WEBVTT

1
00:00:00.400 --> 00:00:04.400
Or a 10 F-16 and kc-135 experience. I'm

2
00:00:03.400 --> 00:00:06.200
also was assigned to the F-16 program.

3
00:00:07.700 --> 00:00:08.600
USAF

4
00:00:09.500 --> 00:00:14.100
testified school graduate and instructor pilot. There also has

5
00:00:13.100 --> 00:00:17.100
worked at Cal span Northwest Airlines and

6
00:00:16.100 --> 00:00:19.300
now is working with Airbus on

7
00:00:19.300 --> 00:00:22.100
designs for their fly-by-wire aircraft and their modern

8
00:00:22.100 --> 00:00:24.800
aircraft including the A380 and the a400m.

9
00:00:25.400 --> 00:00:28.400
So, please welcome Terry to the

10
00:00:28.400 --> 00:00:29.200
podium.

11
00:00:39.300 --> 00:00:42.400
Good morning, everyone glad to be here and this has

12
00:00:42.400 --> 00:00:45.600
been a terrific workshop and I'm hoping that I can pass along some

13
00:00:45.600 --> 00:00:48.600
of my previous knowledge and experience to all

14
00:00:48.600 --> 00:00:51.400
of you who are still in the industry active. And as

15
00:00:51.400 --> 00:00:53.800
I kind of Fade Away into Consulting world.

16
00:00:55.200 --> 00:00:58.800
So what I'd like to talk to you about today is give

17
00:00:58.800 --> 00:01:02.100
you some conventional design examples and then

18
00:01:01.100 --> 00:01:04.300
go into how we develop the F-16 and

19
00:01:04.300 --> 00:01:07.700
tested it at high AOA briefly touch

20
00:01:07.700 --> 00:01:10.400
on saturated flight controls and then

21
00:01:10.400 --> 00:01:13.600
move on to how you test fly by wire in

22
00:01:13.600 --> 00:01:16.300
transport airplane with some hard

23
00:01:16.300 --> 00:01:20.100
lessons and showing you the safety history. I'll conclude

24
00:01:19.100 --> 00:01:22.900
with Lessons Learned and then take a peek into

25
00:01:22.900 --> 00:01:25.100
the future as to what what I think we need to be

26
00:01:25.100 --> 00:01:26.900
focusing on in the future.

27
00:01:27.800 --> 00:01:30.500

So let's look at some airplanes that we

28
00:01:30.500 --> 00:01:33.500
that we all know very well. The first one is the t-38.

29
00:01:33.500 --> 00:01:36.500
It's been in service for 60 years and has had

30
00:01:36.500 --> 00:01:39.900
an excellent safety record. It will not depart controlled

31
00:01:39.900 --> 00:01:42.500
flight and many people have tried and part

32
00:01:42.500 --> 00:01:45.800
of the reason for that is as a small stabulator large

33
00:01:45.800 --> 00:01:48.500
vertical fin. So it's plenty of directional stability

34
00:01:48.500 --> 00:01:51.600
small Rudder. So you can't develop large jaw angles

35
00:01:51.600 --> 00:01:54.800
and Centerline thrust with closely spaced engines

36
00:01:54.800 --> 00:01:57.500
very very successful design, but completely

37
00:01:57.500 --> 00:01:58.800
non-fly-by-wire.

38
00:01:59.900 --> 00:02:02.500
Then you go to the F4 great airplane

39
00:02:02.500 --> 00:02:06.100
great performance and load carrying capability world's best

40
00:02:06.100 --> 00:02:07.300
supersonic dump truck.

41
00:02:10.200 --> 00:02:13.800
But as you can see, it has very complex aerodynamics. And you

42
00:02:13.800 --> 00:02:16.300
know, it's got bent down horizontal tail. It's got bent up

43
00:02:16.300 --> 00:02:20.400
wingtips and a snag on the Leading Edge and all of that are aerodynamic fixes,

44
00:02:20.400 --> 00:02:23.300
but even then it's needed pitch. Yaw and

45
00:02:23.300 --> 00:02:26.400
roll augmentation at high AOA at

46
00:02:26.400 --> 00:02:29.500
very high adverse Shaw. So if you were going to roll at high AOA,

47
00:02:29.500 --> 00:02:32.400
you had to keep the stick in the center while you were pulling back and roll

48
00:02:32.400 --> 00:02:33.400
the airplane with rudder.

49
00:02:34.100 --> 00:02:37.700
There's a lot of accidents in this airplane due to loss of

50
00:02:37.700 --> 00:02:40.600
control and I remember when I flew it operationally we

51
00:02:40.600 --> 00:02:42.200
were having one about every two months.

52
00:02:43.200 --> 00:02:44.500
pretty high accident rate

53
00:02:45.400 --> 00:02:46.700
and we go to the F-16.

54
00:02:47.600 --> 00:02:50.500
The first all fly by wire fighter airplane. I

55
00:02:50.500 --> 00:02:53.200
was fortunate enough to work on this program as a

56
00:02:53.200 --> 00:02:55.100
program manager not as a test pilot.

57
00:02:55.800 --> 00:02:59.100
As you can see really has outstanding aerodynamics. It's

58
00:02:58.100 --> 00:03:02.400
a very clean configuration

59
00:03:01.400 --> 00:03:04.300
flight controls are protected in

60
00:03:04.300 --> 00:03:07.800
Pitch role and yaw, and to date 40

61
00:03:07.800 --> 00:03:10.500
years after it's been in production. It still has an excellent

62
00:03:10.500 --> 00:03:13.200
loss of control safety record. One thing that

63
00:03:13.200 --> 00:03:16.400
I want to point out and I'm going to refer to later on as these

64
00:03:16.400 --> 00:03:19.300
vortices that are Shed from the extension of the Leading Edge

65
00:03:19.300 --> 00:03:22.300
and you notice how they remain intact until they get

66
00:03:22.300 --> 00:03:25.800
just passed the tail. That's an important function of

67
00:03:25.800 --> 00:03:28.600

the design of the F-16 which gives it better directional

68
00:03:28.600 --> 00:03:29.200
stability.

