Accident
Investigation Board
Norway

Issued January 2020

# REPORT SL 2020/03

# REPORT ON AIR ACCIDENT AT OSLO AIRPORT GARDERMOEN ON 11 JANUARY 2017 WITH CESSNA AIRCRAFT COMPANY 560 ENCORE, LN-IDB, OPERATED BY HESNES AIR AS

*This report has been translated into English and published by the AIBN to facilitate access by international readers. As accurate as the translation might be, the original Norwegian text takes precedence as the report of reference.*

**Photos: AIBN and Trond Isaksen/OSL**

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## AIR ACCIDENT REPORT

| | |
|---|---|
| Aircraft information: | Cessna Aircraft Company 560 Encore |
| Nationality and registration: | Norwegian, LN-IDB |
| Owner: | Hesnes Flyinvest II AS |
| Operator: | Hesnes Air AS |
| Crew: | Commander and First Officer |
| Passengers: | None |
| Location: | Oslo Airport Gardermoen (ENGM), Norway |
| Time of accident: | Wednesday, 11 January 2017 at 1619 hours |

All times given in this report are local time (UTC + 1 hour) unless otherwise stated.

## NOTIFICATION OF THE INCIDENT

At 1753 hours, the Accident Investigation Board Norway (AIBN) was notified by supervisor Gardermoen TWR that a Cessna Citation from Hesnes Air AS had lost control shortly after take-off. The crew called Mayday, but cancelled this later when control was regained.

AIBN started its investigation the day after the incident. The Flight Data Recorder and Cockpit Voice Recorder were removed and transported to England, where the data was downloaded by the UK Air Accidents Investigation Branch.

The company's Deputy Manager Flight Operations filled out the form *NF-2007 Reporting accidents and incidents in civil aviation* based on information from the affected crew. The company classified the case as a serious aviation incident.

In accordance with ICAO Annex 13, Aircraft Accident and Incident Investigation, AIBN notified the Investigation authority in the US (National Transportation Safety Board, NTSB), where the aircraft was manufactured. The NTSB appointed an accredited representative who assisted in the investigation with the support of advisers from Textron Aviation (owner of Cessna Aircraft Company). AIBN also informed the European Aviation Safety Agency (EASA), the UK Air Accidents Investigation Branch (AAIB), the International Civil Aviation Organization (ICAO) and the Civil Aviation Authority Norway (CAA-N) that AIBN was starting an investigation of the incident. The investigation changed status to an air accident when it became clear that the aircraft was substantially damaged.

## SUMMARY

On Wednesday, 11 January 2017, LN-IDB, a Cessna Citation from Hesnes Air AS, had flown a passenger from Bern in Switzerland to Oslo Airport Gardermoen. The crew had planned a shortest possible ground stop before flying to Torp Sandefjord Airport. The Commander flew the aircraft (PF), while the First Officer monitored the flying (PM). During the ground stop at Gardermoen, only one engine was stopped while the First Officer completed an external inspection of the aircraft.

He did not observe any ice or anything out of the ordinary on the areas of the aircraft that could be inspected.

The investigation has proven that there were icing conditions at Gardermoen and in the airspace above the airport. After flying from Switzerland for more than two hours in approximately minus 50°C, the aircraft's surfaces (fuselage and wings) were more than likely chilled. When the crew requested taxi clearance, they were assigned a different runway than expected. This entailed a longer taxi time and thus longer exposure to the prevailing weather conditions. The aircraft's ground stop lasted approximately 15 minutes at an air temperature of 0°C. The taxiways and runway were covered with 3-6 mm of slush and it was snowing when the aircraft took off.

Initially, the take-off proceeded as normal. The landing gear was retracted and both pilots observed that the speed was rapidly approaching 200 kt, which is the maximum speed with flaps deployed. As the flaps were retracted, the crew experienced a violent nose-down movement and the pilots were "hanging by their seat belts", while the aircraft started sharply banking to the left. Following the accident, data from the Flight Data Recorder (FDR) showed that the aircraft at this moment experienced negative 2.62 G.

The Commander did not trust the instruments while the First Officer, which was Pilot Monitoring (PM) had better situational awareness. The First Officer quickly took control and started a pull-out from the dive. The aircraft descended below the cloud base, and even though it was dark, the pilots could glimpse the ground. The control was regained and the aircraft levelled off 170 ft above the ground. The aircraft was overstressed to 5.99 G during the pull-out. The crew called "MAYDAY" to the Air Traffic Control. Once control was regained, the "MAYDAY" was cancelled and the flight continued towards Torp where an approach and landing took place without further problems.

The investigation has not revealed any technical malfunctions in the aircraft and its control systems. AIBN has determined that a probable explanation for the aircraft's sudden dive is that the tailplane stalled as a result of icing caused by contamination from slush spray from the runway and/or from falling snow and sleet.

The aircraft's anti and de-icing systems on the wings and tailplane were switched on, but AIBN's assessment is that the systems were not suitable to remove this relevant type of ice and snow. With the existing conditions at Gardermoen during the ground stop, AIBN is of the opinion that the aircraft should have been de-iced before take-off.

This accident shows the significance of functioning crew resource management (CRM) in the cockpit when an unexpected and extreme flight situation occurs. In this instance, the First Officer's situational awareness and initial pull-out saved the crew. The investigation has also revealed unfortunate practices for the CAA-N's approval of Air Operators Certificate (AOC) and approval of organisations, but no correlation has been established between this and the accident.

AIBN is issuing two safety recommendations based on this investigation.

# 1. FACTUAL INFORMATION

## 1.1 History of the flight

1.1.1 Hesnes Air AS flight HSG03 started from Bern Airport, Switzerland, on 11 January 2017 at 1330 hours and landed at Oslo Airport Gardermoen (ENGM) at 1603 hours. The flight was scheduled to be flown at FL380, where the air temperature was minus 45°C. During the flight, the altitude was increased to FL430 where the air temperature was minus 50°C. A total of three people were on board; the Commander, First Officer and one passenger. The Commander was Pilot Flying (PF) and the First Officer was Pilot Monitoring (PM).

1.1.2 The crew has explained to AIBN that they did discuss the return flight as early as the evening before the departure from Bern, and that they would make the ground stop as brief as possible at Gardermoen. They would leave one engine running, and the First Officer would follow the passenger out of the aircraft and then perform an external inspection of the aircraft. They planned to avoid refuelling and de-icing if weather conditions permitted it.

1.1.3 The crew followed this plan during the ground stop in front of the GA terminal at Gardermoen. Because one engine was running when they deplaned the passenger and luggage, the First Officer only carried out a Pre Flight Inspection on one side of the aircraft. The First Officer observed water on one of the wings, and presumed that this was also the case on the other wing and tailplane.

1.1.4 While the First Officer was out of the cockpit, the Commander programmed the Flight Management system with the flight from Gardermoen to Torp. The Commander presumed that, by avoiding de-icing, they would be cleared for take-off from runway 19R and thus save additional time (see Figure 8).

1.1.5 When the First Officer returned to the cockpit, the Commander had already completed parts of the checklist items that must be carried out before taxiing. In addition he had obtained clearance to Torp and received taxi clearance. At the same time, he had informed ground control that they did not want de-icing. As opposed to the presumption that they would be assigned take-off from runway 19R, they received taxi clearance for runway 19L via taxiway C3. The Commander asked the First Officer to inform ground control that they did not want de-icing, in the hope that they would then be cleared for take-off from runway 19R. When taxiing from the GA terminal to runway 19L, they would normally be cleared via taxiway C2 and further east via de-icing platform B-North, but on the day in question, taxiway C2 was closed (see 1.7.5). Taxiing started at 1614 hours.

1.1.6 When HSG03 was cleared to taxi via taxiway C3 instead of via C2, this reinforced the Commander's assumption that they would be cleared for take-off on runway 19R. However, they were cleared further east toward runway 19L, and the Commander then realised that they were approaching a need for de-icing, and there was a certain urgency to get in the air. While taxiing toward runway 19L, ground control asked them to confirm that they did not want de-icing, which the First Officer confirmed. As there were no aircraft ahead of them, they received immediate clearance for take-off position on runway 19L.

1.1.7 The pre-take-off checklist, including "wing/engine anti-ice" and "tailplane" de-icing system in auto, was completed. According to the audio recording from the Cockpit Voice Recorder (CVR), the de-icing system for the tail was set to Auto (see 1.6.5). The aircraft was cleared for take-off on runway 19L and started take-off at 1618 hours. Take-off was initiated with an RPM of 88%.

1.1.8 The aircraft was light on weight and therefore accelerated very quickly during take-off. The normal climb angle in the first phase of the departure is approx. 12° pitch. The aircraft will normally maintain an indicated speed under the flap limit, which is 200 KIAS. This climb angle is normally held in order to keep the speed below 200 KIAS, up to approx. 1,500 ft, which is the acceleration height at which flaps are retracted. It is PF's duty to adjust the climb angle so that 200 KIAS is not exceeded.

1.1.9 The Flight Data Recorder (FDR) shows that normal Gs increased from 1.21 to a maximum of 1.44 and the pitch increased from approx. 21.0° to approx. 25.5°. PF compensated for the speed increase by pulling the aircraft's nose further up to keep the speed below the maximum (200 KIAS) with flaps deployed. In spite of a climb angle of 25.5° pitch to keep the speed down, the speed increased to 202.5 KIAS before the pitch was reduced. This occurred at an altitude of approximately 2 100 ft MSL (Pressure Altitude (PA) approx. 4 100 ft).

1.1.10 The FDR shows that the aircraft's nose started to drop, while flaps up was initiated at the same time. Cessna has confirmed that the normal trim change for Cessna 560 Encore is, as for most low-winged aircraft, nose down when deploying flaps and nose up when retracting flaps. At the same time, the normal G started to drop from 1.15 to 0.9 G.

1.1.11 The FDR data also shows that the aircraft's nose continued to drop steadily to negative 33.6° pitch with negative 2.62 G as the lowest G load. After this, the normal G started to increase again (during the crew's intervention). At this time, the speed was 230 KIAS and increasing. A rapid succession of "Voice Commands" from the EGPWS system (Enhanced Ground Proximity Warning System) is audible in the recorded audio from the CVR: "Sink Rate, Pull Up, Too Low Terrain, Windshear, Bank Angle".

1.1.12 In this phase the Commander was not active on the controls and the PM/First Officer therefore took control and initiated the pull-out. From then on the negative Gs were reduced. The max nose down attitude of negative 53° was achieved at plus 2 G. Positive Gs increased and reached 5.99 at negative 22° pitch, approx. 10 seconds after flaps up was initiated. The aircraft's altitude above ground level was then approx. 500 feet. At about the same time, when the plane entered visual conditions, PF also pulled hard on the flight controls.

1.1.13 This helped ensuring that the aircraft changed its flight path from a dive to a relatively quick climb, which resulted in the aircraft experiencing excessive G forces, and preventing the aircraft from flying into the ground.

1.1.14 The aircraft's nose passed through the horizon with 0° pitch and 2.13 G. The max speed of 325 KIAS was achieved at plus 7° pitch and plus 0.45 G. At the lowest, the aircraft's altitude above ground level was approx. 170 feet before the crew regained control and resumed the ascent.

1.1.15 At a nose position of plus 9.4° pitch, normal Gs varied between 0.5 and 2.0 G. From this time, the climb angle increased from approx. 9° to a max of 21.5° pitch and the aircraft continued a normal climb.

1.1.16 The crew has explained to AIBN that they hesitated somewhat before continuing the climb after the pull-out. This was because the Commander did not trust the instruments. Once they had the aircraft climbing and approached IMC, the Commander pushed the yoke forward while the PF/First Officer still had control. He did this to prevent the aircraft from entering the clouds. The First Officer convinced the Commander that the instruments were correct and that they should climb further into the clouds. The Commander refers to two factors he believes may have led him to distrust the instruments:

- Firstly, he had read a report regarding a postal aircraft which crashed in Sweden January 2016[1], and had discussed this accident with other pilots in the company for training purposes. The Swedish Accident Investigation Authority's investigation showed that an instrument error had occurred on the accident aircraft, and that the pilots were unable to discover this in time. Both pilots were fatally injured.

- Secondly, he had an experience from flight simulator training that had affected him. In the simulator, he was "pilot monitoring" and had, without being aware of it, an error affecting the attitude indicator. When the other pilot in the simulator made a turn, it looked like he was turning in the wrong direction. The Commander then took over the controls in the simulator and corrected the turn. However, he had not checked the other two attitude indicators, and therefore did not discover that it was his attitude indicator that was incorrect. However, the Commander has explained that no simulated scenarios have been close to what the crew was exposed to with LN-IDB.

1.1.17 The engines were left in take-off position during the entire pull-out and the speed increased to 325 kt. The FDR shows that engine power was reduced from a max of 86/85% after the pull-out at a 4.6° climb angle, which only corresponds to a slow climb. The minimum engine power was approx. 39/39%, which was maintained until climb angle 18.6°. From here, engine power increased to approx. 84/83%, which was maintained until the aircraft levelled out at approx. 16,000 ft QNH (approx. FL150). Since the "post take-off check list" not was completed, the crew had left out the altimeter change from QNH to QNE /1013 hPa. This led the PF (First Officer) to level out at a lower altitude than assigned by Air Traffic Control. The Commander cancelled the Mayday and the error was resolved once the altitude was reported. The altimeter setting was set to 1013 hPa and since there were little traffic, the crew was allowed to continue to Torp at FL150. Normally, after take off, the altimeter will be set to 1013 hPa at transition altitude or when cleared to a Flight Level (FL).

1.1.18 Further routines and checklists were partially completed in accordance with the Standard Operating Procedure (SOP). The crew was vectored in to Torp. They entered visual conditions at approx. 3,500 ft and flew visually for the rest of the approach, landing at Sandefjord Airport Torp at 1638 hours.

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[1] https://www.havkom.see/assets/reports/RL-2016_11.pdf

## 1.2 Injuries to persons

*Table 1: Injuries to persons*

| Injuries | Crew | Passengers | Others |
|---|---|---|---|
| Fatalities | | | |
| Serious | | | |
| Light/none | 2 | | |

## 1.3 Damage to aircraft

See item 1.12.2 for details. Due to extent of the damages to the aircraft, AIBN changed the classification from a serious aircraft incident to an air accident.

## 1.4 Other damage

None.

## 1.5 Personnel information

### 1.5.1 Commander

1.5.1.1 The Commander held a valid Airline Transport Pilot Licence ATPL (A)/IR valid through 30 November 2017, with rights for Cessna 500/550/560. The Commander had a valid class 1 medical certificate through 15 February 2017 without limitations.

1.5.1.2 The Commander completed his pilot training in 1991. He had pilot experience from various airline companies before he began flying at Hesnes Air in 2014.

1.5.1.3 The Commander was the Manager Flight Operations (MFO) at Hesnes Air and also had a number of assistant roles in the company (see Figure 18).

*Table 2: Flying experience Commander*

| Flying experience | All types | On type |
|---|---|---|
| Last 24 hours | 3 | 3 |
| Last 3 days | 3 | 3 |
| Last 30 days | 4 | 4 |
| Last 90 days | 40 | 40 |
| Total | 12 500 | 300 |

1.5.1.4 The crew arrived in Bern on Sunday, and did not have active duty for the next 3 days. The crew had eaten dinner the day before the incident, and returned to the hotel to sleep before midnight. The day after, they had breakfast and departed for the airport around 9 o'clock. They departed at 1330. The Commander has stated that he felt adequately rested during the flight from Switzerland.

### 1.5.2 First Officer

1.5.2.1 The First Officer held a valid Commercial Pilot Licence CPL(A)/IR valid through 31 December 2017, with rights for Cessna 500/550/560. The First Officer held a class 1 medical certificate valid through 5 March 2017 without limitations.

1.5.2.2 The First Officer completed his pilot training in the USA in 2012 and worked as an instructor/pilot at Torp for three years before he was hired by Hesnes Air in 2015.

*Table 3: Flying experience First Officer*

| Flying experience | All types | On type |
|---|---|---|
| Last 24 hours | 3 | 3 |
| Last 3 days | 6 | 6 |
| Last 30 days | 9 | 9 |
| Last 90 days | 55 | 55 |
| Total | 1 500 | 240 |

1.5.2.3 When asked by AIBN, the First Officer confirmed that he felt adequately rested before the flight.

## 1.6 Aircraft information

### 1.6.1 <u>Introduction</u>

LN-IDB, a Cessna 560 Encore with serial number 560-0637 was manufactured in 2003. The aircraft type is certified for two pilots, commander and co-pilot. The cabin has room for 7 passengers.


*Figure 1: Cessna 560 Encore, LN-IDB. Photo: Hesnes Air AS*

1.6.2 LN-IDB flight time

After landing at Torp on 11 January 2017, the aircraft had a total flight time of 3847:47 hours and a total of 2,730 cycles/landings. Both engines had the same operating time as the aircraft.

1.6.3 Airworthiness Review Certificate (ARC)

1.6.3.1 The ARC was valid through 26 February 2017.

1.6.3.2 The last Phase 60 inspection (every 500 flight hours) was carried out on 30 January 2015 at 3 419 flight hours and 2 440 landings. There were 71 hours left before this inspection had to be repeated.

1.6.3.3 The last Phase ML inspection (every 300 flight hours) was carried out on 19 May 2016 at 3 628 flight hours and 2 590 landings. There were 80 hours left before this inspection had to be repeated.

1.6.3.4 A Daily Inspection (DI) had been carried out by the crew and signed in the aircraft's technical logbook.

1.6.3.5 Investigations of LN-IDB following the accident have not revealed factors to indicate that the aircraft was not airworthy at the time of the incident. The investigations has not revealed any technical failures in the control systems or in the trim systems (cf. Appendix B).

1.6.4 Mass and balance

The max allowed take-off mass was 16,630 lbs (7,543 kg). At the time of the incident, the aircraft's mass was 12,534 lbs (5,685 kg) with two pilots and 1,700 lbs (771 kg) of fuel. The aircraft's balance was 302.28 inches, which was within the CG limit of 296 - 304.1 inches.

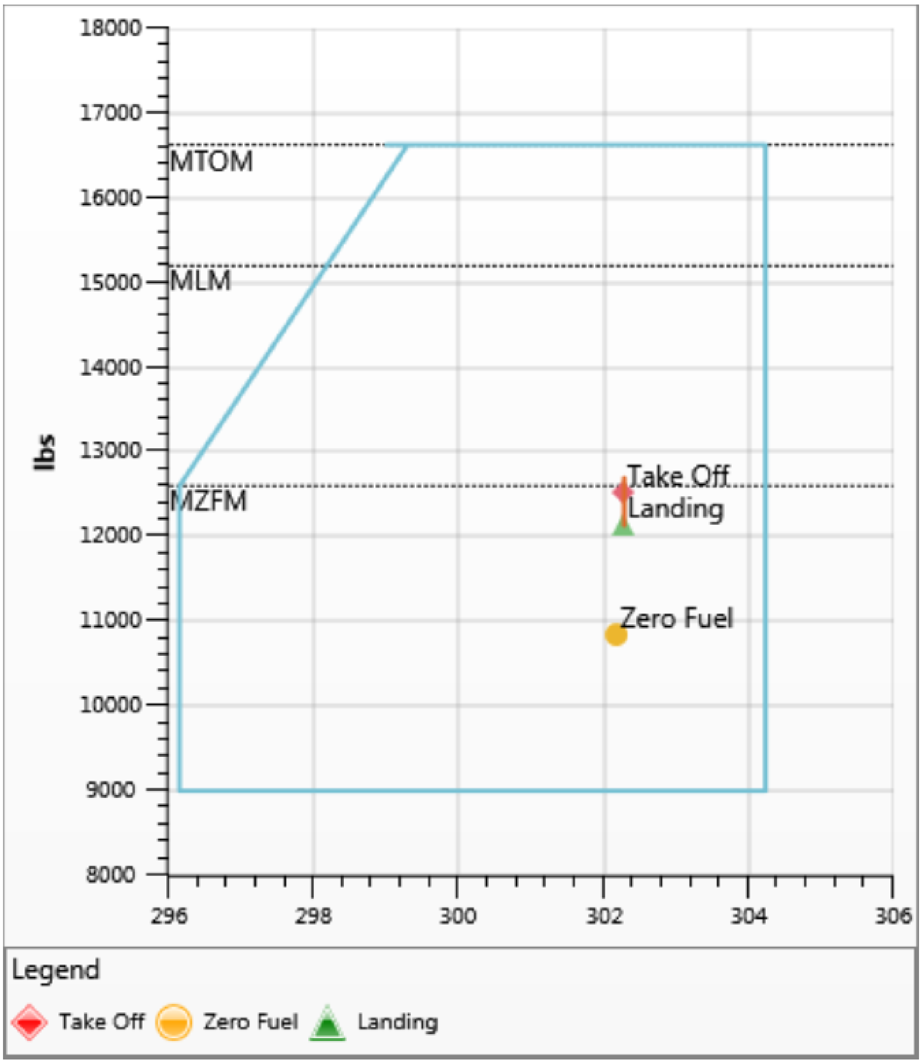



*Figure 2: LN-IDB weight and balance diagram. Source: Hesnes Air AS*

## 1.6.5 Anti and de-icing system

This aircraft type is equipped with hot air anti- and de-icing on the wings and pneumatic "boots" to de-ice the tailplane (tailplane de-icing). The "Wing and Engine Anti-Ice system" was switched on before take-off in accordance with the check list. At the same time, the "Tailplane de-icing system" was set to Auto (CVR time 07:18). Take-off was initiated with an engine RPM of 88% (CVR time 07:43). This indicates that the "boots" had completed a full cycle (18 sec) before take-off started. With the system in Auto, a full cycle is followed by a rest period of 3 minutes before next activation. This means that the tailplane de-icing system was inactive during the take-off phase and throughout the sequence of events.

## 1.6.6 Load Factor Limitations

1.6.6.1 LN-IDB experienced loads of -2.62 and +5.99 G. The Limit Load Factor (LLF) for 560 flaps up is -1.44 to + 3.6 G and the Ultimate Load Factor (ULF = LLF x 1.5) is -2.16 to +5.40 G. The aircraft was overstressed well above ULF and considered not to be economically viable to repair.

1.6.6.2 The following is quoted from Hesnes Air AS OM-B as regards G limitations:

*OM-B 1.1.11 Load factor*

*- C560*

*Flaps Up position (0°): -1.44 to +3.6G at 16.630 pounds*

*Flaps T.O., T.O. & APPR, and LAND position (7° to 35°): +0.0 to +2.0G at 16.630 pounds*

*Flaps LAND position (35°): +3.46G at 15.200 pounds*

1.6.7 The aircraft's take-off position and slush spray pattern

1.6.7.1 Figure 3 shows the aircraft's position during take-off, obtained from FDR data. The yellow line shows that the aircraft's nose position was 5-7° above the horizon before the main wheels left the ground. The figure also shows the aircraft's speed, altitude, nose position and normal G value. The dip in barometric altitude at the aircraft's 7° pitch, shows when the wing develops lift and is an indication that the aircraft experienced ground effect, which resulted in increased pressure under the aircraft, until the pressure declined again when the aircraft climbed further away from the runway. The peak in normal G value shows when the PF pulled the yoke back to raise the nose position to take-off position 5-7°. At this time, the aircraft was pitched up higher, with its tailplane closer to the runway. This meant that there was more airspace between the underside of the wings and the runway, resulting in the tailplane being closer to the runway. The tailplane is therefore presumed to be more exposed to both slush spray from the main gear and the falling snow.

1.6.7.2 Note that altitude as registered by the FDR is based on the standard altimeter setting for Flight Level, which is 1013 hPa. The difference between the altimeter setting for standard altitude and the setting for height above sea level (QNH=965 hPa), was 48 hPa. 1 hPa corresponds to 30 ft at the sea level, which yields an altitude difference of 1,440 ft. This must be added to the elevation of Gardermoen (673 ft), which thus provides the aircraft's altitude during take-off, 673 + 1,440 ft = 2,113 ft.

