Custom Flight Test Display
1
00:00:01.640 --> 00:00:02.760
All right. This next paper,

2
00:00:03.800 --> 00:00:07.550
I heard about this idea a couple of years ago, and when you guys

3
00:00:07.620 --> 00:00:08.170
submitted

4
00:00:09.820 --> 00:00:13.340
the abstract, I was thrilled to see that we could present this today.

5
00:00:13.420 --> 00:00:17.139
So we've all had flight test displays in our

6
00:00:17.200 --> 00:00:21.060
cockpits. They're usually a separate display. They're off to the side.

7
00:00:21.090 --> 00:00:25.060
They're usually not created very well, from my experience.

8
00:00:26.540 --> 00:00:29.840
But in Boeing, they've taken this to the next step, and we

9
00:00:30.560 --> 00:00:34.460
have a great chance here to listen to Chris and Dunes.

10
00:00:34.520 --> 00:00:37.560
I'm glad you have a call sign, because I couldn't say your name.

11
00:00:37.800 --> 00:00:41.260
And Chris and Dunes are going to talk about the custom flight

12
00:00:41.600 --> 00:00:44.820
test display, the initial deployment, and lessons learned.

13
00:00:44.880 --> 00:00:48.520
So between them, 40-plus years of flight test experience.

14

00:00:48.580 --> 00:00:50.320
So welcome to the stage, Chris and Dune.

15
00:01:05.200 --> 00:01:08.920
All right. So when I joined commercial flight tests 20 years

16
00:01:08.960 --> 00:01:12.940
ago, it was on this 777 that we were using as a flying

17
00:01:13.020 --> 00:01:16.480
test bed for the prototype 787 flight control laws.

18
00:01:16.910 --> 00:01:20.700
And it was a really incredible program to be on, and

19
00:01:20.740 --> 00:01:24.610
then early on, I began to encounter all of the different tools and

20
00:01:24.610 --> 00:01:28.020
equipment that we have to install on our airplanes, and to turn it into a

21
00:01:28.060 --> 00:01:31.570
proper test asset. And I'll point out two of those right now.

22
00:01:32.260 --> 00:01:34.160
First one is up on the glare shield.

23
00:01:34.440 --> 00:01:37.820
It's this digital display we call LADS, and it's where we keep our backup

24
00:01:37.860 --> 00:01:41.140
panels. And then on the

25
00:01:41.800 --> 00:01:45.480
side of the screen here, we have these two auxiliary displays that we
call LADS.

26
00:01:46.240 --> 00:01:49.680
And that was just a great addition to this era of flight test,

27
00:01:50.060 --> 00:01:53.840

because it did bring a better visualization of those critical

28
00:01:53.900 --> 00:01:57.780
flight test parameters that we need to fly our maneuvers, and we did

29
00:01:57.840 --> 00:02:00.060
that with a lab view-generated display.

30
00:02:01.760 --> 00:02:05.700
But if we fast-forward to this time last year, our airplanes,

31
00:02:05.860 --> 00:02:09.640
avionics, and computing had all taken several leaps forward in technology,

32
00:02:10.400 --> 00:02:13.500
but our flight test tool architecture had remained static for

33
00:02:14.160 --> 00:02:16.020
largely the better part of three decades.

34
00:02:16.600 --> 00:02:20.580
And during this time, I received more experience with

35
00:02:20.880 --> 00:02:24.720
our tools and recognized just how we

36
00:02:24.840 --> 00:02:28.680
were compensating for the lack of information where we wanted

37
00:02:28.740 --> 00:02:28.880
it.

38
00:02:30.300 --> 00:02:33.900
And if we take a little bit closer look at LADS, and this is one of our

39
00:02:34.320 --> 00:02:36.260
more commonly used displays,

40
00:02:37.060 --> 00:02:40.930
I have all the information I need here, but it takes a bit of

41
00:02:41.020 --> 00:02:44.880
time to orient to the display and then decipher what's on it.

42
00:02:45.560 --> 00:02:49.240
And if I go from a more normal envelope to a high-speed realm,

43
00:02:49.880 --> 00:02:53.540
well, we change the display, my parameters move,

44
00:02:54.020 --> 00:02:54.370
and

45
00:02:55.340 --> 00:02:57.140
how we present them change as well.

46
00:02:58.520 --> 00:03:02.340
LADS predates any type of modern attempt at a human

47
00:03:02.380 --> 00:03:03.320
factors approach.

48
00:03:04.280 --> 00:03:07.440
Not only are the parameters moving on the display,

49
00:03:08.300 --> 00:03:12.220
but the display itself begins to move around depending on the test asset

50
00:03:12.280 --> 00:03:16.090
I'm flying of the day. There was no attempt

51
00:03:17.340 --> 00:03:20.990
to standardize its location. It was always an afterthought, and its

52
00:03:21.020 --> 00:03:24.810
location's always a compromise. So at the end of the day, I

53
00:03:24.840 --> 00:03:25.660
wind up with

54

00:03:26.560 --> 00:03:30.549
a huge distribution of information scattered about the flight deck that

55
00:03:30.620 --> 00:03:34.310
I then have to fuse in my mind to determine the aircraft state and then
what I want

56
00:03:34.320 --> 00:03:38.300
to do with it. So that observe, orient, detect, and act

57
00:03:38.340 --> 00:03:40.420
loop, that OODA loop, was just massive.

58
00:03:41.960 --> 00:03:45.880
So we had a small group of us that launched a project with the goal

59
00:03:46.040 --> 00:03:47.300
of shortening that OODA loop,

60
00:03:48.520 --> 00:03:51.860
and in our hearts, we knew that if we could do that, we would

61
00:03:52.100 --> 00:03:55.720
see benefits in safety, quality, and efficiency.

62
00:03:55.730 --> 00:03:59.620
And I wanted to do it in a way so that I could drive that information to
where

63
00:03:59.680 --> 00:04:03.410
I'm going to control it in a way that was intuitive to the pilots and

64
00:04:03.540 --> 00:04:07.230
leveraged our existing flight deck design.

