeller speed divided by 60, is right in that, uh,

68
00:04:14.560 --> 00:04:17.580
25 to 30 hertz range, which is very important to many.

69
00:04:17.580 --> 00:04:22.210
The other modes in our aircraft are vibration modes. Uh, struts,

70
00:04:22.590 --> 00:04:25.730
struts have modes of their own, uh, they those modes.

71
00:04:25.730 --> 00:04:30.210
Couple with the wing and the spon at the fuss lodge. The attachment
points,

72
00:04:30.670 --> 00:04:34.290
the location where we design the struts to interface of the wing has a
direct

73
00:04:34.290 --> 00:04:38.170
influence on the flutter characteristics of the wing because the struts
imply

74
00:04:38.270 --> 00:04:41.550
and implied, um, torsion axis, right?

75
00:04:43.130 --> 00:04:46.310
Uh, and then we have a very unusual performance regime.

76
00:04:47.080 --> 00:04:50.380

The airplanes that I've done since I came to Cessna in 1998,

77
00:04:50.400 --> 00:04:54.780
and obviously the Lear jets before that are high speed jet aircraft, low drag,

78
00:04:54.780 --> 00:04:58.540
high speed, high mock. This is a high drag, low mock airplane.

79
00:04:59.040 --> 00:05:01.020
The low mo numbers should make it easier,

80
00:05:01.280 --> 00:05:04.770
but the high drag state geared down and bolted, uh,

81
00:05:04.910 --> 00:05:09.130
should make it more difficult a drag e to, to make a flight fluter test safe,

82
00:05:09.790 --> 00:05:12.010
reduce drag or increase thrust. Okay?

83
00:05:12.010 --> 00:05:14.370
But we can't change the airplane once it gets to us.

84
00:05:15.390 --> 00:05:18.450
So the more drag you've got on the ship, the steeper the dissent angles,

85
00:05:18.450 --> 00:05:20.490
the steeper the dissent rates. Okay,

86
00:05:22.920 --> 00:05:24.690
just a little overview of our analytical model.

87
00:05:24.880 --> 00:05:27.690
It's very simple because it needs to be, it's, uh,

88
00:05:27.970 --> 00:05:31.970
a beam type representation of the structure or a wing, for example,

89
00:05:32.070 --> 00:05:33.010

or a control surface,

90
00:05:33.110 --> 00:05:38.010
or the fuse lodge is idealized as a beam with assigned mass and stiffness

91
00:05:38.010 --> 00:05:42.570
properties, which are deducible from, uh, mass properties analysis and from, uh,

92
00:05:42.570 --> 00:05:47.360
ground vibration testing. Uh, and we use double lattice aerodynamics,

93
00:05:47.360 --> 00:05:49.840
very well proven, very appropriate to this, uh,

94
00:05:50.760 --> 00:05:54.560
configuration with moderate aspect ratios, low sweep angles, uh,

95
00:05:54.760 --> 00:05:59.740
moderate mock numbers. So this model is designed for design early on.

96
00:06:00.490 --> 00:06:02.100
It's used at the very beginning.

97
00:06:02.160 --> 00:06:05.220
We are using it at the very beginning to support flight testing.

98
00:06:06.070 --> 00:06:10.610
Flight one is envelope expansion because previously the speed limit was in the

99
00:06:10.610 --> 00:06:15.330
hangar. Now it's going to be a, uh, a higher speed than that. Um,

100
00:06:16.270 --> 00:06:18.970
so we are involved the flutter guys in telemetry.

101
00:06:18.970 --> 00:06:21.490
The aircraft in the early flying, uh,

102
00:06:21.960 --> 00:06:26.960

that not only ensures that we are seeing the airplane we designed in the

103
00:06:26.970 --> 00:06:28.760
modal space, in the frequency space,

104
00:06:29.890 --> 00:06:33.230
it helps us learn the airplane the way it talks back to us. Okay?

105
00:06:33.650 --> 00:06:38.280
And then eventually, of course, uh, complete envelope expansion to, uh,

106
00:06:38.280 --> 00:06:41.710
accommodate the flight floater test. Whoops, here we go.

107
00:06:43.100 --> 00:06:47.920
So I apologize for this. Um, highly colorful spaghetti. Just very briefly.

108
00:06:47.920 --> 00:06:51.960
I want you to see the language that the ship talks to us from the analytical

109
00:06:52.050 --> 00:06:55.880
space. That stacked pair of plots over there is the VGF plot.

110
00:06:56.710 --> 00:07:00.720
It's good for one airplane configuration at one altitude.

111
00:07:00.940 --> 00:07:04.200
So there are gonna be thousands of them to, to do the airplane completely.

112
00:07:04.200 --> 00:07:07.990
Look at the bottom plot. First horizontal axis is air speed.

113
00:07:08.270 --> 00:07:12.550
Vertical axis is frequency. Frequency of what? Frequency of the, uh,

114
00:07:12.710 --> 00:07:15.270
structural modes in the airplane could be a bending mode,

115

00:07:15.270 --> 00:07:20.140
could be a torsion mode, a control surface rotation mode. Um, and as you note,

116
00:07:20.140 --> 00:07:23.620
you notice that as the air speed changes, those frequencies change.

117
00:07:24.670 --> 00:07:27.240
They converge and diverge, they coalesce.

118
00:07:28.020 --> 00:07:31.080
And what you don't see in that bottom plot is not only the frequencies change,

119
00:07:31.080 --> 00:07:35.220
but the phase relationships between those modes,

120
00:07:35.220 --> 00:07:38.680
those vibration modes change. Now look at the top plot.

121
00:07:39.530 --> 00:07:44.150
That's the stability plot. The G portion, G for damping, G for damping.

122
00:07:44.850 --> 00:07:48.880
Um, b, the way we make that plot in the United States,

123
00:07:48.880 --> 00:07:50.840
which is upside down from the way they do it in Europe,

124
00:07:51.290 --> 00:07:56.100
below the axis implies stability. That is to say, uh,

125
00:07:56.160 --> 00:07:59.300
the aero elastic system displaced from an equilibrium condition by an

126
00:07:59.460 --> 00:08:02.860
infinitesimal disturbance will damp out.

127
00:08:03.330 --> 00:08:08.180
That vibration above the axis is unstable so that that same displacement

128

00:08:08.450 --> 00:08:13.020
accelerates to infinity in theory and injures the aircraft.

129
00:08:13.770 --> 00:08:17.760
Right on that zero axis is neutral stability. So that a,

130
00:08:17.760 --> 00:08:21.800
there is no damping but no acceleration of the vibration to infinity.

131
00:08:22.350 --> 00:08:25.080
That blown up portion of the plot, um,

132
00:08:25.490 --> 00:08:27.040
shows some of the things we're looking for.