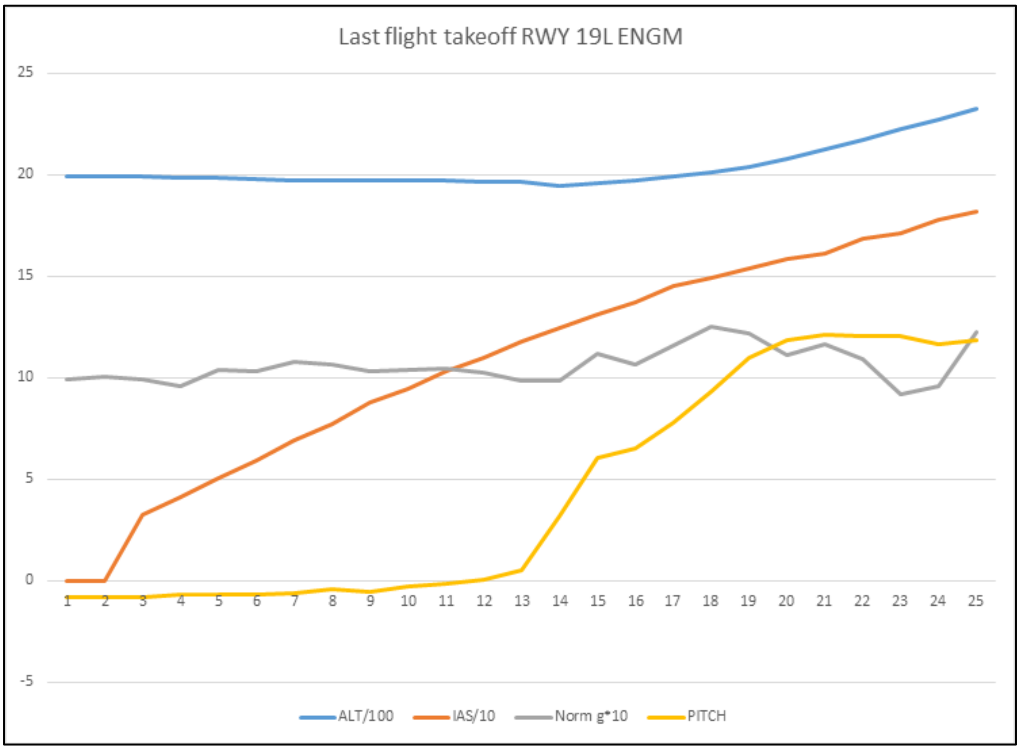
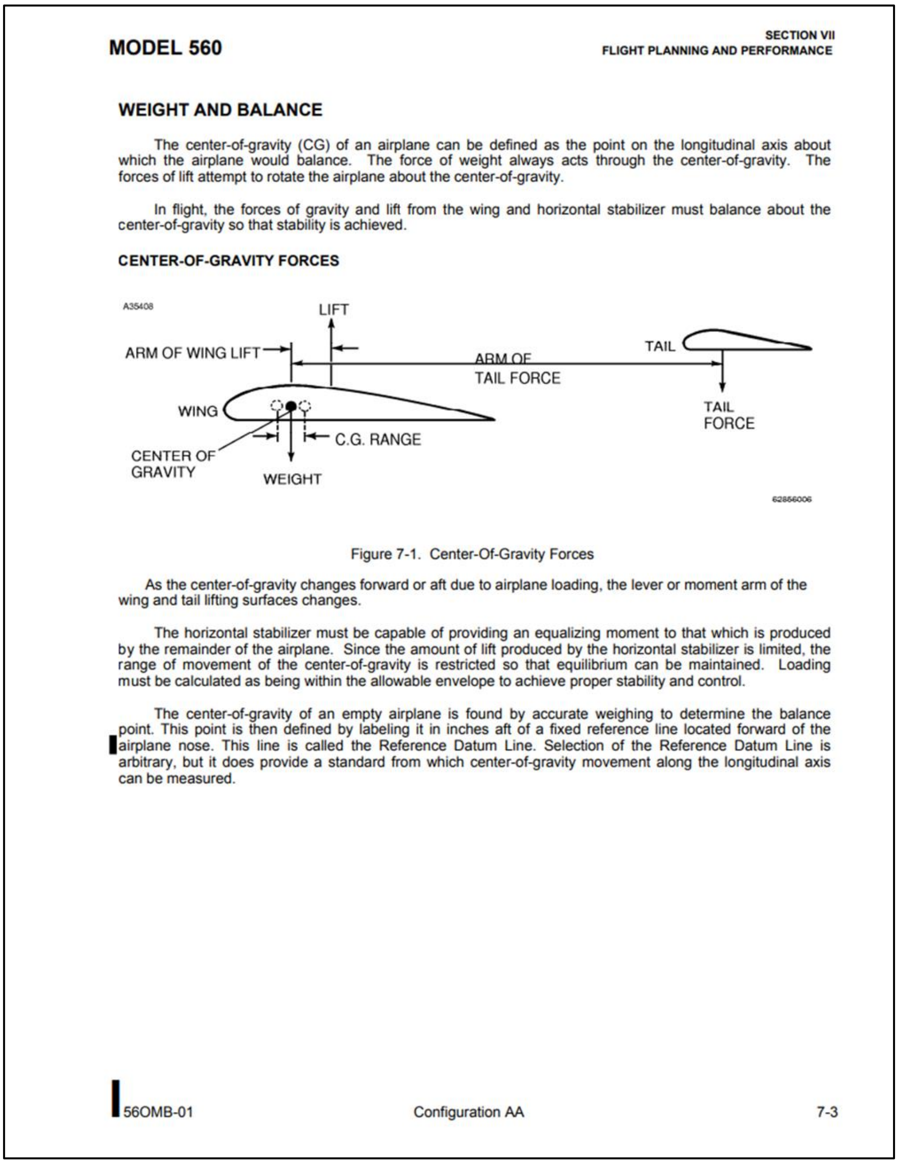



*Figure 3: LN-IDB's take-off position and flight path. Source: FDR data*

## 1.6.8 Schematic diagram for weight and balance


MODEL 560

SECTION VII
FLIGHT PLANNING AND PERFORMANCE

**WEIGHT AND BALANCE**

The center-of-gravity (CG) of an airplane can be defined as the point on the longitudinal axis about which the airplane would balance. The force of weight always acts through the center-of-gravity. The forces of lift attempt to rotate the airplane about the center-of-gravity.

In flight, the forces of gravity and lift from the wing and horizontal stabilizer must balance about the center-of-gravity so that stability is achieved.

**CENTER-OF-GRAVITY FORCES**



Figure 7-1. Center-Of-Gravity Forces

As the center-of-gravity changes forward or aft due to airplane loading, the lever or moment arm of the wing and tail lifting surfaces changes.

The horizontal stabilizer must be capable of providing an equalizing moment to that which is produced by the remainder of the airplane. Since the amount of lift produced by the horizontal stabilizer is limited, the range of movement of the center-of-gravity is restricted so that equilibrium can be maintained. Loading must be calculated as being within the allowable envelope to achieve proper stability and control.

The center-of-gravity of an empty airplane is found by accurate weighing to determine the balance point. This point is then defined by labeling it in inches aft of a fixed reference line located forward of the airplane nose. This line is called the Reference Datum Line. Selection of the Reference Datum Line is arbitrary, but it does provide a standard from which center-of-gravity movement along the longitudinal axis can be measured.

56OMB-01 Configuration AA 7-3

*Figure 4: Note the negative lift on the tailplane. Source: Cessna FM Model 560*

## 1.6.9 Textron Aviation: certification test on water-covered runway

1.6.9.1 Textron Aviation owns Cessna Aircraft Company and AIBN asked the company whether or not tests had been carried out to determine whether slush spray from the aircraft wheels can accumulate on the aircraft's tailplane. Textron Aviation referred to certification tests undertaken on a water-covered runway in November 1999:

***Summary of Spray Patterns observed during Model 560 Encore***

***Water Ingestion Testing (Type Certification data)***

*Water ingestion testing of the Model 560 Encore was conducted in November of 1999, as part of the type certification program. A minimum water depth of 0.5 inches was evaluated, consistent with the AFM limitation regarding maximum allowable water/slush depth on a runway surface for takeoff/landing operations. Data obtained during that testing was reviewed for this summary.*

*The water spray pattern observed from the nosewheel, which utilizes a tire with a chine, is directed to the outboard edge of the engine inlet and below the center-line of the engine. Stated differently, looking aft (into the engine inlet) from the front of the airplane, the V-shaped water plume typically just brushes the outer edge of the lower outboard quadrant of each engine inlet, with much of the plume not making direct contact with the inlet/nacelle. Significant quantities of water are thus prevented from entering the engines. On this trajectory, the water plume does not impact the horizontal tail; but rather passes below, and just outboard of, the tip of the horizontal tail.*

*From the main wheels, the inboard portion of the V-shaped spray pattern was observed to be significantly blocked by the flaps at the trailing edge of the wing, and even by the engine pylon and fuselage itself, to some extent; thereby preventing spray contact with the horizontal tail. The outboard portion of the V-shaped spray pattern was partially blocked by the wing flap (the tapered shape of the wing results in a reduced distance from the main gear to the trailing edge as you move outboard on the wing). The portion of the spray that was not blocked by the trailing edge passes outboard and slightly below the tip of the horizontal tail.*

*Based on these observations from water ingestion testing, it is concluded that an accumulation of contamination on the horizontal tail surfaces, resulting from operation on a slush-covered runway, is unlikely.*

1.6.9.2 The Operating Manual for Citation Encore model 560-0539 thru-5000 states:

*trace or light amounts of icing on horizontal tail can significantly alter airfoil characteristics which will affect stability and control of the aircraft.*

## 1.7 Meteorological information

### 1.7.1 The weather situation

1.7.1.1 AIBN has received a report from the Norwegian Meteorological Institute concerning the weather conditions around Gardermoen on 11 January 2017 at 1400-1800 hours, from the ground up to an altitude of approx. 3 500 ft.

1.7.1.2 A deep low-pressure system of approx. 965 hPa was located south-west of Oslo at 1300 hours and slowly moved to the east. This low-pressure system was accompanied by an occluded front with light to moderate precipitation west, north and east of the low-pressure centre (yellow/orange).

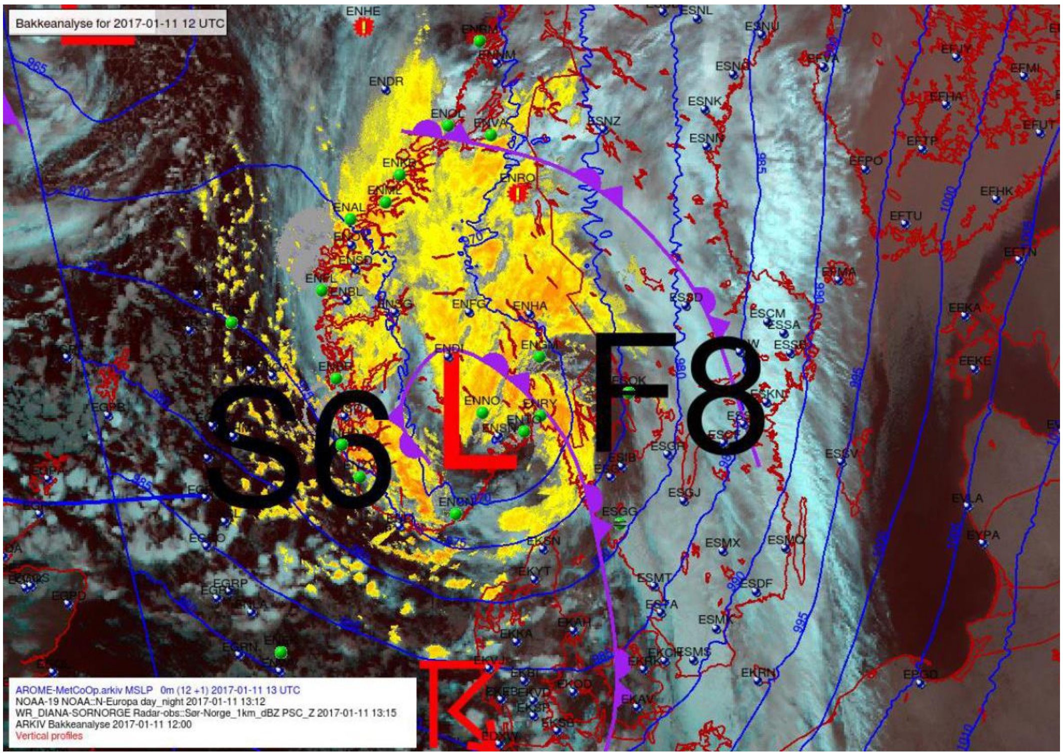



*Figure 5: Combined ground analysis on 11 January 2017 at 1300 hours and weather radar at 1400 hours. The yellow field is precipitation. Source: MET Norway.*

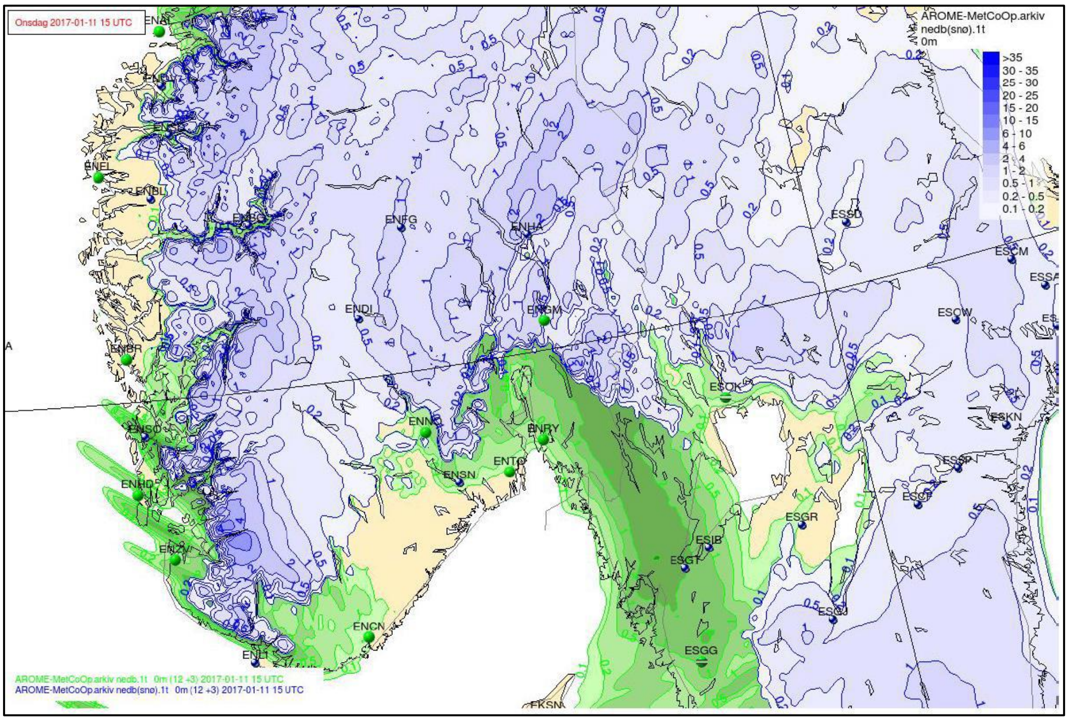



*Figure 6: Precipitation/snow at ground level per hour on 11 January at 1600 UTC. Green is rain, shades of blue are sleet/snow. There is snowfall over ENGM. Source: MET Norway*

*Figure 7: Weather at Gardermoen at 1615 hours, just before LN-IDB's departure. The image shows that there was snowfall. Photo: Avinor*

### 1.7.2 METAR

1650 ENGM 111650Z 36006KT 5000 -RA BR SCT002 BKN015 00/M01 Q0965 TEMPO 3000 -SNRA BR BKN008=

1620 ENGM 111620Z 02007KT 350V050 6000 -SN SCT004 BKN007 00/M01 Q0965 TEMPO 3000 -SN=

1550 ENGM 111550Z 03005KT 010V070 6000 -SNRA OVC004 00/M00 Q0965 TEMPO 3000 -SN=

1520 METAR ENGM 111520Z 03005KT 350V100 4200 -SN BR OVC004 00/M01 Q0965 TEMPO 2500 -SN BKN006=

### 1.7.3 TAF

TAF 1547 AMD ENGM 1115/1212 14008 KT 5000 –SNRA SCT005 BKN010 TEMPO 1115/1119 1400 SN VV004 BECMG 1118/1120 34010KT FEW020 SCT050 PROB40 TEMPO 1120/1123 33015G28KT BECMG 1200/1202 20007 =

### 1.7.4 SIGMET

WAN031 ENMI 111535
ENOS AIRMET A04 VALID 111600/112000 ENMI-
ENOR NORWAY FIR OCNL MOD ICE FCST WI N5850 E1010 – N6200 E00730 – N6200 E01225 – N6115 E01300 _ N6010 E01235 – N5650 E01140 – N5850 E01010 SFC/FL180 MOV ENE WKN=

SIGMET covered central Eastern Norway, including the counties of Østfold, Vestfold, Buskerud, Oslo, Akershus and parts of Oppland and Hedmark.

### 1.7.5 SNOWTAM 0076

A) ENGM
B) 01111718 C) 01L
F) 6/6/6 G) 3/3/3 H) 4/4/4
B) 01111621 C) 01R
F) 5/6/6 G) 6/3/3 H) 4/4/4
N) A3 B2 C2/CLSD B1 B9/6 ALL REMAINING TWYS/5
R) APRON NORWEGIAN/CLSD APRON B NORTH/6
ALL REMAINING APRONS/5
T) RWY 01L CONTAMINATION/100/100/100/PERCENT
RWY 01R
OBSERVATION TIME RWY 01R 201701111621
CONTAMINATION/100/100/100/PERCENT

SNOWTAM shows that, at 1621 hours (two minutes after the incident), runway 01R/19L was covered by 3 mm of slush on the northern two-thirds of the runway, and 6 mm of wet snow on the last one-third to the south. This means that the part of the runway LN-IDB used was covered by 3 mm of slush. The SNOWTAM shows that no chemicals had been applied on the runway.

All open taxiways were covered by wet snow or slush.

### 1.7.6 Wind shear, turbulence and wake turbulence

No wind shear or turbulence was notified or reported in Eastern Norway. Three minutes before LN-IDB's departure, a Boeing 737 took off from the same runway. In order to prevent influence from wake turbulence, the minimum separation requirement during take-off is two minutes between these aircraft types.

## 1.8 Navigational aids

Not relevant.

## 1.9 Communications

The following frequencies were relevant during the ground stop at Gardermoen:

ENGM Clearance Delivery frequency, 121.675 MHz
ENGM Ground frequency, 121.600 MHz
ENGM Tower W frequency, 118.300 MHz
ENGM Tower E frequency, 120.100 MHz

While taxiing to runway 19L, the crew received clearance from TWR W on frequency 118.3 MHz to cross runway 19R via C1, continuing on via N, V, T and B8 to take-off position on runway 19L.

After crossing runway 19R, LN-IDB was handed over to GND on frequency 121.6 MHz When LN-IDB approached runway 19L, it was handed over to TWR E frequency 120.1 MHz, where they received take-off clearance.

## 1.10 Aerodrome information

### 1.10.1 De-icing platforms

Gardermoen has a de-icing platform for runway 19L (B-North) and one for 01R (B-South), as well as one for runway 19R (A-North) and one for 01L (A-South). During the relevant incident, de-icing platform B-North for runway 19L was in use.

LN-IDB taxied past de-icing platform B-North without de-icing.

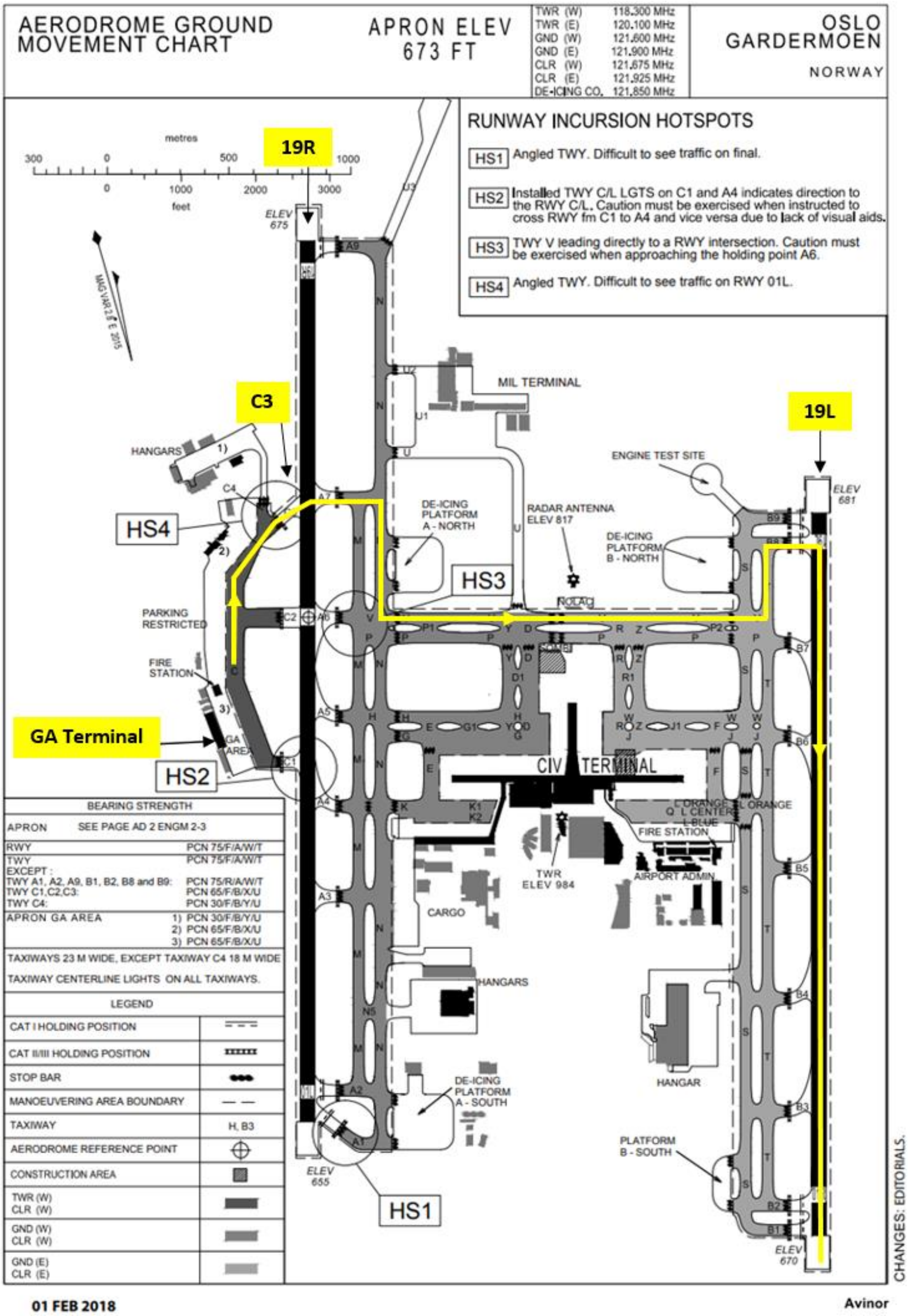



*Figure 8: Map of Gardermoen Airport with LN-IDB's taxi route from the GA Terminal to take-off on runway 19L. Markers in yellow were added by AIBN. Source: AIP Norway*

## 1.11 Flight recorders

### 1.11.1 Introduction

The aircraft was equipped with two recorders, one for voice (Cockpit Voice Recorder) and one for technical data (Flight Data Recorder). Both recorders were removed from the aircraft, and two inspectors from AIBN brought them to AIBN's UK counterpart (AAIB) at Farnborough in England to download data. Data from both units have been important for this investigation.

### 1.11.2 Cockpit Voice Recorder (CVR)

The CVR was of the type L3 Communications Model FA 2100. CVR P/N2100-1020-02, S/N 000183914. The CVR registered audio on 3 channels, one "voice channel" for each pilot, as well as a Cockpit Area Microphone (CAM). The CVR had recorded two hours of audio, of which the last 30 minutes were of high quality.

### 1.11.3 Flight Data Recorder (FDR)

1.11.3.1 The FDR was of the type Honeywell Solid State Memory. FDR P/N 980-4700-025, S/N SSFDR-08292. The Flight Data Recorder held data on e.g. altitude, speed, flap position, pitch and roll angle, G loads and engine parameters. Unlike most FDR’s it did not register the control surface and yoke positions, which would have been highly beneficial in this investigation.

1.11.3.2 On 20 January 2017, AIBN transferred the FDR data to Cessna Aircraft and asked whether they, based on the data, could explain the incident. Cessna responded as follows on 27 January 2017:

> *Our flight test department has looked the FDR data over and provided the following opinion: The event was NOT precipitated by an aerodynamic stall. The data shows the autopilot was never engaged, but it appears the pilot was doing a fine job of managing airspeed and everything else right up to the point that the event occurs. At 200 KIAS, the only way the airplane would stall is if it had a significant amount of normal acceleration. The data shows a small increase in normal acceleration above 1g as the pitch is increased to around 25-26 degrees to maintain 200 KIAS (not at all unusual for a very light-weight 560), but that is not enough to generate a stall. As flaps are retracted from 7 to 0, the airplane starts to pitch over rapidly and a dramatic reduction in normal acceleration is recorded. Retracting flaps from 7 to 0 degrees at 200 KIAS will not result in a pitch-over to zero-g, but that's what the data shows. The left wing drop occurred after the pitch-over event, while the pitch attitude was well below -30 deg and normal acceleration was well below -2g.*

At this time, Cessna did not believe that the aircraft contributed to the incident, nor that it could have been exposed to wing icing. Tailplane icing was not discussed.

During AIBN's subsequent meeting with Textron Aviation in Wichita, Kansas on 30 October 2017, AIBN discussed possible hypotheses with Textron Aviation. The conclusion was that Textron Aviation agreed with the AIBN that the only explanation for the incident was tailplane stall.

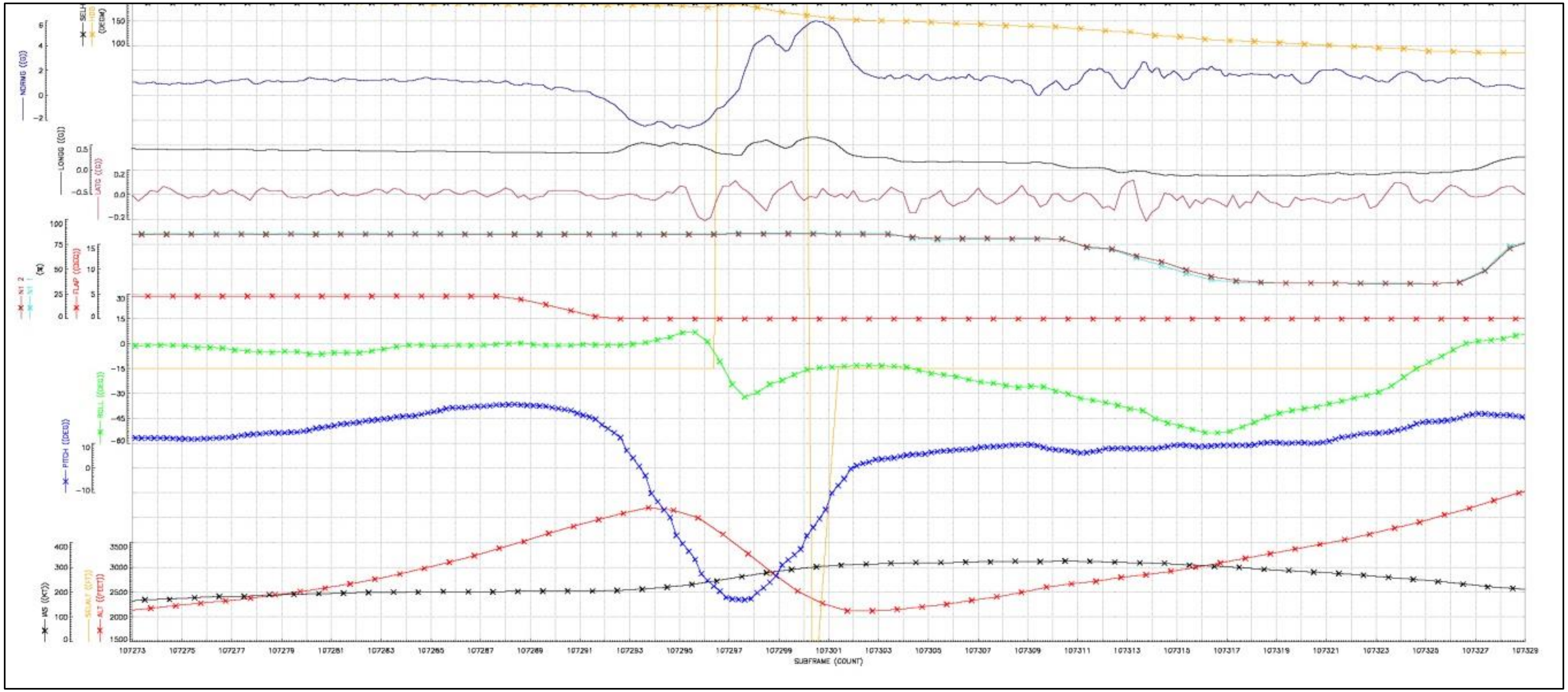


*Figure 9: Printout from Flight Data Recorder. Source: FDR data from LN-IDB*

## 1.12 Location and damage to the aircraft

### 1.12.1 Location

The accident occurred just after take-off from runway 19L at Gardermoen. At the lowest, the aircraft's altitude was approx. 170 feet above ground, which occurred just to the west of the village Sand. Figure 10 is a radar plot based on positions received from Avinor.