69
00:03:31.200 --> 00:03:35.400
So how did we develop the flight control system on the F-16? It

70
00:03:34.400 --> 00:03:37.100
started by General Dynamics going into

71
00:03:37.100 --> 00:03:40.100
the wind tunnel and doing more than 200 entries until they got

72
00:03:40.100 --> 00:03:43.100
the design the Leading Edge shape so that it would provide that

73
00:03:43.100 --> 00:03:46.600
high energy Vortex which bursts aft

74
00:03:46.600 --> 00:03:47.500
of the vertical fin.

75
00:03:48.200 --> 00:03:51.800
Then we had to decide how to set the angle of attack limiter. We

76
00:03:51.800 --> 00:03:54.400
determine in Flight tests that CN beta goes

77
00:03:54.400 --> 00:03:57.300
to zero at about 29 degrees angle of attack. So we

78
00:03:57.300 --> 00:04:00.300
said okay, we don't want the airplane to depart in yah. So

79
00:04:00.300 --> 00:04:03.500
let's conservatively set the alpha limiter at 25.2 degrees

80
00:04:03.500 --> 00:04:06.600
in 1G flight at higher

81
00:04:06.600 --> 00:04:09.200
G levels. The F-16. Alpha limiter is a function of

82
00:04:09.200 --> 00:04:13.400
both G and angle of attack up to 9g's it's

83
00:04:12.400 --> 00:04:15.900
G command to 15 degrees away then

84
00:04:15.900 --> 00:04:19.100
Blends into G AOA to 25.5 degrees

85
00:04:18.100 --> 00:04:21.700
AOA. It also has Rudder

86
00:04:21.700 --> 00:04:25.000
travel limiting so that at high AOA rotor travel

87
00:04:24.400 --> 00:04:27.100
no matter what the pilot does on the router goes to

88
00:04:27.100 --> 00:04:28.800
zero at 26 degrees.

89
00:04:29.800 --> 00:04:32.200
In the role axis. The max roll rate is

90
00:04:32.200 --> 00:04:36.000
normally 300 degrees per second in the cruise configuration, but

91
00:04:35.400 --> 00:04:38.300
it decreases if AOA is above 15

92
00:04:38.300 --> 00:04:41.900
AirSpeed below 259 and the

93
00:04:41.900 --> 00:04:44.600
horizontal tail below five degrees trailing Edge

94
00:04:44.600 --> 00:04:47.600

down that very last point. There

95
00:04:47.600 --> 00:04:50.100
is saying that we're not going to

96
00:04:50.100 --> 00:04:53.400
allow you to use the horizontal tail to roll because

97
00:04:53.400 --> 00:04:56.100
we need the horizontal tail for pitch control.

98
00:04:56.900 --> 00:04:59.300
The other thing to mention about the F-16 in the

99
00:04:59.300 --> 00:05:02.400
Rolex is the airplane rolls about the velocity Vector.

100
00:05:02.400 --> 00:05:05.600
So if you're rolling it at 25 degrees

101
00:05:05.600 --> 00:05:08.200
angle of attack, the nose is going to slice around

102
00:05:08.200 --> 00:05:10.800
as it follows the velocity Vector during the role.

103
00:05:13.100 --> 00:05:17.100
So if you set the angle the tachometer at 25.5.

104
00:05:18.800 --> 00:05:21.200
How do you test the airplane at even higher angles of

105
00:05:21.200 --> 00:05:24.300
attack? So you have to develop a flight test technique which

106
00:05:24.300 --> 00:05:27.500
may have already been in place. But the one that we used was you start

107
00:05:27.500 --> 00:05:31.200
with about 300 knots of flight Level 310 climb 80

108
00:05:31.200 --> 00:05:34.200
degrees nose high and at 180 knots initiate a

109
00:05:34.200 --> 00:05:34.900
full stick roll.

110
00:05:35.700 --> 00:05:38.300
So the role generally is completed about flight level

111
00:05:38.300 --> 00:05:41.400
350. So you've got a lot of altitude to play

112
00:05:41.400 --> 00:05:44.200
with as your plane is coming downhill and when you

113
00:05:44.200 --> 00:05:47.300
get to the apex of the climb if everything is working, right

114
00:05:47.300 --> 00:05:50.400
the airplane will start down at a very very high

115
00:05:50.400 --> 00:05:51.400
angle attack.

116
00:05:52.200 --> 00:05:55.400
So it's you should be able to do this in an upright

117
00:05:55.400 --> 00:05:56.800
Wings level descent.

118
00:05:57.300 --> 00:06:00.500
Now when we were doing this early in the test program,

119
00:06:00.500 --> 00:06:03.500
we had one event where the airplane hung

120
00:06:03.500 --> 00:06:06.300
up in a deep stall. So the airplane was balanced at a

121
00:06:06.300 --> 00:06:07.000

very high alpha.

122
00:06:07.600 --> 00:06:10.200
And no matter what the pilot did with the flight

123
00:06:10.200 --> 00:06:13.200
controls it wouldn't recover. So the parachute had to

124
00:06:13.200 --> 00:06:16.300
be used on that on that one time only during this

125
00:06:16.300 --> 00:06:16.900
test program.

126
00:06:17.800 --> 00:06:20.300
But what we discovered looking at the flight test

127
00:06:20.300 --> 00:06:23.400
data afterwards was is that as Philo Striker

128
00:06:23.400 --> 00:06:26.400
began to move the stick down and then back up and then back down

129
00:06:26.400 --> 00:06:29.300
and then back up during the test. We did have

130
00:06:29.300 --> 00:06:30.800
a little bit of pitch control.