65
00:04:07.290 --> 00:04:10.220
We also knew that we weren't the only ones with this issue.

66
00:04:10.920 --> 00:04:14.790
So we started looking around the rest of the industry, and unfortunately,
we didn't

67
00:04:14.820 --> 00:04:18.300
find a lot that excited us in the transport and the commuter world.

68
00:04:18.721 --> 00:04:21.800
But we did find some interesting stuff happening, especially with our sister

69
00:04:21.860 --> 00:04:24.580
organization out of St. Louis on their T-7.

70
00:04:25.100 --> 00:04:27.840
And they had tremendous success in their test program.

71
00:04:28.330 --> 00:04:30.040
And when we engaged their chief pilot,

72
00:04:30.900 --> 00:04:34.480
we learned that that was an outgrowth of an earlier F-15 project,

73
00:04:34.870 --> 00:04:38.640
and he also pointed us to an earlier society paper from the B-2

74
00:04:38.680 --> 00:04:40.430
community on flight test aids.

75
00:04:41.420 --> 00:04:44.860
And all of that came down to, yes indeed, getting the

76
00:04:44.910 --> 00:04:47.320
information in front of the pilot where they needed it

77
00:04:48.140 --> 00:04:49.960
did wind up with tangible benefits.

78
00:04:51.140 --> 00:04:53.980
So we were able to get that small team out to St. Louis.

79
00:04:54.200 --> 00:04:58.080
I was able to fly the T-7 simulator and get some first-hand experience with

80
00:04:58.180 --> 00:05:02.100
their tools, and we just came back incredibly inspired and

81
00:05:02.120 --> 00:05:03.180
with a couple of takeaways.

82
00:05:04.260 --> 00:05:08.200
Like I said, getting that information in front of the pilot is

83
00:05:08.320 --> 00:05:09.180
going to be the benefit here.

84
00:05:10.000 --> 00:05:13.540
They use a HUD. Commercial transport, we're still forward display-driven

85
00:05:13.600 --> 00:05:17.440
airplanes, but then this gives me an opportunity to use greater

86
00:05:17.560 --> 00:05:19.120
colors, shapes, and symbols.

87
00:05:19.920 --> 00:05:23.380
And then one of the cool things that allowed

88
00:05:23.820 --> 00:05:27.560
T-7 to be successful is that they're a small, vertically integrated

89
00:05:27.620 --> 00:05:31.540
team that most importantly controlled their own software, and this would
turn

90
00:05:31.580 --> 00:05:33.550
out to be our enabler as well.

91
00:05:35.360 --> 00:05:38.100
So when we came back, there were some simple things that we knew that we
really

92
00:05:38.140 --> 00:05:41.860
wanted to do, like getting NZ adjacent to our airspeed,

93
00:05:42.420 --> 00:05:46.280
and then I also wanted to make sure that we had target and limit information on

94
00:05:46.300 --> 00:05:49.940
there as well. That greater use of color allows me to

95
00:05:49.960 --> 00:05:52.900
provide a cue to our pilots that

96
00:05:53.840 --> 00:05:55.280
once we cross the maneuver target,

97
00:05:56.200 --> 00:05:57.240
it's now time to recover.

98
00:05:58.340 --> 00:06:01.600
I can also provide a greater awareness to safety limits.

99
00:06:01.740 --> 00:06:03.820
In this case, knock it off, it's time to go

100
00:06:03.860 --> 00:06:07.808
home.Speaking of greater

101
00:06:07.848 --> 00:06:11.528
awareness, we spend a lot of time in a high-speed realm with no

102
00:06:11.568 --> 00:06:15.148
production information regarding dive

103
00:06:15.308 --> 00:06:15.798
speeds,

104
00:06:16.628 --> 00:06:19.188
proximity to aerodynamic knee, things like that.

105
00:06:19.528 --> 00:06:23.468
We're able to add that information on here, and these amber yellow

106

00:06:23.548 --> 00:06:26.948
color crosshatches wind up converging, giving me a nice

107
00:06:27.208 --> 00:06:30.068
X keep out area as I dive down on the knee.

108
00:06:31.068 --> 00:06:34.628
We also have a lot of real estate on our displays that have a commercial purpose,

109
00:06:35.148 --> 00:06:37.628
but just are blank during flight test.

110
00:06:38.208 --> 00:06:41.347
So I was able to repurpose the lower left. This is the new panels.

111
00:06:41.648 --> 00:06:44.908
It's multi-parameter, and there's labels and units to go with

112
00:06:44.968 --> 00:06:48.328
our data. And all this other area here

113
00:06:49.068 --> 00:06:52.668
is ripe for new tools and features that enable other parts of flight

114
00:06:52.748 --> 00:06:56.668
testing. And what we wind up with is a highly customizable

115
00:06:56.688 --> 00:07:00.648
flight test display that we call Vera, and

116
00:07:00.668 --> 00:07:04.538
we named it Vera to honor Vera Martonovich, who was one of

117
00:07:04.588 --> 00:07:08.108
our engineers and leaders. She was incredibly supportive of this

118
00:07:08.128 --> 00:07:11.467
project, and unfortunately passed away a few years ago.

119
00:07:11.988 --> 00:07:12.188

So

120
00:07:13.308 --> 00:07:13.648
with that.

121
00:07:15.828 --> 00:07:16.108
All right.

122
00:07:17.068 --> 00:07:18.748
So let's talk a little bit about the design of Vera.

123
00:07:19.608 --> 00:07:23.548
So as Caps mentioned, based on past research, we knew that providing

124
00:07:23.568 --> 00:07:27.488
information in graphical form would lower the cognitive load of the pilot,

125
00:07:27.528 --> 00:07:31.468
so we took that to heart. So one of our goals was to

126
00:07:31.508 --> 00:07:35.228
reduce the number of memorized test plan items we were asking of our pilots.