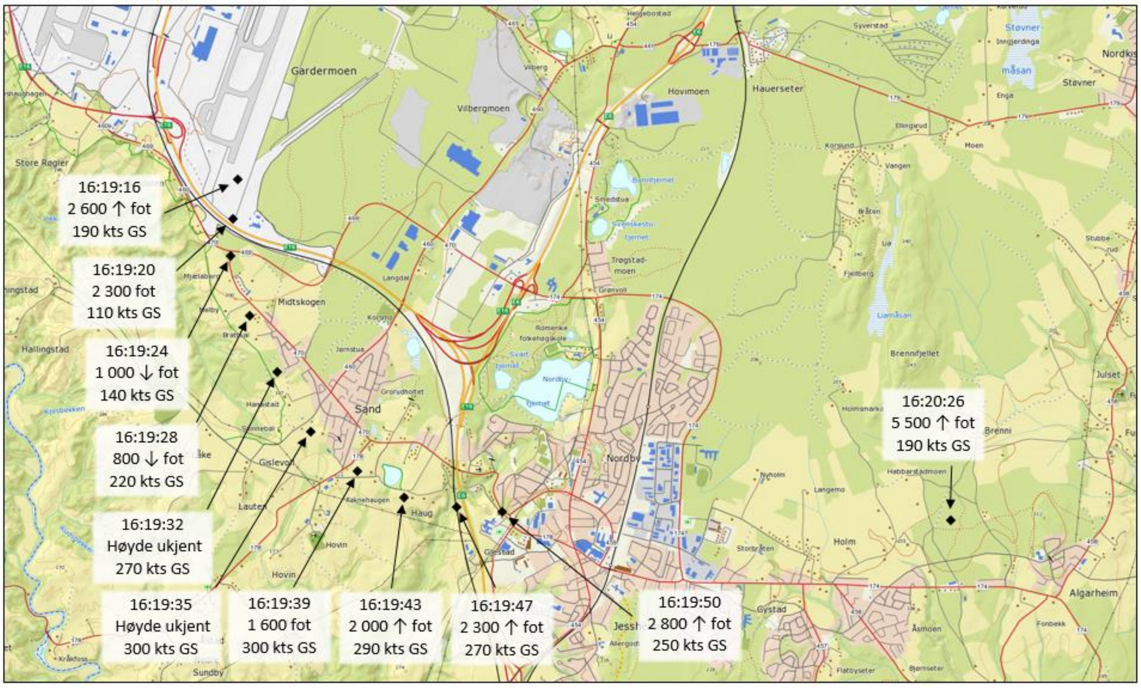



*Figure 10: Estimated path of the flight based on radar data from Avinor. Map: © Norwegian Mapping Authority*

### 1.12.2 Damage to the aircraft

1.12.2.1 Due to the high G loads to which the aircraft was exposed, deformations occurred in multiple places on the top side of both wings. Deformations also occurred on engine nacelles and on the fuselage over the wings (see Figure 11 and Appendix B for details). The aircraft was so damaged that it was not found economically viable to repair it.

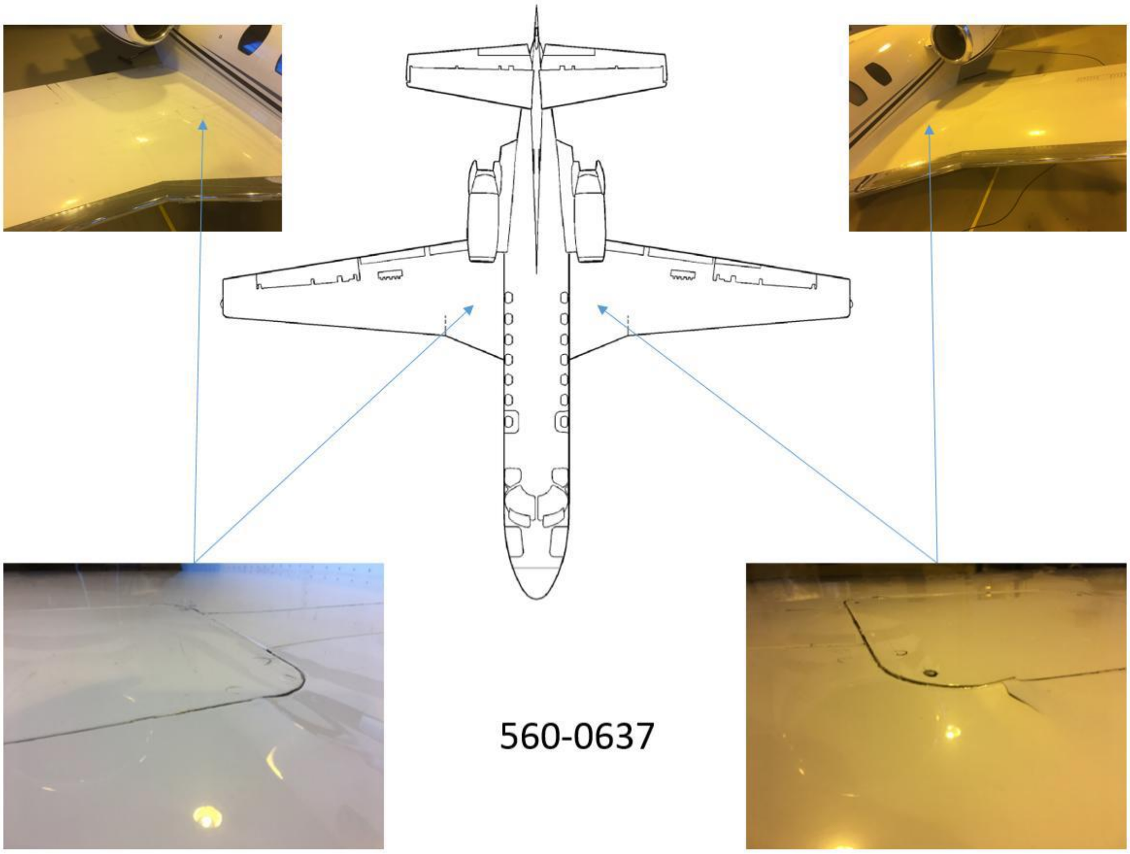



*Figure 11: Visible damage to the top of the wings. Source: Hesnes Air AS*

1.12.2.2 AIBN, in collaboration with the technical department of Hesnes Air and Textron Aviation, completed tests on the aircraft's control and trim systems without finding any faults that could have contributed to the accident occurring.

## 1.13 Medical and pathological information

1.13.1 In order to avoid any subsequent discussion regarding possible drug effects, the crew wanted to deliver a blood test. They therefore contacted Sandefjord police and explained that they had been involved in a serious aviation incident. The crew and company were informed by the police that in that case a criminal case had to be established against them as the police could not take a voluntary test. Within a few hours and several phone calls to the police and emergency room, the company decided to end further attempts to deliver blood tests. The AIBN has no evidence to suggest that the crew was under the influence of drugs.

1.13.2 The Norwegian Aviation Act (Act No. 101 of 11 June 1993) §6-13 regarding Alcohol testing, breath test, blood sample says:

> *The police can administer a preliminary breath test and preliminary test of whether a person is affected by other intoxicants or sedatives, when*
>
> 1. *there are grounds to believe that the person has infringed on the provisions in Section 6-1 or 6-12,*
> 2. *the person is involved, with or without culpability, in an air accident or aircraft incident,*

*3. when this is required as part of controlling aviation activities.*

*If the test result or other factors give reasons to believe that the provisions in Sections 6-11 or 6-12 [Influence of alcohol, etc. or Compulsory temperance] have been infringed, the police can undertake a special investigation as to whether there are signs or symptoms of being under the influence of intoxicating or narcotic substances and subject the person to a breath test, blood sample, saliva sample or clinical examination by a physician to seek to determine the influence. The person shall generally only be subject to this if he/she refuses to submit to a breath test or preliminary test of whether the operator is under the influence of alcohol or other intoxicants or sedatives.*

## 1.14 Fire

Not relevant for this investigation.

## 1.15 Survival aspects

The crew were strapped in with lap- and shoulder harness in accordance with the regulations.

## 1.16 Special investigations

### 1.16.1 Model simulation prepared by Coventry University

1.16.1.1 On assignment from AIBN, Coventry University in the UK carried out an analysis of a generic (equivalent) category of aircraft and the incident. The analysis and model simulations show that if the tailplane loses efficiency, the aircraft's nose will pitch (bunt) down. The analysis is included in its entirety in Appendix E.

1.16.1.2 Figure 12 shows that the aircraft's longitudinal stability is reduced proportional to lower efficiency in the tailplane, e.g. in connection with contamination in the form of ice, frozen snow or slush. Run 1 shows the aircraft's normal longitudinal stability without a contaminated tailplane. Run 2 shows stability with a contaminated tailplane at 80% efficiency. Runs 9, 3 and 4 respectively show increasing instability in pitch alongside increasing levels of contamination/diminishing tailplane efficiency, such as in connection with stalling due to icing.

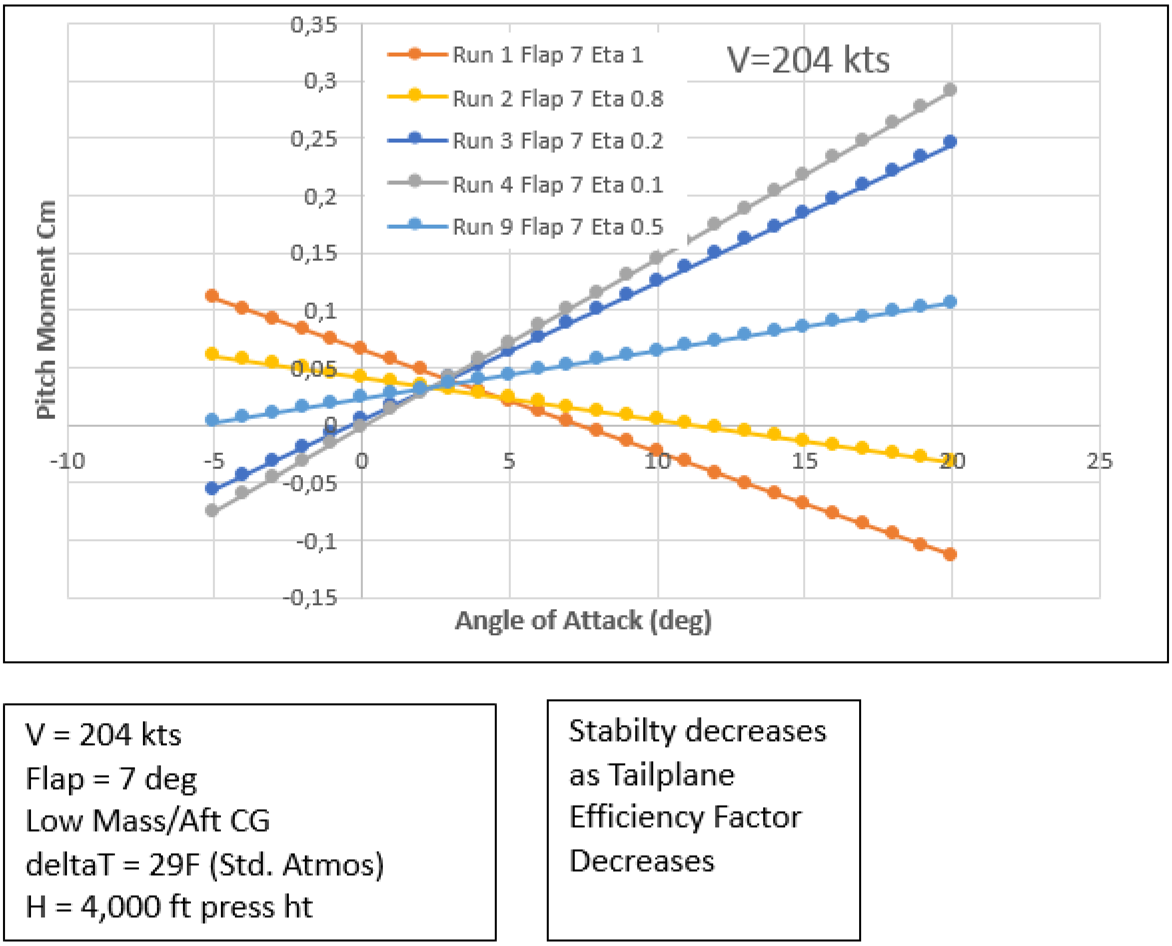



*Figure 12: Longitudinal Stability (Cm) vs Angle of Attack (deg). Illustration: Coventry University cf. Appendix E*

1.16.1.3 Figure 13 shows a gradual reduction of the stability indicator Static Margin (% MAC) as a function of Tailplane Efficiency Factor (TEF) (such as contamination in the form of icing). We can see that the aircraft is neutrally stable at approx. 68% TEF, and unstable at 20% TEF.

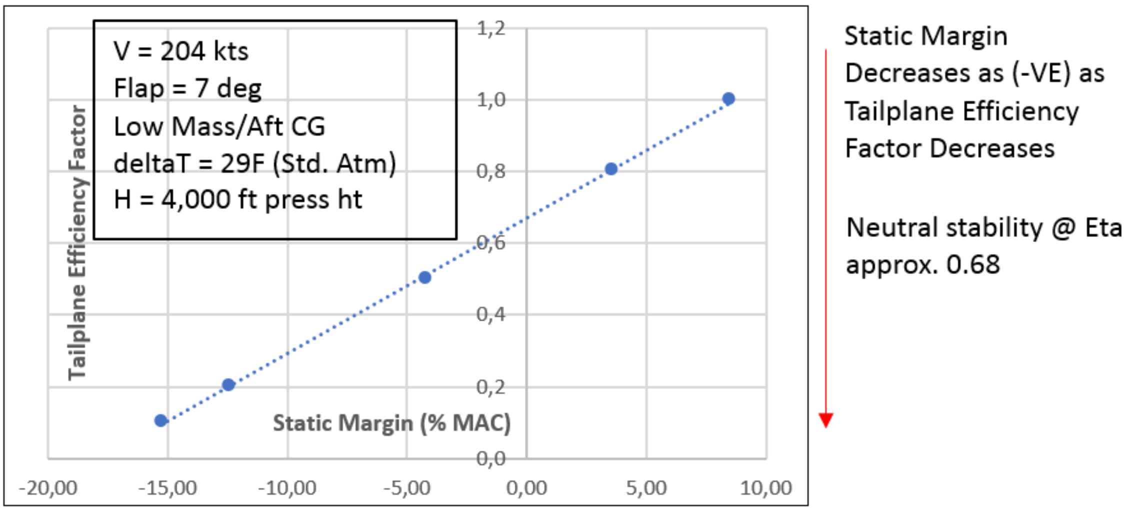



*Figure 13: Static Margin (% MAC) vs Tailplane Efficiency Factor (TEF). Illustration: Coventry University cf. Appendix E*

1.16.1.4 Figure 14 shows compensating elevator deflection to counteract reduced tailplane efficiency.

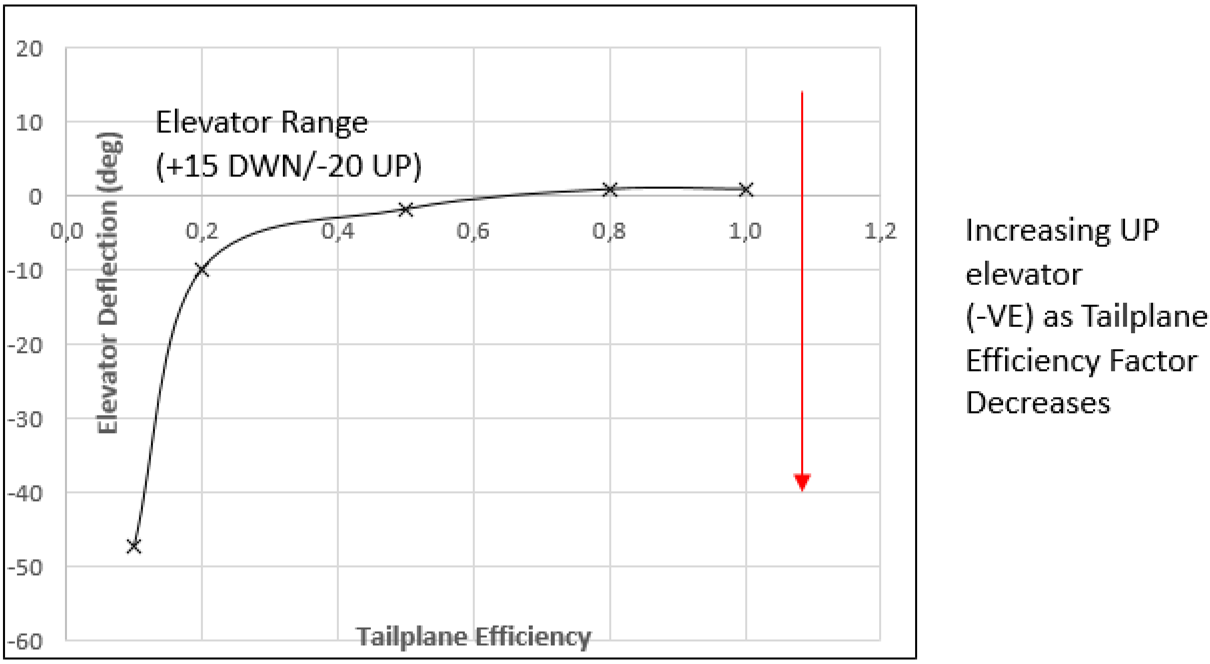



*Figure 14: Elevator Deflection (deg) vs Tailplane Efficiency Factor (TEF). Illustration: Coventry University cf. Appendix E*

1.16.1.5 Figure 15 shows the effect of retracting flaps when stalling the tailplane. Retracting flaps will reduce the aircraft's pitch down (nose down) movement.

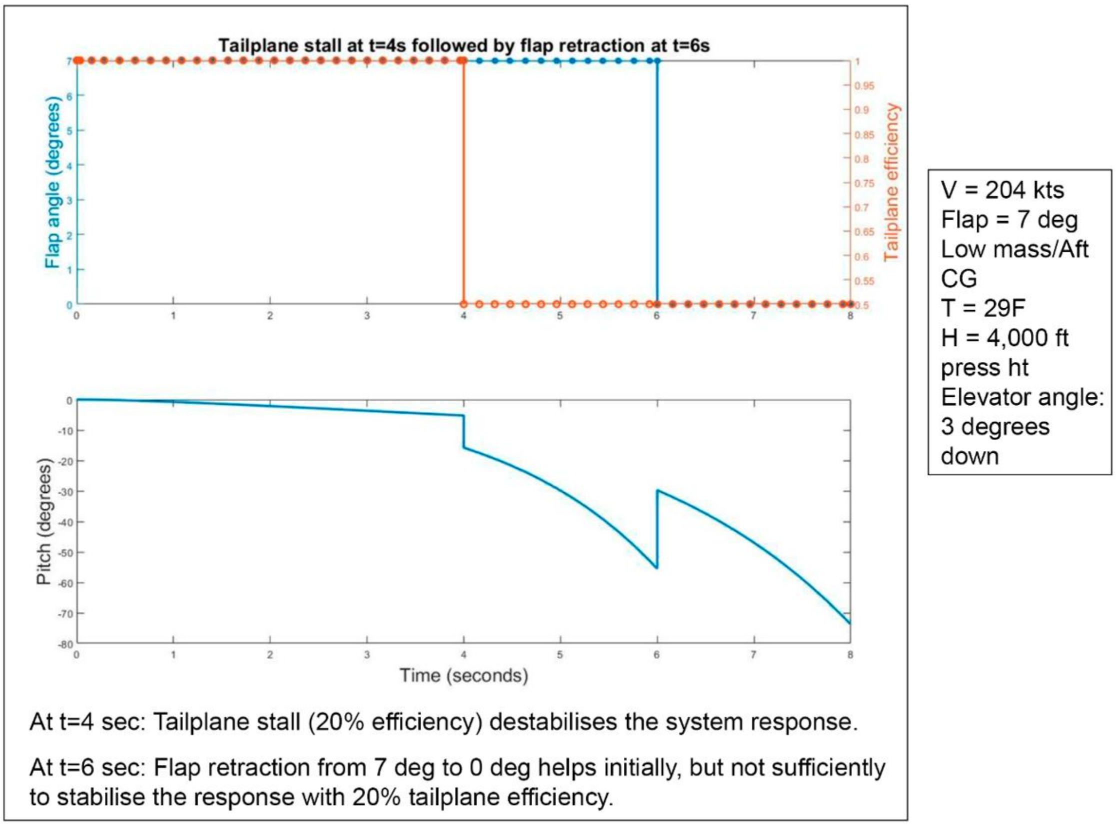



*Figure 15: Tailplane stall followed by flap retraction. Illustration: Coventry University cf. Appendix E*

1.16.1.6 The red line in Figure 16 shows that the aircraft is unstable at 20% tailplane effect (tailplane stall).

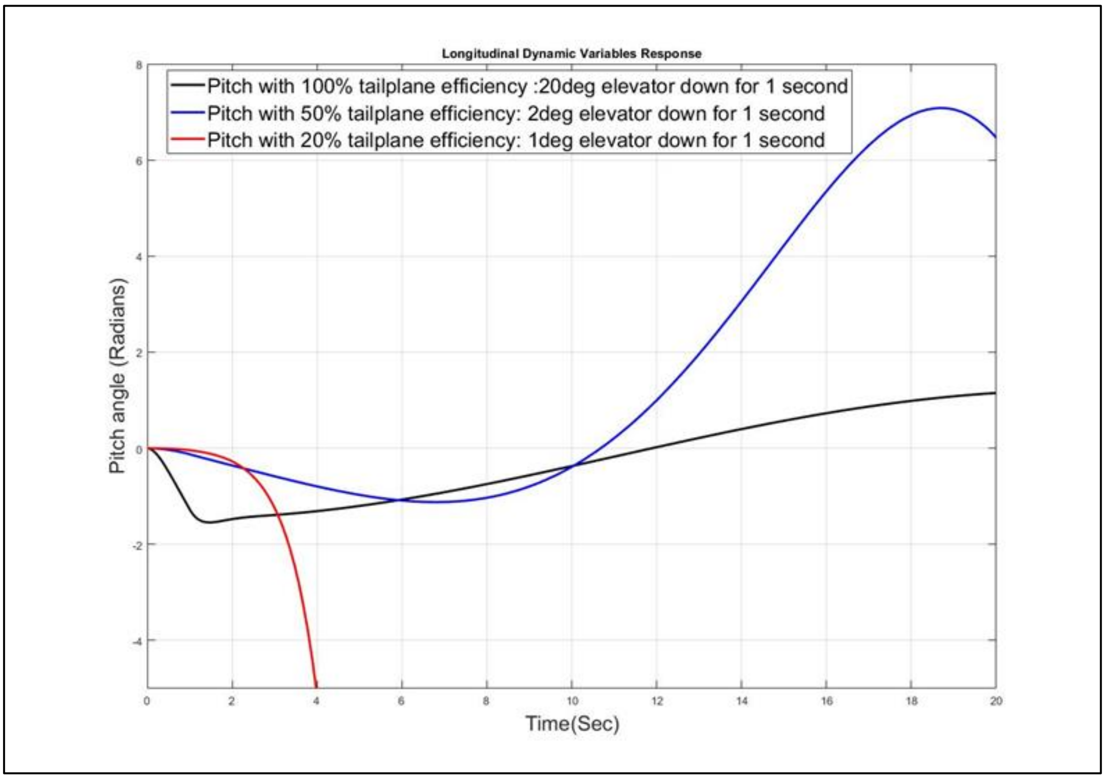



*Figure 16: Longitudinal Dynamic Pitch Responses at 100%, 50% and 20% Tailplane Efficiency Factor. Illustration: Coventry University cf. Appendix E*

1.16.1.7 The three lines in Figure 17 indicate that a potential contamination of the tailplane will result in a TEF reduced to below 50%, in addition to making the aircraft unstable (divergent) at 20% tailplane effect (tailplane stall). The red line in the figure shows that, over time, the "pitch angle" changes rapidly develop negative values at 20% TEF, which will result in the aircraft being exposed to negative G forces.

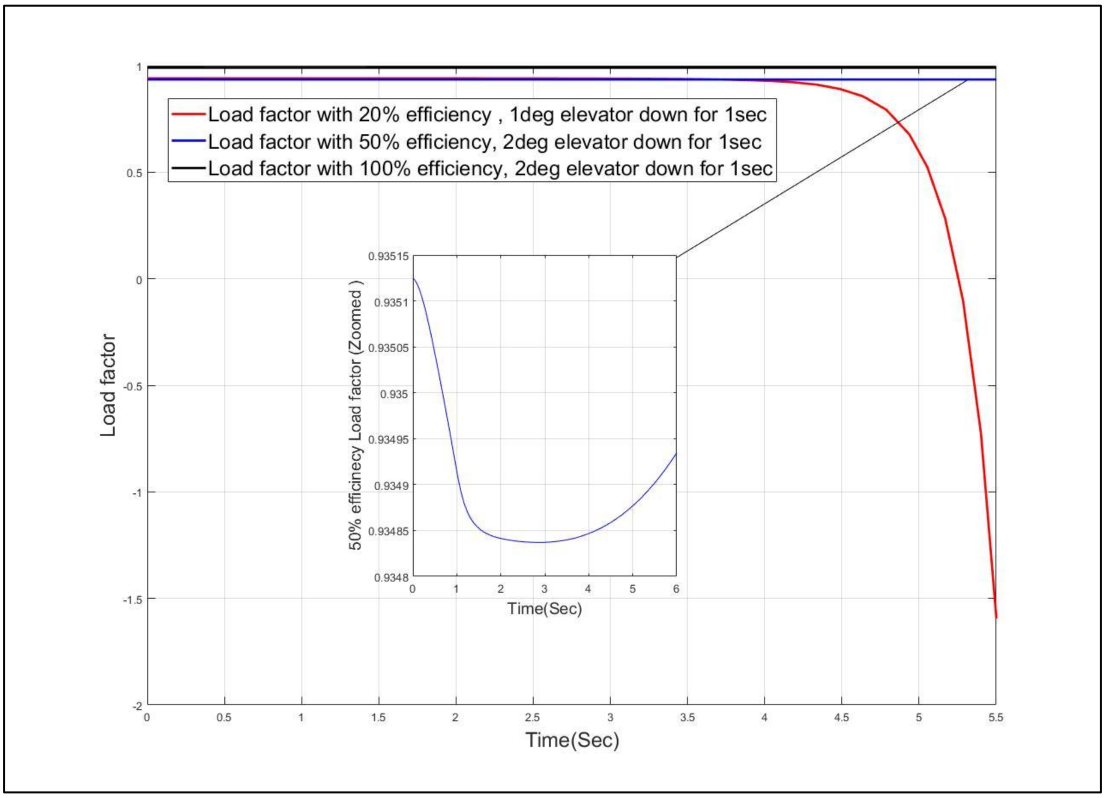



*Figure 17: Load Factor as a result of elevator inputs that 100%, 50% and 20% Tailplane Efficiency Factor. Illustration: Coventry University cf. Appendix E*

1.16.2 Coventry University concluded as follows (see Appendix E):

> *The results suggest that the 'generic' business jet aircraft is used in the analysis is statically and dynamically stable when horizontal tailplane efficiency is greater than 80%. When tailplane efficiency is reduced to 20% (simulating a 'tailplane stall'), the aircraft is statically and dynamically unstable, smaller and shorter elevator commands produce large pitch responses and negative 'G' may be quickly reached within a short time period.*

## 1.17 Organisational and management information

1.17.1 <u>Organisation requirements for air operations</u>

1.17.1.1 EASA's corporate organisation requirements are laid out in Annex III Organisation Requirements for Air Operations (PART-ORO) to Regulation (EU) No 965/2012 concerning pan-European provisions for air operations (EASA-OPS). The following is quoted from ORO.GEN.210(c):

> *The operator shall have sufficient qualified personnel for the planned tasks and activities to be performed in accordance with the applicable requirements.*

1.17.1.2 ORO.AOC.135[2] also requires the operator to nominate at least four people to oversee management and follow-up of the following areas: 1) flight operations, (2) crew training, (3) ground operations, and (4) continuing airworthiness.

