

Modernized Flight Test Technique for Porpoising Boundary Investigation

1

00:00:01.020 --> 00:00:03.900

This next paper is neat.

2

00:00:04.840 --> 00:00:08.500

I think a lot of us have flown float planes before,

3

00:00:09.320 --> 00:00:12.880

and some of us were able to fly a float

4

00:00:12.960 --> 00:00:16.270

helicopter at Naval Test Pilot School. I think at one time we had that.

5

00:00:16.320 --> 00:00:20.200

We were doing autorotations with floats to the water. That was interesting.

6

00:00:21.300 --> 00:00:24.760

But has anybody out here, except for these two guys over here, done any

7

00:00:24.840 --> 00:00:25.910

seaplane testing?

8

00:00:27.820 --> 00:00:28.540

I've got a couple.

9

00:00:29.760 --> 00:00:32.040

Good. I would imagine you have. Yes.

10

00:00:33.180 --> 00:00:36.839

Yeah. So when this paper came up, I was like, "Hey, this is

11

00:00:36.920 --> 00:00:40.730

cool." How do you test seaplanes? What are the

12

00:00:40.800 --> 00:00:42.600

different test techniques that are needed?

13

00:00:43.720 --> 00:00:44.420

And so Tariq

14

00:00:45.800 --> 00:00:48.700  
and Markus are here today to talk about

15

00:00:49.920 --> 00:00:53.680  
interesting test techniques that are needed in this different

16

00:00:53.720 --> 00:00:55.940  
type of aircraft that we don't normally see.

17

00:00:55.980 --> 00:00:58.500  
So without further ado, Tariq and Markus.

18

00:01:13.100 --> 00:01:15.420  
Good morning. My name is Markus Schadl.

19

00:01:15.760 --> 00:01:19.450  
I am the chief flight test pilot of Dornier

20

00:01:19.480 --> 00:01:23.240  
Seawings. Together with my colleague, Tariq Türkmen,

21

00:01:23.500 --> 00:01:27.400  
we will present you the flight test technique that we developed during

22

00:01:27.480 --> 00:01:31.240  
our testing of the Dornier Seastar airplane last year in

23

00:01:31.300 --> 00:01:31.680  
Norway.

24

00:01:34.060 --> 00:01:37.640  
In this presentation, we will give you an overview of the Seastar

25

00:01:37.720 --> 00:01:38.080  
program,

26

00:01:39.200 --> 00:01:40.440  
our test objectives.

27

00:01:41.820 --> 00:01:44.640

We explain shortly the traditional test methods

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00:01:45.720 --> 00:01:48.240

and present our updated test technique.

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00:01:49.800 --> 00:01:53.640

We will then compare both methods and close with some lesson

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00:01:53.720 --> 00:01:56.260

learned. At the end, there will be time for questions.

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00:01:58.280 --> 00:02:02.020

Let's start with an overview of the Dornier Seastar program.

32

00:02:03.340 --> 00:02:07.160

The legacy Dornier Seastar was certified in

33

00:02:07.200 --> 00:02:08.120

1990.

34

00:02:09.700 --> 00:02:12.480

It's a Part 23 commuter airplane,

35

00:02:13.900 --> 00:02:15.400

was certified against

36

00:02:17.020 --> 00:02:20.660

Part 23 in Germany and on the FAA side

37

00:02:21.620 --> 00:02:23.780

for VFR and IFR operation.

38

00:02:25.160 --> 00:02:26.800

The airplane is an all-composite,

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00:02:28.220 --> 00:02:29.260

amphibious airplane.

40

00:02:30.480 --> 00:02:34.220

It's powered by two PD 6 turbine engine,

41

00:02:35.740 --> 00:02:38.600  
and the max takeoff weight is 4,600 kilogram.

42

00:02:40.880 --> 00:02:44.760  
The airplane was never produced because after the certification,

43

00:02:44.800 --> 00:02:47.760  
the program was stopped and put on hibernation mode.

44

00:02:48.540 --> 00:02:51.060  
Twenty-five years later, it was picked up again,

45

00:02:52.120 --> 00:02:55.880  
and there were major changes that needed to be updated on the

46

00:02:55.920 --> 00:02:59.400  
airplane because we needed new avionics system, the

47

00:03:00.180 --> 00:03:03.710  
supplier for the landing gear and hydraulics system was no longer  
available,

48

00:03:04.160 --> 00:03:07.060  
and also a weight increase was necessary.

49

00:03:09.520 --> 00:03:12.210  
The new certification requirement now is

50

00:03:12.420 --> 00:03:15.860  
EASA CS-23 Amendment 6,

51

00:03:16.760 --> 00:03:18.580  
and we built two prototype airplane.

52

00:03:19.720 --> 00:03:22.710  
First flight of the first prototype airplane was 2020.

53

00:03:23.740 --> 00:03:26.400  
Second airplane flew in 2024.

54

00:03:27.340 --> 00:03:31.260

Together, the airplanes have accumulated about 400 flight test

55

00:03:31.300 --> 00:03:31.580

hours.

56

00:03:35.380 --> 00:03:39.240

In order to get you a good idea of the airplane, we have presented

57

00:03:39.820 --> 00:03:43.660

a short video here of our flight test in Norway.

58

00:03:54.440 --> 00:05:10.600

Our

59

00:05:10.640 --> 00:05:14.500

test objectives for that campaign was to ensure that the aircraft has

60

00:05:14.560 --> 00:05:18.360

adequate handling qualities, and it does not have any dangerous or

61

00:05:18.540 --> 00:05:20.680

uncontrollable purposes and characteristics.

62

00:05:21.220 --> 00:05:24.160

We also needed to establish operational limits,

63

00:05:24.800 --> 00:05:28.640

performance data, and also the procedures for the AFM.

64

00:05:31.880 --> 00:05:35.340

Before we go into the test techniques, I want to define some seaplane

65

00:05:35.440 --> 00:05:36.200

terminology.