127
00:07:35.748 --> 00:07:39.428
Pre Vera, we would sometimes ask pilots, "Remember

128
00:07:39.448 --> 00:07:43.318
the targets, various types of limits." And

129
00:07:44.128 --> 00:07:47.728
we're talking about in the maneuver, obviously it's on the test plan, but

130
00:07:48.328 --> 00:07:51.028
for example, tolerances. So pilots would have to do mental math.

131
00:07:51.068 --> 00:07:54.648
Okay, my airspeed target is X plus or minus five knots, carry the

132
00:07:54.688 --> 00:07:56.968

one. We wanted to get rid of all of that, right?

133
00:07:57.348 --> 00:08:01.288
So, as Caps put it, we're changing the exercise to put the thing

134
00:08:01.328 --> 00:08:05.078
on the thing, and as a structures guy, I say, while you're at it,

135
00:08:05.188 --> 00:08:08.788
avoid this other thing. So let me give you some examples.

136
00:08:09.738 --> 00:08:12.848
Load factor tape. Pretty easy, we got a tape.

137
00:08:12.888 --> 00:08:16.347
That's thing one. We got a target. That's thing two. Put thing one on thing two.

138
00:08:18.048 --> 00:08:21.988
Column pull. We have thing one, put it on thing two to make

139
00:08:22.028 --> 00:08:26.008
a target. In the moment of the maneuver, the actual value of the target

140
00:08:26.068 --> 00:08:26.808
is irrelevant.

141
00:08:28.508 --> 00:08:31.868
Pitch target. No longer does the pilot have to

142
00:08:31.908 --> 00:08:35.168
interpolate between lines on the pitch ladder to get the target.

143
00:08:35.528 --> 00:08:39.408
They just take thing one, put it on thing two, the exercise is done.

144
00:08:40.268 --> 00:08:40.588
And

145
00:08:41.548 --> 00:08:45.028

I'm a structures guy, for God's sakes, Caps, avoid the red, avoid the other thing.

146
00:08:46.508 --> 00:08:50.268
Okay. And then from a hardware perspective, so

147
00:08:50.388 --> 00:08:54.358
we take our Vera computer that generates the display and plug it

148
00:08:54.368 --> 00:08:56.098
into one of the outboard displays.

149
00:08:56.688 --> 00:08:59.968
As you can see from the diagram, our system is completely

150
00:09:00.148 --> 00:09:02.667
federated from the production avionics.

151
00:09:03.308 --> 00:09:06.948
So what this does is that we are not beholden to

152
00:09:07.048 --> 00:09:10.608
the assurance level of the production avionics.

153
00:09:11.068 --> 00:09:14.688
We get away with this because as part of our safety analysis, we determine

154
00:09:14.768 --> 00:09:18.528
that a production PFD will be available to the pilots at all

155
00:09:18.588 --> 00:09:22.468
times. So what we do is we take that DAL A

156
00:09:22.528 --> 00:09:26.508
assured PFD, we move it to the inboard display, and Vera is

157
00:09:26.588 --> 00:09:27.868
up on the outboard display.

158
00:09:29.028 --> 00:09:32.768

And so we benefit from this because now owning this software

159
00:09:32.848 --> 00:09:36.128
stack, like Caps pointed out, we can iterate on Vera

160
00:09:36.828 --> 00:09:40.528
and bring more improvements and new features in a matter

161
00:09:40.588 --> 00:09:43.658
of months, weeks, and even days for fixes if

162
00:09:43.708 --> 00:09:45.848
necessary. So we're

163
00:09:46.948 --> 00:09:50.728
definitely benefiting from owning the software stack and keeping it

164
00:09:50.768 --> 00:09:52.508
within our group.

165
00:09:55.048 --> 00:09:56.928
I want to talk about our feature development a little bit.

166
00:09:57.068 --> 00:10:00.888
So this is a process we developed to bring new stuff to

167
00:10:00.988 --> 00:10:04.977
Vera, and it's a little bit of our secret sauce I want to share because I think

168
00:10:05.008 --> 00:10:06.708
we've had a lot of success with it.

169
00:10:07.868 --> 00:10:08.007
So

170
00:10:08.988 --> 00:10:12.708
the way it works is we decide we need a new feature because we've

171
00:10:12.768 --> 00:10:15.828
identified a deficiency in one of our previous tools,

172
00:10:16.388 --> 00:10:19.568
or we have a test series that has a lot of repeats.

173
00:10:20.188 --> 00:10:24.107
So what we'll do is we'll bring the test experts, the SMEs, into

174
00:10:24.148 --> 00:10:27.107
a room, and we'll decompose the maneuver. We'll break it down.

175
00:10:27.508 --> 00:10:30.688
Why are we doing the maneuver? What are we trying to get?

176
00:10:31.428 --> 00:10:35.068
What are the steps of the maneuver? And we'll just break it all out.

177
00:10:35.808 --> 00:10:39.648
Then we run through STPA to generate a set of requirements.

178
00:10:40.588 --> 00:10:43.998
We'll design it, test it in the simulator, iterate a couple times,

179
00:10:44.728 --> 00:10:46.248
until we're happy, we come up with a release.

180
00:10:46.988 --> 00:10:50.548
So I'm going to pontificate a little bit on STPA.

181
00:10:51.708 --> 00:10:54.878
Those of you who have seen me up here behind the podium before know that we're

182
00:10:54.968 --> 00:10:58.908
advocates of STPA, and in this project, we sort of

183
00:10:58.968 --> 00:11:02.558
realized what it is, why it was benefiting us so much,

184
00:11:02.748 --> 00:11:04.008
and this is what I want to share.

185
00:11:05.028 --> 00:11:05.908
In STPA,

186
00:11:07.928 --> 00:11:10.708
at a high level, what you're doing is you're taking your system, and you're

187
00:11:10.728 --> 00:11:14.428
breaking it down into a series of control loops with a controller, a controlled

188
00:11:14.508 --> 00:11:15.048
process,

189
00:11:16.028 --> 00:11:18.968
your control actions, and then the feedback to close the loop. Okay?