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[2] An Air Operators Certificate is an operator permit issued by a state's aviation authorities to the operator of an aircraft in order to carry out commercial aviation.

1.17.1.3 The Acceptable Means of Compliance (AMC) and Guidance Material (GM) for Annex III PART-ORO allow for a person to have multiple nominated roles, but this depends on the scope and complexity of the operations:

*AMC1 ORO.AOC.135(a) Personnel requirements:*

*(a) The person may hold more than one of the nominated posts if such an arrangement is considered suitable and properly matched to the scale and scope of the operation.*

*AMC2 ORO.AOC.135(a) Personnel requirements:*

*(a) The acceptability of a single person holding several posts, possibly in combination with being the accountable manager, should depend upon the nature and scale of the operation. The two main areas of concern should be competence and an individual's capacity to meet his/her responsibilities.*

*(b) As regards competence in different areas of responsibility, there should not be any difference from the requirements applicable to persons holding only one post.*

*(c) The capacity of an individual to meet his/her responsibilities should primarily be dependent upon the scale of the operation. However, the complexity of the organisation or of the operation may prevent, or limit, combinations of posts which may be acceptable in other circumstances.*

1.17.1.4 EASA considers an operator to be non-complex if it has fewer than 20 full-time equivalents (FTEs). However, AMC1 ORO.GEN.200(b) subsection (b) indicates that an operator with fewer than 20 FTEs can be considered complex if it, for example, carries out operations with different types of aircraft.

1.17.2 Hesnes Air AS - organisation

1.17.2.1 At the time of the accident, Hesnes Air operated both aircraft and helicopters. The company's Fixed Wing branch consisted of nine pilots, including the Flight Operations Manager; five captains and four first officers. In the Rotary Wing (helicopter), the company had three pilots.

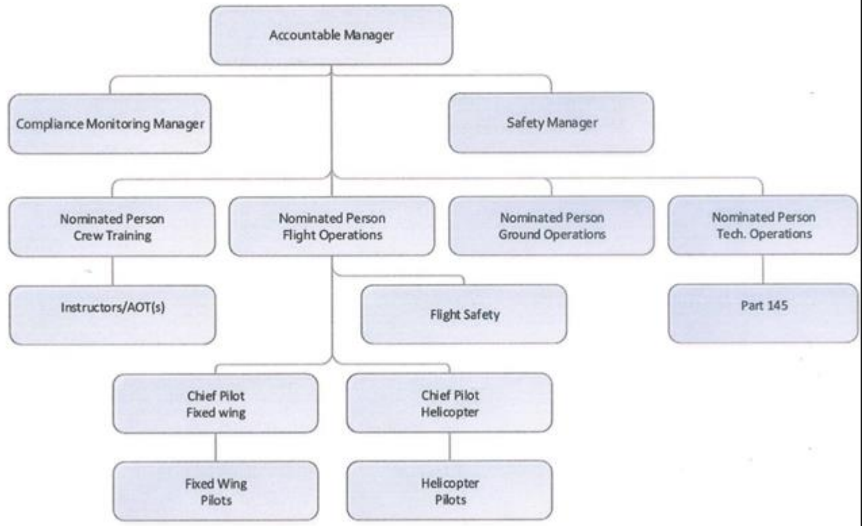
1.17.2.2 Hesnes Air AS' organisation (see Figure 18) was approved by the Civil Aviation Authority Norway, through the approved Operations Manual - OM-A rev. 6 of 2 June 2016.

1.17.2.3 Hesnes Air had the following four Nominated Persons: Manager Flight Operations (MFO) (Flight Operations Manager and Commander in the accident), Manager Crew Training (MCT), Manager Ground Operations (MGO) and Manager Continuing Airworthiness (MCA).

HESNES AIR AS OM-A

Chapter 1 – Organization and Responsibility

**1.1.2 Organization according to PART OPS** **ORO.GEN.210 (C)**




**1.2 NOMINATED PERSONS AND MANAGEMENT PERSONELL** **ORO.GEN.210**

**1.2.1 Personnel requirements** **ORO.AOC.135**

Any person nominated to Hesnes Air organisation shall be contracted to this work. Accountable Manager is responsible for properly training of all personnel assigned to or directly involved in ground and flight operations. The person should not be nominated by another holder of an AOC, unless agreed with Hesnes Air and the competent authorities concerned. Specific competence requirements for nominated persons are listed in GM2 ORO.AOC.135 (a). Other personnel requirements are listed in AMC1/2 ORO.AOC.135 (a). In an EASA-OPS organization, four Nominated Persons are required. Hesnes Air Nominated Persons and NCAA approved personnel are:

*Table 1: Management personnel*

| Title | Name | Deputy |
|---|---|---|
| Accountable Manager (AM) | A | B |
| Safety Manager (SM) | A | B |
| Manager Flight Operations (MFO) - Nominated Person | B | C |
| Manager Continuing Airworthiness (MCA) - Nominated Person | D | E |
| Manager Crew Training (MCT) - Nominated Person | F | B |
| Manager Ground Operations (MGO) - Nominated Person | F | B |
| Compliance Monitoring Manager (CMM) | A | B |

Revision: 6 Date: 02.06.2016 Page: 2

*Figure 18: Organisation and responsibilities at the time of the accident.*
*Source: OM-A Hesnes Air AS*

The organisation was in the next revision of OM-A revision 7, dated 16 March 2017, changed to;

| Title | Name | Assistant |
|---|---|---|
| Accountable Manager (AM) | A | |
| Safety Manager (SM) | A | |
| Manager Flight Operations (MFO) – Nominated Person | C | G |
| Manager Continuing Airworthiness (MCA) – Nominated Person | D | E |
| Manager Crew Training (MCT) – Nominated Person | F | H |
| Manager Ground Operations (MGO) – Nominated Person | F | |
| Compliance Monitoring Manager (CMM) | A | |

*Figure 19: Table 1 OM-A rev. 7 dated 16 March 2017. Source: Hesnes Air AS*

The letters in the two columns represent people. It is evident that a few people have been changed, while the double roles remain unchanged. The "Deputy" column is relabelled with "Assistant".

1.17.2.4 *Combination of positions*

Both before and after this organisational change in Hesnes Air AS, which both were approved by the Civil Aviation Authority Norway, the Accountable Manager (AM) held all of the essential positions within safety management and control in the company. In addition to being supreme responsible for the safety of the company as a Accountable Manager, AM also held the positions of Safety Manager (SM) and Compliance Monitoring Manager (CMM).

1.17.2.5 *Management System Manual*

Chapter 4 – Safety Accountability and Responsibilities - in Hesnes Air AS' MSM lays out the competency requirements for AM, SM and CMM (see also Appendix D, AIC 2/17 with enclosures).

*4.1 SAFETY RESPONSIBILITIES*

*Accountable Manager (AM) ORO.GEN.210 (a)*

*The AM shall ensure that all activities can be financed and carried out in accordance with the applicable requirements. The overall safety accountability in the company is the responsibility of the AM. The safety accountability is managed through the Management System. The AM is responsible for establishing and maintaining the Management System as described in this manual.*

*…*

*Safety Manager (SM) ORO.GEN.200 (a)(1)*

*The SM acts as the focal point and is responsible for the development, administration and maintenance of the Management System. The functions of the SM are to facilitate hazard identification, risk analysis and management; monitor the implementation of actions taken to mitigate risks as listed in this manual; provide periodic reports on safety performance; ensure maintenance of safety management documentation; ensure that there is safety management training available and that it meets acceptable standards; provide advice on safety matters; and ensure initiation and follow-up of internal occurrence, incident and accident investigations. The SM is the focal point for collecting and analysing* *hazards and maintaining a register of hazards, risks, and risk controls (mitigations).*

***SM reports to the Accountable Manager (AM).***

*The SM is responsible for the supervision and facilitation of the processes to support managers in developing processes, procedures and work instructions for the staff under their supervision to perform their activities in a safe manner.*

*…*

*This information shall form the basis for SM's decisions regarding priorities and investments in safety improvements. The promulgation of safety information shall be coordinated on an overall level in order to highlight common focus areas.*

*Nominated Persons*

*The Nominated Persons (NPs) have the responsibility within their own area. Each NP shall establish a system to secure compliance with relevant authority requirements. Relevant new requirements shall be presented at the SRB/Management Meeting. Duties and responsibilities are specified in OM-A 1.3 and Continued Airworthiness Management Exposition (CAME). When required according to OM-A chapter 11, report Occurrences, Incidents, Serious Incidents and Accidents on behalf of Hesnes Air to NCAA and Accident Investigation Board Norway (AIBN).*

*Compliance Monitoring Manager (CMM)*

*The CMM shall ensure that the Company's activities are monitored for compliance with the applicable regulatory requirements, including those regarding the Management System Manual (MSM), additional company requirements and procedures, and that these activities are being carried out properly under the supervision of the relevant managers. The CMM shall ensure that the compliance monitoring program is properly implemented, maintained and continually reviewed and improved, ref. Compliance Monitoring Programme.*

***The CMM reports to the Accountable Manager (AM).***

*…*

1.17.3 Other organizational matters

1.17.3.1 In AIBN's meeting with management in Hesnes Air AS in May 2018, it emerged that the Manager Flight Operations had devoted considerable efforts to preparing a new operations manual for the company.

1.17.4 Hesnes Air AS – use of de-icing

Hesnes Air AS' use of de-icing is explained in the company's OM-A and OM-B:

***OM-A 8.2.4 Ice and other contaminants CAT.OP.MPA.250/SPO.OP.175***

*It is the CMDR's responsibility to ensure when required, that the aircraft is de-iced before takeoff. Procedures and special requirements stated in the AFM shall be adhered to. If no specific limitations are stated in these manuals, the wings, tail plane, vertical fin, and any control surface shall be free of rime, ice or snow during takeoff. Approved de-/anti-icing fluids are required for use on company* *aircraft. Hesnes Air is not equipped with any de-icing facilities and all de-icing of company aircraft will be performed by other approved operators. The CMDR shall order de-icing before starting engines. When entering the de-icing area, a communication shall be established with the de-icing personnel. The communication shall be maintained during de-icing and the CMDR shall receive a verbal report when de-icing is completed. In lieu of any approved ISO (AEA) type anti-icing fluid, or equivalent fluid, the CMDR must decide after his own judgement the procedure/fluid to be used.*

***OM-B 1.1.14 Airframe contamination***

*- Take-off is prohibited with frost in one or more of the following critical areas:*
*- Wing leading edge*
*- Upper wing surface*
*- Windshield*
*- Take-off is prohibited with ice, snow or slush adhering to one or more of the following critical areas:*
*-Wing leading edge and upper wing surface*
*- Flight control surfaces including all hinge gaps*
*- Horizontal stabilizer*
*- Vertical stabilizer*
*- Engine inlets*
*- Top of engine pylons*
*- Windshield*
*- All static ports*
*- Angle-of-attack vanes*
*- Upper surface of nose forward of windshield*

***Notes:***
*Refer to OM-A 8.2.4 for information regarding ground de-icing and anti-icing procedures.*

***OM-B 2.3.1 General***
*It is the responsibility of the CMDR to ensure that the Pre-flight inspection (PFI) is carried out before each flight, and signed for in the PFI column of the Technical Log. MEL considerations regarding minimum equipment requirement to meet operating rules for operation in RVSM etc., refer to "Quick reference list - special approval operations" in the checklist advisory information page (back of the Normal Checklist).*
*The PFI may be performed by either the CMDR or the Copilot. The purpose of the PFI is to ensure the integrity of the Aircraft. The PFI procedure is described in the Pre-Flight Inspection Checklist.*
*When performing the PFI, make a general check for security, condition, and cleanliness of the airplane and components. Check particularly for damage, condition of tires, flight controls, fuel, oil, hydraulic fluid leakage, security of access panels, and blockage of ventilation inlets and drain ports. Ensure all ground safety pins, control locks, covers, tie-downs, and chocks are removed and stowed.*

***OM-B 2.3.2 Contamination check***
*A contamination check shall be performed before every departure (ref OM-A 8.2.2.9).*

*Before take-off, the CMDR shall:*
*- Verify that the inlet cowling is free of ice or snow;*
*- Verify that the fan is free to rotate.*

*Snow or ice that accumulates on the fan spinner or fan blades during shutdown periods (typically blowing snow, showers etc.) must always be removed before engine start. Small amounts of snow or ice (any type) that accumulates on the fan spinner or fan blades as a result of operation in icing conditions, such as during approach or taxi in, is allowed if the fan is free to rotate and the snow or ice is removed using the ice shedding procedure (run up) during taxi out and before setting take-off thrust.*

***Notes:***
*The CMDR shall request fan spinner/fan blades to be de-iced before start-up, if there should be any doubt if within safe limits.*

### 1.17.5 Hesnes Air AS' agreement on de-icing at OSL Gardermoen

Hesnes Air AS had an agreement with Aviator-OSL AS for de-icing services at OSL Gardermoen, as reproduced below.

PARAGRAPH 1. HANDLING SERVICES AND CHARGES
1.1 For a single ground handling consisting of the arrival and the subsequent departure at agreed timings of the same aircraft, the Handling Company shall provide the following services of Annex A at the following rates.
De-icing/Anti-icing services and Snow/Ice removal according to Carriers Instructions

| | |
|---|---|
| 3.5.1 | Provide headsets |
| 3.5.2(d) | *Perform ramp to flight deck communication, for purpose of informing Flight crew of results, fluids and H.O.T.* |
| 3.16.2 | Perform "pre" de/anti-icing inspection and advise flight crew or Carriers representative of results. *This can be done as a recommendation as upper wing surfaces are not visible from the ground. On request.* |
| 3.16.3 | Perform clear ice check, if required for operating aircraft type. *On request..* |
| 3.16.4 (a)(1)(2) | Provide anti-icing units and de-icing units. |
| 3.16.5 | Provide de-icing/anti-icing fluids. |
| 3.16.6 | Remove frost, ice and snow from aircraft using de-icing fluid. Fluids to receive purity and contamination inspection prior to use. |
| 3.16.7 | Apply anti-icing fluid to aircraft. |
| 3.16.8 | Supervise performance of de-icing/anti-icing operations. |
| 3.16.9 | Perform final inspection after de-icing/anti-icing operations. *Final Inspection after De-/Anti-Icing to be performed by qualified staff of the Handling Company.* |

*Figure 20: Agreement for de-icing services at OSL Gardermoen. Source: Hesnes Air AS*

1.17.6 Hesnes Air AS – ground stop practice

1.17.6.1 The Commander has explained to AIBN that they would sometimes carry out ground stops with one engine running. When Hesnes Air was asked whether this could occur, Hesnes Air has stated that this is not standard procedure. The company went on to answer that it was not standard practice among pilots to do ground stops with one engine running, neither before nor after the incident.

1.17.6.2 The company's OM-A chapter 8.2.2.2 states that it is only in the case of time-critical transport of certain types of organs that the right engine can be kept running while the entry door is open and the crew is waiting for the delivery. The operation manual does not allow for general permission to board or drop off passengers with an engine running.

## 1.18 Other information

1.18.1 Tailplane stall as a result of icing

1.18.1.1 An aircraft's longitudinal stability is balanced by the tailplane. The aircraft's centre of gravity (CG) will normally be in front of the aircraft's centre of lift (CL), so the aircraft will generally have a nose-down moment on CG. This moment is balanced by a negative lift on the tailplane (see Figure 4).

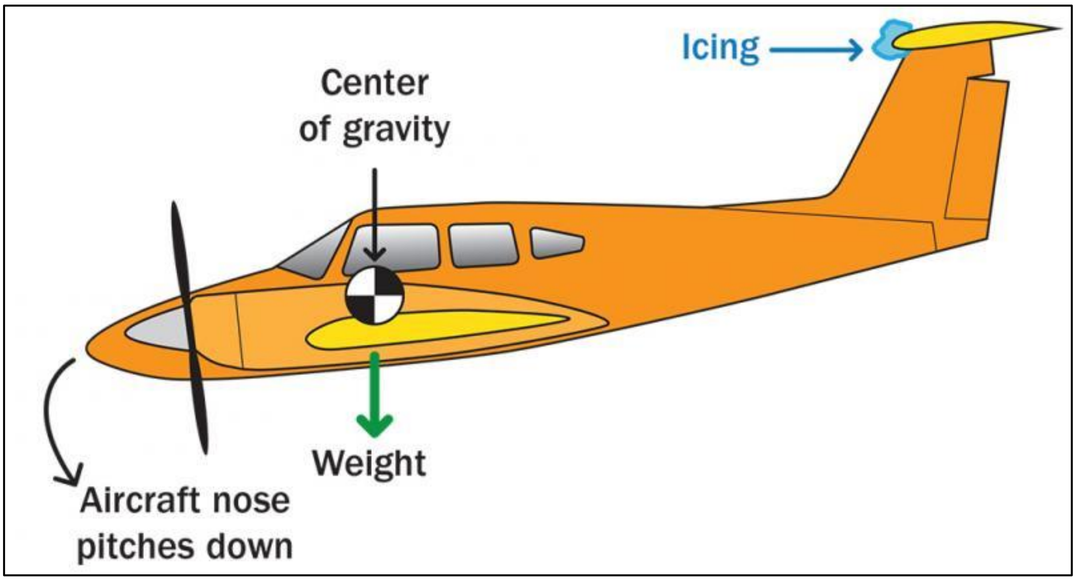



*Figure 21: Tailplane stall as a result of icing. Source: "How to recover from Tailplane Icing" (Ross Detwiler)*

1.18.1.2 If the tailplane stalls due to icing, the aircraft's nose will be pushed down by a moment depending on the aircraft's CG position, altitude, speed, configuration and elevator deflection/trim setting. This will cause the aircraft to experience negative acceleration (negative Gs).

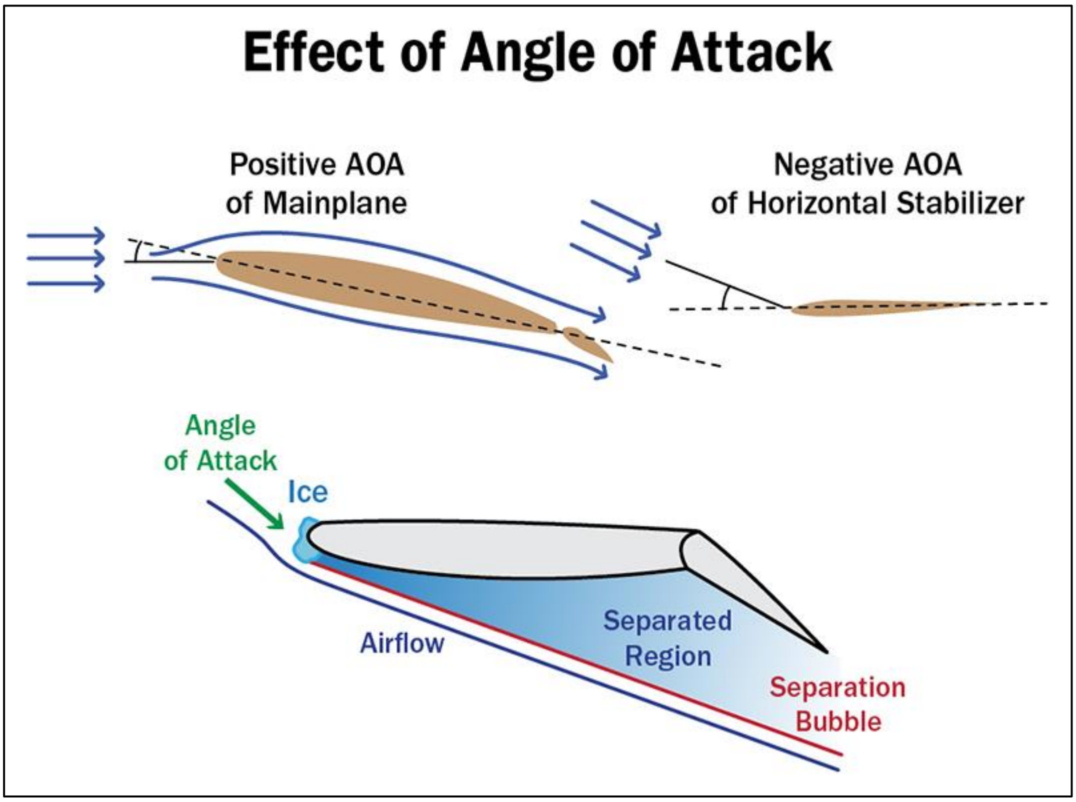



*Figure 22: The effect of increased negative angle of attack on the tailplane. Source: "How to recover from Tailplane Icing" (Ross Detwiler)*

1.18.1.3 The risk of the tailplane stalling due to icing increases when the flaps are deployed. An increased negative angle of attack on the tailplane will increase the risk of stalling and losing the tailplane's balance force (trim force).

1.18.1.4 Tailplane stall as a result of icing is a known causal factor. However, all known instances are associated with deploying flaps, which causes increased downwash (downward air currents) from the wing, and thus increased negative angle of attack on the tailplane. On the other hand, in this instance, the incident coincided with retracting flaps.

1.18.1.5 Retracting flaps reduces the wing's downwash and thus also reduces the tailplane's negative angle of attack. This also reduces the risk of tailplane stall due to icing. Retracting flaps is part of the recovery procedure for Tailplane stall.

1.18.1.6 Appendix C describes tailplane stalling as a result of icing.

***Wing Stall vs. Tailplane Stall***

*In a conventional wing stall, the airplane pitches down due to a loss of lift. A tailplane stall also results in pitching down, but because tail-down force has been lost. This is why stall recovery techniques are opposite. Aircraft flight manuals can differ, but here are NASA's general guidelines to recovery:*

*Wing Stall Recovery:*

1. *-Add Power*
2. *-Relax back pressure or push yoke forward*

*Tailplane Stall Recovery:*

1. *-Pull back on the yoke*
2. *-Reduce Flaps*
3. *-Reduce Power: This is aircraft specific based on engine location in relation to CG and how power changes angle of attack. (Engines mounted above the CG will create a stronger pitching down moment as power increases)*

1.18.1.7 AIBN is not familiar with any accident investigations associated with tailplane stall as a result of icing, and which was initiated by retracting flaps. All known instances of tailplane stall have been as a result of deploying flaps when there is ice on the tailplane.

### 1.19 Useful or efficient investigation methods

None of the investigation methods used requires particular mentioning.

# 2. ANALYSIS

### 2.1 Introduction

At the outset of the analysis, we will present potential explanations that the investigation can rule out. Then we will describe the most probable explanation for why the pilots suddenly lost control of the aircraft. This is followed by a discussion of flight operations and human factors that are relevant for the accident. The investigation has also identified a few organisational and supervisory matters that will be discussed in more detail. Finally, there is a discussion regarding factors that contributed to the loss of control not ending up in a fatal accident.

### 2.2 Eliminating potential explanations

Multiple explanations could potentially have led to the accident. AIBN has assessed them, and has determined that the following explanations can be ruled out:

2.2.1 <u>The aircraft's technical condition</u>

According to AIBN's investigations, the aircraft was airworthy at the time of the accident and the investigation of the aircraft following the accident has not revealed any faults in the control and trim systems (cf. Appendix B).

2.2.2 <u>The crew's handling after take-off until loss of control</u>

The investigation has not revealed that the crew's manoeuvring contributed to the loss of control occurring. AIBN is basing this on interviews with both crew members, as well as analysis of available data from the Flight Data Recorder and the audio from the Cockpit Voice Recorder.

2.2.3 <u>Extreme turbulence or wind shear</u>

At the time in question, wind conditions were calm at ground level and up to cruising altitude, with wind speeds below 10 knots. No turbulence had been reported. AIBN therefore believes that one can rule out that turbulence/wind shear could have caused a pitch down to negative 2.62 G. The CVR registered among other warnings "windshear warning" from the EGPWS system (cf. 1.1.11) during the period when the aircraft was exposed to negative G. This is natural when the aircraft's nose suddenly "pitched" down to minus 33.6 ° and normal acceleration went from plus 1G to minus 2.62G. Thus, Angle of Attack (AoA) was changed from positive to negative, which the system's programming would interpret as "windshear".

2.2.4 Wake turbulence

AIBN can rule out that wake turbulence contributed as a factor, since LN-IDB's departure took place three minutes behind a Boeing 737 taking off from the same runway.

2.2.5 Pitch Trim Runaway

In a meeting with Cessna in Wichita on 30 October 2017, AIBN was clarified that the trim system in the Cessna 560 Encore does not have the control authority to cause negative 2.62 G, which far exceeds the certification restriction of negative 1.44 G. AIBN thus rules out trim runaway as a contributing factor.

2.2.6 Somatogravic illusion

A somatogravic illusion is a sensory impression caused by e.g. rapid acceleration after take-off. This can result in the PF reducing the climb and could even push the yoke forward so that the aircraft stops climbing and starts descending. The FDR and CVR data indicate that the crew were aware of the speed increase and were concerned with not exceeding the flaps limit of 200 KIAS. This resulted in a deliberate increase in climb angle, which is not conducive to a somatogravic illusion. AIBN thus rules out somatogravic illusion as a contributing factor.

2.2.7 Stalling caused by icing on the wing

2.2.7.1 It was icing conditions at Gardermoen at the time in question, and CVR data confirm that the "Wing anti-ice system" and "Tailplane de-icing system" were switched on before take-off. However, a wing stall would not cause negative Gs. AIBN therefore agrees with Cessna's initial assessment that the incident was not triggered by a wing stall (cf. 1.11.3.2).

2.2.8 Stalling as a result of flaps position or flaps retraction

2.2.8.1 It has not been possible for AIBN, based on FDR data, to link the initiation of the incident to flaps retraction. In line with general flight mechanics, retracting flaps will reduce "downwash" and negative angle of attack on the tailplane, which in turn will reduce the risk of tailplane stalling. All known instances of tailplane stall as a result of icing were initiated by deploying flaps. This increased "downwash" and negative angle of attack, thus exceeding the tailplane's stalling angle. On this basis, AIBN believes it can rule out that retracting flaps caused the tailplane to stall.