131
00:06:31.700 --> 00:06:34.400
And the result of that was we put a manual pitch

132
00:06:34.400 --> 00:06:37.400
override switch in so that we could get direct control

133
00:06:37.400 --> 00:06:40.500
of the horizontal tail and get an even higher deflection because

134
00:06:40.500 --> 00:06:43.900
the flight control system was trying to drive the nose down and

135
00:06:43.900 --> 00:06:46.200
he had just a little bit of control. So let's

136
00:06:46.200 --> 00:06:49.600
give him a little bit more and the result of that was the

137
00:06:49.600 --> 00:06:52.600
ability to in a training environment to have

138
00:06:52.600 --> 00:06:55.700
an instructor in the back and go out and demonstrate the

139
00:06:55.700 --> 00:06:58.700
Deep stall to operational pilot

140
00:06:58.700 --> 00:07:02.100
and let him recover using the mpo switch. No

141
00:07:01.100 --> 00:07:04.200
spin shoot is required because that's a very very

142
00:07:04.200 --> 00:07:07.200
repeatable maneuver and that's what you want for an airplane

143
00:07:07.200 --> 00:07:07.800
of this type.

144
00:07:09.900 --> 00:07:12.500
Then we gave the airplane to the Warfighter and

145
00:07:12.500 --> 00:07:15.400
what they found it was a low-level

146
00:07:15.400 --> 00:07:18.100
Mission heavy wing loading. They were in the

147
00:07:18.100 --> 00:07:21.100
pilot was engaged by defensive Fighters. He did a pitch up in

148
00:07:21.100 --> 00:07:25.300

role into the defensive Fighters and lost control ejected safely,

149
00:07:24.300 --> 00:07:27.500
but we learned that with heavy

150
00:07:27.500 --> 00:07:30.300
wingstores at high angle attack. There was a

151
00:07:30.300 --> 00:07:33.500
possibility for the airplane depart to depart so that

152
00:07:33.500 --> 00:07:36.300
resulted in the Cat 1 cat 3

153
00:07:36.300 --> 00:07:39.400
switch to limit AOA and G with heavywing stores.

154
00:07:40.600 --> 00:07:43.200
I'm going to show you a chart here. Now. This

155
00:07:43.200 --> 00:07:47.200
is the F-16 Alpha G envelope and you can see the

156
00:07:46.200 --> 00:07:49.300
red line the major Red Line. There is the

157
00:07:49.300 --> 00:07:52.900
normal envelope and then with heavy Wing store loadings the envelope

158
00:07:52.900 --> 00:07:53.800
begins to decrease.

159
00:07:56.100 --> 00:07:59.300
Before I talk about this particular event what I

160
00:07:59.300 --> 00:08:02.500
want to mention, I want to go back to the F-16 program just a

161
00:08:02.500 --> 00:08:05.900
little bit because it what I'm going to say is Jermaine to this audience
based

162
00:08:05.900 --> 00:08:07.100
on the discussions that we've had.

163
00:08:08.300 --> 00:08:11.300
We started flying the highway test program at Edwards and

164
00:08:11.300 --> 00:08:12.800
we were flying two sorties a day.

165
00:08:13.500 --> 00:08:16.300
And systems command, which was

166
00:08:16.300 --> 00:08:19.700
headquartered at that time in Washington DC said, you know,

167
00:08:19.700 --> 00:08:22.300
we're really not comfortable with you flying twice a day

168
00:08:22.300 --> 00:08:25.300
and we were we were upset about that because we

169
00:08:25.300 --> 00:08:28.500
were under schedule pressure. We wanted to complete the high angle attack

170
00:08:28.500 --> 00:08:31.800
test program, you know on schedule or you do

171
00:08:31.800 --> 00:08:34.100
the best we can and this would slow us down by

172
00:08:34.100 --> 00:08:35.900
you know, essentially double our time.

173
00:08:36.700 --> 00:08:39.300
And at the time we were upset about it, but looking back on

174
00:08:39.300 --> 00:08:42.500
it. I think that that was probably the right decision because we

175

00:08:42.500 --> 00:08:45.400
weren't taking enough time to look through the data after

176
00:08:45.400 --> 00:08:48.800
each flight and I think that's an important thing to

177
00:08:48.800 --> 00:08:52.100
consider if you're under program pressure. What are

178
00:08:51.100 --> 00:08:54.400
you really trying? You know, where are they

179
00:08:54.400 --> 00:08:57.300
giving you enough time to look at your data? That's the thing

180
00:08:57.300 --> 00:09:00.800
that we we remember from that now if you

181
00:09:00.800 --> 00:09:04.400
remember I made that comment on the F-16 it certain

182
00:09:04.400 --> 00:09:07.600
angle of attack you lose the ability for the horizontal to

183
00:09:07.600 --> 00:09:10.200
provide role and that's so that you

184
00:09:10.200 --> 00:09:13.100
don't saturate the flight controls. This is an example

185
00:09:13.100 --> 00:09:16.200
of the controls being saturated during a high angle

186
00:09:16.200 --> 00:09:19.200
attack Landing. There's this flight number six on the

187
00:09:19.200 --> 00:09:23.100
number one Jas 39 Griffin in Sweden pilot

188
00:09:22.100 --> 00:09:25.600
is landing in Gusty wind conditions, and

189
00:09:25.600 --> 00:09:28.600
and there's a Pio and the flight controls become

190
00:09:28.600 --> 00:09:30.700
saturated and just can't control the airplane.

191
00:09:33.700 --> 00:09:35.500
First time will be this is in real time.

192
00:09:37.400 --> 00:09:40.900
And the second one will be in slow motion. Now the

193
00:09:40.900 --> 00:09:43.300
thing that I noticed after looking at this over and over

194
00:09:43.300 --> 00:09:46.200
and over again is that the speed brakes were all so extended and

195
00:09:46.200 --> 00:09:49.500
the speed brakes are right in front of the elevans. We can

196
00:09:49.500 --> 00:09:52.900
see the canards working really really hard. We

197
00:09:52.900 --> 00:09:55.200
can't see what the elevans are doing. But this is

198
00:09:55.200 --> 00:09:57.700
an example of flight controls becoming saturated.