190
00:11:20.128 --> 00:11:23.168
In our system, what we're really focusing on is the

191
00:11:23.208 --> 00:11:26.228
pilot-to-airplane control loop, right?

192
00:11:26.328 --> 00:11:29.668
And so the sensors, that's all the data we're gathering on the aircraft.

193
00:11:30.228 --> 00:11:33.948
The process model is how the pilot assembles

194
00:11:34.688 --> 00:11:36.268
an understanding of the airplane's state.

195
00:11:36.738 --> 00:11:40.098
The control algorithm is the decision-making process.

196
00:11:40.208 --> 00:11:43.868
What do they do with that process model, and then the control algorithms is the

197
00:11:43.948 --> 00:11:46.408
output, or sorry, the control actions is the output.

198
00:11:47.728 --> 00:11:47.948
Okay.

199
00:11:49.008 --> 00:11:52.308
Those of you in this community may be more familiar with the OODA loop.

200
00:11:53.168 --> 00:11:56.108
The OODA loop, observe, orient, decide, act.

201
00:11:56.768 --> 00:12:00.348
Well, it turns out, and this is what we realized, this is the same

202
00:12:00.408 --> 00:12:04.288
rose by two different names. The OODA loop actually maps onto the

203
00:12:04.448 --> 00:12:04.888
STPA

204
00:12:06.108 --> 00:12:09.650
control loop quite wellAnd so what we're doing when we go through this

205
00:12:09.700 --> 00:12:13.340
process is evaluating each step of the OODA

206
00:12:13.380 --> 00:12:17.320
loop and looking for deficiencies and timing issues

207
00:12:17.820 --> 00:12:19.860
and finding mitigations for those.

208
00:12:20.900 --> 00:12:24.019
Okay. So how did it help Vera directly?

209
00:12:24.080 --> 00:12:28.059
So at the highest level, we're decomposing a maneuver, and we're

210
00:12:28.110 --> 00:12:28.710
looking at

211

00:12:29.780 --> 00:12:32.850
what are the things that the pilot is trying to do in that

212
00:12:32.880 --> 00:12:35.140
maneuver. And so Vera

213
00:12:36.060 --> 00:12:38.980
is part of the sensor to

214
00:12:39.740 --> 00:12:43.680
process model step. It's providing the data in

215
00:12:43.900 --> 00:12:47.280
the form that the pilot can digest. And what is the data they need?

216
00:12:47.820 --> 00:12:49.340
That's the first level of what we're doing.

217
00:12:49.780 --> 00:12:53.080
What is the critical feedback the pilot needs for that specific maneuver,

218
00:12:53.980 --> 00:12:57.840
and when do they need it? So that's the first benefit from this process.

219
00:12:58.600 --> 00:12:59.020
Secondly,

220
00:13:00.690 --> 00:13:04.140
we had displays before. We had LADS, we had panels.

221
00:13:04.180 --> 00:13:08.080
But the pilot process model would take a little bit of

222
00:13:08.140 --> 00:13:09.480
time to orient, to

223
00:13:10.620 --> 00:13:13.860
understand what the airplane state is, and we would compensate for that.

224
00:13:14.040 --> 00:13:17.960
Sometimes we would have the pilot not flying become a talking

225
00:13:18.080 --> 00:13:21.860
G-meter. That takes some of their cognitive

226
00:13:21.900 --> 00:13:25.200
load away. But even as a talking G-meter, there's a lag there.

227
00:13:25.340 --> 00:13:28.840
So the orient step was expanded, and

228
00:13:29.500 --> 00:13:33.440
the benefit of Vera is that we can develop a feature

229
00:13:33.480 --> 00:13:34.820
in a way that the pilot

230
00:13:35.800 --> 00:13:39.540
flying can absorb that data, observe that data, absorb it,

231
00:13:39.960 --> 00:13:41.980
and make a determination much quicker.

232
00:13:42.300 --> 00:13:46.020
So we've sped up the orient step. That's the second benefit from this

233
00:13:46.120 --> 00:13:50.060
process. And then finally, this is another

234
00:13:50.070 --> 00:13:53.460
realization we had. So what's the control algorithm

235
00:13:54.000 --> 00:13:57.740
in our case? Well, in our case, that's the test plan or the test
procedure.

236
00:13:58.060 --> 00:14:01.420
That's the steps we're asking the pilots to take to conduct the maneuver.

237
00:14:01.920 --> 00:14:05.830
And then the controls is just whatever control actions, it's just the

238
00:14:05.860 --> 00:14:09.020
controls, the thing we're asking the pilot to close the loop on.

239
00:14:10.000 --> 00:14:10.240
So

240
00:14:11.180 --> 00:14:14.180
it turns out, when we went through this journey with

241
00:14:15.040 --> 00:14:18.460
subject matter experts, we found out that some of our test

242
00:14:18.480 --> 00:14:22.220
procedures, and even some of our controls, were based on that

243
00:14:22.260 --> 00:14:26.140
legacy OODA loop. There were compensations built in to

244
00:14:26.160 --> 00:14:29.000
accommodate the fact that the orient step was so long.

245
00:14:29.610 --> 00:14:33.040
And so by taking everybody through this journey, we were able

246
00:14:33.100 --> 00:14:37.080
to elevate the entire test. We could educate the team

247
00:14:37.120 --> 00:14:40.920
on what we were doing, improve test procedures, improve

248
00:14:41.000 --> 00:14:44.480
control actions, and really just get

249
00:14:44.940 --> 00:14:46.920
engineers the data that they actually wanted.

250
00:14:47.980 --> 00:14:51.100
All right, so that's a little bit on our feature process.

251
00:14:51.140 --> 00:14:53.240

So now we're going to talk about deployment.

252
00:14:56.820 --> 00:15:00.600
All right. So after a lot of development and testing, we

253
00:15:00.640 --> 00:15:04.240
graduated through safety of flight, and we had our first deployment

254
00:15:04.540 --> 00:15:08.060
last summer for a summer of performance flight

255
00:15:08.120 --> 00:15:11.640
testing, and that was certification flight testing, which also meant our

256
00:15:11.660 --> 00:15:14.720
regulator was also one of our first users.