2.2.8.2 Figure 15 from Coventry University's model simulation shows that extending flaps reduces the aircraft's longitudinal stability, and that retracting flaps increases stability. This is in line with general flight mechanics principle and AIBN's hypothesis that retracting the flaps did not trigger the aircraft's pitch down (bunt) (cf. Appendix E).

## 2.3 Probable explanations of how the loss of control occurred

2.3.1 In chapter 2.2, AIBN considered and ruled out multiple potential explanations of how the loss of control occurred. AIBN is therefore left with only one likely explanation of why the accident occurred, which is that the tailplane lost its ability to produce negative lift. AIBN believes that this was most likely caused by contamination of the underside and leading edge of the horizontal stabiliser due to icing caused by slush spray from the runway and from falling snow and sleet. This is described in more detail below. Tailplane stall as a result of icing is a known causal factor. However, all known instances are associated with extending flaps. In this instance, the incident coincides with retracting flaps. AIBN does not have a clear answer as to why the stall not occurred at another time. When the tailplane stalled, the contamination had probably reached a critical amount in relation to the aircraft's speed and angle of attack.

2.3.2 Taxiways and the runway were covered by 3 to 6 mm of snow and slush (cf. paragraph 1.7.5), and the aircraft's surfaces were most likely chilled after flying for 2,5 hours in temperatures approaching minus 50°C. It is not possible to determine the relevant surface temperature after a ground stop totalling 15 minutes in an air temperature of 0°C. AIBN believes the surface of wings and hull were colder than the air temperature and thus on the negative side, but it is not possible to know exactly how cold the aircraft's surface temperature was at take-off.

2.3.3 Cessna refers to certification tests on a water-covered runway (ref. chapter 1.6.9) and believes that spray from the wheels cannot reach the tailplane. In this case, there were 3 mm slush on the runway's departure section. The average density of slush is 0.81 g/cm$^3$ and is therefore lighter than water (1 g/cm$^3$). At a lower density, the spread of the slush spray will be more diffuse than water spray, increasing the likelihood that the slush can hit the tail surface. Before departure, the aircraft will have 5-7° pitch angle before "weight on wheels" disappear, and in this phase the tail surface will be closer to the ground and more exposed to both slush spray and falling snow.

2.3.4 If spray from the main wheels reached the leading edge and underside of the tailplane, the de-icing system will have no effect. The boots were inflated just before take-off and were in a rest period throughout the departure. AIBN believes that slush may have attached itself directly to the "boots" and the chilled aluminium structure behind the "boots", and thereby contaminated the tailplane. In addition, there was falling snow during the entire ground stop and the departure. The Accident Investigation Board refers to the Operating Manual for Citation Encore model where it is warned that even light icing on the horizontal tail can affect stability of the aircraft (cf. 1.6.9.2). In a meeting with Textron Aviation, the company agreed with the AIBN that the incident must have been caused by a tailplane stall.

2.3.5 An analysis from Coventry University (CU) concludes that a tailplane effect of less than 68% will make the aircraft unstable. The analysis is based on a generic model and the values will not be identical to the accident aircraft. AIBN has focused on the fact that the tailplane was fully stalled and has not addressed the impact which various degrees of contamination has had on the aircraft's stability. The analysis also shows that, at an efficiency of 20%, the aircraft will be unstable.

2.3.6 The aircraft was not de-iced at Gardermoen before take-off and AIBN believes that this may have been of significance for the loss of control, cf. 1.6.9.2 and the warning from Textron Aviation regarding icing on the horizontal tail.

2.3.7 CVR data confirm the crew's explanation to AIBN that the "Wing anti-ice system" and "Tailplane de-icing system" were switched on before take-off. However, the CVR timing shows that 25 seconds passed from when the de-icing "boots" were set to auto until take-off was initiated. This means that the system would have "cycled" through an 18-second "cycle" and was in a 3 minutes rest period throughout the departure, including through the incident.

2.3.8 De-icing using "boots", even through activation, appears to only be marginally effective against the type of contamination that was relevant at Gardermoen. AIBN therefore believes that the certifying authorities should assess other de-icing systems for new aircraft types.

## 2.4 Flight operations and human factors

### 2.4.1 <u>The crew's plan for a brief ground stop at Gardermoen</u>

2.4.1.1 The crew planned a brief ground stop at Gardermoen and therefore uplifted enough fuel before take-off from Bern to fly to the base at Torp without having to top off at Gardermoen. To further shorten the duration of the ground stop, one engine was kept running as the passenger and luggage were deplaned. This means that the Pre Flight Inspection was only carried out on one side of the aircraft. The First Officer observed water on one of the wings, and presumed that this was also the case on the other wing and tailplane.

2.4.1.2 The Commander had a clear intention to make the ground stop as short as possible. By refraining from de-icing the aircraft, the Commander was counting on them receiving clearance to take off from runway 19R, which is located alongside the GA terminal at Gardermoen, where the aircraft was parked. This would entail a short time for taxiing, and thus contribute to the shortest possible ground stop and thus brief exposure to snowfall before take-off.

### 2.4.2 <u>The crew's actions and Hesnes Air's routines</u>

2.4.2.1 One important part of the Pre Flight Inspection is to thoroughly check the entire aircraft for contamination, including the wings, tailplane and top of engine pylons. This is difficult to carry out thoroughly in the dark and with one engine running. The Commander has explained that brief ground stops are occasionally carried out with one engine running. However, the operations manual did not give the option to keep one engine running during this ground stop (cf. 1.17.6). It was unfortunate that the aircraft was not de-iced, which resulted in a safety barrier being excluded.

2.4.2.2 It is also clear from the company's Operations Manual that the Commander is responsible for ensuring that the aircraft is de-iced when circumstances so warrant. OM-A 8.2.4 specifies that particularly "*the wings, Tailplane, vertical fin, and any control surface shall be free of rime, ice or snow during takeoff*".

2.4.2.3 The weather conditions at Gardermoen at the time in question implied de-icing, although snow that hit the hull and wings apparently melted into water. AIBN has found no documentation in Hesnes Air OM-A or OM-B to indicate that a Commander or Flight Operations Manager can make exceptions from this requirement.

2.4.3 Why didn't the crew change the plan and de-ice the aircraft before take-off from Gardermoen?

2.4.3.1 In this the case, there would, insofar as AIBN knows, not be any disadvantages of significance associated with arriving at Torp a bit later. Neither would it have entailed increased expenses for de-icing for the company, as this is invoiced to the customer. The crew continued to stick to the plan of a shortest possible ground stop in spite of the fact that:

- Air Traffic Control gave clearance for runway 19L, and not 19R as the crew had hoped, which meant that they would spend more time on the ground before the aircraft could take off. This increased the likelihood of snow and ice settling on the wing and tail surfaces.

- While taxiing before take-off, the First Officer saw at least four Boeing 737s being de-iced at de-icing-platform B-North.

- Air Traffic Control asked the crew to confirm that they did not want de-icing, as the Commander had told them while the aircraft was parked a few minutes before. The First Officer confirmed that they did not want de-icing.

2.4.3.2 The First Officer has explained to AIBN that he felt unsure during taxiing. He later reflected on the fact that this could be attributed to his limited experience with winter operations. Also that preparations for the next flight had been cut short and were carried out quicker than normal due to the plan to have the shortest possible ground stop. He therefore felt a bit behind at times, but did not notify the Commander about this. Had the First Officer told the Commander that he was not entirely comfortable with the situation, the Commander could have had an extra opportunity to reconsider the plan to have the shortest possible ground stop without de-icing.

2.4.3.3 The crew's behaviour in this situation is consistent with a known phenomenon in aviation – "plan continuation bias." This phenomenon is characterised by sticking to the original plan, in spite of indications that the situation has changed, and that there is a need to reconsider the plan one is following. Another characteristic is that the decision to stick to the plan under changing circumstances does not necessarily have a rational basis, for example, it could simply be a general desire to get home as quickly as possible.

2.4.4 How did the crew avoid a collision with the ground?

2.4.4.1 *Introduction*

When the aircraft's pitch dropped rapidly, and the pilots were exposed to up to 2.62 negative Gs while banking (rolling) to the left, the vestibular systems in their inner ears were subject to a massive impact. This led to spatial disorientation for both pilots, most likely in both the pitch and roll planes. Under the influence of strong negative G forces without visual references, the pilots reacted differently.

2.4.4.2 *Commander*

The Commander explained that the transition from a completely normal situation to the dramatic change in the aircraft's position, where he saw an unusually large amount of brown (ground) on the attitude indicator, overwhelmed him. He was then convinced that the instrument was reading wrong and that they could impact the ground. The Commander did not trust his instruments until the aircraft came below the cloud layer and into visual flight conditions.

2.4.4.3 AIBN believes that knowledge about the postal aircraft and the experience in the simulator contributed to the Commander's rapid conclusion that they were not going to survive. It is logical for pilots who are suddenly exposed to an unusually substantial physical, operative and psychological pressure to potentially make erroneous conclusions or function at a different level than expected in a given situation.

2.4.4.4 *First Officer*

As the aircraft's pitch suddenly changed and the First Officer was subjected to strong negative G forces, he nevertheless saw that all three artificial horizons changed colour at the same time. He thus did not come to the same conclusion with regard to instrument error as the Commander did. The First Officer took over the controls and started to pull the yoke back. Experience shows that "pilot flying" often uses more of his/her cognitive capacity than "pilot monitoring," and the First Officer could therefore have been better suited to maintain his situational awareness, and start controlling the aircraft, than the Commander.

2.4.4.5 AIBN does not have technical data showing the Commander and First Officer's precise individual inputs on the yoke during the decisive seconds of the pull-out. Based on interviews with the crew, AIBN believe it is most likely that the First Officer took over the controls and initially was the most active pilot during the pull-out.

2.4.5 Crew Resource Management (CRM)

2.4.5.1 It appears as though the Commander had laid a plan for a shortest possible ground stop at Gardermoen even before take-off in Switzerland. Nothing has emerged in interviews between the Commander, the First Officer and AIBN to indicate that the First Officer expressed disagreement with the Commander as regards to carrying out the ground stop with one engine running. He also accepted the Commander's decision not to carry out de-icing.

2.4.5.2 After the incident, the First Officer stated that the ground stop was somewhat "rushed" and that he "was a bit behind". This was his first flight where de-icing was an issue and he wasn't sure if his feeling of not being comfortable with the situation was professionally justified or if it was due to inexperience. In the AIBN's opinion, the First Officer could have shared his concerns with the Commander during the ground stop at Gardermoen in line with good CRM.

2.4.5.3 During the actual flight, however, it was clear that the First Officer carried out his role in the cockpit as intended. He was Pilot Monitoring (PM) and completed his tasks in accordance with learned routines. When the incident occurred, the First Officer was aware of the aircraft's position and flight path and took control over the aircraft in accordance with the learned procedure for PM in accordance with CRM and "airmanship". AIBN believes it was decisive that the co-pilot started the recovery early so that a crash was avoided. The separation from the ground was only 170 ft when control was regained.

2.4.5.4 After the pull-out was completed, the co-pilot convinced the Commander that the instruments gave correct information. The AIBN believes that it was good CRM by the Commander to accept that the co-pilot wanted to re-enter the clouds. During the remainder of the flight, CRM worked as expected.

2.4.6 Pilot training

2.4.6.1 This accident sheds light on a dilemma: knowledge about aviation accidents and training for abnormal situations in the simulator is a lasting source of learning and professional updates for pilots. At the same time, this accident shows that precisely such knowledge appears to have contributed to one of the pilots ceasing to function for a few critical seconds. The question is thus how the airlines and individual pilots can prevent such unfortunate events by learning from accidents and abnormal situations in the simulator.

2.4.6.2 As a result of multiple LOC-I[3] accidents, the FAA and EASA have introduced requirements for training in Upset Prevention and Recovery (UPRT), which will better enable pilots to recognise the initial phases of abnormal flight attitude and correct the aircraft. Such training can be carried out in the simulator, which also trains the pilots in CRM. This accident is an example on the importance for pilots to exercise recovering from unusual and upset flight attitudes. Reports from previous investigations can with advantage be used in simulator training.

## 2.5 Organisational matters

2.5.1 The Accident Investigation Board considers it unfortunate that the Accountable Manager also held the positions of Safety Manager and Compliance Monitoring Manager. The trade-offs between commercial and safety considerations will by this organisation only be assessed and decided by a single person. The purpose of the requirement to have SM and CMM is to ensure that safety and quality work is given sufficient priority in the company.

2.5.2 The investigation has not shown a connection between the accident and the fact that AM was also SM and CMM. The AIBN believes equally that combining positions in this way is unfortunate and should be avoided for reasons of general aviation safety.

## 2.6 Supervisory matters

2.6.1 Both the Safety Manager (SM) and Compliance Monitoring Manager (CMM) should according to EASA's guidelines report to the Accountable Manager (AM). In this company, all three of these functions were held by one and the same person. The Civil Aviation Authority Norway had approved this organisation.

2.6.2 The EASA regulations (cf. paragraph 1.17.1) allow for one person to have multiple positions/functions. The Civil Aviation Authority Norway has stated to AIBN that it is highly restrictive as regards accepting that one person holds multiple positions in larger,

[3] Loss Of Control – In-flight.

complex organisations. The Civil Aviation Authority Norway considered Hesnes Air AS to be a complex organisation.

2.6.3 AIBN questions whether the Civil Aviation Authority Norway should change their routines for approving organisations in line with the intent of the EASA regulations. AIBN believes that the intent of roles that report to the AM is precisely to act as a corrective or a safety barrier in order to maintain expected safety.

## 2.7 Why the incident went well

2.7.1 When the aircraft suddenly bunted over by up to negative 2.62 G, the lap- and shoulder harness prevented the crew from being lifted from their seats. This means that both pilots were still fully capable of pulling their respective yokes back.

2.7.2 During the incident, the aircraft was exposed to overloads of negative 2.62 and positive 5.99 G. Both loads exceed the aircraft type's certification restrictions (cf. Item 1.6.6). Thus, Ultimate Load Factor of negative 2.16 and positive 5.40 G was exceeded with large structural damage to the aircraft as a result. It is significant that the pilots had to pull + 6 G's to avoid flying into the ground. With an automatic restriction of AOA and G loads, the aircraft would have impacted the ground.

2.7.3 The pilots' interactions contributed to a favourable outcome. The negative load was sudden and overwhelmed the pilots. At negative 2,62 G, the pilots were hanging by their safety harnesses and everything loose in the cockpit was flying around. They both experienced spatial disorientation. When the Commander (PF) was convinced that the instruments were reading wrong, the First Officer (PM) observed that all three artificial horizons were reading the same. He therefore trusted the instruments, took over the controls and pulled hard on the yoke. This was entirely in keeping with the role of Pilot Monitoring. The Commander actively contributed to the pull-out after gaining visual contact with the ground. The crew's action in this situation clearly demonstrates the importance of having two pilots solving difficult tasks together.

2.7.4 The First Officer started by immediately pulling hard on the yoke to pull out of the dive. The flaps had already been retracted and the only action remaining was to reduce engine power. This had been forgotten in the confusion, which resulted in the speed increasing rapidly to approximately 300 KIAS. However, AIBN believes that the rapid increase in speed provided a positive contribution toward clearing the tailplane stall and thus resulted in rapid control response.

2.7.5 One would have to pull very hard on the yoke to achieve positive 5,99 G. This is an indication that the First Officer, and eventually the Commander, realised the risk of impacting the ground during the pull-out and thus pulled as hard as they could. AIBN considers the situation the crew was in to be so extreme that it was the powerful pull-out with a high G load that saved them from a fatal accident.

## 2.8 Toxicological test / blood samples and the role of the police

AIBN is surprised that the police chose not to take blood samples once the crew themselves made contact and informed them that they had been involved in a serious incident. Pursuant to Section 6-13 of the Aviation Act, as quoted in paragraph 1.13.2, the police could have chosen to take blood samples of the crew. AIBN believes this should have been carried out, especially to eliminate the potential suspicion that a crew member under the influence was a factor contributing to the accident. AIBN has no grounds to presume that the crew were under the influence of drugs or alcohol and would like to commend the company and the crew for making a considerable effort to clarify this issue.

# 3. CONCLUSIONS

## 3.1 Primary conclusion

3.1.1 The probable explanation for the aircraft suddenly diving, is that the tailplane stalled. AIBN has not found other explanations for this than slush spray from the runway and falling snow and sleet settled on the tailplane's leading edge and underside during taxi and take-off. This contamination is presumed to have frozen to ice.

3.1.2 The aircraft's anti and de-icing systems on the wings and tailplane were switched on, but the tailplane de-icing system had completed a "cycle" before take-off and was in rest mode during take-off. In the assessment by AIBN, the aircraft's anti- and de-icing systems were not suitable to remove the type of ice and snow that had most likely settled on the aircraft's tailplane. The aircraft should have been de-iced before take-off, in line with the company's de-icing procedure, to avoid potential consequences of contamination on the tailplane.

3.1.3 This accident shows the significance of good crew resource management (CRM) in the cockpit when an unexpected and extreme flight situation occurs. In this instance, the First Officer's situational awareness and initial pull-out contributed to the aircraft not crashing.

## 3.2 Investigation results

a) The aircraft was registered in accordance with the regulations and had a valid environmental and airworthiness certificate.

b) The aircraft's mass and the location of its centre of gravity were within the permitted limits at the time of the incident.

c) The crew members had valid certificates and privileges for the aircraft type.

d) The crew has stated that they were sufficiently rested.

e) AIBN, in collaboration with the technical department of Hesnes Air and Textron Aviation, has been unable to prove technical malfunctions in the aircraft's control and trim systems that could have contributed to the accident occurring.

f) The Commander deviated from standard procedure during the ground stop at Gardermoen by leaving one engine running. This meant that the First Officer could not carry out a complete Pre-Flight Inspection as prescribed in the company's procedures.

g) The aircraft's systems to prevent and remove ice were functioning according to specifications and were switched on during take-off. However, AIBN believes that the tail surface de-ice system did not remove contamination under the prevailing icing conditions.

h) The crew planned a short ground stop at Gardermoen and chose not to de-ice the aircraft before take-off.

i) The fuselage, including the tailplane, was chilled after flying in low temperatures during the previous flight. The AIBN has not quantified to what extent this has contributed to a potential build-up of contamination.

j) Slush spray from the runway and falling snow and sleet most likely settled on the tailplane's leading edge and underside during taxi and take-off. This contamination is presumed to have frozen to ice. This reduced the tailplane's ability to produce negative lift.

k) The tailplane on LN-IDB most likely stalled as a result of ice mixed with snow that had frozen to the tailplane's leading edge and underside during taxi and take-off.

l) The weather conditions at Gardermoen and the company's procedures for de-icing indicated that the aircraft should have been de-iced before take-off.

m) The cooperation between the pilots (CRM) did not work optimally as intended during the ground stop at Gardermoen.

n) When the tailplane stalled, the Commander (PF) was convinced that the aircraft's instruments were indicating wrong.

o) Both pilots were highly affected by negative G forces, and experienced spatial disorientation.

p) The First Officer (PM) took over the controls and initiated the pull-out. After the loss of control and during the flight to Torp, the crew cooperation functioned well (CRM).

q) It was not economically viable to repair the aircraft due to the extent of the damage.

r) Allowing one person in a company to hold several key roles linked to safety work may have unfortunate consequences.

s) The investigation shows that there is a discrepancy between the CAA-N’s approval of organizations and what appears to be the intention in EASA’s regulations.

# 4. SAFETY RECOMMENDATIONS

The Accident Investigation Board Norway (AIBN) makes the following safety recommendations[4]

**Safety recommendation SL no. 2020/01T**

On Wednesday, 11 January 2017, the crew lost control of a Cessna 560 Encore at low altitude after take-off. The most probable explanation for the aircraft's sudden dive, is that the tailplane stalled as a result of icing from slush spray from the runway and from falling snow and sleet. The aircraft's rubber de-icing "boots" were in automatic mode and inactive during the take-off and when the stall occurred. Textron/Cessna has informed AIBN that they not previously have experienced loss of control as a result of icing on the tailplane on their aircraft models.

AIBN recommends that Textron/Cessna inform all its customers that operate Cessna Citations about this accident and about the risk of contamination on the tailplane in the form of ice or other substances witch can result in the tailplane stalling.

**Safety recommendation SL no. 2020/02T**

On Wednesday, 11 January 2017, the crew lost control of a Cessna 560 Encore at low altitude after take-off. The Accountable Manager (AM) held several key roles within safety. The presumably monitoring and corrective roles, as appears to be the intend through EASA’s PART-ORO, were thus absent.

AIBN recommends that the Civil Aviation Authority Norway changes its routines for approving organisations in line with the intent of the EASA regulation.

Accident Investigation Board Norway

Lillestrøm, 30 January 2020

[4] The Ministry of Transport ensures that safety recommendations are presented to the aviation authorities and/or other relevant ministries for assessment and follow-up, cf. Section 8 of the Regulations relating to public investigation of air traffic accidents and incidents in civil aviation.

# APPENDICES

# APPENDIX A: ABBREVIATIONS

| | |
|---|---|
| AAIB | Air Accidents Investigation Branch |
| AFM | Aircraft Flight Manual |
| AGL | Above Ground Level |
| AIC | Aeronautical Information Circular |
| AM | Accountable Manager |
| AMC | Acceptable Means of Compliance |
| AOA | Angle Of Attack |
| AOC | Air Operator Certification |
| ARB | Airworthiness Review Board |
| ATC | Air Traffic Control |
| ATPL | Airline Transport Pilot Licence |
| CAA-N | Civil Aviation Authority Norway |
| CG | Centre of Gravity |
| CL | Centre of Lift |
| CMDR | Commander |
| CMM | Compliance Monitoring Manager |
| CPL | Commercial Pilot Licence |
| CRM | Crew Resource Management |
| CVR | Cockpit Voice Recorder |
| EASA | European Aviation Safety Agency |
| EGPWS | Enhanced Ground Proximity Warning System |
| FAA | Federal Aviation Administration |
| FD | Flight Director |
| FDR | Flight Data Recorder |
| FMS | Flight Management System |
| FL | Flight Level |
| FTE | Full Time Employees (Unsure whether this is the correct term?) |
| GA | General Aviation |
| GM | Guidance Material |

| | |
|---|---|
| HA | Hesnes Air AS |
| hPa | hectopascal (air pressure) |
| ICAO | International Civil Aviation Organization |
| IR | Instrument Rating |
| IMC | Instrument Meteorological Conditions |
| KIAS | Knots Indicated Airspeed |
| Kt | Knots (nautical miles pr hour) |
| LLF | Limit Load Factor |
| LT | Luftfartstilsynet (Civil Aviation Authority Norway) |
| LOC-I | Loss of Control In-flight |
| METAR | Meteorological Aerodrome Report |
| MCA | Manager Continuing Airworthiness |
| MCT | Manager Crew Training |
| MEL | Minimum Equipment List |
| MFO | Manager Flight Operations |
| MGO | Manager Ground Operations |
| MM | Management Meeting |
| MSM | Management System Manual |
| MSL | Mean Sea Level |
| NASA | National Aeronautics and Space Administration |
| NTSB | National Transportation Safety Board |
| OM | Operations Manual |
| ORO | Organisation Requirements for Air Operations |
| PF | Pilot Flying |
| PFI | Pre-flight Inspection |
| PM | Pilot Monitoring |
| SIGMET | Significant Meteorological Information |
| SM | Safety Manager |
| SOP | Standard Operating Procedures |
| SRB | Safety Review Board |
| TAF | Terminal Aerodrome Forecast |

| | |
|---|---|
| TAWS | Terrain Awareness and Warning System |
| TSO | Technical Standard Order |
| ULF | Ultimate Load Factor |

TEXTRON AVIATION
WICHITA CITATION SERVICE CENTER
2121 S HOOVER RD
WICHITA KS 67209-2821

Customer Service Team Structures

MODEL NO: 560 REPORT NO: DE-560-0637-CG

# On-Site Damage Assessment

Damage to Left & Right Hand Stub Wings During Flight.

REPORT DATE: 24 February 2017

PREPARED BY: Craig Ganderton
Textron Aviation Customer Support
Structures Engineer

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Textron Aviation
2121 S Hoover Rd
Wichita, Kansas 67209-2821

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Report DE-560-0637-CG
Aircraft 560-0637

## 1.0 BACKGROUND

Operator: Hesnes Air AS
Registration: LN-IDB
Hours: 3847:47
Cycles: 2730

Summary: On Wednesday 11 January 2017, the aircraft took off from Oslo-Gardermoen Airport, Norway for a short flight to Sandefjord-Torp Airport, Norway. At 2,000ft the aircraft went into a steep dive, the pilot regained control at 200ft. The aircraft then landed at Sandefjord-Torp Airport without any further incident. A significant crease was found on both left and right upper stub wings.

An on-site damage evaluation was requested and was conducted by Textron Aviation Customer Service on 20 February 2017.