199
00:10:00.300 --> 00:10:03.600
Pilot survived this he actually

200
00:10:03.600 --> 00:10:05.700
was able to walk away with just a broken arm.

201
00:10:11.300 --> 00:10:11.500
Okay.

202

00:10:12.900 --> 00:10:15.200
So let's talk about commercial airplanes. Now. I was

203
00:10:15.200 --> 00:10:18.500
fortunate enough to go to Airbus and fly all the models of Airbus

204
00:10:18.500 --> 00:10:21.100
airplanes that they have and and do a

205
00:10:21.100 --> 00:10:24.400
lot of these hangover Tech Maneuvers said that I'm going to discuss this is

206
00:10:24.400 --> 00:10:27.800
A320 MSN. Number one. This is a photograph taken

207
00:10:27.800 --> 00:10:31.200
while they were installing the winglets on the airplane. And this

208
00:10:30.200 --> 00:10:33.700
is actually the hanger where the airplane was originally

209
00:10:33.700 --> 00:10:34.300
constructed.

210
00:10:35.200 --> 00:10:38.500
It's a typical transport airplane low Wing engine

211
00:10:38.500 --> 00:10:41.900
underwing engines and a trimmable horizontal stabilizer does

212
00:10:41.900 --> 00:10:45.300
not have a I mean, it has a elevator and

213
00:10:44.300 --> 00:10:47.500
stabilizer rather than an offline tail.

214
00:10:49.200 --> 00:10:52.700
So let's talk about the Airbus design production of protections

215
00:10:52.700 --> 00:10:55.200

briefly angle of attack

216
00:10:55.200 --> 00:10:58.400
is set as Alpha Max with a margin to Alpha stall

217
00:10:58.400 --> 00:11:01.100
Max pitch attitude is limited to

218
00:11:01.100 --> 00:11:04.300
plus 30 and minus 15 and Max G is

219
00:11:04.300 --> 00:11:07.600
said at plus 2.5 and minus 1 in the

220
00:11:07.600 --> 00:11:10.600
roll axis. It's as neutral spiral up

221
00:11:10.600 --> 00:11:13.600
to plus or minus 33 stable spiral

222
00:11:13.600 --> 00:11:16.800
from plus or minus 67 or plus or minus 33,

223
00:11:16.800 --> 00:11:19.200
then the max Bank angle is limited

224
00:11:19.200 --> 00:11:22.600
to plus or minus 67 in the axis. There

225
00:11:22.600 --> 00:11:25.300
are specific limitations on rotor deflection. And these

226
00:11:25.300 --> 00:11:28.300
are all hard limits. These are not soft limits at the pilot can

227
00:11:28.300 --> 00:11:29.800
fly through

228
00:11:31.800 --> 00:11:34.100
So how do you test for limits like that

229
00:11:34.100 --> 00:11:37.100
on a transport and category airplane? First of all, I

230
00:11:37.100 --> 00:11:40.400
got to define the envelope. So you've got to do it at minimum to maximum

231
00:11:40.400 --> 00:11:44.700
weight over the entire CG range mid-forward and

232
00:11:44.700 --> 00:11:47.400
then fcgs all flap slat and

233
00:11:47.400 --> 00:11:50.400
speed brake configurations and over the entire speed and

234
00:11:50.400 --> 00:11:53.200
mock envelope and you must set the limit so that you still have

235
00:11:53.200 --> 00:11:56.400
aircraft maneuverability. You can't limit the Pilot's ability

236
00:11:56.400 --> 00:11:59.100
of maneuver and have really really tight limits.

237
00:12:00.300 --> 00:12:03.400
So you plan for sufficient? Margin

238
00:12:03.400 --> 00:12:05.200
between Alpha Max and Alpha stall?

239
00:12:05.700 --> 00:12:08.200
And you have to account for a little bit of overshoot when

240
00:12:08.200 --> 00:12:11.400
you assault the limiters because there will be some overshoot and then

241
00:12:11.400 --> 00:12:14.600
plan for being free of restrictions for the airline pilot

242
00:12:14.600 --> 00:12:17.800

between V2 minimum on takeoff and vref

243
00:12:17.800 --> 00:12:18.400
on approach.

244
00:12:19.300 --> 00:12:22.700
And it also must include the effects of alpha floor. Now Alpha

245
00:12:22.700 --> 00:12:25.400
floor may be kind of a quote unquote

246
00:12:25.400 --> 00:12:28.300
a foreign concept to people but what it is, is that a

247
00:12:28.300 --> 00:12:31.900
specific angle of attack and angle of attack rate no matter

248
00:12:31.900 --> 00:12:34.800
what the thrust levers are set at the airplane automatically

249
00:12:34.800 --> 00:12:37.700
goes to take off go around thrust. That's Alpha floor.

250
00:12:37.700 --> 00:12:41.100
I think it was named to because all of

251
00:12:41.100 --> 00:12:44.300
the aeronautical terms were used and they were trying to find an English word

252
00:12:44.300 --> 00:12:47.300
that would work and flooring. The accelerator on

253
00:12:47.300 --> 00:12:50.100
your car is probably the most common thing that we can all relate to

254
00:12:50.100 --> 00:12:51.500
and they picked Alpha floor.

255
00:12:52.500 --> 00:12:55.300
Just a guess. However, I never understood exactly how they

256
00:12:55.300 --> 00:12:55.600
did it.

257
00:12:56.500 --> 00:12:59.300
This is a clf occur that shows you a little bit about

258
00:12:59.300 --> 00:13:02.400
where the limits are. And if you look at the black band

259
00:13:02.400 --> 00:13:05.400
here, this is the threshold where Alpha floor becomes active.

260
00:13:06.200 --> 00:13:09.800
And the margin is important here. This is the margin between Alpha

261
00:13:09.800 --> 00:13:11.500
Max and Alpha stall.