257
00:15:14.760 --> 00:15:18.320
We started off with our minimum viable product, and that was to support the

258
00:15:18.340 --> 00:15:21.820
simulated ice shapes, and we wound up with some really

259
00:15:22.220 --> 00:15:25.560
good early indicators that we were on the right path

260
00:15:25.600 --> 00:15:28.500
here. Then we had our first

261
00:15:28.820 --> 00:15:32.700
purpose-built feature release supporting takeoff performance using that

262
00:15:32.780 --> 00:15:36.590
same process that Dunes just went over, and we'll dive a little bit deeper into

263
00:15:36.680 --> 00:15:36.880
that.

264
00:15:37.700 --> 00:15:41.060

So as Dunes mentioned, we wanted to get all of those

265
00:15:41.140 --> 00:15:44.880
memorized items out of the test plan, out of my head,

266
00:15:45.540 --> 00:15:46.560
and onto a display.

267
00:15:47.600 --> 00:15:51.069
So we wound up creating a number of different features to support that testing,

268
00:15:51.500 --> 00:15:54.720
and the first one I'll go over is over on the left side of the screen.

269
00:15:54.780 --> 00:15:56.740
This is our thrust setting tool.

270
00:15:57.600 --> 00:16:01.320
Our production equipment didn't have the fidelity or the

271
00:16:01.340 --> 00:16:05.330
control that we needed to set the desired thrusts for this type of testing,

272
00:16:05.780 --> 00:16:07.849
so we made a tool for that. And

273
00:16:08.700 --> 00:16:11.040
the way that we do it at Boeing is we split the flight deck.

274
00:16:11.080 --> 00:16:12.700
The pilot monitoring has thrust controls.

275
00:16:12.760 --> 00:16:16.040
The pilot flying has stick and rudder, typical flight controls.

276
00:16:16.860 --> 00:16:20.460
And we were able to get that

277
00:16:20.520 --> 00:16:22.880

cognitive load out of the pilot monitoring.

278
00:16:22.940 --> 00:16:25.400
Just put the thing on the thing, it turns green, and you're about your way, and you

279
00:16:25.420 --> 00:16:28.290
can go worry about the next critical phases of the test maneuver.

280
00:16:29.759 --> 00:16:32.820
On the attitude indicator, Dunes already mentioned the pitch target, the theta

281
00:16:32.840 --> 00:16:36.800
target, and then we had two additional features, both inceptors, one

282
00:16:36.820 --> 00:16:40.640
to the left side of the airspeed, one at the six o'clock position on the

283
00:16:40.920 --> 00:16:44.840
screen. And in a pre-Vera world for takeoff performance

284
00:16:44.860 --> 00:16:48.660
testing, we're trying to target a column pull or a

285
00:16:48.700 --> 00:16:52.400
deflection, and it usually meant that I was holding short of the runway,

286
00:16:52.620 --> 00:16:56.480
doing seated rows, trying to train my muscles, train the body where that

287
00:16:56.490 --> 00:16:59.890
desired point was, and that target changes every

288
00:16:59.900 --> 00:17:03.760
condition. And then inevitably, you go down the runway, you do the pull, it's too

289
00:17:03.820 --> 00:17:06.980
much pull, too little pull, you blow the condition, you come back and do it again.

290
00:17:07.921 --> 00:17:10.220
So we were able to change that there.

291
00:17:10.260 --> 00:17:10.820
With these

292
00:17:12.800 --> 00:17:16.681
better inceptor information, I can now provide a second attempt,

293
00:17:16.870 --> 00:17:20.620
that first crisp open loop pull, fine-tune it, and we were able to save
some

294
00:17:20.661 --> 00:17:23.740
conditions. I would have never done that in a previous world.

295
00:17:24.980 --> 00:17:27.421
This is an example of one of those conditions.

296
00:17:27.641 --> 00:17:31.200
It is a simulated single engine, under-sped, abuse

297
00:17:31.280 --> 00:17:31.840
takeoff.

298
00:17:32.720 --> 00:17:36.020
And here we go. Real quickly, thrust target,

299
00:17:36.800 --> 00:17:39.280
put the thing on the thing, it turns green. Thrust is set.

300
00:17:39.420 --> 00:17:43.200
The airplane is barely moving. Now, that pilot

301
00:17:43.240 --> 00:17:46.630
monitoring is able to go focus on safety pilot tasks,

302
00:17:47.080 --> 00:17:50.240
and pilot flying is doing their directional control jobs.

303

00:17:50.960 --> 00:17:54.760
As we start speeding up, we'll start seeing the first magenta tick

304
00:17:54.800 --> 00:17:56.500
coming down on the airspeed indicator.

305
00:17:57.000 --> 00:18:00.760
This is going to be the cue to our pilot monitoring to

306
00:18:00.780 --> 00:18:02.660
bring the right engine back to idle.

307
00:18:03.300 --> 00:18:04.780
So we'll see that here in a second.

308
00:18:08.220 --> 00:18:09.940
Right engine's going to come back to idle,

309
00:18:11.020 --> 00:18:14.340
and then the next target we get is going to be the cue to the pilot flying for a

310
00:18:14.380 --> 00:18:17.728
crisp column pull.Right about there.

311
00:18:17.808 --> 00:18:21.648
We over pull back to the target, and then we're able to make

312
00:18:21.728 --> 00:18:23.788
that adjustment prior to the airplane really reacting.

313
00:18:24.068 --> 00:18:27.008
Go grab theta, then we're going to go settle on airspeed.

314
00:18:27.568 --> 00:18:30.788
And we had such great success with these features being

315
00:18:30.828 --> 00:18:33.748
deployed. We saw a 44%

316
00:18:33.848 --> 00:18:37.428

increase in first pass quality attributed to

317
00:18:37.568 --> 00:18:41.188
pilot technique. Said a little bit differently, that was

318
00:18:41.408 --> 00:18:44.768
30 high-risk takeoff points we did not have to go

319
00:18:44.828 --> 00:18:47.128
re-attempt because we had better tools.