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**Figure 1.0 Major Damage Locations on the Model 560**

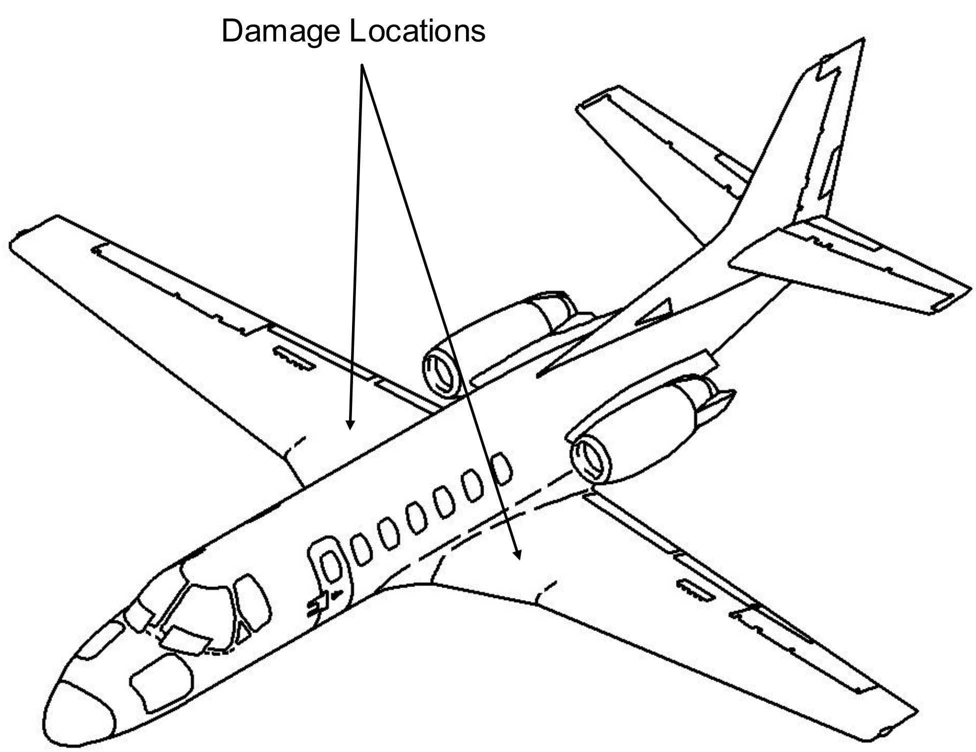


Figure 1.1 View of aircraft after being recovered


Figure 1.3 LH Wing Damage Locations

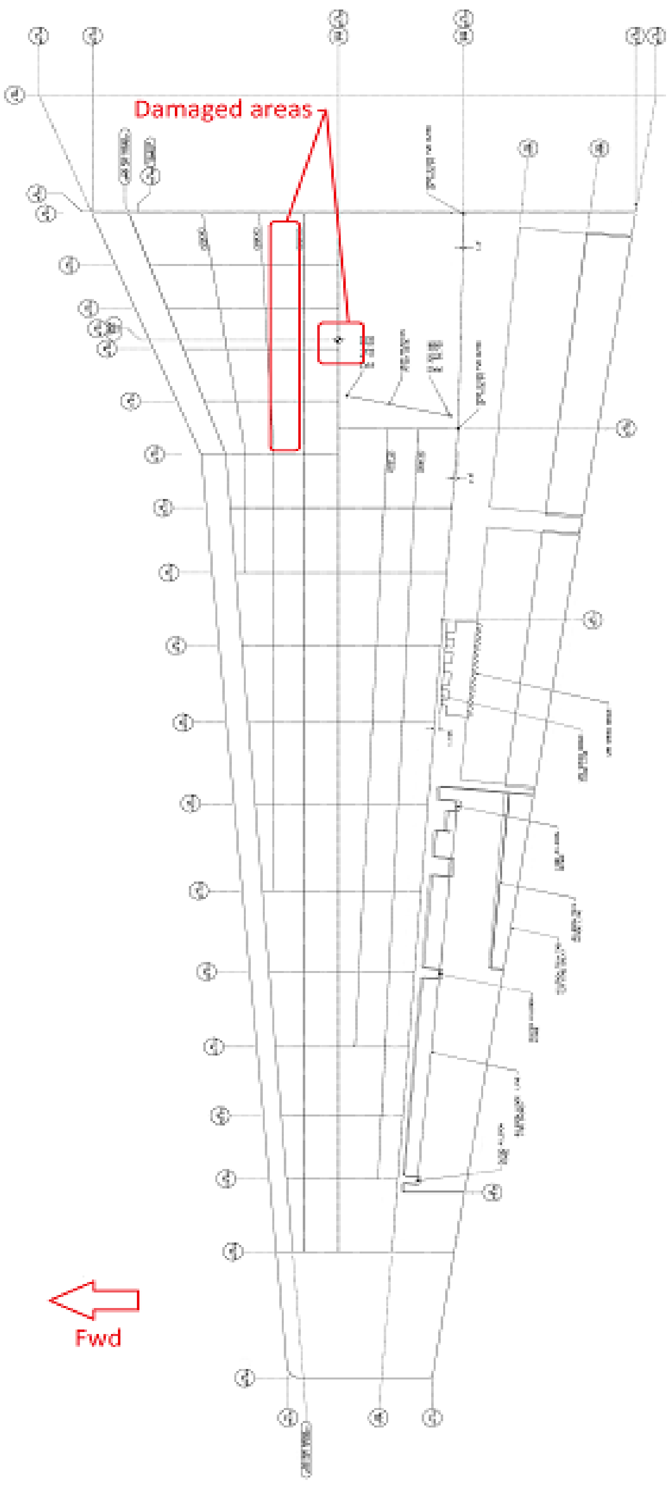
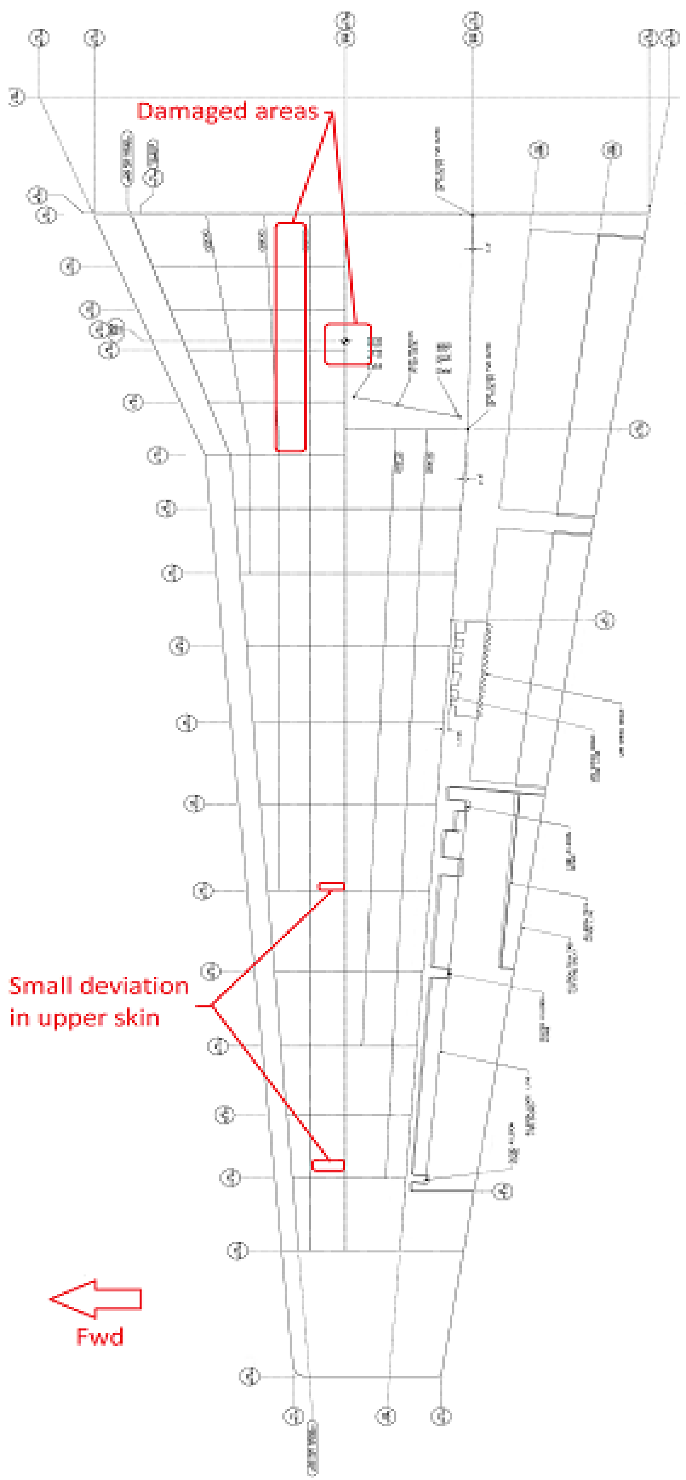
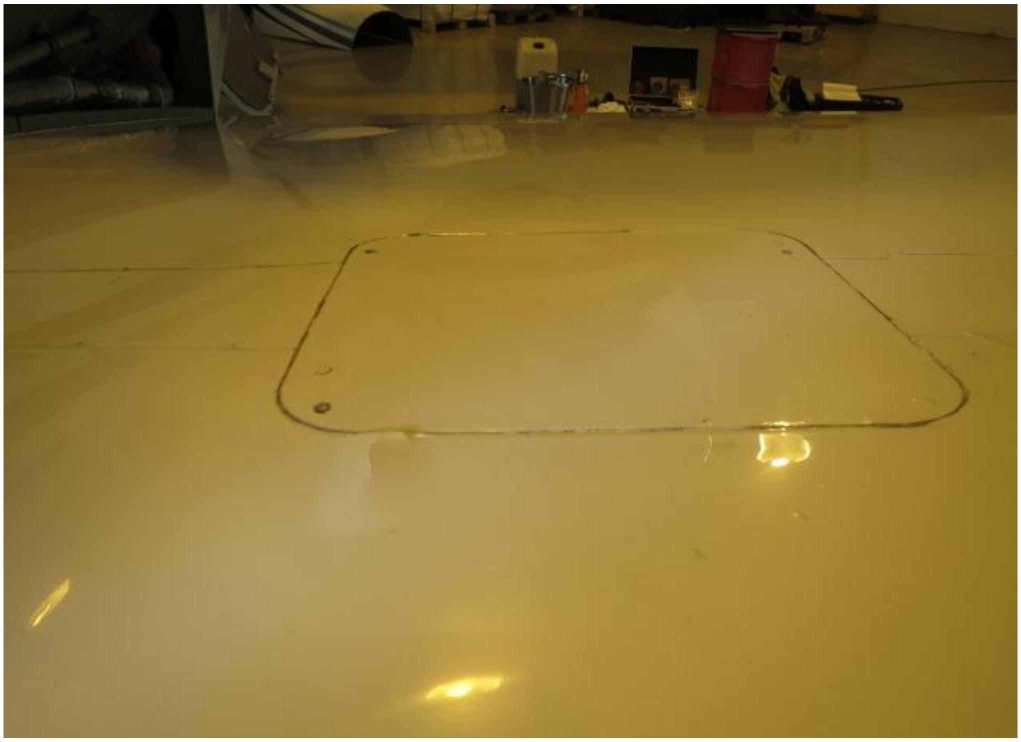



Figure 1.4 RH Wing Damage Locations


Damaged areas
Small deviation in upper skin
Fwd

1.4 Crease in LH Upper Stub Wing Skin - WS 60.50



1.5 Crease in RH Upper Stub Wing Skin - WS 60.50

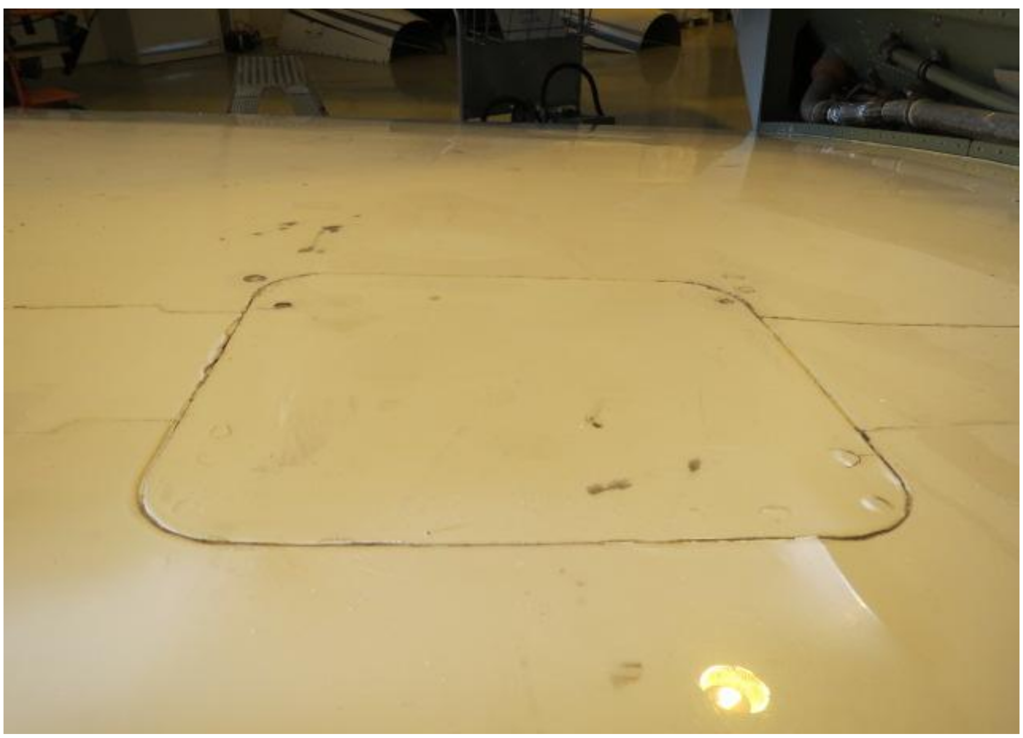


Figure 1.6 Raised Areas on RH Upper Stub Wing Skin

Figure 1.7 Raised Areas on LH Upper Stub Wing Skin

Figure 1.8 Contour Deviations – LH & RH Fuselage Side Skin and Engine Nacelle Upper Skins

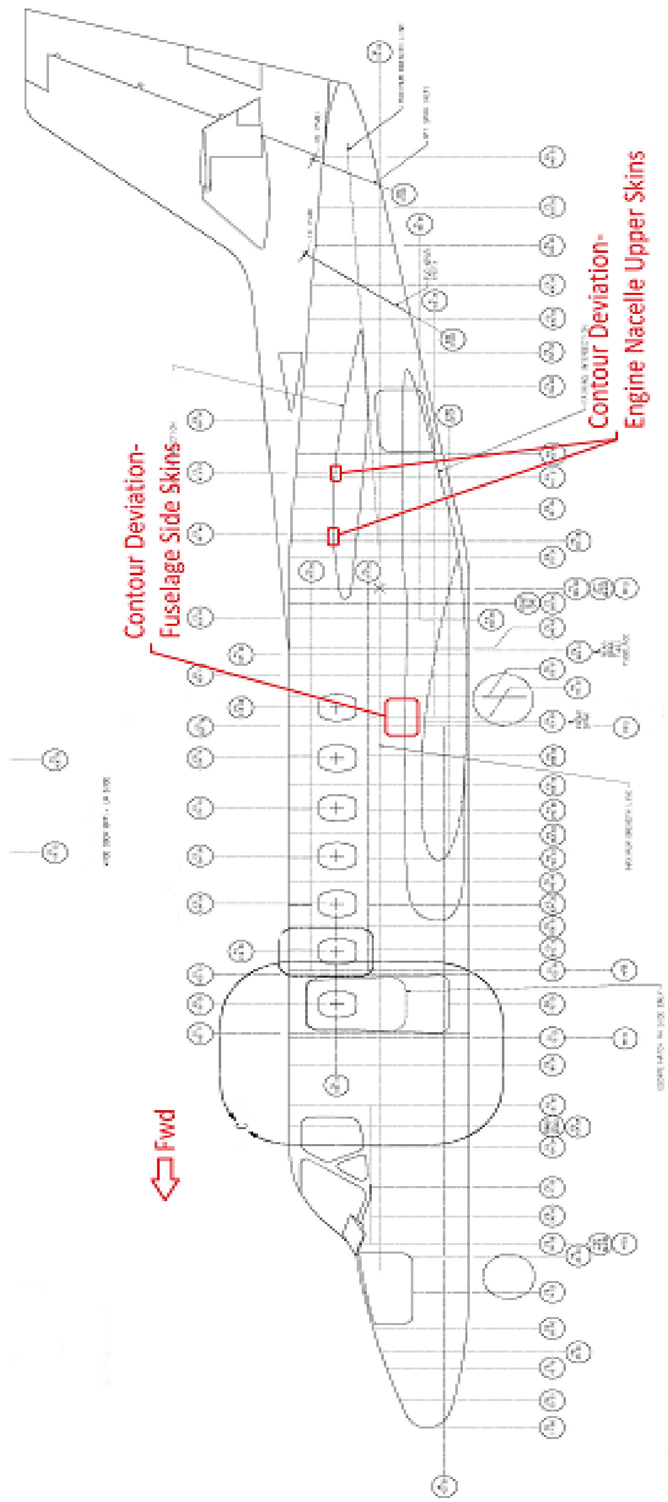


Fig 1.9 RH Fuselage Side Skin Contour Deviation – FS 309.90

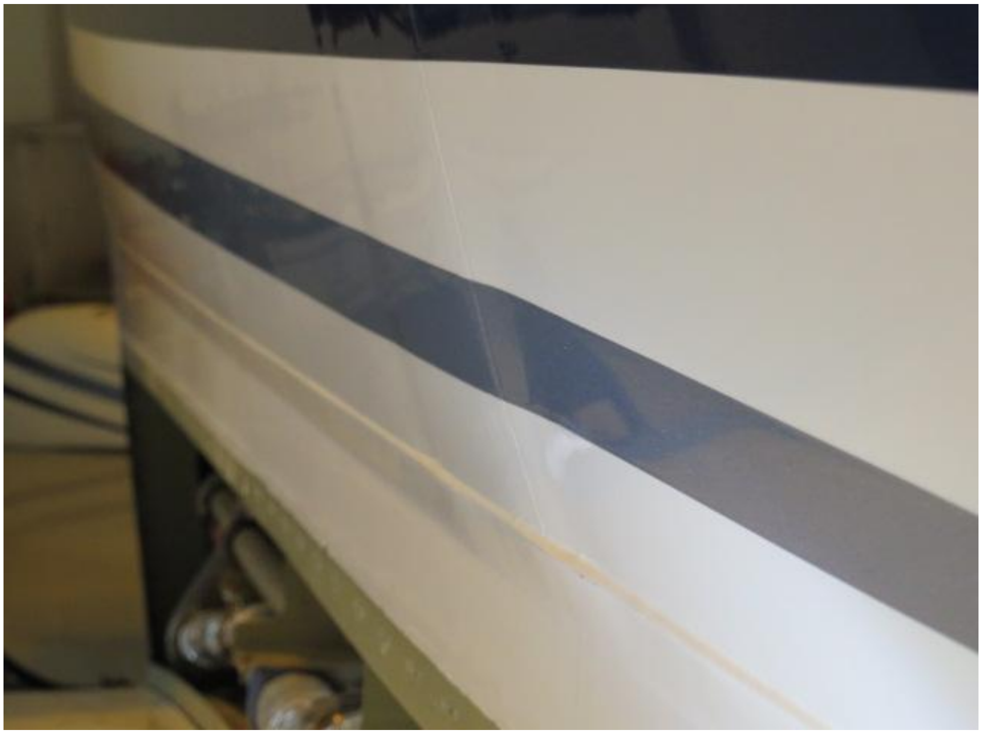


Fig 1.10 LH Fuselage Side Skin Contour Deviation FS 309.90

Figure 1.11 Fuselage Side Skin Contour Deviation FS 309.90

Figure 1.12 LH Engine Nacelle Upper Skin Deviations – FS 387.48 & FS 413.07

Figure 1.13 RH Engine Nacelle Upper Skin Deviations – FS 387.48 & FS 413.07

## 2.0 GENERAL ASSESMENT GUIDELINES

The following assessment in Section 3.0, listed by ATA chapter, provides a description and location of structural damage, a parts list, as well as recommended repairs where applicable. All Textron Aviation developed repairs will be designed and incorporated, such that the inspection program as specified in Chapter 5 of the Model 560 Series Maintenance Manual will remain unchanged and that the original, certified configuration of the aircraft will also remain unchanged.

It should be noted that this damage assessment provides part numbers of assemblies/installations that may come with additional parts that are not needed. Fabricating assemblies/installations in this method will facilitate the existing manufacturing process and reduce the overall purchase costs when compared to the fabrication of a non-production partial assembly/installation. In general, all of the part numbers provided are the part numbers during original manufacturing. Actual part numbers delivered may in fact be replacement part numbers.

The scope of this damage assessment does not take into account any damage that may have occurred to the engines, electrical, avionic, hydraulic and pneumatic systems, as well as all other non-structural items. These items must be evaluated within the appropriate publication or returned to the manufacturer for inspection and disposition.

Due to the limited access to the sub-structure, along with paint/primer coverage, some damage may not have been discovered during the on-site evaluation. The following evaluation is based on the access that was available at the time of the on-site evaluation.

3.0 DAMAGE ASSESMENT

## 1.1 Chapter 27 Flight Controls

Condition #1: Excessive forces were applied to all flight controls during the flight.

Disposition: *All flight control cables and runs should be inspected for damage to pulley brackets and other support structure. All cables should be replaced.

## 1.2 Chapter 53 Fuselage

Condition #2: LH & RH Wing Spar/Carry-Thru Spar Lugs.

Disposition: **Perform "Main Carry-Thru To Wing Spar" Inspection in accordance Model 500 Series NDT Manual, Part 4 53-10-03.

Condition #3: Creases to both left & right hand stub wing upper skin at approximately WS 60.50.

Disposition: Remove and replace in accordance with the appropriate chapters of the Model 560 Maintenance Manual & Structure Repair Manual.

| P/N | Description | Reference |
|---|---|---|
| 6521220-1 | Skin Bond Assy – LH Upper | IPC 53-30-00 |
| 6521220-2 | Skin Bond Assy – RH Upper | IPC 53-30-00 |
| 6522672-3 | Access Panel – LH & RH | N/A |

Condition #4: Small creases to left & right hand stub wing upper skin access panels between WS 30.073 – WS 91.073.

Disposition: Remove and replace in accordance with the appropriate chapters of the Model 560 Maintenance Manual & Structure Repair Manual.

| P/N | Description | Reference |
|---|---|---|
| 6521548-1 | Access Door Bond Assy – LH & RH | IPC 53-30-00 |
| 6521548-18 | Access Door Bond Assy – LH & RH | IPC 53-30-00 |
| 6521548-5 | Access Door Bond Assy – LH & RH | IPC 53-30-00 |
| 6511166-51 | Access Door Bond Assy – LH & RH | IPC 53-30-00 |

Condition #5: Contour deviations to left and right hand fuselage side skins – FS 309.90

Disposition: *Visually inspect the fuselage external and internal structure and skins at the surrounding areas for buckled components. Access was limited at the time of the Structural Damage Evaluation. Further inspection is required to verify there is no failure of the substructure components.

| P/N | Description | Reference |
|---|---|---|
| 6511335-5 | Skin Assy – LH Center Bonded | IPC 53-30-00 |
| 6511335-6 | Skin Assy – RH Center Bonded | IPC 53-30-00 |

Condition #6: LH & RH Main Spar Carry-Thru Spar.

Disposition: **Perform "Main Spar Carry-Thru Assembly" Inspection in accordance with Model 500 Series NDT Manual, Part 6 53-10-02.

## 1.3 Chapter 55 Stabilizers

Condition #7: Horizontal Stabilizer – LH & RH.

Disposition: *Visually inspect the horizontal stabilizer structure, skins and attachments for buckled or cracked components. Access was limited at the time of the Structural Damage Evaluation. Further inspection is required to verify there is no failure of the substructure components.

| P/N | Description | Reference |
|---|---|---|
| 6532000-32 | Stabilizer Assy | IPC 55-10-00 |

Condition #8: Elevators – LH & RH.

Disposition: *Visually inspect the vertical fin structure, skins and attachments for buckled or cracked components. Access was limited at the time of the Structural Damage Evaluation. Further inspection is required to verify there is no failure of the substructure components.

| P/N | Description | Reference |
|---|---|---|
| 6534000-45 | Elevator - LH | IPC 55-20-00 |
| 6534000-46 | Elevator - RH | IPC 55-20-00 |

Condition #9: Vertical Fin.

Disposition: *Visually inspect the vertical fin structure, skins and attachments for buckled or cracked components. Access was limited at the time of the Structural Damage Evaluation. Further inspection is required to verify there is no failure of the substructure components.

| P/N | Description | Reference |
|---|---|---|
| 6531011-1 | Vertical Fin - Assy | IPC 55-10-00 |

Condition #10: Rudder.

Disposition: *Visually inspect the rudder structure, skins and attachments for buckled or cracked components. Access was limited at the time of the Structural Damage Evaluation. Further inspection is required to verify there is no failure of the substructure components

| P/N | Description | Reference |
|---|---|---|
| 6633000-31 | Rudder - Assy | IPC 55-40-00 |

Condition #11: Vertical & Horizontal Stabilizers and installation locations.

Disposition: *Visually inspect the stabilizer structure and skins for buckled or cracked components. Access was limited at the time of the Structural Damage Evaluation. Further inspection is required to verify there is no failure of the substructure components.

| P/N | Description | Reference |
|---|---|---|
| 0531006-114 | Vertical Stabilizer Assy | IPC 55-30-00 |
| 2432000-4 | Stabilizer Assy | IPC 55-10-00 |

## 1.4 Chapter 57 Wings

Condition #12: LH & RH Wing Assembly.

Disposition: *Visually inspect the wing structure and skins for buckled or cracked components. Access was limited at the time of the Structural Damage Evaluation. Further inspection is required to verify there is no failure of the structural components.

| P/N | Description | Reference |
|---|---|---|

| | | |
|---|---|---|
| 6522201-1 | Outbd Wing Assy – LH | N/A |
| 6522201-2 | Outbd Wing Assy - RH | N/A |

Condition #13: LH & RH Wing Inboard Main Spar.

Disposition: **Perform “Inboard Lower Main Wing Spar Cap And Spar Strap Inspection” in accordance with Model 500 Series NDT Manual, Part 6 57-10-03.

Condition #14: LH & RH Wing Outboard Main Spar.

Disposition: **Perform “Outboard Lower Main Wing Spar Cap And Strap Inspection” in accordance with Model 500 Series NDT Manual, Part 6 57-10-04.

Condition #15: LH & RH Wing Main Spar.

Disposition: **Perform “Outboard Lower Main Wing Spar Cap And Spar Cap Inspection” in accordance with Model 500 Series NDT Manual, Part 6 57-10-04.

Condition #16: LH & RH Wing Inboard Rear Spar.

Disposition: **Perform “Inboard Lower Rear Wing Spar Cap Inspection” in accordance with Model 500 Series NDT Manual, Part 6 57-10-05.

Condition #17: LH & RH Wing Outboard Rear Spar.

Disposition: **Perform “Outboard Lower Rear Wing Spar Cap And Strap Inspection” in accordance with Model 500 Series NDT Manual, Part 6 57-10-06.

Condition #18: LH & RH Ailerons.

Disposition: *Visually inspect both the LH & RH ailerons for buckled or cracked components. Access was limited at the time of the Structure Damage Evaluation. Further inspection is required to verify there is no failure of the substructure components.

| P/N | Description | Reference |
|---|---|---|
| 6524113-9 | Aileron Assy – LH | IPC 57-60-00 |
| 6524010-10 | Aileron Assy – RH | IPC 57-60-00 |

Condition #19: LH & RH Inboard/Outboard Flaps.

Disposition: *Visually inspect both LH & RH flaps for buckled or cracked components. Access was limited at the time of the Structure Damage Evaluation. Further Inspection is required to verify there is no failure of substructure components.

| P/N | Description | Reference |
|---|---|---|
| 6525130-37 | Flap Assy – LH Inbd | IPC 57-50-01 |
| 6525130-38 | Flap Assy – RH Inbd | IPC 57-50-01 |
| 6525135-35 | Flap Assy – LH Outbd | IPC 57-50-01 |
| 6525135-36 | Flap Assy – RH Outbd | IPC 57-50-01 |

*A complete visual inspection is to be performed of the wings, flaps, fuselage, stabilizers, rudder, elevators and ailerons in accordance with the appropriate chapters of the Model 560 Maintenance Manual and Model 560 Structure Repair Manual. If additional damage is found please contact Textron Aviation Customer Support Team Structures for disposition.