133
00:08:29.260 --> 00:08:32.840
We have basically three speeds in the airplane. We care about vc,

134
00:08:32.840 --> 00:08:34.880
which is like VMO V dive,

135
00:08:35.300 --> 00:08:38.080
and then a analytical clearance beyond dive,

136
00:08:38.330 --> 00:08:42.120
which comes from statute in part 23. It's 20% beyond dive.

137
00:08:43.260 --> 00:08:48.120
Um, so you see in the blown up portion, we have several instability indicated.

138
00:08:48.150 --> 00:08:52.440
They're all beyond V dive, which is required by the statute and safety,

139
00:08:53.340 --> 00:08:58.080
and they're all beyond or or below 3% damping at

140
00:08:58.080 --> 00:08:59.160
1.2 V dive.

141
00:08:59.340 --> 00:09:02.400

All of those are compliant and all of those are safe to flight fluter.

142
00:09:02.780 --> 00:09:05.830
If they're right, we'll come back to that. Um,

143
00:09:05.830 --> 00:09:09.830
notice also that for example, that first, that the,

144
00:09:09.850 --> 00:09:12.470
the fir one that crosses first is the critical mechanism.

145
00:09:12.670 --> 00:09:16.670
A mechanism is a confluence of modes with a phase relationship,

146
00:09:16.680 --> 00:09:21.430
which implies flutter implies instability. Um,

147
00:09:22.250 --> 00:09:26.710
the first one there, the red xs, it's, it's called, let's see here.

148
00:09:29.100 --> 00:09:33.720
And asymmetric horizontal stab torsion plus elevator torsion with tab

149
00:09:34.080 --> 00:09:37.440
rotation. Now, nothing about those plots tells me that, how did I,

150
00:09:37.860 --> 00:09:39.640
how did I characterize that? Well,

151
00:09:39.640 --> 00:09:43.520
we have to characterize all the instabilities to prove to our regulatory friends

152
00:09:43.520 --> 00:09:47.200
that we know what we're talking about. We understand the airplane. Okay?

153
00:09:47.200 --> 00:09:51.690
So how do we do that? That's called complex modal visualization.

154
00:09:52.110 --> 00:09:54.210
And when I see an instability,

155
00:09:54.490 --> 00:09:58.130
I can interrogate it analytically to find out what parts of the airplane are

156
00:09:58.330 --> 00:10:01.930
involved in that instability. For example, let's see if we can make this work.

157
00:10:04.090 --> 00:10:08.220
Okay, look at that puppy go. What you see there, first,

158
00:10:08.250 --> 00:10:11.260
this is a great, great example of world flutter.

159
00:10:11.260 --> 00:10:15.860
World flutter is the combination of gyroscopic forces in those big

160
00:10:15.860 --> 00:10:20.760
propeller disks with other, potentially other modes in the airplane.

161
00:10:20.780 --> 00:10:25.730
So what we see there is the propeller disks processing

162
00:10:25.830 --> 00:10:29.130
and not in phase, right? That's a non-symmetrical effect.

163
00:10:29.710 --> 00:10:34.480
And we also see that they're coupled into wing bending. Okay? So this is,

164
00:10:34.630 --> 00:10:39.580
this is a whirl flutter illustration, but is that actually the instability?

165
00:10:40.210 --> 00:10:43.180
It's actually not whirl flutter is part of this mechanism,

166
00:10:43.250 --> 00:10:47.970
part of this visualization. But look carefully at the, the close wing tip.

167

00:10:47.970 --> 00:10:50.490
For example. Notice that as the wing tip is going down,

168
00:10:50.950 --> 00:10:54.940
the aeron is going trailing edge up as the wing tip is going up,

169
00:10:54.960 --> 00:10:59.490
the aeron is trailing edge down. That's the source of instability, right?

170
00:10:59.710 --> 00:11:04.330
The aeron is phased with that wing bending in such a way as to help it become

171
00:11:04.610 --> 00:11:07.330
unstable. So this is wing bending,

172
00:11:07.330 --> 00:11:09.690
aeleron rotation flutter with a world component.

173
00:11:10.140 --> 00:11:12.690
Let's compare that to this guy over here.

174
00:11:14.710 --> 00:11:19.340
Here you also see the engine, the cells in bending,

175
00:11:19.660 --> 00:11:24.010
vertical bending, but there's no recession of the propellers. This,

176
00:11:24.010 --> 00:11:28.210
there's no world component here. Instead what's the flutter mechanism? Well,

177
00:11:28.210 --> 00:11:31.250
this is classic. This is like page two of a flutter textbook.

178
00:11:32.400 --> 00:11:36.680
I don't have a flutter textbook, but if I did, this would be page two. So I,

179
00:11:37.120 --> 00:11:39.290
I learned on the job, uh,

180
00:11:40.230 --> 00:11:44.680
notice as the wing is torsion leading edge down,

181
00:11:45.310 --> 00:11:49.040
it's also bending leading edge down as the wing is torsion leading edge up,

182
00:11:49.040 --> 00:11:52.120
it's bending, leading edge up. That's the source of instability.

183
00:11:52.120 --> 00:11:54.120
This is classical wing bending, torsion flutters.

184
00:11:54.120 --> 00:11:56.000
So we do that for all of the mechanisms, right,

185
00:11:56.470 --> 00:11:59.440
that we identify in our VGF plots.

186
00:12:01.640 --> 00:12:05.140
So once you've got a model, you want a robust model,

187
00:12:05.160 --> 00:12:06.420
you want a robust prediction,

188
00:12:06.420 --> 00:12:10.100
you want the the airplane to be safe and certifiable under a variety of

189
00:12:10.100 --> 00:12:10.920
variations.

190
00:12:10.920 --> 00:12:14.460
The first thing we do is find out what we call the nominal configuration,

191
00:12:14.460 --> 00:12:17.580
which is the combination of payload and fuel,

192
00:12:17.870 --> 00:12:20.020
which gives you the most critical flutter picture.

193

00:12:20.920 --> 00:12:23.500
And we use that for basically the rest of the analysis, right?

194
00:12:24.080 --> 00:12:25.700
So control surface weight and balance,

195
00:12:25.700 --> 00:12:28.820
because we have to establish balance specs for instructions for continuing air

196
00:12:28.820 --> 00:12:33.540
worthiness. Um, we have a passenger version and a freighter version.

197
00:12:33.540 --> 00:12:36.500
They're different because the passenger version has windows and extra doors.

198
00:12:36.720 --> 00:12:39.660
So the weight is different and the fuselage stiffness is different.

199
00:12:39.840 --> 00:12:40.700
That's a variation.

200
00:12:40.730 --> 00:12:44.660
This is also the only airplane I've ever worked on where the DI system is

201
00:12:45.380 --> 00:12:46.540
optional, okay?