262
00:13:13.100 --> 00:13:16.800
So to tune the AOA protection she Begin by determining Alpha

263
00:13:16.800 --> 00:13:19.400
stall and all the configurations and examine the

264
00:13:19.400 --> 00:13:22.500
effects of mock weight landing gear and thrust and then

265
00:13:22.500 --> 00:13:25.100
through all these Maneuvers that you do make sure that you

266
00:13:25.100 --> 00:13:28.900
don't enter deterrent buffet. And the reason for that is if you're

267
00:13:28.900 --> 00:13:31.500
doing an escape maneuver, or see if

268
00:13:31.500 --> 00:13:34.200
see fit maneuver, the airline pilot doesn't want to have

269

00:13:34.200 --> 00:13:37.500
so much above that. He thinks I'm going to stall the airplane and relax

270
00:13:37.500 --> 00:13:40.300
the stick if you're trying to avoid them out and you won't

271
00:13:40.300 --> 00:13:43.100
don't want to relax the stick. You want to go all the way to fall back

272
00:13:43.100 --> 00:13:43.400
stick.

273
00:13:44.100 --> 00:13:47.100
We do however in set of Tolerance of

274
00:13:47.100 --> 00:13:50.500
a buffet of 0.2 G and it's allowed at the pilot seat.

275
00:13:51.100 --> 00:13:54.900
And then by analysis determine alpha-prot

276
00:13:54.900 --> 00:13:57.200
which is the thresholder where the protections begin

277
00:13:57.200 --> 00:14:00.100
Alpha floor and Alpha Max and then you

278
00:14:00.100 --> 00:14:03.500
do a buildup in Maneuvers slow decel. Why

279
00:14:03.500 --> 00:14:06.100
not per second to Alpha Max with idle thrust and

280
00:14:06.100 --> 00:14:09.600
without Alpha floor activating then at

281
00:14:09.600 --> 00:14:12.600
Alpha Max assault the role axis of the airplane including

282
00:14:12.600 --> 00:14:15.300
reversals and then holding an alpha

283
00:14:15.300 --> 00:14:18.400
Max increase thrust from idle to toga which is take off go around

284
00:14:18.400 --> 00:14:21.800
and then repeat what Alpha floor active so

285
00:14:21.800 --> 00:14:24.700
Alpha floor will come on you can selectively determine

286
00:14:24.700 --> 00:14:27.100
when earlier and then you do it and let

287
00:14:27.100 --> 00:14:30.400
Alpha floor automatically become active and then

288
00:14:30.400 --> 00:14:33.300
you do a D cell instead of one not per second due to three knots

289
00:14:33.300 --> 00:14:36.600
per second and then repeat and you bank to

290
00:14:36.600 --> 00:14:39.100
bank Maneuvers and then repeat with Alpha floor

291
00:14:39.100 --> 00:14:39.600
active.

292
00:14:40.700 --> 00:14:43.500
So once you've determined what the

293
00:14:43.500 --> 00:14:46.300
limits are then you figure out how to test them and the

294
00:14:46.300 --> 00:14:49.200
two Maneuvers that Airbus uses are the gpws maneuver.

295
00:14:49.800 --> 00:14:52.500
And they start from VLS plus 10 and a

296

00:14:52.500 --> 00:14:55.500
description of VLS is is that VLS is

297
00:14:55.500 --> 00:14:58.900
the lowest speed that you can select on the autopilot and

298
00:14:58.900 --> 00:15:01.200
the auto thrust so obviously you don't want the

299
00:15:01.200 --> 00:15:04.400
auto thrust to be able to hold you at the stall speed. You

300
00:15:04.400 --> 00:15:07.500
want it to be able to hold you at a speed but not below a certain

301
00:15:07.500 --> 00:15:10.200
one because then the flight control system can't help you

302
00:15:10.200 --> 00:15:13.700
at all. The second one is an avoidance maneuver from

303
00:15:13.700 --> 00:15:16.800
VLS plus 10 with thrust for level flight then

304
00:15:16.800 --> 00:15:19.300
you put the stick in the corner and let Alpha Four

305
00:15:19.300 --> 00:15:20.200
engage.

306
00:15:21.100 --> 00:15:24.600
Then you do a buildup from that point deceleration's to

307
00:15:24.600 --> 00:15:27.200
not per second followed by the GPS maneuver at

308
00:15:27.200 --> 00:15:30.700
VLS and repeat then with the avoidance maneuver at

309
00:15:30.700 --> 00:15:31.300
VLS.

310
00:15:32.100 --> 00:15:35.600
And we can do this and give you an example. I would take as

311
00:15:35.600 --> 00:15:38.500
a demo for customers and other authorities

312
00:15:38.500 --> 00:15:41.100
in the A380 and we would be at about

313
00:15:41.100 --> 00:15:45.000
220 knots and select flaps configuration to

314
00:15:44.200 --> 00:15:47.300
and then I would say without touching

315
00:15:47.300 --> 00:15:50.600
the thrust levers pull fullback stick just from a normal

316
00:15:50.600 --> 00:15:53.600
level flight condition. You pull fullback stick not

317
00:15:53.600 --> 00:15:56.400
touching the thrust levers Alpha floor would

318
00:15:56.400 --> 00:15:59.100
engage and the airplane would start a climb and

319
00:15:59.100 --> 00:16:02.600
in a little bit of a recovery and stabilize and

320
00:16:02.600 --> 00:16:05.500
then I say, okay now put the stick in the corner and you

321
00:16:05.500 --> 00:16:08.100
hold the stick in the corner and the A380 would go into

322
00:16:08.100 --> 00:16:11.900
about a 30 degree bank and a pirouette at about 210 knots.