Perform the following Unscheduled Maintenance Checks for “Hard or Overweight Landing Check”, “Severe Turbulence and/or Maneuvers Checks” and “Overspeed Check” in accordance with the Model 560 Maintenance Manual 5-50-00.

**Perform NDT inspections in accordance with the Model 500 Series Nondestructive Testing Manual. If additional findings are found please contact Textron Aviation Customer Support Team Structures for disposition.

## 4.0 GENERAL

This report may be used as a guide for repair facilities to provide a bid for the cost of return to service.

Inspection, removal, testing, and reinstallation of all components which have been affected by the damage incident and/or subsequent repair, must be referenced to the applicable Textron Aviation Engineering repair drawings, the Model 560 Maintenance Manual, the Model 560 Structural Repair Manual and/or the applicable vendor manual/recommendations.

Should there be additional structural items be found damaged which are not addressed by this damage evaluation document, by the repair description, or by the documents listed in the General section of this report, contact Textron Aviation Customer Support Team Structures for disposition.

Care must be taken during the disassembly phase of the repair to avoid over-sizing the fastener holes. Existing fasteners should be identified and marked adjacent to the holes on the part to be removed before their removal. The removed part can then be used as a guide for fastener installation. If at any point there is any question as to which fastener should be used, contact Textron Aviation Customer Support Engineering. The manufacturing drawings will be researched and the correct data provided.

It is recommended that all of the major ID inspections be accomplished in conjunction with the repairs. The inspection and repair documentation can be used as a basis for the return to service of this aircraft. Any deviation from the manufacturer's recommendations contained within this report may result in loss of their ability to provide engineering, technical support or parts for this aircraft.

If the decision is made to repair certain damaged parts of the aircraft; Structures Engineering can evaluate and disposition the areas recommended for repair in Section 3.0. Although it is not appropriate to include engineering costs in this document, they can be provided to the repairing facility upon request once the repair evaluation is complete.

Part costs and back ordered part lead times must be obtained by contacting Textron Aviation Parts Department (TAPD +1-316-517-5603 or parts@txtav.com.

# Most Pilots Don't Know How To Recover From This Type Of Stall

- By Swayne Martin
- 12/22/2015
- Boldmethod.com

As pilots, most of us are familiar with structural icing and the dangerous, sometimes fatal, situations it can cause. But did you know that icing on your horizontal stabilizer can result in a tailplane stall that requires opposite stall recovery techniques?

## Aircraft That Are Affected

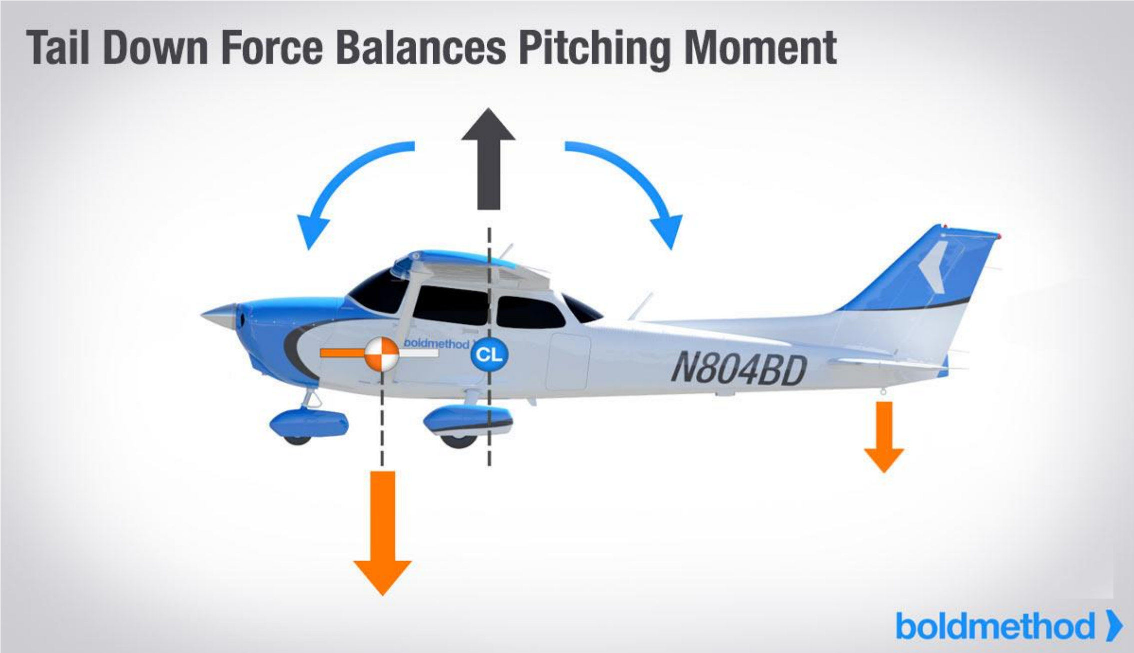
A tailplane is another word for your horizontal stabilizer. Aircraft that use unpowered controls (those that use aerodynamic balance) to keep stick controls neutral are most susceptible to tailplane icing. In general, this applies to aircraft with a fixed leading edge horizontal stabilizer, where the elevator moves and is held neutral during flight by elevator trim tabs.

Tailplane stalls result from ice accumulation on the leading edge of the horizontal stabilizer. So airplanes with no de-icing or anti-icing systems that fly into icing conditions are most at risk. And even if you have a known-ice equipped aircraft, if your equipment fails or isn't used properly, you'll be just as susceptible. *Throughout the article, remember that tailplane icing stalls are uncommon and most frequently seen on mid-sized turbo-prop aircraft flying through icing conditions.*

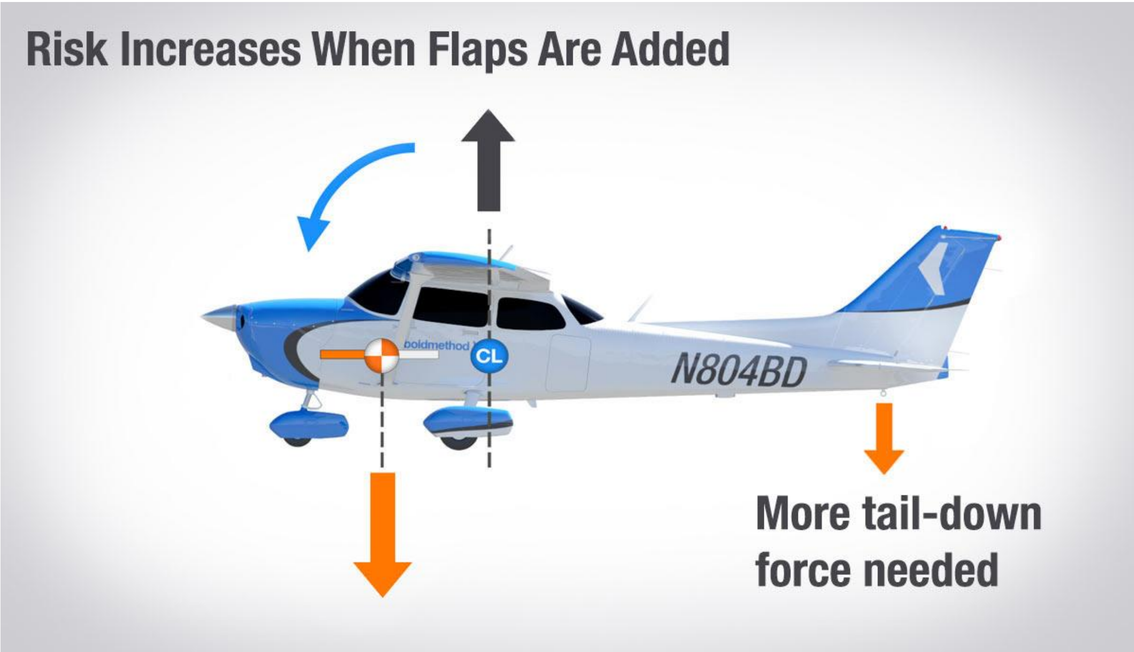
Jason Pineau

## When Tailplane Icing Occurs

As you probably know, in straight and level flight, the vertical forces acting on an aircraft are weight (downward), the wing's lift (upward), and the tail's component of lift (downward, which is also called "tail-down force"). Since the center of gravity is almost always forward of the aircraft's center of lift, a downward pitching moment is created which must be counteracted by tail-down force. And to achieve this downward lift, the tailplane is designed like an upside-down wing.

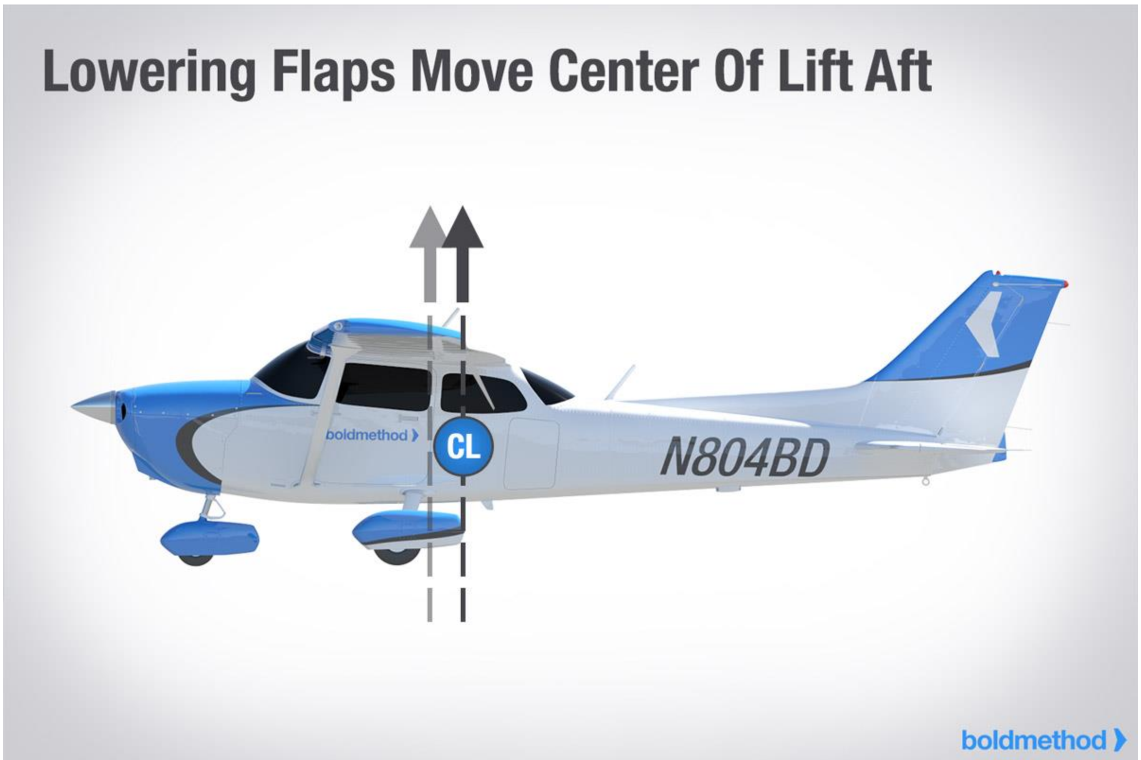



During cruise, ice isn't as big of a concern on the tail as it is on the wings. This is because the the tail is usually at a low angle of attack and nowhere near performance limits. Any separated airflow around the tailplane stays relatively close to the ice buildup, allowing a majority of the effective airflow to remain attached around the tailplane and elevator. This changes and the greatest risk of a tailplane stall occurs when you increase flaps, or sometimes, power.

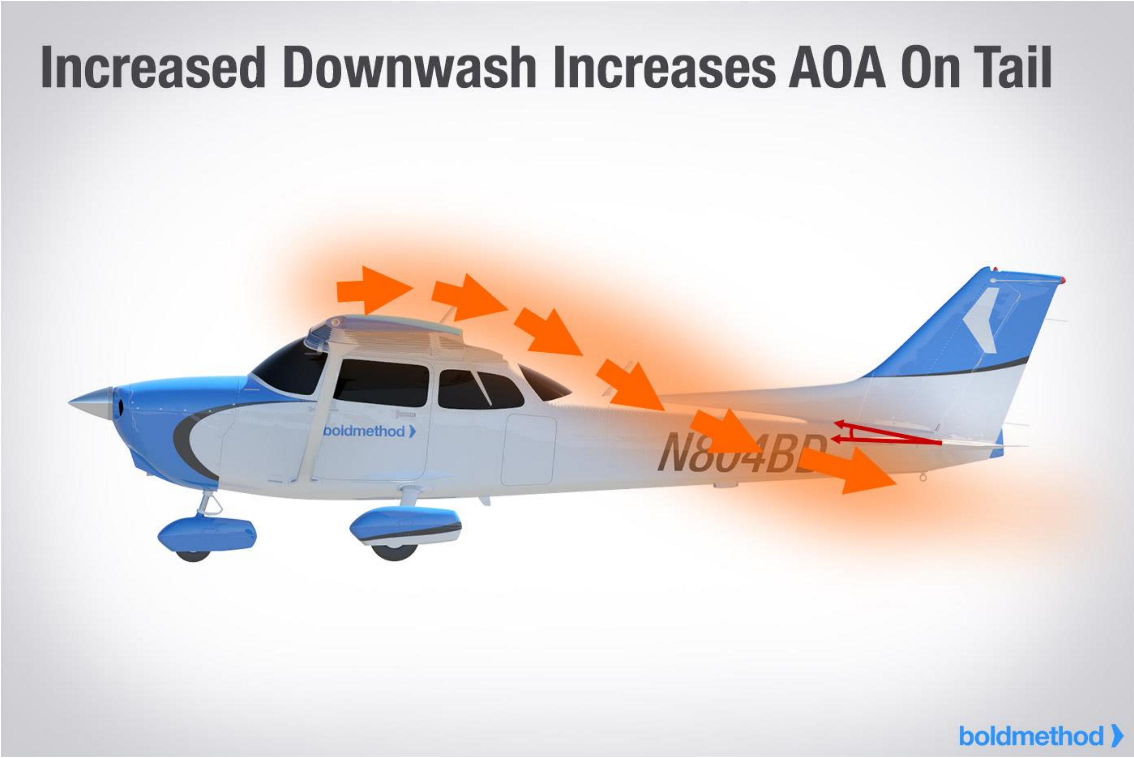



A few things happen as you add flaps:

**1) The wing's center of lift moves aft**, creating a large pitching down moment that the horizontal stabilizer must counteract.

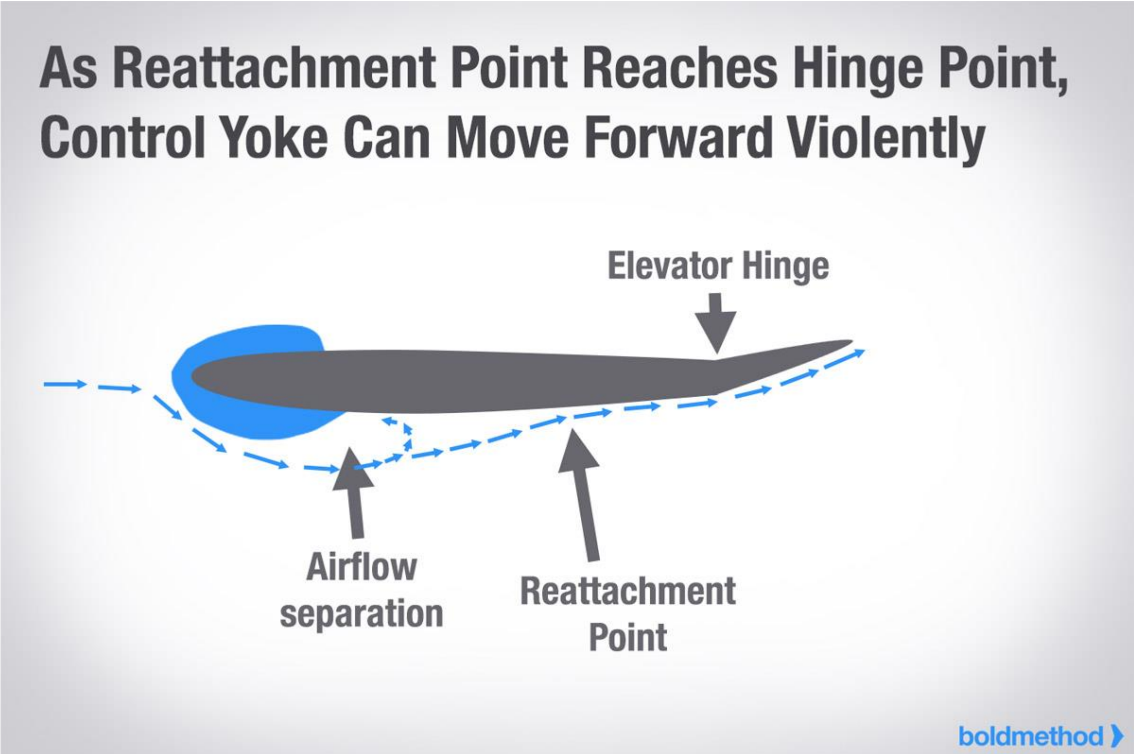



**2) The tail's angle of attack increases** due to the increased wing downwash.




**3) More downward lift may be required** as the aircraft reaches equilibrium. This is accomplished by pulling back on the yoke and moving the elevator's trailing edge upward. Consequently the flap extension drives the horizontal stabilizer towards its critical angle of attack.


This is when tailplane icing becomes a serious problem. Even a small amount of icing will interfere with airflow around the lower surface of the horizontal stabilizer, resulting in airflow separation. So as angle of attack increases, the re-attachment point for separated airflow moves aft. If this new re-attachment point extends over enough of the elevator, beyond the hinge point, the moveable elevator control surface will fill the airflow void and move downward, causing the airplane to pitch downward.



In short, large flap deflections, which produce large amounts of downwash, result in high angles of attack on the tailplane. With any ice accumulation on the leading edge of the horizontal stabilizer, increasing flaps, and sometimes power, will increase airflow separation around the tailplane. This is when you're most at risk for a tailplane stall.

## Warning Signs

Although they differ based on aircraft and airfoil type, here are some of the common warning signs that NASA discovered when it comes to tailplane stalls:

1. **-Lightening of the controls (stick feels light in the forward direction)**
2. **-Difficulty trimming the airplane**
3. **-Onset of pilot induced oscillations**
4. **-Buffeting in the controls, not the airframe**

Most of these symptoms were noted with flaps at full deflection. In extreme conditions, a rapid pitch down control pulse can be felt and recovery may be impossible on final approach due to low-altitude. Also, if you're flying on autopilot, you'll probably miss many of these signs because you won't get any tactile feedback from the controls.

## Wing Stall vs. Tailplane Stall

In a conventional wing stall, the airplane pitches down due to a loss of lift. A tailplane stall also results in pitching down, but because tail-down force has been lost. This is why stall recovery techniques are opposite. Aircraft flight manuals can differ, but here are NASA's general guidelines to recovery:

**Wing Stall Recovery:**

1. -Add Power
2. -Relax back pressure or push yoke forward

**Tailplane Stall Recovery:**

1. -Pull back on the yoke
2. -Reduce Flaps
3. -Reduce Power: This is aircraft specific based on engine location in relation to CG and how power changes angle of attack. *(Engines mounted above the CG will create a stronger pitching down moment as power increases)*

## Identifying The Stall

Identifying a wing stall vs. a tailplane stall isn't easy since the differences in warning signs are subtle. You need to be able to differentiate airframe buffet from control buffet. With airframe buffet, you will get feedback through the seat of your pants, as opposed to just the buffeting of the controls in a tailplane stall. **The greatest risk pilots face is misinterpreting a stall incorrectly, be it a wing stall or rare tailplane stall.**

Aircraft configuration and speed is another way to identify the stall correctly. If flaps are lowered at the higher end of flap extension speed limits and there is an elevator control buffet, chances are there is a tailplane icing problem. The higher the speed with flaps extended, the more susceptible the aircraft is to a tailplane stall.


Jason Pineau

## What You Can Do

If the aircraft is equipped with a pneumatic de-icing system, it goes without saying that you'll want to activate the system several times to try to clear the ice off of your horizontal stabilizer. If you still experience problems, you might have to land with reduced flaps. And if you're airplane isn't equipped with a de-icing system, exit icing conditions as quickly as possible and make a judgement on how quickly you need to land. Just remember how you were trained to deal with icing encounters and be aware that changing aircraft configuration could put you at greater risk of a tailplane stall.

Jason Pineau

Easy enough, right? If the leading edge of your horizontal stabilizer accumulates ice and airflow separation increases around the tailplane due to an increased angle of attack, you're at great risk for a tailplane stall. And while tailplane stalls may be uncommon, knowing the warning signs and recovery techniques could save you from a potentially devastating accident.

# Akseptering av ledende personell i luftfartselskaper

AIC-N 02/17 26 JAN

**Generelt**

Denne AIC-N erstatter AIC-N 24/16.

Reglene om akseptering av ledende personell i luftfartsselskaper finnes i det felleseuropeiske regelverket for sivil luftfart som gjelder i Norge.

Kravene til ledende personell er beskrevet i regelverket som gjelder på det enkelte området. Generelt vurderes imidlertid hver enkelt kandidats erfaring, kompetanse, personlige egenskaper og holdninger, i forhold til virksomhetens kompleksitet, størrelse og omfang.

Oversikten under viser hvor man finner reglene om de enkelte stillingene.

**Flere stillinger**

Reglene åpner i noen grad for at en person kan inneha flere stillinger. Vilkårene for dette er angitt i de respektive regelverkene. Kombinasjon av flere stillinger krever i alle tilfeller tillatelse fra Luftfartstilsynet etter en skjønnsmessig vurdering. Dersom en person skal inneha flere stillinger må vedkommende i det minste tilfredsstille kvalifikasjonskravene for alle stillingene. I tillegg vil det måtte vurderes hvorvidt det anses overkommelig og forsvarlig at vedkommende skal ivareta oppgavene som ligger til stillingene.

**Søknad**

Søknad om akseptering av ledende personell sendes til:
Luftfartstilsynet
P.O.Box 243
NO-8001 Bodø

Søknaden skal inneholde oversikt over kandidatens utdanning og erfaring, relevante sertifikater og rettighetsbevis.

For stilling som "Nominated person" (NP) skal det legges ved utfylt EASA form 4, som finnes på Luftfartstilsynets nettside under fanen: aktører > skjema > nominering av ledende personell.

Der forutsettes at selskapet gjør et Assesment/vurdering av kandidaten til den pågjeldende stillingen, som vedlegges søknaden.

For stilling som ansvarlig leder ("Accountable manager") skal det også vedlegges uttømmende politiattest som er utstedt i Norge eller et annet EØS-land, og som ikke er eldre enn tre måneder.

Som del av Luftfartstilsynets behandling av søknad om akseptering av ledende personell vil Luftfartstilsynet innkalle kandidaten til en samtale. For visse typer stillinger krever Luftfartstilsynet også at kandidaten avlegger en prøve.

## Accountable manager

**Regelverk:**

- Forskrift om lufttransporttjenester i EØS (BSL A 2-1) og tilhørende forordning 1008/2008, artikkel 7
- Forordning 965/2012, Part-ORO (bl.a. ORO.GEN.210, ORO.AOC.100) med tilhørende AMC og GM.
- Forordning 1321/2014, Part M, M.A. 706. Se også AIC-N 01/17.

**Veiledende kompetansekrav**
Det forventes bred kjennskap til virksomheten, samt generell kjennskap til de aktuelle luftfarts-bestemmelsene.
Forventet kunnskap om regelverk og annen dokumentasjon er angitt i vedlegg 1.
Det legges også vekt på om plasseringen av stillingen innebærer reell myndighet og økonomisk råderett.

**Merknad**
Kandidat innkalles til samtale.

## NP Flight OPS

**Regelverk**
Forordning 965/2012, Part ORO (bl.a. ORO.GEN.210, ORO.AOC.100, ORO.AOC.135, ORO.SPO.100) med tilhørende AMC og GM.

**Veiledende kompetansekrav**
Vedkommende bør ha relevant utdanning og flygererfaring fra et luftfartsforetak med tilsvarende operasjoner som vedkommende søkes akseptert inn i.
Vedkommende bør ha minst 5 års relevant praksis, hvorav minst 2 år tilknyttet administrativ luftfartsvirksomhet.

Vedkommende bør inneha eller innehatt flygersertifikat med rettigheter som er relevant for operasjonen som skal utføres i regi av de aktuelle luftfartsselskapet. Dersom vedkommende ikke innehar et slikt gyldig sertifikat, kreves det at selskapet har oppnevnt en assisterende flygesjef som innehar et slikt sertifikat med tilhørende gyldige rettigheter.

Vurdering av vedkommende baseres på en samlet vurdering av faglige kvalifikasjoner, tidligere praksis og personlige egenskaper, herunder tidligere utvist forståelse og respekt for luftfartsloven med tilhørende forskrifter. Vurderingen foretas på bakgrunn av luftfartsforetakets operasjonsområde. I et større luftfartsforetak eller foretak med vidt operasjonsspektrum der vedkommende kan basere seg på støtte fra en operativ organisasjon, vurderes kvalifikasjonene i lys av dette.

Se også GM2 ORO.AOC.135(a) og GM2 ORO.SPO.100(a) (dersom relevant)
Forventet kunnskap om regelverk og annen dokumentasjon er angitt i vedlegg 1.

**Merknad**
Kandidat innkalles til samtale med prøve. I tilfeller hvor godkjenning av flygesjef skjer under forutsetning av at det er oppnevnt en assisterende flygesjef, vil også assisterende flygesjef bli innkalt samtale og prøve.

## NP Maintenance/Continuing Airworthiness Manager

**Regelverk**
Det vises til AIC-N 01/17.

## NP Crew Training

**Regelverk**
Forordning 965/2012, Part ORO (bl.a. ORO.GEN.210, ORO.AOC.100, ORO.AOC.135, ORO.SPO.100) med tilhørende AMC og GM.

Veiledende kompetansekrav
Vedkommende bør inneha gyldig autorisasjon som typerettighetsinstruktør (TRI) på luftfartøy type(r) eller klasse(r) som er relevant for operasjonen som skal utføres av det aktuelle luftfartsselskapet. Dersom vedkommende ikke innehar dette, kreves det at selskapet har oppnevnt en assisterende treningssjef som innehar slik gyldig TRI.
Treningssjefen skal også ha god kunnskap om luftfartsselskapets treningskonsept for flygere, kabinbesetninger og annet relevant personale som skal ha trening under selskapets operasjon og/eller godkjennelser.

Vedkommende bør ha minst 5 års relevant praksis, hvorav minst 2 år tilknyttet administrativ luftfartsvirksomhet.
Se også GM2 ORO.AOC.135(a) og GM2 ORO.SPO.100(a) (dersom relevant)
Forventet kunnskap om regelverk og annen dokumentasjon er angitt i vedlegg 1.

Merknad
Kandidat innkalles til samtale. I tilfeller hvor godkjenning av treningssjef skjer under forutsetning av at det er oppnevnt en assisterende treningssjef, vil også assisterende treningssjef bli innkalt samtale.