66

00:05:38.000 --> 00:05:41.320

If you do a water takeoff, you have several distinct

67

00:05:41.580 --> 00:05:44.300

phases that are characteristic by

68

00:05:45.100 --> 00:05:47.080

speed and also by pitch.

69

00:05:48.100 --> 00:05:50.480

Let's start with the displacement taxi.

70

00:05:50.720 --> 00:05:54.360

Typically, this is a phase where you have very low speed, around five

71

00:05:54.420 --> 00:05:54.720

knots.

72

00:05:55.560 --> 00:05:59.380

The airplane does not have any significant waves, behaves like a boat,

73

00:05:59.920 --> 00:06:01.880

and it's more or less level, depending on

74

00:06:02.160 --> 00:06:05.082

CG.If the speed is increased,

75

00:06:05.912 --> 00:06:09.852

we speed up and we reach, at some stage, the

76

00:06:09.892 --> 00:06:12.012

maximum displacement hull speed.

77

00:06:14.212 --> 00:06:17.232

The airplane has a high wave,

78

00:06:17.472 --> 00:06:21.452

and if you have more power available, you can start climbing up

79

00:06:21.512 --> 00:06:22.192

on this wave.

80

00:06:25.872 --> 00:06:27.792

If the airplane reached the top of the wave,

81

00:06:29.312 --> 00:06:33.282  
then the power demand is decreased significantly,

82  
00:06:33.312 --> 00:06:34.132  
and the airplane

83  
00:06:35.392 --> 00:06:39.192  
will enter the step taxi phase,

84  
00:06:39.672 --> 00:06:42.632  
where the pitch angle will be slightly reduced.

85  
00:06:43.292 --> 00:06:44.032  
As the airplane

86  
00:06:44.912 --> 00:06:47.172  
is in this phase, it behaves like a speedboat.

87  
00:06:49.412 --> 00:06:53.022  
Going faster and faster, the airplane flight control will become effective,

88  
00:06:53.732 --> 00:06:56.032  
and the pilot will have to manage

89  
00:06:56.832 --> 00:07:00.772  
the pitch attitude of the airplane to stay in a safe corridor

90  
00:07:00.832 --> 00:07:01.612  
during the takeoff.

91  
00:07:03.172 --> 00:07:06.212  
So we have to investigate the porpoising

92  
00:07:06.252 --> 00:07:10.152  
boundaries to define that safe corridor and flight test.

93  
00:07:11.592 --> 00:07:13.292  
To define what is porpoising,

94  
00:07:14.692 --> 00:07:18.652

I have a definition here. It's a sustained or increased oscillation in heave

95

00:07:18.672 --> 00:07:22.112

and pitch, and it's typically very dangerous for seaplanes

96

00:07:22.592 --> 00:07:26.512

because it leads to high structural loads and also can end up

97

00:07:26.552 --> 00:07:30.472

in a loss of control or an unintended takeoff

98

00:07:30.512 --> 00:07:33.372

at very low energy state and a stall close to the water.

99

00:07:34.572 --> 00:07:38.012

Let's have a look at the video here to see how that

100

00:07:38.872 --> 00:07:39.272

works.

101

00:07:40.472 --> 00:07:44.432

This is a normal takeoff. The airplane goes through the phases as

102

00:07:44.472 --> 00:07:47.152

discussed before. It goes on step,

103

00:07:48.492 --> 00:07:48.832

and

104

00:07:49.732 --> 00:07:52.272

for some reason, it starts that oscillation.

105

00:07:53.512 --> 00:07:57.092

And the oscillation is divergent, and the pilot in this video

106

00:07:57.432 --> 00:08:00.252

did the classical recovery method for this.

107

00:08:00.792 --> 00:08:03.312

He was cutting the power and aborting the takeoff.

108

00:08:04.812 --> 00:08:08.532

The question now is how do we define our safe

109

00:08:08.592 --> 00:08:10.132

envelope in flight test,

110

00:08:11.092 --> 00:08:14.352

and how do we find these boundaries?

111

00:08:15.232 --> 00:08:17.372

Tarik will tell you how we did this.

112

00:08:21.572 --> 00:08:22.872

So the question,

113

00:08:23.932 --> 00:08:27.512

how to find boundaries, let's start with the boring stuff

114

00:08:27.832 --> 00:08:31.672

that we need to learn first, what to do, how to

115

00:08:31.732 --> 00:08:33.793

do. So we start scanning

116

00:08:35.033 --> 00:08:36.052

our legacy data,

117

00:08:37.033 --> 00:08:40.151

the legacy aircraft data, and the literature scan.

118

00:08:41.072 --> 00:08:43.452

Unfortunately, picture was not so bright there.

119

00:08:44.252 --> 00:08:47.832

We have limited legacy data because the previous aircraft's

120

00:08:47.892 --> 00:08:51.772

handheld FDI. We have available pilot comments,

121

00:08:51.912 --> 00:08:55.872  
pilot statements, and we have changes on the airplane.

122  
00:08:56.461 --> 00:09:00.372  
There was no CFD, no towing tank test,

123  
00:09:00.512 --> 00:09:03.992  
which was the wind tunnel test equivalent

124  
00:09:04.452 --> 00:09:04.712  
in the

125  
00:09:05.852 --> 00:09:09.612  
boat world, and it was not possible to perform

126  
00:09:09.712 --> 00:09:13.612  
research reference flight tests that time with the legacy aircraft.

127  
00:09:14.152 --> 00:09:17.332  
When we go with the literature, we have mil spec back from

128  
00:09:17.372 --> 00:09:20.432  
1960s. We didn't get anything else.

129  
00:09:21.032 --> 00:09:22.812  
We have a few scientific

130  
00:09:23.892 --> 00:09:24.332  
papers.