323

00:16:11.900 --> 00:16:14.300
It's a it's a if you

324
00:16:14.300 --> 00:16:17.500
test correctly you will get a very high performance out

325
00:16:17.500 --> 00:16:20.400
of the airplane, which I thought was amazing just as

326
00:16:20.400 --> 00:16:23.300
a side note when we took the A380 to

327
00:16:23.300 --> 00:16:26.400
Oshkosh in 2009. We were describing to

328
00:16:26.400 --> 00:16:29.000
the FAA about the air show routine that we were going to

329
00:16:29.100 --> 00:16:31.200
do and the FAA was very firm that

330
00:16:32.300 --> 00:16:35.500
We don't allow transport category airplanes to do air show Maneuvers

331
00:16:35.500 --> 00:16:38.600
over 45 degrees of bank and with and

332
00:16:38.600 --> 00:16:41.400
we kind of rejoice when they said that because the angle that

333
00:16:41.400 --> 00:16:44.300
the angle of bank due to the flight control

334
00:16:44.300 --> 00:16:47.700
system limitations was restricted to 45 degrees automatically,

335
00:16:47.700 --> 00:16:50.500
so we didn't have to worry about it. We could put the stick anywhere.

336
00:16:50.500 --> 00:16:52.800
We wanted to never exceed 45 degrees of Bank.

337
00:16:54.100 --> 00:16:57.100
Then the cev maneuver came up by one of

338
00:16:57.100 --> 00:17:00.800
the authority Pilots named Gemma Grand and he

339
00:17:00.800 --> 00:17:03.200
said what I'm going to do is a fast D cell from the

340
00:17:03.200 --> 00:17:06.400
flap extension speed with thrust for level flight to the

341
00:17:06.400 --> 00:17:09.000
alpha protection threshold. And then I'm gonna

342
00:17:09.300 --> 00:17:12.500
go full back stick at Alpha pot and let Alpha floor

343
00:17:12.500 --> 00:17:15.400
Go Active and that was a real assault that Airbus had

344
00:17:15.400 --> 00:17:18.100
not planned on it turned out it worked. Well a little

345
00:17:18.100 --> 00:17:22.100
bit of adjustments on the tuning but it was something that Airbus had

346
00:17:21.100 --> 00:17:24.200
not thought about until the authority Pilots came

347
00:17:24.200 --> 00:17:25.400
and evaluated the airplane.

348
00:17:26.200 --> 00:17:29.500
Then you go to Highmark. You do wind up turn testing

349
00:17:29.500 --> 00:17:32.800
from alpha to Alpha Max from 0.55 to

350

00:17:32.800 --> 00:17:35.600
MMO check that the Buffett onset

351
00:17:35.600 --> 00:17:39.000
doesn't exceed 0.2 G's at the pilot seat and and

352
00:17:38.400 --> 00:17:41.500
check that at Alpha Max and then

353
00:17:41.500 --> 00:17:44.900
the final settings of all of the protections Alpha

354
00:17:44.900 --> 00:17:47.200
prod Alpha floor and Alpha Max are frozen after you

355
00:17:47.200 --> 00:17:50.500
go back out and test the airplane with artificial ice shapes

356
00:17:50.500 --> 00:17:51.100
on the wings.

357
00:17:53.400 --> 00:17:56.900
Now in 1999, this is

358
00:17:56.900 --> 00:17:59.000
something I got involved when before I was

359
00:17:59.400 --> 00:18:03.500
hired at Airbus Ron Rogers myself and Steve

360
00:18:03.500 --> 00:18:07.500
Stowe went to Airbus and flew the A330 200 and

361
00:18:06.500 --> 00:18:09.200
we were trying to investigate the best

362
00:18:09.200 --> 00:18:12.400
way to do a gpws maneuver.

363
00:18:12.400 --> 00:18:15.900
And this was as a result of the Cali American

364
00:18:15.900 --> 00:18:17.900
Airlines accident in Cali Colombia.

365
00:18:18.600 --> 00:18:21.300
And what we found was is that a few if you

366
00:18:21.300 --> 00:18:25.200
do a three-degree per second pull-up which was being recommended

367
00:18:24.200 --> 00:18:27.300
by the airlines because what

368
00:18:27.300 --> 00:18:30.300
the airlines wanted to do was we want to pull up to be

369
00:18:30.300 --> 00:18:33.100
flown the same way no matter whether you're in a flyboir airplane or

370
00:18:33.100 --> 00:18:36.000
a conventional airplane, and we wanted to look at the

371
00:18:36.600 --> 00:18:39.500
difference in the two airplane types. So we went in about

372
00:18:39.500 --> 00:18:42.100
a three degree per second pull up and you can see that it

373
00:18:42.100 --> 00:18:45.600
loses more altitude than if you do a fullback stick

374
00:18:45.600 --> 00:18:48.200
at and gives you about six degrees

375
00:18:48.200 --> 00:18:48.700
per second.

376
00:18:49.900 --> 00:18:52.600
So the the time below the altitude

377

00:18:52.600 --> 00:18:55.200
is for the fly by

378
00:18:55.200 --> 00:18:58.700
wire airplane 5.3 seconds. And if

379
00:18:58.700 --> 00:19:01.500
you use the 3.2 degrees per second at 7.8

380
00:19:01.500 --> 00:19:04.200
seconds, but that's not the true significance of

381
00:19:04.200 --> 00:19:07.300
this chart. The true significance of this chart is

382
00:19:07.300 --> 00:19:10.700
is by the time the Three Degree

383
00:19:10.700 --> 00:19:13.700
per second pull-up gets back to the original altitude.

384
00:19:13.700 --> 00:19:17.200
The fullback stick is 115

385
00:19:16.200 --> 00:19:19.500
feet above that altitude. And if you're in the mountains doing

386
00:19:19.500 --> 00:19:22.200
a gpws maneuver, that is very significant.

387
00:19:24.400 --> 00:19:27.500
So there are hard lessons here when you're developing

388
00:19:27.500 --> 00:19:30.600
a fly by wire airplane. You don't catch everything just

389
00:19:30.600 --> 00:19:34.000
like in the F-16. We didn't catch the departure at

390
00:19:33.400 --> 00:19:36.100
high angle of attack with a heavy store loading.