202
00:12:46.640 --> 00:12:50.620
DI to us is different mass and potentially different stiffness along the leading

203
00:12:50.670 --> 00:12:55.660
edges of the surfaces. So different modes, right? Uh,

204
00:12:56.410 --> 00:12:58.220
effective icing in normal operation.

205
00:12:58.220 --> 00:13:02.500
ICE to us is a buildup of extra mass on leading edges. Uh,

206
00:13:02.500 --> 00:13:04.860
even when the DI system works, that doesn't mean you don't have ice,

207
00:13:04.880 --> 00:13:07.000
you just have less, um,

208
00:13:07.000 --> 00:13:11.400
effective propeller RPM with jets. Do I care? No.

209
00:13:12.180 --> 00:13:16.510
But with the tur prop, different RPM means a different flutter solution,

210
00:13:16.580 --> 00:13:18.710
different oral flutter solution potentially.

211
00:13:18.710 --> 00:13:22.990
Does it matter what we have to find out? Uh, variation. Let's see, where am I?

212
00:13:22.990 --> 00:13:26.510
Yeah, variations in control. Surface rotational stiffness. Um,

213
00:13:27.370 --> 00:13:31.790
is the pilot holding on hard? Is it just an autopilot load? Um,

214
00:13:32.130 --> 00:13:35.350
is something else, uh, blocking or jamming a control. Okay,

215
00:13:35.650 --> 00:13:37.870
so that changes control surface rotational modes,

216
00:13:37.870 --> 00:13:40.390
which changes flutter solution. Uh,

217
00:13:40.450 --> 00:13:44.510
and then parametric variations in the structural stiffness of the distributed

218
00:13:44.510 --> 00:13:49.350
components. Generally what happens if we're 20% off on wing bending, stiffness,

219
00:13:49.370 --> 00:13:52.550
is the airplane still safe? Torsion, stiffness, that sort of thing, okay?

220
00:13:52.800 --> 00:13:55.910
Parametric variations to show robustness. Robustness rather.

221
00:13:56.610 --> 00:14:01.110
And then about two thirds of a flutter analysis report is failure
conditions.

222
00:14:02.380 --> 00:14:02.700
Uh,

223
00:14:02.700 --> 00:14:07.640
tab push rod disconnects control surface disconnects and jams in part 23
are

224
00:14:07.640 --> 00:14:10.880
not actually required to do jams because in part 23,

225
00:14:10.880 --> 00:14:14.810
you're not required to be able to disconnect left and right sides fly the
side.

226
00:14:14.810 --> 00:14:15.890
That's free. However,

227
00:14:16.300 --> 00:14:20.050
since it's theoretically possible to fly the ship on the tabs with jam
controls

228
00:14:20.050 --> 00:14:23.410
mm-hmm. We check for that. Um,

229
00:14:23.880 --> 00:14:27.490
fatigue cracking and major structural sub assemblies. Failure of the DI
system,

230
00:14:27.490 --> 00:14:31.650
which means more weight fatigue, cracks are point stiffness reductions,

231
00:14:32.520 --> 00:14:34.730
fuel and balance. What happened if one wing's not feeding?

232
00:14:34.830 --> 00:14:36.370
Now the airplane is heavy on one side.

233
00:14:36.430 --> 00:14:40.050
You've got different modes over here than you do over there. Uh,

234
00:14:40.050 --> 00:14:44.610
engine failure with a jet, do I care? No. But with the propeller aircraft,

235
00:14:44.610 --> 00:14:45.570
with the turbo prop

236
00:14:47.090 --> 00:14:49.930
left at or right caging engine,

237
00:14:49.980 --> 00:14:53.200
those are two different solutions because the airplane is nominally symmetrical,

238
00:14:53.420 --> 00:14:56.200
but the propeller rotations are not mirrored across the center line.

239
00:14:56.220 --> 00:15:01.080
And then there's the double failure case. Uh, and then let's see,

240
00:15:01.080 --> 00:15:03.800
what else? Uh, engine rotor, non-con containment, uh,

241
00:15:03.990 --> 00:15:08.880
turbine stage frags and blows fragments through the fuselage point

242
00:15:08.880 --> 00:15:09.920
stiffness reduction.

243
00:15:10.220 --> 00:15:15.200
So just for the certification analysis is about 1,700 flutter

244
00:15:15.200 --> 00:15:17.960
runs. And over the course of the program, there's tens of thousands.

245
00:15:21.520 --> 00:15:24.310
So how do you know your model's any good?

246
00:15:25.740 --> 00:15:28.360
That's the purpose of the ground vibration test. It is,

247
00:15:28.550 --> 00:15:32.280
it's easy to get the idea that since we do the ground vibration test and then we

248
00:15:32.280 --> 00:15:33.280
do the flight fluter test,

249
00:15:33.420 --> 00:15:36.640
the ground vibration test must give us some kind of answer that says it's okay

250
00:15:36.640 --> 00:15:38.960
to fly the airplane to dive. That's not true.

251
00:15:39.230 --> 00:15:42.280
What the ground vibration test does is validate the analytical model.

252
00:15:42.980 --> 00:15:45.520
That's what tells you you're okay to go to dive. Okay?

253
00:15:46.060 --> 00:15:50.690
So look over here on the right side. That's the ground vibration test,

254
00:15:50.690 --> 00:15:54.410
which is pretty much required by reg, by the regulatory space, the,

255
00:15:54.410 --> 00:15:58.740
the G V T of the entire airplane. Um, but before we get there,

256
00:15:59.360 --> 00:16:00.700
we do what's not required.

257
00:16:00.920 --> 00:16:05.300
And we do component tests of major sub-assemblies like a wing, uh,

258
00:16:05.300 --> 00:16:07.620
the horizontal stabilizer, each control surface.

259
00:16:07.920 --> 00:16:10.780
The reason is we get really good high quality,

260
00:16:11.170 --> 00:16:15.020
high signal to noise answers about important chunks of the airplane so that by

261
00:16:15.020 --> 00:16:19.180
the time we put the whole thing together, we've got most of the answer.

262
00:16:19.760 --> 00:16:24.450
So the G V T in its best sense becomes a validation rather than

263
00:16:24.980 --> 00:16:29.590
telling us that we're wrong and we need to change something, right? Okay,

264
00:16:29.770 --> 00:16:32.070
so we got our G V T.

265
00:16:34.320 --> 00:16:37.210
What does that really mean? Well, in a ground vibration test,

266
00:16:37.210 --> 00:16:41.890
what you do is put programmed energy into the airframe at certain points,

267
00:16:42.740 --> 00:16:44.880
and you read what the airplane tells.

268
00:16:45.140 --> 00:16:48.880
It says back to you in frequencies and mode shapes with,

269
00:16:49.420 --> 00:16:53.800
in this case 330 accelerometers distributed around the airplane on structural

270
00:16:53.800 --> 00:16:58.740
hard points. Um, spar rib intersections, for example. Okay,

271
00:16:59.040 --> 00:17:02.980
on the wing, the tail, the fuselage, the control surfaces, uh,

272
00:17:02.980 --> 00:17:03.813
some examples there.