131  
00:09:25.932 --> 00:09:29.832  
And deep discussions where to perform these tests.

132  
00:09:30.252 --> 00:09:33.812  
Long story short, we need wide, long test water

133  
00:09:33.892 --> 00:09:37.492  
surface. Since we are amphibious, to be able to

134  
00:09:37.532 --> 00:09:41.492  
increase the options, a runway close and in

135

00:09:41.572 --> 00:09:43.092

between a ramp connection,

136

00:09:44.132 --> 00:09:45.932

which end up with Motoden, Norway.

137

00:09:46.812 --> 00:09:49.692

Training prior to campaign, several trainings.

138

00:09:49.792 --> 00:09:53.312

But two examples that I put here, it's

139

00:09:53.372 --> 00:09:57.232

underwater escape training and the boat training for the crew

140

00:09:57.932 --> 00:10:00.372

because we used safety boat all the time.

141

00:10:01.272 --> 00:10:04.972

Test readiness, yesterday we talk about the management,

142

00:10:05.152 --> 00:10:08.132

the pressure, the program management stuff.

143

00:10:08.252 --> 00:10:11.352

So I can only say that it's intensive

144

00:10:11.432 --> 00:10:15.272

multidisciplinary planning coordination because it's expected to

145

00:10:15.352 --> 00:10:17.912

keep flying while making the aircraft ready.

146

00:10:19.292 --> 00:10:22.852

And the test planning from requirement to

147

00:10:23.211 --> 00:10:27.132

risk assessment to test card. So it's basically we will focus on

148

00:10:27.192 --> 00:10:29.752  
the technique. So from the literature,

149

00:10:30.832 --> 00:10:34.652  
back from '60s, there is one technique defined, which

150

00:10:34.712 --> 00:10:37.192  
is fixed elevator acceleration method.

151

00:10:38.132 --> 00:10:38.212  
So,

152

00:10:40.392 --> 00:10:43.852  
it's advised to perform repeated

153

00:10:44.392 --> 00:10:48.072  
accelerated runs to take off with fixed

154

00:10:48.112 --> 00:10:49.192  
elevator setting.

155

00:10:50.212 --> 00:10:51.452  
And the other

156

00:10:52.392 --> 00:10:56.352  
source says the same during this takeoff runs, that the

157

00:10:56.392 --> 00:10:58.192  
elevator angle is held constant.

158

00:10:59.232 --> 00:10:59.512  
So

159

00:11:00.372 --> 00:11:04.192  
on the left-hand side, you see a graph, then the lines.

160

00:11:04.472 --> 00:11:08.352  
Basically, it's advised to follow those lines that we have an

161

00:11:08.412 --> 00:11:09.412  
animated version.

162

00:11:10.492 --> 00:11:11.952

So freeze your elevator,

163

00:11:12.872 --> 00:11:16.312

advance power, aircraft come on step till takeoff.

164

00:11:16.372 --> 00:11:20.212

It just follows a path on the ground speed versus pitch angle, the

165

00:11:20.252 --> 00:11:21.552

speed versus pitch angle

166

00:11:23.112 --> 00:11:24.292

graph. And

167

00:11:25.232 --> 00:11:27.572

you try one more time with another setting,

168

00:11:28.392 --> 00:11:32.232

and you try one more time until you hit porpoising

169

00:11:32.252 --> 00:11:32.752

boundary.

170

00:11:34.732 --> 00:11:36.392

And same for the lower

171

00:11:37.612 --> 00:11:41.152

boundary, then another intersection with the

172

00:11:41.172 --> 00:11:42.192

porpoising boundary.

173

00:11:43.172 --> 00:11:46.272

Another question here, what's the definition of X?

174

00:11:46.572 --> 00:11:49.172

How will we know that we hit the X over there?

175

00:11:50.032 --> 00:11:51.552

Again, the same sources

176

00:11:52.732 --> 00:11:55.752

gave a magic number, two degrees. These are mil spec.

177

00:11:57.732 --> 00:12:01.692

So oscillation in pitch is equal to or greater than

178

00:12:01.832 --> 00:12:03.272

two degrees. The other one says

179

00:12:04.112 --> 00:12:08.032

spread in pitch, it's two degrees, means that it's also the

180

00:12:08.072 --> 00:12:10.962

abort criteria. As soon as you see two, then knock it

181

00:12:11.032 --> 00:12:14.922

off. So we start discussing

182

00:12:15.002 --> 00:12:16.152

about what can go wrong.

183

00:12:17.742 --> 00:12:21.252

The same resources, we have

184

00:12:21.342 --> 00:12:24.702

a paragraph which mentioning the towing tank test.

185

00:12:24.812 --> 00:12:27.942

Then later on, the paragraph follows with real testing.

186

00:12:29.022 --> 00:12:32.202

During one of the seaplane testing, the seaplane hit a

187

00:12:32.262 --> 00:12:35.582

small wave caused by a little boat,

188

00:12:36.162 --> 00:12:40.032

then went into an uncontrolled porpoise phase, then

189

00:12:40.882 --> 00:12:42.802

it's lost.

190

00:12:43.922 --> 00:12:45.822

So we try to narrow down

191

00:12:47.362 --> 00:12:50.662

our possible hazards by performing our THAs,

192

00:12:51.302 --> 00:12:55.282

and these were the main hazards related to porpoising,

193

00:12:55.702 --> 00:12:59.062

excessive dipole porpoising, so the porpoising itself is a risk.

194

00:12:59.562 --> 00:13:03.382

Unintentional low-energy airborne stall close to water surface,

195

00:13:03.512 --> 00:13:07.342

abnormal contact with water surface, nose over, tail strike,

196

00:13:08.162 --> 00:13:11.902

G exceedance, skipping, and structural damage.

197

00:13:11.982 --> 00:13:15.782

So the residual criticality that we consider it's medium to high.

198

00:13:18.421 --> 00:13:20.642

We start planning to perform this method.