391
00:19:37.100 --> 00:19:40.200
At Airbus there was an A330 test airplane and crew

392
00:19:40.200 --> 00:19:42.100
lost during an initial climb.

393
00:19:43.700 --> 00:19:46.100
Normally in Toulouse when you do a normal takeoff, the

394
00:19:46.100 --> 00:19:49.600
first altitude to level off at is 4,000 feet, but there

395
00:19:49.600 --> 00:19:52.700
was conflicting traffic that day and the level off altitude

396
00:19:52.700 --> 00:19:55.100
was changed to 1500 feet. So you

397
00:19:55.100 --> 00:19:57.200
put that up in the autopilot control window.

398
00:19:58.100 --> 00:20:01.300
The right seat pilot was flying the CG was near the AFT limit.

399
00:20:01.300 --> 00:20:04.500
They had an incorrect stabilator setting not consistent with

400
00:20:04.500 --> 00:20:07.600
the CG and the capture altitude was set at 1500

401
00:20:07.600 --> 00:20:07.800
feet.

402
00:20:08.500 --> 00:20:12.100
The piled in the right seat flying did a really aggressive rotation

403
00:20:11.100 --> 00:20:14.400
and he put it to an excessive

404

00:20:14.400 --> 00:20:17.600
pitch attitude. Normally you'd see 15 to 18 degrees on an

405
00:20:17.600 --> 00:20:20.200
A330 take off. He was all the way up at 25

406
00:20:20.200 --> 00:20:23.200
degrees and the captain was distracted because he was trying to do

407
00:20:23.200 --> 00:20:26.400
the tests. He wanted to see if the altitude capture would

408
00:20:26.400 --> 00:20:29.500
work with an engine cut. You know, it's just

409
00:20:29.500 --> 00:20:32.200
not a V1 cut, but right after takeoff, so he was

410
00:20:32.200 --> 00:20:35.600
distracted by engaging the autopilot bringing the left engine

411
00:20:35.600 --> 00:20:38.200
to idle pulling the blue hydraulic circuit breaker and

412
00:20:38.200 --> 00:20:41.700
when he came back in to look out to see what was happening, the airplane

413
00:20:41.700 --> 00:20:43.900
was rapidly decelerating toward a stall.

414
00:20:44.500 --> 00:20:47.400
because of the rapid climate altitude capture

415
00:20:47.400 --> 00:20:50.100
occurred probably 500 feet below the

416
00:20:50.100 --> 00:20:52.300
altitude that it was set to capture at

417
00:20:53.400 --> 00:20:56.300
and what Airbus didn't realize at that time on

418
00:20:56.300 --> 00:20:59.500
this particular test was that when the autopilot went

419
00:20:59.500 --> 00:21:02.400
into altitude capture. There was no angle of

420
00:21:02.400 --> 00:21:03.000
attack protection.

421
00:21:04.100 --> 00:21:07.200
So the airplane stalled one engine at toga

422
00:21:07.200 --> 00:21:10.400
the other at idle the tapton took control the airplane reduce the

423
00:21:10.400 --> 00:21:13.800
right engine back to idle to get the asymmetry correct recovered from

424
00:21:13.800 --> 00:21:16.400
the stall, but it was too low to avoid

425
00:21:16.400 --> 00:21:19.500
hitting the ground this accident occurred right in

426
00:21:19.500 --> 00:21:21.800
front of the factory where the airplane was built.

427
00:21:24.600 --> 00:21:26.000
Air France 447

428
00:21:26.700 --> 00:21:30.300
another example of not not of doing

429
00:21:30.300 --> 00:21:33.100
your best to design the airplane, but there was a

430
00:21:33.100 --> 00:21:36.300
fault in the design Peter tubes were blocked with ice

431

00:21:36.300 --> 00:21:39.300
crystals at high altitude and AirSpeed was lost for about one minute.

432
00:21:40.200 --> 00:21:43.500
The flight control system then was designed to revert to

433
00:21:43.500 --> 00:21:45.400
alternate law with no Alpha protection.

434
00:21:46.800 --> 00:21:49.400
So no Alpha protection you figure

435
00:21:49.400 --> 00:21:52.400
okay, you're up at Cruise two degrees angle attack. No

436
00:21:52.400 --> 00:21:55.200
problem. No worries, but the flight crew had

437
00:21:55.200 --> 00:21:58.300
very confusing indications. They ended up stalling the airplane

438
00:21:58.300 --> 00:22:01.400
with fullback stick and the airplane descended Wings level

439
00:22:01.400 --> 00:22:03.800
at about 40 AOA all the way to the water.

440
00:22:05.300 --> 00:22:08.500
Now I had a discussion with Tom Tilden who recently retired from

441
00:22:08.500 --> 00:22:12.300
United Airlines as a test pilot and Tom

442
00:22:11.300 --> 00:22:14.300
is very concerned about looking at the data

443
00:22:14.300 --> 00:22:17.400
in this accident saying that when they had fullback stick

444
00:22:17.400 --> 00:22:20.900
for that long, the horizontal tale went full

445
00:22:20.900 --> 00:22:23.100
Leading Edge down and when he looked

446
00:22:23.100 --> 00:22:26.600
at when Tom looked at the data on the Bea report, he

447
00:22:26.600 --> 00:22:29.700
said as there were times from the Pilot's relaxed fullback

448
00:22:29.700 --> 00:22:32.300
stick, but I didn't see the horizontal tale

449
00:22:32.300 --> 00:22:33.200
change position.