273
00:17:04.120 --> 00:17:08.100
We put energy into the airframe with those big 50 pound ash cans,

274
00:17:08.100 --> 00:17:09.940
which are electric magnetic, magnetic shakers.

275
00:17:10.170 --> 00:17:14.140
They can put in a burst of energy that's random over a frequency range,

276
00:17:14.250 --> 00:17:15.083
like pink noise,

277
00:17:15.680 --> 00:17:19.220
or they can dwell at a frequency or they can sweep through a range of

278
00:17:19.220 --> 00:17:21.490
frequencies, right? Depending on what we're doing,

279
00:17:21.490 --> 00:17:22.890
we'll use different excitations.

280
00:17:23.630 --> 00:17:27.810
So there we're exciting the wing notice there's a 45 degree angle block
there

281
00:17:28.430 --> 00:17:31.730
so that we get some motion in in plane and some motion in bending.

282
00:17:31.950 --> 00:17:36.410
And we're at the front spar so that we get torsion also, um,

283

00:17:37.180 --> 00:17:40.470
same thing, vertical fin. Then we have, uh, uh, we're exciting in aeron.

284
00:17:40.470 --> 00:17:45.290
We do the control surfaces to get those modes. And then on the engine two,

285
00:17:45.290 --> 00:17:48.490
because we need those modes for the world flutter analysis, right?

286
00:17:50.920 --> 00:17:53.250
Well, that's what the GVT does. And then once you've got the data,

287
00:17:53.720 --> 00:17:55.320
what do you do with it? Well,

288
00:17:55.320 --> 00:17:57.720
you compare it to what your analytical model is telling you.

289
00:17:57.980 --> 00:18:01.880
And if you're off somewhere, you will adjust the analytical model.

290
00:18:03.150 --> 00:18:04.570
In practice, it works like this.

291
00:18:04.950 --> 00:18:08.290
We know what the mass properties of the airplane are to a very high degree of

292
00:18:08.290 --> 00:18:11.570
precision because you can weigh things because we have a mass properties group.

293
00:18:12.600 --> 00:18:13.430
Um,

294
00:18:13.430 --> 00:18:17.180
those guys are amazingly accurate accountants with different output units than

295
00:18:17.180 --> 00:18:21.940

dollars and cents. They can on an aluminum airplane, they'll be 1% everywhere.

296
00:18:22.600 --> 00:18:24.700
So what we're really looking for is stiffness.

297
00:18:25.530 --> 00:18:30.040
Frequency is proportional to the square root of stiffness over mass.

298
00:18:30.300 --> 00:18:33.400
If I measure the frequency and know the mass, I can back out the stiffness.

299
00:18:33.400 --> 00:18:34.560
That's what A G V T does.

300
00:18:35.820 --> 00:18:39.680
And then we publish a correlation in one of our certification documents,

301
00:18:39.680 --> 00:18:43.640
which gives a comparison of what the G V T says and what the analysis says.

302
00:18:43.640 --> 00:18:47.320
And the percent difference in the fundamental low frequency modes.

303
00:18:47.560 --> 00:18:52.070
We're looking for 5% or better as the modes get higher, how high,

304
00:18:52.250 --> 00:18:54.150
how how high do we care about? Well,

305
00:18:54.560 --> 00:18:59.510
stuff starts not to matter for aero elastic purposes at 60 hertz,

306
00:18:59.510 --> 00:19:02.470
maybe 70 depending on the airframe. After that,

307
00:19:02.470 --> 00:19:04.710
it's little panels fluttering around.

308

00:19:04.710 --> 00:19:08.760
And that's not of interest to the flutter problem. Um,

309
00:19:09.850 --> 00:19:13.110
so, uh, there's a comparison over there. Let's see. Uh,

310
00:19:13.210 --> 00:19:17.470
the test frequency is 9.4. The gvt or the femme was telling us 9.9.

311
00:19:17.470 --> 00:19:21.620
That's a difference of 5.4%. Pretty good. And as I say jokingly,

312
00:19:21.620 --> 00:19:22.620
they're all just that good.

313
00:19:22.760 --> 00:19:27.300
But actually the we considering how complicated that airframe is,

314
00:19:27.890 --> 00:19:31.780
moly, and considering how different it is from what we're used to the,

315
00:19:32.360 --> 00:19:35.700
the guys setting up the test set, the model did a really great job,

316
00:19:36.710 --> 00:19:40.140
very successful test. But once you've got that, now you're ready to go fast.

317
00:19:42.100 --> 00:19:47.000
Uh, thought of this stuff is gonna be obvious to you guys, but uh,

318
00:19:47.450 --> 00:19:48.680
we'll just go through 'em briefly.

319
00:19:48.980 --> 00:19:53.560
The crew is well rusted and the crew includes the flutter guys on the ground

320
00:19:53.940 --> 00:19:56.440
in the telemetry room. They're part of that crew.

321

00:19:56.900 --> 00:20:01.680
So crew duty hours apply to us. Two, were very well rehearsed on procedures and,

322
00:20:01.780 --> 00:20:05.680
uh, the expected conditions. Adequate, adequate briefing, uh,

323
00:20:05.680 --> 00:20:08.360
inclusive of aircraft, state, and environmental conditions.

324
00:20:08.540 --> 00:20:11.900
If you're gonna be part of the test, you have to attend the briefing. Okay?

325
00:20:13.860 --> 00:20:17.040
Uh, we have special, we have special instrumentation suite on the aircraft.

326
00:20:18.120 --> 00:20:20.100
That's, there's a lot of instruments on the aircraft,

327
00:20:20.100 --> 00:20:21.940
but there's a special suite just for flight, flutter,

328
00:20:23.330 --> 00:20:26.730
egress aids installed in the cabin to give the guys a fighting chance if they

329
00:20:26.730 --> 00:20:31.560
need to leave in a rush. Um, and the aircraft is equipped with, uh,

330
00:20:31.590 --> 00:20:35.200
high speed recovery shoots, basically streamers. Um,

331
00:20:36.650 --> 00:20:37.710
and there's a chase aircraft.

332
00:20:37.730 --> 00:20:40.830
And that chase aircraft has to be selected such that it's a normal operating

333
00:20:40.830 --> 00:20:44.150

regime, includes the dive boundary of the aircraft under test,

334
00:20:44.350 --> 00:20:49.060
because after all, we're flutter testing one aircraft, not both of them. Um,

335
00:20:49.390 --> 00:20:51.580
procedures, and this is pretty important, all that,

336
00:20:51.800 --> 00:20:53.540
all the test points are observed in,

337
00:20:53.540 --> 00:20:56.980
observed in real time by the flutter folks and by the chase aircraft.