199

00:13:21.642 --> 00:13:25.062

We even requested our flight control system engineers to

200

00:13:25.322 --> 00:13:28.522

design a stick fixture, because

201

00:13:29.562 --> 00:13:33.302

the thing that you will do, the technique that you will do, you advance

202

00:13:33.362 --> 00:13:35.242  
power, you need a fixed elevator setting.

203  
00:13:35.342 --> 00:13:39.202  
Speed is changing, power is there, that you have vibration coming from  
the

204  
00:13:39.222 --> 00:13:43.082  
water surface. It's impossible to keep the elevator fixed under these

205  
00:13:43.122 --> 00:13:46.962  
circumstances. You need some kind of fixture with quick-release function.

206  
00:13:49.522 --> 00:13:53.422  
We deepened the safety-related discussions,

207  
00:13:54.622 --> 00:13:57.842  
and we came up with some

208  
00:13:57.922 --> 00:14:01.792  
more concerns which addressed better.

209  
00:14:02.882 --> 00:14:06.522  
So the first one, the dynamic high power approach to porpoising

210  
00:14:06.602 --> 00:14:09.632  
boundary condition. So if you have

211  
00:14:09.802 --> 00:14:13.322  
any

212  
00:14:13.382 --> 00:14:17.032  
specific instable area in a specific speed,

213  
00:14:17.482 --> 00:14:21.222  
the speed just building up, that most probably you passed that condition

214  
00:14:21.302 --> 00:14:23.482  
already, it may mask the instability.

215  
00:14:24.342 --> 00:14:28.062

And if you are using the stick fixture, time

216

00:14:28.122 --> 00:14:30.982

delay of removing the stick fixture,

217

00:14:32.502 --> 00:14:35.902

and also in the area that you have mechanical obstruction

218

00:14:36.582 --> 00:14:38.382

in case aircraft becomes airborne

219

00:14:39.622 --> 00:14:41.322

or in case of test abort.

220

00:14:42.222 --> 00:14:46.162

And we have transition phases, as Marcus explained, that it's coming

221

00:14:46.302 --> 00:14:49.852

onto step, off the step, that risk of having uncontrolled porpoising on

222

00:14:49.942 --> 00:14:51.922

transition phases, it's there.

223

00:14:52.852 --> 00:14:56.342

And prediction of aircraft behavior for the next run, it's super

224

00:14:56.362 --> 00:15:00.302

limited. You do your shuts and expect them, it's

225

00:15:00.582 --> 00:15:01.122

still fine.

226

00:15:03.402 --> 00:15:07.342

And test technique is not reflecting operational procedures

227

00:15:07.402 --> 00:15:11.302

in terms of pilot coupling, because you remove the pilot from the loop,  
at

228

00:15:11.362 --> 00:15:15.252

least the majority of the run, and control forces

229

00:15:15.302 --> 00:15:16.402

that you cannot

230

00:15:17.422 --> 00:15:21.242

gather the data. And in terms of test efficiency, it's

231

00:15:21.302 --> 00:15:24.782

difficult to map porpoising boundaries with regular intervals.

232

00:15:24.862 --> 00:15:28.622

You just change the parameter, and you just wait until the

233

00:15:28.682 --> 00:15:30.922

aircraft airbornes or you hit the porpoising boundary.

234

00:15:32.562 --> 00:15:36.022

So nobody was happy in the room. The test

235

00:15:36.082 --> 00:15:37.682

pilots were not happy,

236

00:15:38.662 --> 00:15:42.402

the FTEs neither. So the question, can we find a safer

237

00:15:42.502 --> 00:15:43.142

test method?

238

00:15:44.782 --> 00:15:48.202

That's how we developed the constant speed

239

00:15:48.522 --> 00:15:52.202

runs method. Again, we are talking about the same graph, the speed

240

00:15:52.262 --> 00:15:53.782

versus pitch.

241

00:15:54.962 --> 00:15:58.862

So the test technique, basically, the setup, they adjust power to achieve initial

242  
00:15:58.902 --> 00:16:02.722  
target pitch angle and speed. So we come onto step, aircraft is

243  
00:16:02.782 --> 00:16:06.362  
onto step. So it's a speedboat now.

244  
00:16:08.542 --> 00:16:11.562  
Then stabilize pitch angle and freeze power setting.

245  
00:16:11.842 --> 00:16:15.722  
So you have an aircraft staying on the speed, the power is freezed,

246  
00:16:17.202 --> 00:16:20.502  
and the initial pitch that it's there, and

247  
00:16:21.202 --> 00:16:22.682  
start recording, data recording.

248  
00:16:22.722 --> 00:16:26.302  
Record pitch and heave behavior with constant elevator

249  
00:16:26.482 --> 00:16:29.262  
input. That's the stabilization point on the chart.

250  
00:16:30.582 --> 00:16:32.982  
Then the next is the boundary identification.

251  
00:16:33.962 --> 00:16:37.202  
You're just on condition, observe

252  
00:16:38.442 --> 00:16:39.262  
the behavior.

253  
00:16:40.082 --> 00:16:43.462  
When the data is good, go to the next pitch target

254  
00:16:44.342 --> 00:16:45.622  
and do the same over there

255  
00:16:47.062 --> 00:16:50.982

until you reach your boundary definition or the Markov

256

00:16:51.182 --> 00:16:52.082  
criteria reached.

257

00:16:54.102 --> 00:16:57.982  
And you repeat this one for next

258

00:16:58.042 --> 00:16:59.542  
higher target speed.

259

00:17:05.742 --> 00:17:09.722  
So we brought you three examples from our testing.

260

00:17:10.843 --> 00:17:11.682  
The first one,

261

00:17:12.502 --> 00:17:14.982  
maybe let me explain the upper left side.