320
00:18:47.868 --> 00:18:49.308
And said just a little bit differently,

321
00:18:50.438 --> 00:18:53.138
that was also at least eight days that

322
00:18:53.168 --> 00:18:56.268
were avoided in the program schedule

323
00:18:57.688 --> 00:19:00.348
because, again, our pilots had those better tools.

324
00:19:01.248 --> 00:19:02.348
Dunsen?

325
00:19:02.378 --> 00:19:02.688
All right.

326
00:19:03.888 --> 00:19:07.508
Okay, so what would be a presentation without some lessons learned?

327
00:19:07.628 --> 00:19:09.928
So we obviously learned a few things along the way.

328
00:19:11.588 --> 00:19:15.508
The first we learned early on was what my colleague likes to call the

329
00:19:15.568 --> 00:19:19.488
laminated card effect. If you take a document, you

330
00:19:19.508 --> 00:19:22.588
laminate it, put it on the glare shield, it becomes the word of God.

331
00:19:23.248 --> 00:19:26.888
So similarly, we're taking something that looks and

332
00:19:27.048 --> 00:19:30.628
smells and feels like a production PFD and putting it on the outboard

333
00:19:30.648 --> 00:19:32.228
display. So,

334
00:19:34.188 --> 00:19:38.128
we want to take advantage of that positive training, but again, it's not the

335
00:19:38.148 --> 00:19:42.068
DAL A assured PFD. So we wanted to make it clear

336
00:19:42.368 --> 00:19:46.348
what the pilots were looking at. So we made some adjustments like our

337
00:19:46.408 --> 00:19:50.248
logo and a heartbeat, and in some cases, we

338
00:19:50.328 --> 00:19:54.268
deviated purposely from the flight deck philosophy in order to make it

339
00:19:54.308 --> 00:19:55.888
clear what the pilot was actually looking at.

340
00:19:56.348 --> 00:19:59.948
For example, we have the ability to put flight test air

341
00:20:00.008 --> 00:20:03.788
data on that Vera display, so we can source it from the

342
00:20:03.828 --> 00:20:04.608
static cone,

343

00:20:05.468 --> 00:20:08.628
which is great for some of our maneuvers.

344
00:20:08.638 --> 00:20:12.408
And so what we've chosen is that when we're deviating from the

345
00:20:12.448 --> 00:20:16.348
production standard, and throwing a flight test parameter up, we change

346
00:20:16.388 --> 00:20:19.518
the color scheme to be cyan in some features.

347
00:20:19.818 --> 00:20:22.048
So it's clear to the pilot what they're looking at.

348
00:20:25.268 --> 00:20:29.148
On the same lines of the impact of the forward display, a year ago, when we were

349
00:20:29.158 --> 00:20:31.868
deploying the minimum viable product, as we called it,

350
00:20:32.808 --> 00:20:35.988
to fill out the feature suite, we grabbed a couple of features from LAZ and just

351
00:20:36.228 --> 00:20:39.988
plopped it there on the black space, figuring if it worked on LAZ, it's going to

352
00:20:40.028 --> 00:20:42.448
work even better on the forward display.

353
00:20:43.168 --> 00:20:46.788
Not so in some cases. We'll take the speed rate feature, for

354
00:20:46.808 --> 00:20:50.668
example. This is a gross tracking task for, say, a

355
00:20:50.748 --> 00:20:54.488
stall maneuver, we ask the pilots to set an approximate decel

356
00:20:54.568 --> 00:20:58.108
rate, but we're looking for a smooth column pull to stall ID.

357
00:20:58.708 --> 00:20:58.908
Well,

358
00:20:59.748 --> 00:21:03.728
in the simulator, we found pretty quickly that pilots, we gave them a

359
00:21:03.788 --> 00:21:07.028
target on their display, they start chasing it, and they turned it into a

360
00:21:07.068 --> 00:21:10.838
fine-tracking task. And so fortunately, we caught this

361
00:21:10.908 --> 00:21:14.108
early. We figured out, we did some training,

362
00:21:14.248 --> 00:21:17.768
some test card development to make it clear what the actual task was.

363
00:21:18.188 --> 00:21:22.128
But the real lesson here is that feature development process

364
00:21:22.228 --> 00:21:25.608
actually does work, and it would catch and develop the feature

365
00:21:25.988 --> 00:21:29.748
properly to accommodate the maneuver and how we want it to be

366
00:21:29.908 --> 00:21:30.248
used.

367
00:21:32.308 --> 00:21:34.308
Also, about targets.

368
00:21:35.128 --> 00:21:37.188
So for example, on this

369
00:21:38.248 --> 00:21:41.388

column pull feature, target fixation can be a real problem.

370
00:21:41.448 --> 00:21:44.548
We provided a target in magenta, and it changes.

371
00:21:44.588 --> 00:21:48.208
It turns into a very nice shade of green when you hit the target.

372
00:21:48.218 --> 00:21:52.088
Pilots are going to want to hit it. It's honestly like a cat chasing a laser,

373
00:21:52.128 --> 00:21:54.588
right? They're going to want to go after it.

374
00:21:54.728 --> 00:21:58.368
So again, our STPA process caught this

375
00:21:58.788 --> 00:22:02.088
and said, "Okay, we need to have a mitigation in certain cases like takeoff

376
00:22:02.128 --> 00:22:03.488
performance, where

377
00:22:04.568 --> 00:22:08.308
a over pull or a pull in the column could result in a tail

378
00:22:08.368 --> 00:22:11.168
strike, or even worse, a stall and ground effect." So

379
00:22:11.988 --> 00:22:14.048
what we did is we incorporated some logic.