338
00:20:57.920 --> 00:21:00.700
It doesn't say that here, but anybody can call on abort,

339
00:21:00.760 --> 00:21:05.430
it can come from the pilots and can come from us. Truth be told,

340
00:21:05.430 --> 00:21:07.670
usually we'll see things before you guys do,

341
00:21:08.490 --> 00:21:12.150
or it can come from the chase aircraft if they see something they don't like.

342
00:21:13.590 --> 00:21:16.970
Uh, rigorous control room and radio discipline. I know that's hard to believe,

343
00:21:16.970 --> 00:21:19.410
but it's really true. We, uh,

344
00:21:20.630 --> 00:21:24.650
we joke around until it's time to go on point, and then we're very,

345
00:21:24.650 --> 00:21:29.290
very focused, um, rigorous it, I dunno if it says here, rigorous, uh,

346

00:21:30.110 --> 00:21:34.730
communications, right? We practice the radio calls, what the special calls are.

347
00:21:34.730 --> 00:21:38.570
There's a difference between a board and stop test and different reasons for

348
00:21:38.570 --> 00:21:43.170
making those calls, procedures. What happens after those calls are made? Um,

349
00:21:43.590 --> 00:21:47.610
we, this was the first program, uh, going back to, um,

350
00:21:48.300 --> 00:21:51.710
what Rod said. We actually practiced in the, uh,

351
00:21:51.860 --> 00:21:56.070
iron Bird simulator where they had the flight crew driving the computer airplane

352
00:21:56.370 --> 00:21:57.590
up there on the big screens.

353
00:21:57.730 --> 00:22:00.710
And I was sitting off on the steps pretending to make radio calls and telling

354
00:22:00.910 --> 00:22:04.340
'em to do their wraps and sweeps and stuff. Very, very helpful.

355
00:22:05.200 --> 00:22:08.900
But even more helpful than that is the fact that the flutter guys are, uh,

356
00:22:08.900 --> 00:22:13.540
observing the aircraft in low risk states from the very first early

357
00:22:13.540 --> 00:22:16.180
flights. We really know the aircraft pretty well,

358

00:22:16.600 --> 00:22:20.620
almost as well as the pilots do from our standpoint. Um,

359
00:22:22.140 --> 00:22:25.920
as, uh, now we have a new procedure, um, new,

360
00:22:26.100 --> 00:22:30.160
new since Dave Lewandowski and the CJ four. Um,

361
00:22:30.260 --> 00:22:32.320
we map the atmosphere on the way up.

362
00:22:32.570 --> 00:22:37.360
We're looking for sheer layers and temperature layers so that we don't have

363
00:22:37.640 --> 00:22:42.520
accidental over speeds, which they will remember, um, by punching through,

364
00:22:42.980 --> 00:22:44.440
uh, temperature layers,

365
00:22:44.440 --> 00:22:47.280
which change mock number in a discontinuous fashion and can result in

366
00:22:47.280 --> 00:22:50.320
overspeeds. We do not want to certify by overspeed.

367
00:22:50.320 --> 00:22:53.440
We wanna certify by being careful and being accurate.

368
00:22:55.140 --> 00:22:58.960
Uh, and the one down there I added at the last,

369
00:22:58.960 --> 00:23:02.120
because I always thought it was obvious, but it isn't. Uh, everybody,

370
00:23:02.300 --> 00:23:06.080
the flight crew's judgment is never questioned in a matter of safety of flight.

371
00:23:07.360 --> 00:23:12.210
So Stu or Brad or Aaron, you will never hear me say on the ground.

372
00:23:14.600 --> 00:23:19.390
The analysis is fine at this point. Let's just try that one again, okay?

373
00:23:19.390 --> 00:23:22.150
That'll never happen when flight crew's done. We're done.

374
00:23:22.370 --> 00:23:24.310
And we'll find another way. Okay?

375
00:23:27.890 --> 00:23:30.390
So we have test points. These are published in our test plan,

376
00:23:31.240 --> 00:23:34.550
which is a certification document that's the, um,

377
00:23:36.170 --> 00:23:37.240
model. Uh,

378
00:23:37.240 --> 00:23:41.160
4 0 8 is very unusual for us in that typically we're used to jets where maximum

379
00:23:41.600 --> 00:23:44.760
altitude is 40 to 50 V 1000 feet.

380
00:23:45.350 --> 00:23:48.290
So we'll have three test altitudes, a low test altitude,

381
00:23:48.290 --> 00:23:51.290
which is 15,000 because in a high speed aircraft, they need,

382
00:23:51.290 --> 00:23:53.090
the guys need a chance to get out if they have to,

383
00:23:53.590 --> 00:23:56.850
the knee point where the air speed and mock number, uh,

384

00:23:56.890 --> 00:23:59.570
coalesce and then some altitude point close to,

385
00:23:59.570 --> 00:24:02.410
but not at maximum certificated altitude because there's no way you can get

386
00:24:02.410 --> 00:24:06.010
there in level, uh, at, to your, uh, without a dissent.

387
00:24:06.010 --> 00:24:09.510
Nowhere you can get there. No, in the case of the 4 0 8,

388
00:24:09.930 --> 00:24:13.790
the max altitude of the airplane is only 25,000 feet and the knee altitude's

389
00:24:13.790 --> 00:24:14.830
11,000, give or take.

390
00:24:16.100 --> 00:24:20.240
So we have only two test altitude vans and we sort of talked with the flight

391
00:24:20.240 --> 00:24:24.360
crew about it's only 11,000 feet. Is that okay? And the answer is, well, yeah,

392
00:24:24.360 --> 00:24:27.560
because everything's gonna be happen happening much more. Well,

393
00:24:27.580 --> 00:24:31.320
not as quickly as we're used to in the jets. So that was judge safe,

394
00:24:31.320 --> 00:24:35.200
and there's no reason to go at any altitude below that because the difference in

395
00:24:35.200 --> 00:24:39.800
dynamic pressure between 11,000 and zero is insignificant from the standpoint of

396

00:24:39.820 --> 00:24:40.653
the Fluter solution.

397
00:24:44.470 --> 00:24:48.410
So we, what instrumentation, how do we know we're doing good? Well,

398
00:24:48.730 --> 00:24:49.690
remember what the G V T was.

399
00:24:49.690 --> 00:24:52.610
You put energy into the airframe in some controlled and known way,

400
00:24:52.610 --> 00:24:57.310
and you get energy out of the airframe through accelerometers and potentially

401
00:24:57.310 --> 00:25:01.070
other instruments too. The flight fluter test is like a G V T in the sky,

402
00:25:01.780 --> 00:25:04.760
except we don't have the bandwidth for 330 instruments.