262

00:17:15.202 --> 00:17:19.103  
The blue line is the elevated deflection, the red

263

00:17:19.182 --> 00:17:20.343  
one is the pitch,

264

00:17:21.462 --> 00:17:25.222  
the brown one is the G and Z, and the green

265

00:17:25.322 --> 00:17:26.583  
one control force.

266

00:17:28.062 --> 00:17:31.202  
So let me play the video. This is super stable run.

267

00:17:31.352 --> 00:17:34.942  
The first part of the data, we had a fixed elevator

268

00:17:34.962 --> 00:17:38.222  
deflection, minimum oscillation in pitch.

269  
00:17:38.782 --> 00:17:42.702  
We have G oscillation because this is high pitch, high speed test point.

270  
00:17:42.792 --> 00:17:46.162  
That aircraft is basically jumping on water, but no pitch oscillation,

271  
00:17:46.842 --> 00:17:47.322  
so it's

272  
00:17:48.322 --> 00:17:52.282  
all good. And when we say the data is good, luckily, we have

273  
00:17:52.362 --> 00:17:56.282  
strong test pilots. They pull more, go to the next target pitch,

274  
00:17:57.382 --> 00:18:00.902  
then we perform that part. It's stable.

275  
00:18:03.202 --> 00:18:06.502  
This is execution green, test fail green test point.

276  
00:18:11.502 --> 00:18:12.562  
Then stay abort.

277  
00:18:13.382 --> 00:18:13.842  
Next one.

278  
00:18:15.162 --> 00:18:17.002  
Again, the same setup.

279  
00:18:19.062 --> 00:18:20.922  
One difference here that you can see,

280  
00:18:21.522 --> 00:18:24.632  
justpitch

281  
00:18:26.452 --> 00:18:30.032  
behavior here. Then we have a divergent

282  
00:18:31.132 --> 00:18:34.772

pitch behavior together with the heave oscillation, so it's

283

00:18:34.872 --> 00:18:37.332

G and the pitch together, they are oscillating.

284

00:18:38.132 --> 00:18:42.092

We have real-time data analysis capability, so two

285

00:18:42.212 --> 00:18:45.972

pilots, one FT. We have a claustrophobic area for the

286

00:18:46.052 --> 00:18:49.012

FT station, but we can do predictive

287

00:18:49.692 --> 00:18:53.092

decision-making. So after the second, third

288

00:18:53.172 --> 00:18:56.772

cycle, third peak, yeah, okay, we are coming there.

289

00:18:57.232 --> 00:19:00.272

We know what's coming, though, so it will end up with an accident.

290

00:19:03.392 --> 00:19:07.112

The third one, for the porpoising definition, it's not that much black and

291

00:19:07.172 --> 00:19:07.972

white all the time.

292

00:19:09.072 --> 00:19:12.372

So sometimes you observe some oscillation,

293

00:19:13.532 --> 00:19:17.212

then you need to understand the nature of the oscillation very well.

294

00:19:17.652 --> 00:19:20.212

Maybe it's okay, then you

295

00:19:21.372 --> 00:19:22.032

will just

296  
00:19:22.932 --> 00:19:25.892  
say that it's oscillation there, but it's controllable.

297  
00:19:25.952 --> 00:19:26.212  
It's

298  
00:19:27.032 --> 00:19:30.731  
the setup here. Initially, we observed oscillations.

299  
00:19:32.032 --> 00:19:35.652  
Right after the biggest amplitude, as soon as the FT observed that

300  
00:19:35.672 --> 00:19:39.472  
it's decreasing the amplitude, that it's continue, continue, let's

301  
00:19:39.512 --> 00:19:39.872  
observe.

302  
00:19:40.792 --> 00:19:44.612  
So that's one of the case. So regardless of the results, there is one

303  
00:19:44.672 --> 00:19:48.052  
important common point on these three examples.

304  
00:19:48.992 --> 00:19:52.852  
The real-time data capability together with the real-time data

305  
00:19:52.972 --> 00:19:56.672  
monitoring, these techniques gives us time for

306  
00:19:56.832 --> 00:20:00.512  
decision-making. So it starts with a

307  
00:20:00.612 --> 00:20:04.232  
stable condition, then you go with a build-up manner,

308  
00:20:04.792 --> 00:20:07.552  
then you have time to make your decision.

309

00:20:10.052 --> 00:20:13.182

We performed these tests, in total, 15 tests together,

310

00:20:13.432 --> 00:20:17.172

189 data points. Plus, we had

311

00:20:17.652 --> 00:20:21.232

quite remarkable number of water takeoffs and landings,

312

00:20:21.912 --> 00:20:24.892

some of them for the field performance, but data is there.

313

00:20:26.392 --> 00:20:30.292

So the graph that you can see on the right-hand side, it's

314

00:20:30.352 --> 00:20:33.091

the porpoising envelope mapping graph.

315

00:20:33.412 --> 00:20:35.692

So you have green and the red points,

316

00:20:37.712 --> 00:20:41.452

stable and unstable data points. When you reach that stage,

317

00:20:41.512 --> 00:20:43.952

it's more or less you are done.

318

00:20:45.052 --> 00:20:48.992

But we approach data visualization and analysis

319

00:20:49.072 --> 00:20:52.632

part in another way as well by performing a

320

00:20:52.712 --> 00:20:56.072

statistical evaluation. These are the heat maps of the

321

00:20:56.472 --> 00:20:57.252

left-hand side, the

322

00:20:58.192 --> 00:20:59.932

speed versus pitch angle,

323

00:21:01.432 --> 00:21:03.952  
regarding to the time spent on condition.

324

00:21:04.152 --> 00:21:08.032  
So we get all data from the beginning of the campaign till the end

325

00:21:08.792 --> 00:21:10.372  
and created heat maps.

326

00:21:11.892 --> 00:21:15.852  
So the blue one, that means that the aircraft stayed on that condition

327

00:21:15.862 --> 00:21:19.072  
short time, relatively, and the green one long.