380
00:22:14.628 --> 00:22:18.048
When the pilot makes the column pull, the airplane starts to

381
00:22:18.088 --> 00:22:21.508
rotate. At a certain theta trigger, the

382
00:22:22.088 --> 00:22:25.148

target disappears, and when the target disappears, the pilot's going to naturally

383
00:22:25.168 --> 00:22:28.588
move their eye back to the center of the PFD, and they're going to start

384
00:22:28.628 --> 00:22:31.768
chasing the theta target.

385
00:22:32.668 --> 00:22:36.508
So target fixation. Again, our feature development process

386
00:22:36.568 --> 00:22:37.188
really works.

387
00:22:39.548 --> 00:22:40.088
Last one,

388
00:22:41.868 --> 00:22:45.848
a good problem that we had. We were doing a condition with a windup

389
00:22:45.888 --> 00:22:46.858
turn, and

390
00:22:48.688 --> 00:22:52.378
our pilot performed really well. But after the fact, he was

391
00:22:52.408 --> 00:22:56.158
tickling the target, and he started complaining like, "I couldn't really tell if I

392
00:22:56.188 --> 00:22:59.338
was just below or just above the target." And

393
00:22:59.388 --> 00:23:02.598
so my colleague and I looked at each other and was like, "Are you complaining that

394
00:23:02.628 --> 00:23:06.398
you couldn't track to the hundredth of a G?" And so that's not a

395

00:23:06.408 --> 00:23:10.238
problem we've had before. But we did take it to heart, and in our most

396
00:23:10.268 --> 00:23:13.828
recent deployment of Vera, we actually have the ability to put in

397
00:23:13.868 --> 00:23:17.448
tolerances and a color change that indicates to the pilot,

398
00:23:18.228 --> 00:23:20.528
"Hey, that's good enough. You've met the mission.

399
00:23:21.148 --> 00:23:22.168
You can recover."

400
00:23:23.988 --> 00:23:26.228
Okay. Caps is going to bring it home with some conclusions.

401
00:23:28.628 --> 00:23:29.048
All right. So

402
00:23:29.928 --> 00:23:32.388
just a couple final thoughts here.

403
00:23:32.448 --> 00:23:36.288
We designed Vera with the end users in mind, and

404
00:23:36.358 --> 00:23:39.308
those end users were instrumental in the design process.

405
00:23:40.248 --> 00:23:43.838
So we were able to use a human-centered approach to

406
00:23:43.908 --> 00:23:47.618
shortening that OODA loop, and really our results speak for themselves,

407
00:23:47.988 --> 00:23:51.728
and we were able to see tangible benefits in data quality, safety,

408
00:23:51.888 --> 00:23:54.928
and test efficiency. We're currently deployed on the

409
00:23:54.948 --> 00:23:58.828
777-9, the 737-10, and we'll be moving to

410
00:23:58.868 --> 00:24:00.168
some new models here shortly.

411
00:24:01.848 --> 00:24:05.268
And what we showed today is only the first

412
00:24:05.388 --> 00:24:08.968
six months of our deployment. Since then, we are

413
00:24:09.048 --> 00:24:12.948
able to take those lessons learned, those

414
00:24:13.028 --> 00:24:16.408
operational learnings, incorporate them back into our design

415
00:24:16.428 --> 00:24:20.136
processAnd we're just getting ready to

416
00:24:20.196 --> 00:24:23.376
release and deploy our latest version of Vera.

417
00:24:23.706 --> 00:24:27.376
And we're really excited to see how the rest of our test programs

418
00:24:27.476 --> 00:24:30.916
pan out with these better tools compared to that pre-Vera world.

419
00:24:31.596 --> 00:24:34.896
And with that, we're happy to take questions and hopefully

420
00:24:34.956 --> 00:24:36.476
answers.

421
00:24:43.556 --> 00:24:43.856
Dave.

422

00:24:47.696 --> 00:24:50.876
Hey, dudes, Capps, Chris. Thanks a lot for the presentation.

423
00:24:50.956 --> 00:24:54.806
I've been able to see your Vera in operation, and

424
00:24:54.856 --> 00:24:58.736
it's pretty impressive. Just a couple of questions. You mentioned not DALA.

425
00:24:59.116 --> 00:25:02.256
I totally understand not DALA. I'm just curious,

426
00:25:02.356 --> 00:25:04.776
what protections do you have against

427
00:25:05.636 --> 00:25:08.576
frozen data latency, things that you may have in

428
00:25:08.616 --> 00:25:10.186
instrumentations stream,

429
00:25:11.116 --> 00:25:14.956
to assure you're not getting into the garbage, in garbage out in your flight

430
00:25:14.996 --> 00:25:16.216
test operations?

431
00:25:17.886 --> 00:25:21.686
Yeah. Okay, good question, especially because we recently experienced one of

432
00:25:21.736 --> 00:25:25.076
these too. So there's a couple levels.

433
00:25:25.136 --> 00:25:27.856
There's a heartbeat on the display.

434
00:25:27.996 --> 00:25:30.576
That tells us if the Vera computer that's generating the image

435
00:25:32.156 --> 00:25:35.746
is operating at the rate we expect it

436
00:25:35.796 --> 00:25:39.576
to. The data system also is a source of failure.

437
00:25:40.356 --> 00:25:44.186
And so the measurements come with a status flag, and

438
00:25:44.236 --> 00:25:47.936
if they're not showing the appropriate status flag, we actually use the

439
00:25:47.996 --> 00:25:51.696
same sort of failure flags that the production PFD

440
00:25:51.776 --> 00:25:54.316
uses to show that this data is no longer valid.

441
00:25:54.356 --> 00:25:57.576
So if a value is not valid, we don't show it.

442
00:25:58.016 --> 00:26:01.476
So for example, the airspeed tape will show the airspeed failure flag or

443
00:26:02.236 --> 00:26:02.596
whatnot.

444
00:26:03.736 --> 00:26:07.596
So that's our mitigation against data

445
00:26:07.716 --> 00:26:08.756
failures in the back,

446
00:26:10.636 --> 00:26:14.536
but really, we're leveraging the production PFD as the truth source

447
00:26:14.576 --> 00:26:18.096
for any type of real bad situation.