450
00:22:34.200 --> 00:22:38.000
now there he was looking at data about this wide at

451
00:22:37.300 --> 00:22:40.600
Airbus we had data about this wide and you could

452
00:22:40.600 --> 00:22:43.100
see where the the horizontal tail was coming off

453
00:22:43.100 --> 00:22:44.400
the stop, but

454
00:22:45.400 --> 00:22:48.400
That design was probably not correct. You probably not want

455
00:22:48.400 --> 00:22:51.400
to go to that limit with the horizontal tail. And as

456
00:22:51.400 --> 00:22:54.600
another side note about two weeks after we got the data

457
00:22:54.600 --> 00:22:57.800
back from from the ocean on Air France 447. We

458

00:22:57.800 --> 00:23:00.900
were in an sctp Symposium in Europe and

459
00:23:02.100 --> 00:23:05.200
Dennis O'Donoghue from Boeing was there and we discussed this with

460
00:23:05.200 --> 00:23:08.300
Dennis and he says, you know what we're going to when I

461
00:23:08.300 --> 00:23:11.100
get back to Seattle. The first thing I'm going to do is get in the cab and

462
00:23:11.100 --> 00:23:14.300
see if we are vulnerable for this same type of thing with the triple seven.

463
00:23:15.500 --> 00:23:18.400
It's one of the important things about this industry is that

464
00:23:18.400 --> 00:23:19.500
we that we share information.

465
00:23:21.400 --> 00:23:24.100
So to see how successful this is being let's look

466
00:23:24.100 --> 00:23:27.300
at this chart. This is the Airbus fatal accident rate up to

467
00:23:27.300 --> 00:23:30.800
about 2010. I wasn't able to get more current data

468
00:23:30.800 --> 00:23:33.600
than this but it Compares flyby wire

469
00:23:33.600 --> 00:23:36.700
family of airplanes at Airbus versus the conventional wide

470
00:23:36.700 --> 00:23:39.400
body. So that would be the 300 310 and

471

00:23:39.400 --> 00:23:42.900
300 600. So if you look at those flight

472
00:23:42.900 --> 00:23:45.400
cycles, and as the other airplanes came

473
00:23:45.400 --> 00:23:48.500
into the fleet these were being to decrease if you

474
00:23:48.500 --> 00:23:51.100
look at their fatal accident rate. It's pretty flat.

475
00:23:51.800 --> 00:23:54.400
Whereas if you look at the fly-by-wire airplanes up

476
00:23:54.400 --> 00:23:57.400
until 2010 the hours and flight Cycles has

477
00:23:57.400 --> 00:24:00.500
continuously growing going up. But if you look now at

478
00:24:00.500 --> 00:24:03.400
the accident rate, it's dramatically going down.

479
00:24:03.400 --> 00:24:06.500
There were a few A320 accidents right in the very beginning which

480
00:24:06.500 --> 00:24:09.400
which was unfortunate. So that's the true value

481
00:24:09.400 --> 00:24:12.500
of protective flight controls and that's what we need to concentrate on

482
00:24:12.500 --> 00:24:13.100
in the future.

483
00:24:15.600 --> 00:24:18.700
So the Lessons Learned for me. Are you flight

484
00:24:18.700 --> 00:24:21.400
test to acceptable margins based on your safety risk

485
00:24:21.400 --> 00:24:24.200
analysis and then carefully and take the

486
00:24:24.200 --> 00:24:26.100
time to analyze your flight test data.

487
00:24:26.800 --> 00:24:29.100
Identify failure States and test them

488
00:24:29.100 --> 00:24:32.800
exhaustively step back and brainstorm what

489
00:24:32.800 --> 00:24:35.500
might happen, you know, you may be able to find that little Gap

490
00:24:35.500 --> 00:24:38.400
in the flight control system design that didn't fully

491
00:24:38.400 --> 00:24:41.200
protect a Pilots when you probably could if you looked at

492
00:24:41.200 --> 00:24:44.400
it hard enough be software flexible. If you

493
00:24:44.400 --> 00:24:47.100
have the ability to develop new software and you can test

494
00:24:47.100 --> 00:24:50.400
it in flight without in redesigning the flight control

495
00:24:50.400 --> 00:24:53.600
system do that and then never stop searching for

496
00:24:53.600 --> 00:24:55.100
better system redundancy.

497
00:24:56.400 --> 00:25:00.100
So I think it's important even though we provide Lessons

498

00:24:59.100 --> 00:25:02.700
Learned in these in these meetings is to

499
00:25:02.700 --> 00:25:05.500
look into the future and I think the new technology is

500
00:25:05.500 --> 00:25:08.700
going to drive aerodynamic design stealth technology

501
00:25:08.700 --> 00:25:11.400
supersonic flow new configurations with

502
00:25:11.400 --> 00:25:12.900
with multiple thrusters.

503
00:25:13.700 --> 00:25:16.700
And fly by wire technology can provide controllability

504
00:25:16.700 --> 00:25:19.800
through those multiple multiple surfaces

505
00:25:19.800 --> 00:25:22.400
and thrust vectoring but it also is a

506
00:25:22.400 --> 00:25:25.100
huge Matrix to see what the failure states

507
00:25:25.100 --> 00:25:28.200
are throughout that particular air vehicle. So what you

508
00:25:28.200 --> 00:25:32.000
do is use AI for failure analysis and

509
00:25:31.400 --> 00:25:34.700
find the limits of controllability and do

510
00:25:34.700 --> 00:25:37.400
it with very careful flight testing. And the

511
00:25:37.400 --> 00:25:40.400
last thing is this is applicable now to general

512
00:25:40.400 --> 00:25:43.300
aviation aircraft through waking up

513
00:25:43.300 --> 00:25:46.400
the the autopilot servos and

514
00:25:46.400 --> 00:25:49.100
I know that if you talk to Mike Stevens here, he'll tell

515
00:25:49.100 --> 00:25:50.800
you how they do it at Cirrus.

516
00:25:52.100 --> 00:25:52.400
Thank you.

517
00:26:04.600 --> 00:26:05.700
That's my airplane, by the way.

518
00:26:07.600 --> 00:26:07.800
flown Last Summer