328

00:21:19.152 --> 00:21:22.252  
And the hatched area on the left-hand side is the takeoff sequence.

329

00:21:22.292 --> 00:21:25.692  
So maybe a little bit more zoom into

330

00:21:25.712 --> 00:21:27.052  
the takeoff.

331

00:21:27.912 --> 00:21:31.252  
So on the right-hand side is the colored version of the hatched area.

332

00:21:31.692 --> 00:21:35.072  
So you can see clearly that the tested envelope and the

333

00:21:35.272 --> 00:21:38.732  
operational envelope of the aircraft.

334

00:21:41.652 --> 00:21:45.112  
And this is the same strategy for the

335

00:21:45.572 --> 00:21:46.792  
controlled deflection.

336

00:21:48.012 --> 00:21:49.832  
On the left-hand side, then

337  
00:21:51.152 --> 00:21:54.472  
we have the center line. It's the zero position, push and pull.

338  
00:21:55.212 --> 00:21:59.032  
So it showed that as soon as you have slight pull, it's all good.

339  
00:21:59.992 --> 00:22:03.732  
On the right-hand side, as you can see, the tested envelope, we even

340  
00:22:03.812 --> 00:22:07.792  
tested the cases with active push while we are

341  
00:22:07.832 --> 00:22:09.032  
going to take off run,

342  
00:22:09.872 --> 00:22:13.822  
which is not an operational case, but at least we know how

343  
00:22:13.852 --> 00:22:17.012  
much margin in between the operational and non-operational case.

344  
00:22:17.192 --> 00:22:19.852  
So it was a gain from our point of view.

345  
00:22:22.412 --> 00:22:23.732  
After this much

346  
00:22:24.952 --> 00:22:28.692  
tests and the evaluation, I think it's good time to compare the methods.

347  
00:22:29.892 --> 00:22:31.272  
So we discussed

348  
00:22:32.452 --> 00:22:33.112  
most of them.

349  
00:22:34.212 --> 00:22:37.852  
So risk of unexpected porpoising on the improved method,

350

00:22:37.952 --> 00:22:38.892

it's better.

351

00:22:40.002 --> 00:22:43.052

There is no mechanical obstruction on the flight control system.

352

00:22:43.692 --> 00:22:47.551

Pilot response time, which is linked to the previous item for the

353

00:22:47.592 --> 00:22:51.472

recovery action. It's only the human being, the pilot response time.

354

00:22:52.992 --> 00:22:55.532

Control force data, yes, we have it.

355

00:22:56.772 --> 00:23:00.632

Predictability of next data point, we are not going with the technique

356

00:23:00.712 --> 00:23:04.272

all in. We have a stabilized start, then everything under control,

357

00:23:04.892 --> 00:23:08.792

and we go with a build-up manner, so we know more

358

00:23:08.812 --> 00:23:10.232

or less what's coming next.

359

00:23:12.372 --> 00:23:16.012

Smart build-up to limit condition, so we start with the low speed,

360

00:23:16.512 --> 00:23:19.812

then also controlled envelope expansion in pitch.

361

00:23:20.422 --> 00:23:22.772

And the test is pilot-in-the-loop test.

362

00:23:23.952 --> 00:23:27.792

Data precision and repeatability, we had cases that we repeat the test

363

00:23:27.852 --> 00:23:31.312  
condition, its precision and repeatability, it's satisfactory,

364  
00:23:31.952 --> 00:23:34.952  
and regular intervals to map porpoising boundaries.

365  
00:23:36.972 --> 00:23:37.712  
So as summary,

366  
00:23:39.392 --> 00:23:41.272  
overall, during test planning,

367  
00:23:42.252 --> 00:23:45.292  
major risk of traditional methods have been identified.

368  
00:23:46.532 --> 00:23:50.172  
To avoid these risks, the identified risks,

369  
00:23:50.492 --> 00:23:54.292  
a safer way of conducting the test is searched.

370  
00:23:55.292 --> 00:23:58.472  
That's how the constant speed run methods developed,

371  
00:23:59.292 --> 00:24:03.132  
and constant speed run method has been safely, successfully

372  
00:24:03.172 --> 00:24:03.932  
demonstrated.

373  
00:24:05.092 --> 00:24:08.292  
So during the test, we did not have any

374  
00:24:08.452 --> 00:24:10.692  
porpoising-related incident,

375  
00:24:11.852 --> 00:24:15.532  
and that improved method just gave us

376  
00:24:15.792 --> 00:24:17.752  
improved flight test safety.

377

00:24:19.392 --> 00:24:20.452

Our last slide here,

378

00:24:21.392 --> 00:24:24.012

the lessons learned and guidance to future

379

00:24:24.112 --> 00:24:27.685

projects. The lessons learned, the civil certification

380

00:24:27.736 --> 00:24:30.956

requirement for water handling characteristic is

381

00:24:30.996 --> 00:24:34.126

subjective. It starts with the sentence, "No dangerous and

382

00:24:34.156 --> 00:24:36.556

uncontrollable porpoising characteristics."

383

00:24:37.456 --> 00:24:41.056

It gives you more room to make your

384

00:24:41.096 --> 00:24:43.376

decision, but there is a missing guidance

385

00:24:43.456 --> 00:24:46.956

here. So the limited guidance material is

386

00:24:46.976 --> 00:24:50.636

available for seaplane testing. Literature is not up to date.

387

00:24:50.676 --> 00:24:54.556

We are talking about 1960s, so it's not considered we have

388

00:24:55.116 --> 00:24:56.976

state-of-art FDI systems now.

389

00:24:59.036 --> 00:25:02.816

Porpoising definition, in contrast to the first one

390

00:25:02.896 --> 00:25:06.636  
by mil spec, is too strict. Two degrees, it's

391  
00:25:06.676 --> 00:25:09.735  
there, but they are from 1960s, as I said.