403
00:25:05.020 --> 00:25:09.440
So we have accelerometers at the tips of things, wings stabbed vertical fin,

404
00:25:10.180 --> 00:25:15.160
um, typically normal, but also in plain. Uh, since whirl flutter is important,

405
00:25:15.170 --> 00:25:19.360
we've got the engines, uh, instrumented for, uh,

406
00:25:19.580 --> 00:25:20.413
yaw and pitch,

407
00:25:21.130 --> 00:25:25.720
and we've got RDTs at the control surfaces for high frequency,

408
00:25:25.750 --> 00:25:28.560
very accurate control surface rotation information.

409
00:25:30.140 --> 00:25:32.040
And the internal accelerometers,

410
00:25:32.210 --> 00:25:35.840
which is most of them have an A and a B channel so that we don't have to can a

411
00:25:35.840 --> 00:25:37.440
flight if we lose an Excel, right?

412
00:25:37.440 --> 00:25:41.200
We can switch over to the B channel and keep going. Uh, oh.

413
00:25:41.820 --> 00:25:45.360
And we had to instrument the struts too, right? Because those are dynamic items.

414
00:25:45.770 --> 00:25:48.480
Never had to do that before. Um,

415
00:25:49.140 --> 00:25:51.360
and we telemeter all this stuff in real time.

416
00:25:53.060 --> 00:25:57.360
Our setup in, in, um, in Rod's movies,

417
00:25:57.740 --> 00:26:02.040
we saw a large number of people. We don't have that. We have, uh,

418
00:26:02.510 --> 00:26:06.680
typically three flutter guys watching strip charts to each top and bottom,

419
00:26:07.060 --> 00:26:09.480
and then a test director standing behind with the microphone,

420
00:26:09.890 --> 00:26:13.830
which these days is me because, uh,

421
00:26:13.890 --> 00:26:17.710

I'm not afraid to talk on the microphone. And engineers are typically dorky,

422
00:26:17.710 --> 00:26:22.210
geeky guys who are asocial and shy. I'm less of that than,

423
00:26:22.240 --> 00:26:26.640
than the other guys. Um, and so the purpose of this,

424
00:26:26.640 --> 00:26:28.440
and this is language right out of the regulation,

425
00:26:28.540 --> 00:26:32.560
is to show no large or rapid reduction in damping as the dive boundaries

426
00:26:32.760 --> 00:26:34.720
approached. Okay?

427
00:26:37.230 --> 00:26:39.690
So that's how we're gonna read the energy out of the airframe.

428
00:26:39.690 --> 00:26:40.890
How do we get it in? Well,

429
00:26:41.110 --> 00:26:45.000
the thing that you're all familiar with is wraps the impulsive pilot control

430
00:26:45.140 --> 00:26:49.800
inputs. Theoretically a wrap excites all the modes in the structure.

431
00:26:51.030 --> 00:26:53.290
In practice, you'll get, uh,

432
00:26:53.720 --> 00:26:57.810
good excitation up to the natural frequency of the control system you're talking

433
00:26:57.810 --> 00:26:59.770
about. Our arons typically are in the teens,

434

00:27:00.350 --> 00:27:03.810
so we get good excitation up to say 15 hertz, but less above that.

435
00:27:03.870 --> 00:27:06.610
So if we wanna excite the airframe above that,

436
00:27:06.830 --> 00:27:10.400
and if we say that natural turbulence, uh,

437
00:27:10.400 --> 00:27:12.960
airframe turbulence is insufficient, it's questionable.

438
00:27:13.300 --> 00:27:15.600
We don't have any mock number on this airplane to speak of.

439
00:27:15.660 --> 00:27:19.400
So we can't depend on the very excellent broadband excitation you get from

440
00:27:19.400 --> 00:27:23.000
shockwaves standing on the wings and tail, for example. Don't have that here.

441
00:27:24.180 --> 00:27:26.360
We need some kind of artificial excitation system.

442
00:27:26.360 --> 00:27:30.880
We use a system of fixed veins with a rotating slotted cylinder at the trailing

443
00:27:30.880 --> 00:27:32.420
edge. Um,

444
00:27:33.020 --> 00:27:35.900
a rotating cylinder and an onset flow is called a flattener rotor.

445
00:27:35.900 --> 00:27:40.840
It produces lift. You can sail a boat that way. If you have a slot in the, uh,

446
00:27:40.940 --> 00:27:42.600
in the, uh, rotating cylinder,

447
00:27:43.220 --> 00:27:48.070
you generate a periodic force on an airfoil that fixed air foil

448
00:27:49.060 --> 00:27:50.840
at the frequency of the rotation of the cylinder.

449
00:27:50.860 --> 00:27:54.040
That's how we put a range of frequencies into the airframe.

450
00:27:54.040 --> 00:27:56.360
Under our controller, rather under the pilot's control,

451
00:27:56.890 --> 00:28:01.590
we can do symmetric or antis excitation of the wings. The horizontal stabilizer,

452
00:28:02.650 --> 00:28:04.030
uh, symmetric, uh,

453
00:28:04.470 --> 00:28:07.830
anti-Semitic horizontal stabilizer will give us fin bending.

454
00:28:08.170 --> 00:28:13.030
Notice that I'm in the dynamics group, so I wave my arms around a lot. Um,

455
00:28:13.530 --> 00:28:15.070
so that's how we get the energy in.

456
00:28:15.700 --> 00:28:18.500
What does it look like getting the test points? Well,

457
00:28:19.320 --> 00:28:23.150
the low speed ones are pretty easy. You can get 'em in level.

458
00:28:23.150 --> 00:28:25.990
Flight 4 0 8 can't actually go v m O in level flight.

459
00:28:25.990 --> 00:28:29.690
You have to descend even for that. That's a lot of drag on that airplane.

460
00:28:31.230 --> 00:28:35.250
Um, so descents are always necessary, and the faster you go,

461
00:28:35.470 --> 00:28:37.490
the less time you have to be on point.

462
00:28:38.300 --> 00:28:42.960
So to do a sequence of wraps and then two wing act citations and two,

463
00:28:43.700 --> 00:28:46.400
uh, tail act citations, symmetric and asymmetric each.

464
00:28:46.900 --> 00:28:48.440
By the time you get down to the dive boundary,

465
00:28:48.500 --> 00:28:51.800
you may be doing a separate dissent for each one of those, okay?

466
00:28:53.080 --> 00:28:54.900
But as you can see, we got them. Uh,

467
00:28:54.900 --> 00:28:57.740
the blue ones are test points we did with wraps.

468
00:28:57.760 --> 00:29:02.340
The red ones are test points we did with frequency sweeps with the
shakers.

469
00:29:03.040 --> 00:29:06.140
And then the green ones are where we're essentially doing a demonstration
to

470
00:29:06.140 --> 00:29:06.973
fill in those,

471
00:29:07.100 --> 00:29:10.500
a few points between the high altitude and knee altitude test points

472
00:29:13.930 --> 00:29:18.460
now, so all the pieces come back to the airport at the same time.

