RISK MITIGATION FOR STALL FLIGHT TESTING ON A FAR 25 CATEGORY JET AIRPLANE

SHAKE, RATTLE, SKIPPIN' THE ROLL

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Abstract

This paper presents a brief explanation on the background of the routinely performed flight tests at DLR's Oberpfaffenhofen Flight Research Facility as well as changes of approaching those tests and the modified method of compliance flight testing after an inflight departure.

Nomenclature

AOA	= Angle of Attack
CFR	= Code of Federal Regulations
CG	= Center of Gravity
CS 25	= Certification Specifications Part 25 (EASA)
DLR	= German Aerospace Center
EASA	= European Aviation Safety Agency
EEP	= Envelope Expansion Procedure
FAA	= Federal Aviation Administration
FAR 25	= "Federal Aviation Regulation" e.g. CFR 14 Chapter I Subchapter C Part 25 (FAA)
FL	= Flight Level
FT	= Flight Test
(L)FTE	= (Lead) Flight Test Engineer
KCAS	= Knots Calibrated Air Speed
KIAS	= Knots Indicated Air Speed
M	= Mach
n_Z	= normal acceleration
PtF	= Permit to Fly
SOP	= Standard Operational Procedures
THA	= Test Hazard Analysis
TP	= Test Pilot

1. INTRODUCTION

1.1. The German Aerospace Center's Flight Experiments Establishment

The DLR flight facilities in Braunschweig and Oberpfaffenhofen are unique in the German research environment and are operated on a large scale. These facilities provide flight services for DLR research programs, as well as for other national institutions, agencies and companies [1]. The DLR flight research facilities operate eleven research aircraft: an Airbus A320, a DG 300, a Discus-2c, a Dassault Falcon 20-E5, two Dornier Do228, a Gulfstream G550, a Eurocopter Bo105, a Robin DR 400, a Eurocopter EC 135 and a Cessna C208B Grand Caravan, making it the largest research aircraft fleet in Europe. The aircraft based in Oberpfaffenhofen are dedicated to earth observation and atmospheric research.

1.2. Background

With the core objective of providing research platforms, the aircraft at Oberpfaffenhofen are highly modified.

They provide fuselage openings, external stores and other interfaces to meet the demands of the research communities. With changing missions, research infrastructure has to be changed, modified or newly designed and implemented. With regard to flight testing, new setups of external stores have to be put

through the paces of the corresponding FAR/CS 23/25 Subpart B – Flight.
Growing experience and confidence led to the development of a specific Envelope Expansion Procedure, saving significant flight time and cost.

1.3. Test Item Description

The system under test was one of DLR's "Large Aeroplanes" (EASA CS 25), analogue FAR 25 "Transport Category Airplanes".

1.4. Instrumentation

The instrumentation used for flight testing consisted of a basic (atmospheric) data measurement system also capable of collecting basic aircraft data and hand held data.

1.5. Limitations

The test flights were performed in restricted airspace under a PtF. The testing-relevant limitations were: maximum airspeeds up to V_{DF}/M_{DF}, prohibited flight in icing conditions, 10nm distance to CB type clouds. Attitude and angle of incidence were limited.

2. FLIGHT TESTING

2.1. General

The flight tests were performed to show compliance to the relevant paragraphs of Subpart B for a new setup of external stores – fuselage mounted atmospheric probes. The behavior and characteristics of the unmodified aircraft were known to the pilots. The basic philosophy of the tests was to compare the properties of the modified to those of the unmodified aircraft. The setup of the probes was very similar to another, previously tested setup. No significant outcome of the tests was to be expected.

2.2. Stall Testing – FAR 25.201 Stall demonstration

Stalls have to "be shown in straight flight and in 30 degree banked turns" [2]. The paragraph gives further requirements of how to perform the testing and how compliance is shown. For this paper, article (c)(2) "In addition, for turning flight stalls, apply the longitudinal control to achieve airspeed deceleration rates up to 3 knots per second." is of interest in combination with (b)(1) "Flaps, landing gear, and deceleration devices in any likely combination of positions approved for operation".
These tests as well as the other setups required for compliance demonstration were included in the test matrix.

2.3. Stall Testing – FAR 25.203 Stall characteristics

§ 25.203 limits how the aircraft has to behave in the event of the stall and how recovery must be able to be performed. This is basically a qualitative compliant / not compliant assessment following the stall tests of 25.201.

2.4. Stall Testing – FAR 25.207 Stall warning

The stall warning paragraph defines how and when a stall warning has to occur. It defines measures (like audible warnings or a stick shaker) and margins from when the warning occurs until the aircraft actually stalls. As with 25.203, compliance is shown by assessment following the tests of 25.201.