392  
00:25:10.576 --> 00:25:13.396  
And the boundaries may not be purely defined by

393  
00:25:13.896 --> 00:25:17.646  
oscillation. There may be another HMI limit or the

394  
00:25:17.696 --> 00:25:21.336  
system limit that you reach. In our case,

395  
00:25:21.636 --> 00:25:24.336  
on the upper boundary side for our side, we reach

396  
00:25:25.276 --> 00:25:28.746  
a non-operational force limits even we tested them,

397  
00:25:29.736 --> 00:25:31.636  
but we did not observe any porpoise.

398  
00:25:34.036 --> 00:25:37.256  
Traditional porpoising test method has inherent risks.

399  
00:25:38.876 --> 00:25:42.476  
Using the constant speed run method reduce these risks.

400  
00:25:42.526 --> 00:25:45.236  
And what can we say to the future projects?

401  
00:25:46.096 --> 00:25:49.456  
Three items, basically. The first one, porpoising boundary

402  
00:25:49.496 --> 00:25:51.736  
investigation is a demanding test topic.

403  
00:25:52.416 --> 00:25:55.636  
So clarify the test methods and associated risks

404

00:25:56.176 --> 00:25:56.596

early.

405

00:25:57.876 --> 00:26:01.276

Porpoising boundary investigation shall be performed with envelope

406

00:26:01.376 --> 00:26:05.156

expansion discipline, so that was missing on the traditional method.

407

00:26:05.636 --> 00:26:09.456

The capability of having real-time data processing and real-time

408

00:26:09.596 --> 00:26:13.496

boundary definition identification, it's

409

00:26:13.556 --> 00:26:17.336

recommended. And the last bullet point that we like most,

410

00:26:18.776 --> 00:26:22.596

in case needed, use constant speed runs method with confidence.

411

00:26:22.756 --> 00:26:24.816

It has been successfully tested.

412

00:26:25.916 --> 00:26:29.476

Thanks a lot for your attention. So that how the Norwegian summer looks

413

00:26:29.536 --> 00:26:33.076

like. If you have any questions, we are happy to take

414

00:26:33.116 --> 00:26:33.756

them.

415

00:26:40.996 --> 00:26:42.296

Yeah, I see a question in the middle.

416

00:26:46.736 --> 00:26:50.716

The sea

417

00:26:50.756 --> 00:26:53.536  
state conditions looked very calm.

418  
00:26:54.056 --> 00:26:57.436  
Did you vary the sea state on your takeoff testing?

419  
00:26:58.396 --> 00:26:59.916  
That was the first water campaign.

420  
00:27:00.256 --> 00:27:04.016  
We were looking for something that was calm and very limited wind.

421  
00:27:04.156 --> 00:27:08.116  
There's a second water campaign planned where we need crosswind because  
we

422  
00:27:08.196 --> 00:27:11.816  
also have to demonstrate that, and we also need to look into sea

423  
00:27:11.916 --> 00:27:12.276  
states.

424  
00:27:13.136 --> 00:27:14.936  
That's to come next year.

425  
00:27:19.056 --> 00:27:20.296  
There's another question here.

426  
00:27:21.156 --> 00:27:25.096  
Do you plan to investigate pitching moment with engine failure

427  
00:27:25.196 --> 00:27:26.266  
in future campaigns?

428  
00:27:27.066 --> 00:27:30.456  
We did engine failure testing in these

429  
00:27:30.516 --> 00:27:31.136  
campaigns.

430  
00:27:32.456 --> 00:27:35.596

The interesting part that's potentially worth another paper, a

431

00:27:35.636 --> 00:27:39.436  
traditional V1 speed definition does not

432

00:27:39.456 --> 00:27:42.086  
really work. We had an airplane that does have

433

00:27:42.936 --> 00:27:46.296  
not a minimum control speed issue due to the center line thrust.

434

00:27:47.836 --> 00:27:51.656  
What it has is as soon as you fail an engine, you have a pitch-up moment.

435

00:27:53.036 --> 00:27:56.796  
So it might get airborne even if you are on the water

436

00:27:56.976 --> 00:28:00.436  
at the engine failure. We demonstrated that, and

437

00:28:01.416 --> 00:28:04.916  
our proposal for the certification right now is to lower the

438

00:28:04.996 --> 00:28:08.836  
V1 a little bit. We tested this, and

439

00:28:09.236 --> 00:28:12.696  
we also demonstrated that it's not a big issue if it takes off

440

00:28:13.296 --> 00:28:16.856  
and will be re-landed. So there might be an

441

00:28:16.916 --> 00:28:20.856  
initial hop in an engine failure if you're close to the V1, but we

442

00:28:20.936 --> 00:28:24.716  
also successfully demonstrated that this is not a big issue from a

443

00:28:24.756 --> 00:28:25.716  
pilot point of view.

444

00:28:27.636 --> 00:28:29.996

I think you may have already answered part of my question.

445

00:28:30.036 --> 00:28:33.896

The takeoff procedure in this type of airplane, is it a rotation

446

00:28:33.976 --> 00:28:37.836

or is it a deployment of flaps at a certain speed that then kind of lifts you

447

00:28:37.896 --> 00:28:38.486

off the water?

448

00:28:39.076 --> 00:28:39.296

Yeah.

449

00:28:39.316 --> 00:28:42.656

And the follow-on is, these were all static tests.

450

00:28:42.736 --> 00:28:43.456

Is there any

451

00:28:44.755 --> 00:28:48.496

thought of the dynamic motion of the rotation that would

452

00:28:48.516 --> 00:28:49.696

introduce a porpoise?

453

00:28:50.456 --> 00:28:52.756

This is a Part 23 commuter airplane.

454

00:28:52.796 --> 00:28:56.696

It's capable of flying on one engine, so we have to demonstrate engine failure, and

455

00:28:56.716 --> 00:28:58.645

we have to define our engine failure speeds.