473
00:29:18.720 --> 00:29:21.260
So the flight flight test was successful. However,

474
00:29:21.640 --> 00:29:26.460
how do you convince your regulatory friends that you have shown no

475
00:29:26.460 --> 00:29:29.700
larger rapid reduction in damping as the dive boundary is approached?
Well,

476
00:29:30.200 --> 00:29:34.780
if you take your output instrumentation and plot either in a power

477
00:29:34.980 --> 00:29:37.420
spectral density or a frequency response function,

478
00:29:38.610 --> 00:29:42.780
the levels of excitation at different air speeds, we've taken the,

479
00:29:42.800 --> 00:29:46.820
the key away that that tells you what air speeds those different colored
lines

480
00:29:46.920 --> 00:29:51.260
are, because that's a very well kept secret, how fast the 4 0 8 can go.

481
00:29:52.240 --> 00:29:54.900
Um, but what you see here now, I'm, I'm,

482
00:29:54.900 --> 00:29:57.100
this is from one accelerometer on the airframe,

483
00:29:57.220 --> 00:30:00.540
I think because of where I see the modes is probably a wing
accelerometer.

484
00:30:00.560 --> 00:30:02.700
But the idea is that

485
00:30:04.410 --> 00:30:07.510

you see as the, as the air speed increases,

486
00:30:07.610 --> 00:30:11.550
the noise floor of the response goes up because the energy in the airstream

487
00:30:11.750 --> 00:30:16.350
increases as a square of the speed right now. So the whole thing comes up.

488
00:30:16.970 --> 00:30:21.690
What you don't see is one of those peaks suddenly becoming

489
00:30:21.800 --> 00:30:25.060
very sharp and growing by a couple of orders of magnitude.

490
00:30:25.330 --> 00:30:29.290
That would be an indication of an approach to an instability. Okay?

491
00:30:29.320 --> 00:30:30.810
That would be bad news. Well,

492
00:30:30.870 --> 00:30:35.690
our flat flutter test results report is page upon page upon page of

493
00:30:35.690 --> 00:30:40.050
boring plots like this. And then flutter, what you want is boredom, right?

494
00:30:40.790 --> 00:30:41.730
So this,

495
00:30:41.900 --> 00:30:46.890
these show that we have no larger rapid reduction in damping as we, uh,

496
00:30:47.090 --> 00:30:51.880
approach the dive boundary. So I would like to,

497
00:30:52.380 --> 00:30:56.970
uh, keep the, uh, the intensity of the, of the, uh,

498

00:30:58.150 --> 00:30:59.170
the thing going. But frankly,

499
00:30:59.290 --> 00:31:02.850
I have to admit that the 4 0 8 was the easiest flight fluter test I've ever been

500
00:31:03.010 --> 00:31:03.843
involved in.

501
00:31:04.420 --> 00:31:08.160
We did both configurations with and without the di ice boots installed several

502
00:31:08.160 --> 00:31:12.360
months apart because it's a long winded modification in, in three flights.

503
00:31:13.040 --> 00:31:17.300
That's unheard of in my experience of flight fluer test

504
00:31:18.000 --> 00:31:22.940
of one of the jets. It's a campaign. It takes a couple of weeks, many flights,

505
00:31:23.250 --> 00:31:28.030
many do-overs. Um, but this was easy. Why was it easy? Well,

506
00:31:28.230 --> 00:31:29.110
remember at the start I said,

507
00:31:29.580 --> 00:31:32.270
it's gonna be harder because we have a high drag configuration,

508
00:31:32.370 --> 00:31:35.030
but it's gonna be easier because we have a low mock configuration.

509
00:31:35.030 --> 00:31:36.350
Which one of those is gonna win out?

510
00:31:36.850 --> 00:31:40.530
And so it turned out that the absence of mock related effects was,

511
00:31:40.870 --> 00:31:43.510
it was a revelation. Um,

512
00:31:43.600 --> 00:31:48.440
there was no powerful drag rise associated with critical mock. Um, there was,

513
00:31:48.440 --> 00:31:51.000
so there was reduced concerns about atmospheric gradients,

514
00:31:51.000 --> 00:31:53.800
which changed mock number quickly. Um,

515
00:31:53.800 --> 00:31:57.400
there was no controllability issues that you run into with high mock effects.

516
00:31:57.400 --> 00:32:01.080
There's no tuck, there's no roll off. Um,

517
00:32:01.850 --> 00:32:06.010
so the pilots could control the descents with tremendous accuracy.

518
00:32:06.090 --> 00:32:08.690
I think Aaron did one of some of the final dives,

519
00:32:08.690 --> 00:32:11.450
and it was like the airplane was on rails. I've never seen that in a,

520
00:32:11.790 --> 00:32:16.340
in a high mock descent, well, relatively high mock descent. Um,

521
00:32:16.340 --> 00:32:19.940
so there was no concern about other transing effects such as control service

522
00:32:20.170 --> 00:32:21.580
buzz. Um,

523
00:32:22.450 --> 00:32:25.660

despite what you will have read in some academic tests,

524
00:32:26.070 --> 00:32:30.530
texts written by fellows who don't certify airplanes, buzz is not flutter.

525
00:32:30.600 --> 00:32:34.010
It's completely different physics, and we have no predictive means for it.

526
00:32:34.010 --> 00:32:38.090
It's a non-linearity. Um, so what you have to do is avoid buzz.

527
00:32:38.150 --> 00:32:42.120
And we've had some airplanes that had, uh, potential buzz issues,

528
00:32:43.100 --> 00:32:47.130
um, but obviously at point less than 0.5 mach, that's not gonna happen.

529
00:32:48.110 --> 00:32:53.100
Um, and just to cut to the chase, the max, uh,

530
00:32:53.170 --> 00:32:53.970
dissent rates,

531
00:32:53.970 --> 00:32:58.960
were on the order of about 8,000 feet a minute and 18 degrees nose down with the

532
00:32:59.030 --> 00:33:03.680
jets and the high mock drag rise where we see numbers

533
00:33:03.790 --> 00:33:08.720
like approaching 30,000 feet a minute and 30 degrees nose down. Um,

534
00:33:09.020 --> 00:33:12.880
so this was a walk in the park by comparison with any other program I've been

535
00:33:12.880 --> 00:33:15.390
on. And again, the,

536
00:33:16.030 --> 00:33:20.600
there's hardly anything to explain to the regulator because of the nature of the

537
00:33:20.600 --> 00:33:21.433
plots we produced.

538
00:33:22.150 --> 00:33:25.600
Lack of precipitous decreases in damping is cleared by observation.

539
00:33:27.380 --> 00:33:31.840
Any questions? How, how, how good am I there? Not I'm, I'm late, not too late.