448
00:26:24.096 --> 00:26:26.816

There you go. Thanks. Appreciate you guys doing this.

449
00:26:26.856 --> 00:26:30.436
I've spent more time than I want to admit being a talking

450
00:26:30.536 --> 00:26:33.916
G-meter, and I thought there was a better way and approach to this.

451
00:26:34.356 --> 00:26:38.276
Curious why you guys implement it on the PFD and not the HUD, or maybe

452
00:26:38.356 --> 00:26:42.136
you did, and you just didn't talk about it, and what the thought process was

453
00:26:42.176 --> 00:26:42.836
there.

454
00:26:43.036 --> 00:26:46.996
Yeah. Funny story is we started off wanting to go after the HUD, but we found

455
00:26:47.136 --> 00:26:50.646
a quicker and easier way to attack the forward

456
00:26:50.676 --> 00:26:51.186
displays.

457
00:26:52.036 --> 00:26:55.646
The other thing is not all of our commercial products have HUDs,

458
00:26:56.156 --> 00:26:59.016
so we went with the one that could have the most benefit to our test fleet.

459
00:27:00.336 --> 00:27:04.296
But yeah, it's on our horizon. This is a

460
00:27:04.316 --> 00:27:08.196
early stage here, when we're going to wind up spiral designing out

461

00:27:08.256 --> 00:27:10.896
to other capabilities and other products.

462
00:27:11.596 --> 00:27:13.956
And does the pilot monitoring see the same on his display as well?

463
00:27:15.176 --> 00:27:17.516
Yeah. We have the capability to be

464
00:27:18.636 --> 00:27:21.156
repeated anywhere where we're pushing data. Yeah.

465
00:27:21.196 --> 00:27:21.856
Okay, thanks.

466
00:27:22.136 --> 00:27:25.956
Yeah. And I guess, just on that note, the

467
00:27:25.966 --> 00:27:29.776
display is pilot selectable. We have a production switch the pilot can use to

468
00:27:29.796 --> 00:27:32.936
push the PFD inboard, and then Vera pops up.

469
00:27:33.016 --> 00:27:36.236
So control of what they're looking at is completely on the pilot.

470
00:27:38.236 --> 00:27:40.896
Once upon a time, PFD was forbidden territory.

471
00:27:41.396 --> 00:27:41.536
Yep.

472
00:27:45.716 --> 00:27:49.166
From a cost thing, I know you guys may not be able to share exact numbers and

473
00:27:49.216 --> 00:27:53.096
stuff, but the cost of development of Vera versus the cost of the time savings

474
00:27:53.116 --> 00:27:56.556
and operation savings. Have you guys got any metrics on that?

475
00:27:58.396 --> 00:28:01.856
I don't have actual dollars and cents on it, but notionally, it was

476
00:28:01.936 --> 00:28:05.416
very cheap. We did this ourselves. This was internal.

477
00:28:05.516 --> 00:28:09.376
We avoided any type of vendors or suppliers, so

478
00:28:09.436 --> 00:28:13.236
it was basically labor costs for the team, and it's a

479
00:28:13.276 --> 00:28:16.536
small team. We're talking less than a dozen people in

480
00:28:17.036 --> 00:28:20.556
greater Seattle. We have a software group in Germany that's

481
00:28:20.896 --> 00:28:23.016
helping us out with some of the coding.

482
00:28:23.496 --> 00:28:25.176
And then, yeah, it's real small there.

483
00:28:25.516 --> 00:28:28.276
And again, the fact that we control our own

484
00:28:28.316 --> 00:28:31.576
software really keeps the price

485
00:28:31.616 --> 00:28:32.726
down. Do you have anything?

486
00:28:32.756 --> 00:28:36.616
Yeah. And I'll just say, without going into actual numbers, Capps
mentioned

487

00:28:36.656 --> 00:28:39.876
for one test campaign, we saved what we project as eight

488
00:28:40.336 --> 00:28:43.936
days of testing, and that's just that one test campaign.

489
00:28:43.996 --> 00:28:46.156
We've had a year's worth of use since.

490
00:28:46.676 --> 00:28:50.596
So, you could do the math, approximate the amount

491
00:28:50.656 --> 00:28:53.756
of money we could save over the entire test program.

492
00:28:54.376 --> 00:28:57.096
So for the amount of money we spent, the ROI is pretty big.

493
00:29:03.056 --> 00:29:03.266
All right.

494
00:29:03.266 --> 00:29:03.306
All right.

495
00:29:04.116 --> 00:29:04.816
Thank you very much.

496
00:29:05.086 --> 00:29:05.086
Okay.

497
00:29:05.096 --> 00:29:05.495
We have one more question.

498
00:29:05.536 --> 00:29:06.356
Oh, one more question.

499
00:29:08.836 --> 00:29:09.896
Yeah, just a quick one.

500
00:29:11.076 --> 00:29:14.716
It looks like your the thing one, thing two, shows

501
00:29:15.236 --> 00:29:18.356
control position. Does Vera track or

502
00:29:19.216 --> 00:29:22.876
provide queuing for rates of control applications?

503
00:29:25.376 --> 00:29:29.276
Right now, no, but that is a feature capability we could develop

504
00:29:29.296 --> 00:29:30.216
if we had a use for it.

505
00:29:31.156 --> 00:29:31.356
Yep.

506
00:29:35.196 --> 00:29:36.016
Scott's got one.

507
00:29:40.276 --> 00:29:41.536
Really enjoy this

508
00:29:42.976 --> 00:29:43.716
capability.

509
00:29:44.626 --> 00:29:45.776
This is your first step.

510
00:29:46.736 --> 00:29:50.476
If you have your digital flight control systems, is there

511
00:29:51.336 --> 00:29:55.116
the vision of actually automating some of those instead

512
00:29:55.156 --> 00:29:58.936
of having a pilot get there and reach the target and making sure that

513
00:29:58.976 --> 00:29:59.976
it's still there?

514

00:30:02.496 --> 00:30:05.236
I'll say, I hope you'll be back in two years.