456

00:28:59.656 --> 00:29:03.416

From a general technique, how you get this airplane

457

00:29:03.456 --> 00:29:07.386

airborne is you accelerate, you keep it level, you

458

00:29:07.556 --> 00:29:11.476

stay in the pitch corridor. Four degree is a super good target, and

459

00:29:11.556 --> 00:29:15.446

with the new instrumentation we have on the digital flight displays,

460

00:29:15.496 --> 00:29:17.456

that's also easy to do. It's a good guidance.

461

00:29:17.916 --> 00:29:21.656

The old traditional legacy airplane had one of these

462

00:29:21.716 --> 00:29:25.456

artificial horizons where you could adjust your zero pitch.

463

00:29:27.016 --> 00:29:29.796

Then it flies off automatically.

464

00:29:30.776 --> 00:29:34.416

We also demonstrated that once you're above the hump speed,

465

00:29:34.796 --> 00:29:38.256

you could technically take off with one engine. That works.

466

00:29:38.336 --> 00:29:42.236

You need a super long lake, but you're not getting there if

467

00:29:42.256 --> 00:29:45.816

you don't have two engines. So getting on step requires two

468

00:29:45.896 --> 00:29:49.616

engine. Once you're on step, you could also take off with one

469

00:29:49.676 --> 00:29:52.056

engine, but then it will take a lot of distance.

470

00:29:55.356 --> 00:29:55.976

Yes, sir.

471

00:29:57.496 --> 00:29:59.576

Thank you for the presentation. Two questions.

472

00:30:00.316 --> 00:30:03.536

Is the cause of porpoising well understood?

473

00:30:04.496 --> 00:30:07.896

And the second question is, there was a slide where you showed some

474

00:30:07.916 --> 00:30:11.656

oscillations building up, and then they died down, and then the previous slide

475

00:30:11.696 --> 00:30:15.356

before that, as the oscillation were building, you said the FTE called abort, I

476

00:30:15.376 --> 00:30:18.896

guess, at the third peak. So what determines when that

477

00:30:18.916 --> 00:30:20.816

abort call is made?

478

00:30:21.796 --> 00:30:22.696

Oh, I can maybe-

479

00:30:22.956 --> 00:30:23.186

Yeah, that's-

480

00:30:23.186 --> 00:30:26.648

... contribute on the second question of yours. So

481

00:30:27.488 --> 00:30:30.608

for the second video, which

482

00:30:30.908 --> 00:30:34.868

we have the divergent oscillation that we are

483

00:30:34.928 --> 00:30:37.828

real-time monitoring the nature of the oscillation.

484

00:30:37.928 --> 00:30:40.268

We are talking about frequency. If it's

485

00:30:41.308 --> 00:30:45.098

dumping, it's negative, positive dumping, and you have

486

00:30:45.248 --> 00:30:48.428

pretty much the estimation of what will the

487

00:30:49.328 --> 00:30:53.288

oscillation cycle. So

488

00:30:53.828 --> 00:30:57.708

on the second example, it was obvious that it's going

489

00:30:57.748 --> 00:31:01.738

divergent. So that was the reason that

490

00:31:01.768 --> 00:31:04.848

we knock it off. The third one,

491

00:31:06.508 --> 00:31:10.388

the maximum amplitude oscillation did not reach the

492

00:31:10.408 --> 00:31:11.528

predefined, the

493

00:31:13.048 --> 00:31:16.878

one that we defined already, the Nakadof criteria in terms of

494

00:31:16.928 --> 00:31:20.668

amplitude. We just waited, but it's worth to wait

495

00:31:20.708 --> 00:31:24.648

because right after the maximum amplitude oscillation, then

496

00:31:24.728 --> 00:31:27.128

we observed that it started dying down.

497

00:31:27.168 --> 00:31:30.388

It's worth to wait some more, then

498

00:31:31.128 --> 00:31:32.228

it happened that way.

499

00:31:34.348 --> 00:31:36.608

The first question, sorry, can you repeat the first one?

500

00:31:37.228 --> 00:31:40.758

Is the cause of purposing well understood? What causes it?

501

00:31:40.808 --> 00:31:43.388

Yeah, it is well understood. There is also some literature.

502

00:31:43.908 --> 00:31:47.538

It's a motion in heave, and basically what happens,

503

00:31:48.048 --> 00:31:51.458

the contact point to the water moves back and forward, and that

504

00:31:52.188 --> 00:31:55.868

unbalance the airplane, and that issues some pitch

505

00:31:55.988 --> 00:31:59.778

movement, and that again drives the movement of the water

506

00:31:59.868 --> 00:32:03.168

contact points. So with that, it's pretty well understood.

507

00:32:03.248 --> 00:32:06.968

It depends very much on the design of the hull of the

508

00:32:06.988 --> 00:32:10.928

airplane. On the other side, it's also you can do something

509

00:32:11.008 --> 00:32:14.788

that is very stable, but then the performance typically is not very good on water.

510

00:32:15.688 --> 00:32:19.608  
So traditionally for an aircraft in the air that

511  
00:32:20.088 --> 00:32:23.248  
we do everything around the center of gravity position.

512  
00:32:23.768 --> 00:32:27.688  
When you are on water, low speed or high speed, but it's much more dominant on

513  
00:32:27.728 --> 00:32:31.148  
the high speed. We also have another point which is center of buoyancy,

514  
00:32:32.168 --> 00:32:35.788  
the point that the float plane or the

515  
00:32:36.367 --> 00:32:37.668  
boat floats.

516  
00:32:38.468 --> 00:32:41.808  
So that's the decoupling effect that we are talking here.

517  
00:32:42.148 --> 00:32:42.448  
Thank you.

518  
00:32:46.388 --> 00:32:47.108  
Thank you very much.

519  
00:32:48.188 --> 00:32:48.608  
Thank you.