540
00:33:51.150 --> 00:33:53.910
A certain point. You've shown, uh, many, uh,

541
00:33:54.370 --> 00:33:58.550
the many test cases or many cases, I think 1700, uh,

542
00:33:58.670 --> 00:34:03.470
combinations. Yeah. Uh, out of those, obviously you've flight tested only, uh,

543
00:34:04.250 --> 00:34:07.710
way many. Yes. Uh, sorry, way less than that. Um,

544
00:34:08.250 --> 00:34:10.230
how is that decision made of, uh,

545
00:34:10.820 --> 00:34:15.190
Well, the, the large number of analytical cases we've run is to cover the,

546
00:34:15.770 --> 00:34:16.603
um,

547
00:34:16.860 --> 00:34:21.410
regulatory gamut for the certification ar the analytical document for the flight

548

00:34:21.610 --> 00:34:22.443
fluter test.

549
00:34:24.930 --> 00:34:27.470
The airplane is not the production article, it's the prototype.

550
00:34:27.490 --> 00:34:32.030
So it has its own mass properties, right? It's got other things. It,

551
00:34:32.030 --> 00:34:33.750
it doesn't have a conventional interior. The,

552
00:34:33.930 --> 00:34:37.030
the mass properties inside the aircraft are different. Um,

553
00:34:37.370 --> 00:34:39.710
what's important in doing the flight fluter test the same.

554
00:34:39.710 --> 00:34:41.390
That's important in doing the ground vibration test.

555
00:34:41.820 --> 00:34:44.350
It's not that you have a particular configuration,

556
00:34:44.420 --> 00:34:49.150
it's that your model represent that configuration. So the guys will ask,

557
00:34:49.220 --> 00:34:53.940
well, you found the analytically the worst case, um,

558
00:34:54.090 --> 00:34:56.100
fuel and payload combination, which you call nominal.

559
00:34:56.100 --> 00:34:58.940
Does that mean you have to flight test in that configuration? The answer is no,

560
00:34:59.210 --> 00:35:02.780
because we have an analytical model which is loaded to the configuration of the

561

00:35:02.940 --> 00:35:07.620
aircraft under test. What we want to show is not that our model is,

562
00:35:07.970 --> 00:35:09.100
okay, I shouldn't admit this.

563
00:35:09.610 --> 00:35:12.180
What we wanna show is not that our model is perfectly accurate,

564
00:35:12.180 --> 00:35:16.200
we want to show that it is rationally conservative. So I'm gonna,

565
00:35:16.200 --> 00:35:19.320
with my analytical model, predict damping for a given configuration,

566
00:35:19.370 --> 00:35:23.840
known configuration, not necessarily the nominal, I'm gonna predict damping,

567
00:35:23.840 --> 00:35:26.930
which is worse than what we get in flight. Okay?

568
00:35:27.760 --> 00:35:28.900
So does that answer your question?

569
00:35:29.080 --> 00:35:33.940
So if I understand correctly, you build your, uh, test metrics, uh,

570
00:35:34.490 --> 00:35:39.400
with the cases that you need in order to build or validate the model well enough

571
00:35:40.140 --> 00:35:40.950
so that you can,

572
00:35:40.950 --> 00:35:41.400
Well,

573
00:35:41.400 --> 00:35:46.140
actually all we're trying to do is with that one airplane configuration hit

574
00:35:46.320 --> 00:35:50.340
Oh, sorry. Hit the hit, literally hit those test points in the sky. Okay.

575
00:35:50.560 --> 00:35:52.060
So we're trying to cover the altitude,

576
00:35:52.250 --> 00:35:56.420
mock number and air speed range with a known configuration. We're not trying,

577
00:35:56.440 --> 00:36:01.060
we don't go and reload the airplane in some other CG case, for example, right?

578
00:36:01.060 --> 00:36:03.500
The flutter guide doesn't care what the CG of the aircraft is.

579
00:36:03.580 --> 00:36:06.820
I couldn't care less about 500 pounds here or there. I care about

580
00:36:08.670 --> 00:36:12.720
15 ounces in an el in an elevator tab that changes my life, right?

581
00:36:14.060 --> 00:36:14.893
But yeah,

582
00:36:15.550 --> 00:36:19.600
typically loading the airplane will affect the flutter solution analytically,

583
00:36:19.900 --> 00:36:24.360
but it doesn't affect whether it's safe or not. See, okay.

584
00:36:25.070 --> 00:36:25.903
Anybody else?

585
00:36:31.970 --> 00:36:36.230
Uh, I ran a little late. Like I said, it's a pretty good 45 minute, uh, do

586
00:36:36.230 --> 00:36:37.063

Have question?

587
00:36:47.170 --> 00:36:51.190
Yes. Has, uh, amendment 64 changed the way you do fluter?

588
00:36:51.790 --> 00:36:53.030
Excellent question. Um,

589
00:36:53.230 --> 00:36:55.750
I think it said in one of the slides when I buzzed right past it,

590
00:36:55.850 --> 00:36:59.550
the Model four eight, I believe is the first airplane certified to amendment 64.

591
00:36:59.550 --> 00:37:01.510
Yes. And the answer is no,

592
00:37:01.510 --> 00:37:06.190
because Amendment 63 is an acceptable means of compliance to Amendment

593
00:37:06.190 --> 00:37:10.350
64. And there was no flutter related change in Amendment 63,

594
00:37:10.370 --> 00:37:13.870
it stopped changing amendment 62. So our lives have not changed.

595
00:37:13.940 --> 00:37:17.700
What did change is the pile of, uh,

596
00:37:17.700 --> 00:37:22.580
paper associated with it because as you know, the Amendment 64 rule is,

597
00:37:23.610 --> 00:37:28.340
it's Siri, I think it's five lines of suggestions. Right? What that,

598
00:37:28.340 --> 00:37:32.300
what it does is it effectively points to the ASTMs, which look like,

599
00:37:33.260 --> 00:37:37.960
uh, the text at Amendment 63. So it Yeah,

600
00:37:38.020 --> 00:37:40.480
for exactly the ASTMs can change quickly.

601
00:37:40.480 --> 00:37:42.200
That's why they started doing it like that,

602
00:37:43.260 --> 00:37:46.720
so that we can have a regulatory space that is as responsive as the one they,

603
00:37:47.180 --> 00:37:51.080
by industry regulator consensus, like they have SSA does,

604
00:37:52.020 --> 00:37:55.510
they can respond quickly to changes in technology and construction methods and

605
00:37:55.510 --> 00:37:55.750
so on,

606
00:37:55.750 --> 00:37:58.430
which you can't really do when your regulations are federal laws that move at

607
00:37:58.430 --> 00:38:01.250
the speed of Congress. So that's why they did,

608
00:38:01.250 --> 00:38:04.040
that's why they're doing it this way, but it's not easier. Thanks.

609
00:38:04.870 --> 00:38:05.703
Okay.

610
00:38:18.570 --> 00:38:19.200
Thank you Dave.