2.5. Stall Testing – ...is not routine

Testing of nearly all paragraphs and configurations was uneventful, smooth, routine - just like the many times before with similar setups. But just like with other presumably "routine" flight test programs throughout the world, the tide turned at some point.
Within this test program it happened when the test reached 25.201 (c)(2): accelerated turning stalls. With the ac set up to landing configuration, decelerating quickly in a right turn, the airplane stalled and departed controlled flight.
The swift reactions of the TP eventually lead to a nose down movement, reducing the AOA. "Was macht er denn jetzt?" - "What is it doing now?" – A familiar question in an aircraft's cockpit – didn't even have time to be asked. The departure and counter-action just took a split second. What had happened? The highly optimized flight test program resulted in the airplane not being properly stabilized before initiating the stall. The high level of buffet due to the extended flaps and gear as well as the additional manoeuvring loads on the control surfaces had masked weakening of their aerodynamic effectiveness. Post-flight data analysis revealed that the airspeed reduction of three knots per second required by the paragraph had been exceeded by 1/3.

3. OUTCOME – ACTIONS TAKEN AND LESSONS LEARNED

So, what to do? Working closely with DLR's office of airworthiness within DLR's design organization, a new stall certification method - more precisely: an alternative means of compliance - was developed and agreed with the authorities.
Also, additional general and specific safety means were embedded in the flight testing procedures.

3.1. Alternative means of compliance

An aircraft manufacturer tests one prototype with the aim of serial production of 100+ airplanes thereafter. DLR uses off-the-shelf airplanes and modifies each single one regularly, 100+ times during their lifetime.

Although compliance with Subpart B must be shown for each single modification and combinations thereof, another approach to flight test is required to protect the asset.

Alternative means of compliance are designed whenever required to raise the safety level for testing.

A series of reference flights with the unmodified airplane was conducted. It was found that the data scatter was marginally acceptable and that landing flaps or extended gear produced so much vibration buffet and noise, supported by positive manoeuvring loads on the control surfaces that any signs of an imminent departure were being masked.

The alternative means of compliance for the affected paragraphs enhance the safety level by limiting the AOA in the critical configurations and test condition to stall warning onset AOA.

Substantiation before any future test programme must be conducted, showing that it is highly unlikely that the stock AOA vanes are affected by a new modification. Thereafter flight test results in the critical configurations and conditions will be compared to the reference flights with the unmodified airplane comparing AOA at stall warning onset with the corresponding n_z corrected speeds. The procedure is based on the assumption that the behaviour of the airplane beyond stall warning onset is unchanged and unaffected by the modification.

This procedure was accepted by the certifying authority to verify the affected paragraphs of subpart B.

3.2. Additional safety means

The SOP and THAs for all high AOA test procedures of the affected type were updated.

This update included a detailed discussion about the system and a straight explanation of the given departure event.

A very simple graphical "departure of controlled flight flow chart" was added as additional SOP.

Detailed and standardized discussion about the technical and environmental causes of departure of controlled flight is required. Nevertheless it proved too complicated and lengthy to be conducted during the pre-flight briefing.

Counter acting a departure requires simple and clearly defined action. Over complicating pre-flight briefings with extensive monotonous lectures will fatigue and confuse the test crew. This may either lead to a false or delayed action of the TP in an extremely time critical situation with nil tolerance for false action.

The lengthy SOP shall be discussed by the test crew once before each flight test program and not directly before a flight.

The "departure of controlled flight flow chart SOP" however, is to be rehearsed during the pre-flight briefing. It is highly recommended that the test crew move their extremities while reciting the flow chart to train the muscle memory.

More flight test time for the critical tasks was allocated, resulting in a calmer working environment and better inter-crew communication.

3.3. Lessons Learned

LL1: Critically check your testing routines – is the upcoming test really routine?

LL2: Keep human resources in mind when planning the flight test time budget.

LL3: Establish formalisms aimed at LL1 that are performed prior to every flight test.

4. CONCLUSION

The modified and unmodified airplane was graded compliant with the regulations. Whenever DLR is testing modifications to its aircraft not resulting in substantial changes to the basic type, alternative means shall be employed whenever a medium risk level is exceeded.

5. RFERENCES

[1] Website, DLR. (2018, 02 10). www.DLR.de

[2] Regulation, CFR 14, U.S. Government Publishing Office, Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-84, 60 FR 30750, June 9, 1995; Amdt. 25-108, 67 FR 70827, Nov. 26, 2002