NP Ground OPS
Regelverk
Forordning 965/2012, Part ORO (bl.a. ORO.GEN.210, ORO.AOC.100, ORO.AOC.135, ORO.SPO.100).

Veiledende kompetansekrav
Vedkommende bør ha relevant erfaring fra bakkeoperasjons-virksomhet, herunder kunnskap om vekt- og balanse-beregninger, laste- og losseprosedyrer, avisingsprosedyrer og transport av farlig gods.
Vedkommende bør ha minst 5 års relevant praksis, hvorav minst 2 år tilknyttet administrativ luftfartsvirksomhet.
Se også GM2 ORO.AOC.135(a) og GM2 ORO.SPO.100(a) (dersom relevant)
Forventet kunnskap om regelverk og annen dokumentasjon er angitt i vedlegg 1.

Merknad
Kandidat innkalles til samtale.

Compliance Monitoring Manager/Quality Manager
Regelverk
Forordning 965/2012, Part ORO med tilhørende AMC og GM (bl.a. ORO.GEN.200 og AMC1 ORO.GEN.200(a)(6).

Forordning 1321/2014, Part M, M.A. 706. Se også AIC-N 01/17 for krav til Quality Manager.

Veiledende kompetansekrav
Vedkommende må ha kunnskaper om og forståelse for kvalitetssikringsarbeid. Utdanning og erfaring fra kvalitetsrevisjon vektlegges. I tillegg forventes det en bred kjennskap til virksomheten, og god kunnskap om de aktuelle luftfartsbestemmelsene. Vedkommende bør ha minst 5 års relevant yrkeserfaring, hvorav minst 2 år tilknyttet administrativ luftfartsvirksomhet.
Forventet kunnskap om regelverk og annen dokumentasjon er angitt i vedlegg 1.

Merknad
Kandidat innkalles til samtale.

Safety Manager
Regelverk
Forordning 965/2012, Part ORO med tilhørende AMC og GM (bl.a. ORO.GEN.200 og AMC1 ORO.GEN.200(a)(1).

Veiledende kompetansekrav
Vedkommende må ha kunnskaper om og forståelse for risikostyring.
Utdanning og erfaring innen sikkerhetsstyring vektlegges. I tillegg forventes det en bred kjennskap til virksomheten, og god kunnskap om de aktuelle luftfartsbestemmelsene.
Vedkommende bør ha minst 5 års relevant yrkeserfaring, hvorav minst 2 år tilknyttet administrativ luftfartsvirksomhet.
Forventet kunnskap om regelverk og annen dokumentasjon er angitt i vedlegg 1.

Merknad
Kandidat innkalles til samtale

Vedlegg 1. EASA OPS OPERATØRER

**FORVENTET KUNNSKAP OM REGELVERK OG ANNEN DOKUMENTASJON VED PRØVE/SAMTALE**

| **Stilling** | **Pensum** | **Verifikasjonsmetode** |
|---|---|---|
| Ansvarlig leder<br>Accountable Manager | 1. Lover og bestemmelser;<br>Generell kjennskap[1] til aktuelle bestemmelser som inkluderer, men ikke nødvendigvis er begrenset til:<br>• Lov om luftfart<br>• ICAO Annexer, særlig Annex 19<br>• Lisensforordningen (forordning 1008/2008) og forskrift om luftransporttjenester i EØS (BSL A 2-1)<br>• Basisforordningen (forordning 216/2008) og EASA forskriften (BSL A 3-1)<br>• BSL D 1-1 (EASA OPS, forordning 965/2012) inkludert tilhørende AMC/GM, særlig Part ORO:<br>o Subpart GEN — general requirements<br>o Subpart AOC — air operator certification<br>o Subpart DEC — declaration (hvis aktuelt)<br>o Subpart SPO — commercial specialised operations (hvis aktuelt)<br>• Arbeidsmiljøloven<br><br>2. Selskapets dokumentasjon;<br>Generell kjennskap til selskapets drift, herunder kunne redegjøre for:<br>• selskapets operative tillatelser og evt. begrensninger<br>• selskapets håndboksystem<br>• selskapets ledelsessystem<br>• selskapets sikkerhetspolitikk | Samtale<br><br>Aktuelle håndbøker og publikasjoner kan benyttes |
| Flygesjef<br>NP Flight OPS | 1. Lover og bestemmelser;<br>- kandidaten må kunne redegjøre for hovedinnhold i, og forhold mellom de intensjonale og nasjonale regelverk og standarder for luftfart, slik som:<br>• Norske forskrifter om sivil luftfart (BSL serien)<br>• EASA regelverket<br>• PANS OPS (dersom IFR operasjoner)<br>• ICAO Annexer (1,6,14,17,18, 19)<br><br>- kandidaten må spesielt kunne redegjøre for virkeområde, innhold og bruk av: | Skriftlig prøve på norsk, besvares på norsk eller engelsk.<br><br>Aktuelle håndbøker og publikasjoner kan benyttes. |

[1] Må kjenne til hva dokumentet omhandler, hvordan det hører inn i systemet samt kunne finne fram til hovedmomenter.

<table>
<tr>
<td></td>
<td>
<ul>
<li>Lov om luftfart</li>
<li>BSL- serien</li>
<li>BSL D 1-1, forordning 965/2012 (EASA OPS)</li>
<li>BSL C 1-1, forordning 1178/2011 (EASA Air Crew)</li>
<li>AIP, AIC</li>
</ul>
2. Selskapets Operasjons manual/ håndbøker;<br>
- kandidaten må ha kunnskap om selskapets organisasjon og drift, herunder kunne redegjøre for:
<ul>
<li>selskapets sikkerhetspolitikk</li>
<li>selskapets operative tillatelser og evt. begrensninger</li>
<li>organisasjonsstruktur og generelle ansvarsforhold</li>
<li>forhold og sammenheng mellom de ulike håndbøker</li>
<li>operative bestemmelser og operativt personells ansvarsforhold</li>
<li>selskapets styringssystem for operativ virksomhet</li>
<li>selskapets totale ledelsessystem, inkludert sikkerhetsledelse (safety management) og samsvarsovervåkning (compliance monitoring)</li>
<li>prosedyrer for trening og holdningsskapende tiltak i operativ virksomhet</li>
<li>selskapets ulike driftsarter</li>
</ul>
3. Selskapets luftfartøy type(r);<br>
- kandidaten må ha kunnskap om selskapets luftfartøy, herunder;
<ul>
<li>utstyrs- og ytelseskrav</li>
<li>operative prosedyrer</li>
<li>flygehåndbok</li>
</ul>
</td>
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</tr>
<tr>
<td>Sikkerhetsleder<br>(Safety Manager)<br>EASA OPS</td>
<td>
1. Lover og bestemmelser;<br>
- kandidaten må kunne redegjøre for begrep, hensikt og praktiske metoder vedrørende;
<ul>
<li>luftfartsbestemmelser, spesielt BSL D 1-1, forordning 965/2012 (EASA OPS)</li>
<li>krav til ledelsessystemer i luftfart (spesielt EASA OPS, Part ORO)</li>
<li>standarder for kvalitetsledelse</li>
<li>standarder for risikoledelse</li>
<li>standarder for risikovurdering</li>
<li>ICAO Annex 19</li>
</ul>
2. Selskapets Operasjons manual/ håndbøker;<br>
- i tillegg må kandidaten kunne redegjøre for;
<ul>
<li>selskapets sikkerhetspolitikk</li>
<li>selskapets organisasjonsstruktur og generelle</li>
</ul>
</td>
<td>Samtale.<br><br>Aktuelle håndbøker og publikasjoner kan benyttes.</td>
</tr>
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| | | |
|---|---|---|
| | ansvarsforhold<br>• forhold og sammenheng mellom de ulike håndbøker<br>• operative bestemmelser og operativt personells ansvarsforhold<br>• selskapets styringssystem for den operative virksomheten<br>• selskapets ledelsessystem inkludert sikkerhetsledelse (safety management) og samsvarsovervåkning (compliance monitoring)<br>• risikoledelse, særlig risikovurderinger<br>• selskapets ulike driftsarter<br><br>Kandidaten må dokumentere relevant opplæring i:<br>• Sikkerhetsledelsessystem<br>Alternativt:<br>• Kvalitetsledelsessystem, og;<br>• Risikoledelsessystem<br><br>Kandidater som tidligere har vært godkjent som kvalitetssjef i luftfartsselskap, må dokumentere tilleggsopplæring i:<br>• Risikoledelsessystem | |
| Leder samsvarsovervåkning (Compliance monitoring function) | 1. Lover og bestemmelser;<br>- kandidaten må generell kjennskap til begrep, hensikt og praktiske metoder vedrørende;<br>• luftfartsbestemmelser, spesielt BSL D 1-1, forordning 965/2012 (EASA OPS)<br>• krav til ledelsessystemer i luftfart, (spesielt EASA OPS, Part ORO)<br>• standarder for kvalitetsledelse<br>• standarder for risikoledelse<br>• standarder for risikovurdering<br><br>2. Selskapets Operasjons manual/ håndbøker;<br>- i tillegg må kandidaten kunne redegjøre for;<br>• selskapets sikkerhetspolitikk<br>• selskapets organisasjonsstruktur og generelle ansvarsforhold<br>• forhold og sammenheng mellom de ulike håndbøker<br>• operative bestemmelser og operativt personells ansvarsforhold<br>• selskapets styringssystem for den operative virksomheten<br>• selskapets ledelsessystem inkludert sikkerhetsledelse (safety management) og samsvarsovervåkning (compliance monitoring)<br>• samsvarsovervåkning, inkludert<br>o Håndboksystemet | Samtale.<br><br>Aktuelle håndbøker og publikasjoner kan benyttes. |

| | | |
|---|---|---|
| | o Tilhørende prosedyrer<br>o Revisjonsteknikk, rapportering, registrering og oppfølging<br>• selskapets ulike driftsarter<br><br>Kandidaten må dokumentere relevant opplæring i:<br>• samsvarsovervåkning<br>alternativt:<br>• kvalitetsledelsessystem<br><br>Dokumentasjonskravet gjelder ikke kandidater som tidligere har vært godkjent som kvalitetssjef i luftfartsselskap. | |
| Leder besetningstrening NP Crew Training | 1. Lover og bestemmelser;<br>- kandidaten må kunne redegjøre for hovedinnhold i, og forhold mellom de intensjonale og nasjonale regelverk og standarder for luftfart, slik som:<br>• Norske forskrifter om sivil luftfart (BSL serien),<br>• EASA regelverket<br>• ICAO Annex 1,6,14,17,18, 19<br><br>- kandidaten må kunne redegjøre for virkeområde, innhold og bruk av:<br>• Lov om luftfart<br>• BSL-serien<br>• BSL D 1-1, forordning 965/2012 (EASA OPS)<br>• BSL C 1-1, forordning 1178/2011 (EASA Air Crew)<br>• AIP, AIC<br><br>2. Selskapets Operasjons manual/ håndbøker;<br>- kandidaten må ha kunnskap om selskapets organisasjon og drift, herunder kunne redegjøre for:<br>• selskapets operative tillatelser og evt. begrensninger<br>• organisasjonsstruktur og generelle ansvarsforhold<br>• forhold og sammenheng mellom de ulike håndbøker<br>• operative bestemmelser og operativt personells ansvarsforhold<br>• selskapets styringssystem for operativ virksomhet<br>• selskapets totale ledelsessystem, inkludert sikkerhetsledelse (safety management) og samsvarsovervåkning (compliance monitoring)<br>• prosedyrer for trening og holdningsskapende tiltak i operativ virksomhet<br>• selskapets ulike driftsarter | Samtale.<br><br>Aktuelle håndbøker og publikasjoner kan benyttes. |

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<tr><td></td><td></td><td></td></tr>
<tr><td>Leder bakkeoperasjoner (NP Ground OPS)</td><td>1. Lover og bestemmelser;<br>- kandidaten må kunne redegjøre for hovedinnhold i, og forhold mellom de intensjonale og nasjonale regelverk og standarder for luftfart, slik som:<ul><li>Norske forskrifter om sivil luftfart (BSL serien)</li><li>EASA regelverket</li><li>PANS OPS (dersom IFR operasjoner)</li><li>ICAO Annex 1,6,14,17,18, 19</li></ul>- kandidaten må kunne redegjøre for virkeområde, innhold og bruk av:<ul><li>Lov om luftfart</li><li>BSL-serien</li><li>BSL D 1-1, forordning 965/2012 (EASA OPS)</li></ul>2. Selskapets Operasjons manual/ håndbøker;<br>- kandidaten må ha kunnskap om selskapets organisasjon og drift, herunder kunne redegjøre for:<ul><li>selskapets operative tillatelser og evt. begrensninger</li><li>organisasjonsstruktur og generelle ansvarsforhold</li><li>forhold og sammenheng mellom de ulike håndbøker</li><li>operative bestemmelser og operativt personells ansvarsforhold</li><li>selskapets styringssystem for operativ virksomhet</li><li>selskapets totale ledelsessystem, inkludert sikkerhetsledelse (safety management) og samsvarsovervåkning (compliance monitoring)</li><li>prosedyrer for trening og holdningsskapende tiltak i operativ virksomhet</li><li>selskapets ulike driftsarter</li></ul></td><td>Samtale.<br><br>Aktuelle håndbøker og publikasjoner kan benyttes.</td></tr>
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# Air Accident Data Analysis, Modelling & Simulation

## Consultancy Report prepared for:

## Accident Investigation Board of Norway

## Final Report

**June 6th, 2019**

## Executive Summary

The main aim of this study was to provide further insight into Loss of Control Inflight (LoC-I)/Upset events under icing conditions. The main objective was to identify the probable characteristics of a LOC-I/upset event due to tailplane icing for a business jet. Due to the lack of available (stability and control and aerodynamic) data for specific aircraft makes/models, a 'generic business jet' model was used for all analyses. It was not possible to replicate EXACT aircraft dynamics as evidenced by FDR data using modelling & simulation techniques. Flight data analysis was used to determine the flight conditions to be analysed and static and dynamic stability was assessed using established flight dynamics theory and modelling.

The modelling and 'what-if' analysis therefore illustrates trends as a result of changes to selected parameters and not exact data. The degradation of tailplane aerodynamic characteristics due to icing was simulated using an assumed reduction in horizontal tailplane efficiency factor and classical theory supported by a commercial aircraft design software package.

The results are only applicable for short time periods after a given disturbance since a linearised flight model was used about a given trimmed flight condition, no pilot control inputs were available (e.g. yoke pitch/roll, rudder) and no external (environmental) disturbance data were available (e.g. turbulence). The results demonstrate that the 'generic business jet' aircraft used in the analysis is statically and dynamically stable when horizontal tailplane efficiency is greater than 80%. When horizontal tailplane efficiency is reduced to 20% (simulating a 'tailplane stall'), the aircraft is statically and dynamically unstable, smaller and shorter elevator commands produce large pitch responses and negative 'G' may be quickly reached within a short time period.

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## Appendices

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## Glossary of Terms & Nomenclature

| Symbol | Description (Units of Measure) |
|---|---|
| A | State Matrix, depends on stability derivatives and setpoint condition |
| $a_c$ | lateral acceleration (g) |
| $a_n$ | normal acceleration (G) |
| AAL | Above Airfield Level |
| AGL | Above Ground Level |
| AIBN | Accident Investigation Branch of Norway |
| Alt | altitude (ft.) |
| B | Input matrix, depends on control derivatives and actuator layout |
| B1 | Alternative Input matrix, depends on control derivatives and actuator layout & flap setting |
| $C_{M0}$ | Pitching moment contribution, independent of angle of attack |
| $C_{M\alpha}$ | Pitching moment contribution, variation with angle of attack |
| H | height above sea-level (feet) |
| LPO | Long Period Oscillation |
| q | Pitch rate (deg./s) |
| s | Laplace transform variable |
| SPO | Short Period Oscillation |
| T | Temperature (deg. F.) |
| u | Longitudinal speed in X-body axis (+ve forwards) |
| U | Control input vector, components are $\eta$, $\tau$ |
| V | True airspeed (kts) |
| w | Vertical speed Z-body axis (+ve downwards) |
| X | State vector, components are u, w, q, $\theta$ |
| $\alpha$ | Angle of attack (deg.) |
| $\eta$ | Elevator deflection (deg.) |
| $\eta_{HT}$ | horizontal tailplane efficiency factor |
| $\phi$ | roll angle (degrees) |
| $\psi$ | yaw angle (degrees) |
| $\Theta$ | pitch angle (degrees) |
| $\tau$ | throttle input (0<1) |

# 1 Introduction

The main aims and objectives of this study were:-

**Aims**

- To provide further insight into a Loss of Control Inflight (LoC-I)/Upset event in icing conditions.

**Objectives**

- Determine the probable characteristics of the LoC-I/upset event due to tailplane icing;
- Replicate (as far as practical) the aircraft dynamics as evidenced by FDR data using modelling & simulation techniques.

**Approach**

The approach comprises two main areas in relation to accident investigation of a given Loss of Control in Flight/upset:-

- Flight Data Analysis;
- Flight Dynamics Modelling.

The following tasks were confirmed out of scope:-

- Flight Simulation/replay;
- Accident Simulation using Coventry University's Engineering Flight Simulator.

## 1.1 Deliverables

This technical report addresses the following:-

- Analysis of FDR data to determine aircraft state and dynamics using kinematic parameter extraction technique;
- Determine aircraft state and dynamics in 'normal operating conditions' using modelling and fundamental flight mechanics;
- Comparison of results to determine characteristics of the upset event.

**Key Assumptions: -**

The following data was provided by AIBN to conduct the analyses: -

- Digitised flight data for key parameters in CSV/TXT format or similar pre/post event (AIBN);
- Atmospheric/environmental conditions (estimated) at the time of the event (AIBN);
- Aircraft mass and balance at the time of the event (AIBN).

The following data was provided by Coventry University using industry accepted design & analysis software: -

- Estimated aircraft stability & control derivatives for comparable aircraft model (CU);

## 2 Modelling and Simulation Overview

The flying and handling qualities of un-augmented aircraft depend on basic input–output relationships described by the aerodynamic transfer functions which provide a fundamental description of aircraft dynamics (1)(Figure 1). They describe the pilot input and aircraft response relationship as a function of a given flight condition and these may also be affected by environmental factors such as icing. The core of this relationship is the mathematical model of the aircraft, usually referred to as the equations of motion. Theses provide a complete description of response of the aircraft to pilot inputs on the controls, subject to modelling limitations defined at the beginning and are measured in terms of displacement, velocity and acceleration. The initial flight condition describes the conditions under which the analysis is undertaken and includes parameters, such as airspeed, altitude, aircraft geometry, flap setting, mass and trim state.

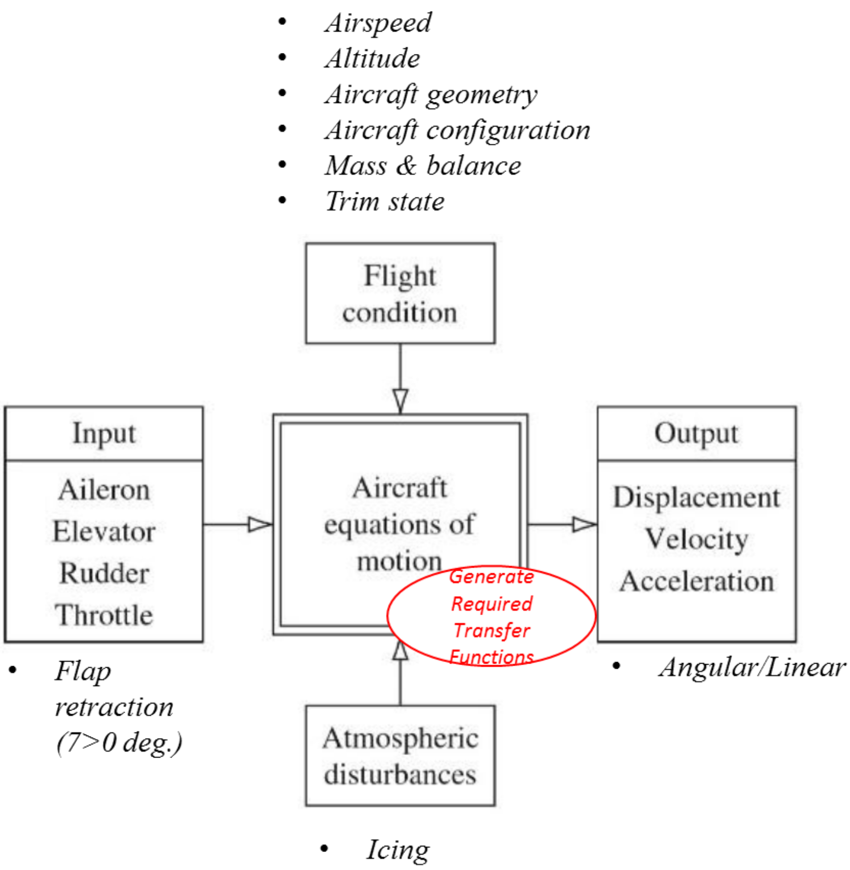


**Figure 1, Modelling & Simulation Overview (Adapted from Cook, 1)**

In order to validate the flight model (Figure 2), where available, actual flight data can be used to compare outputs and differences between the two are used to refine the model or conduct further testing. In the course of this study, the lack of stability, control and aerodynamic properties for the exact aircraft resulted in basic modelling being used to conduct a series of parametric analyses.

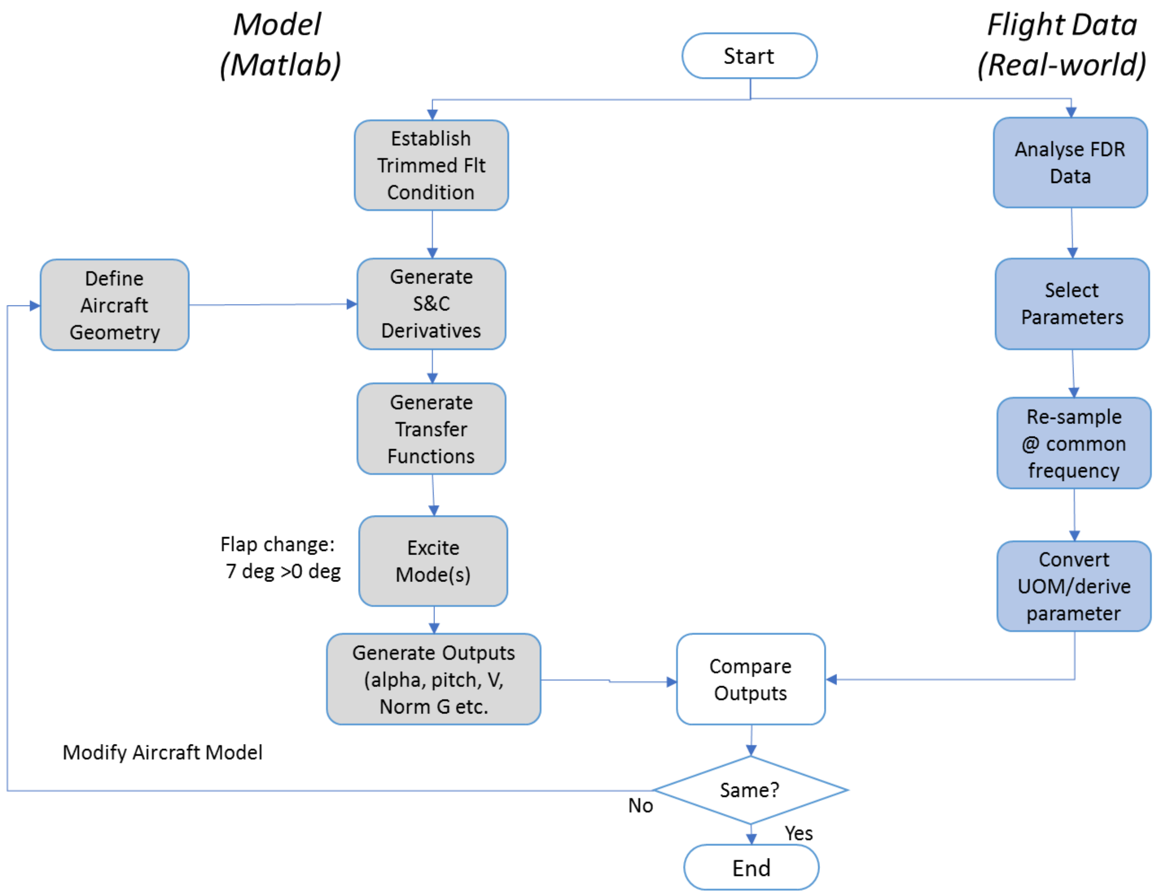


**Figure 2, Model Validation**

# 3 Analysis of Flight Data

Using the available (limited) flight data (Figure 3) the data was re-sampled to enable derivation of additional parameters including flightpath angle and rate of climb/descent. Since the flight data was sampled at different rates, a smoothing spline tool was used in Matlab to smooth out data (Figure 4).

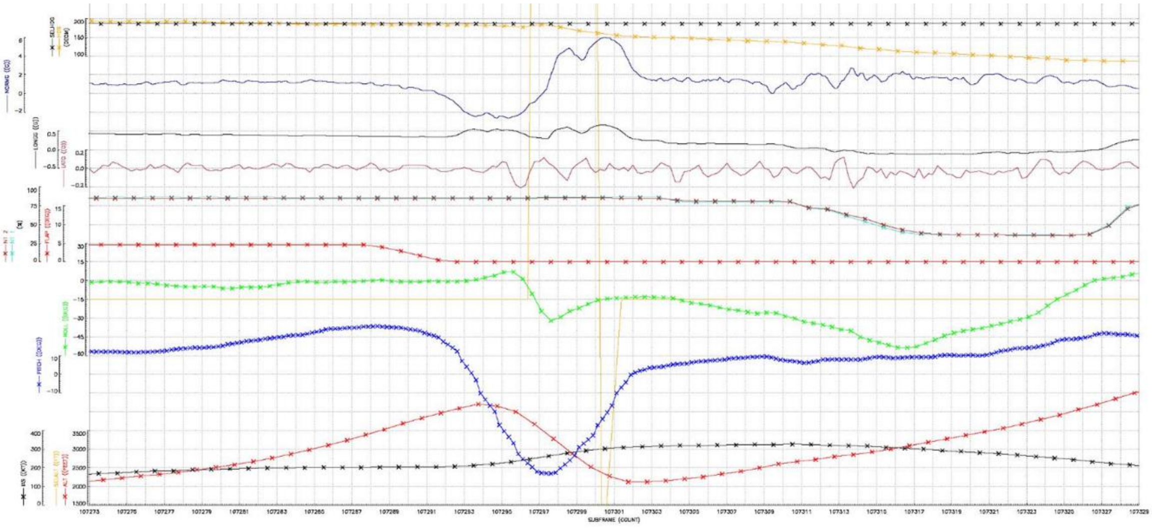

**Figure 3, Flight Data**

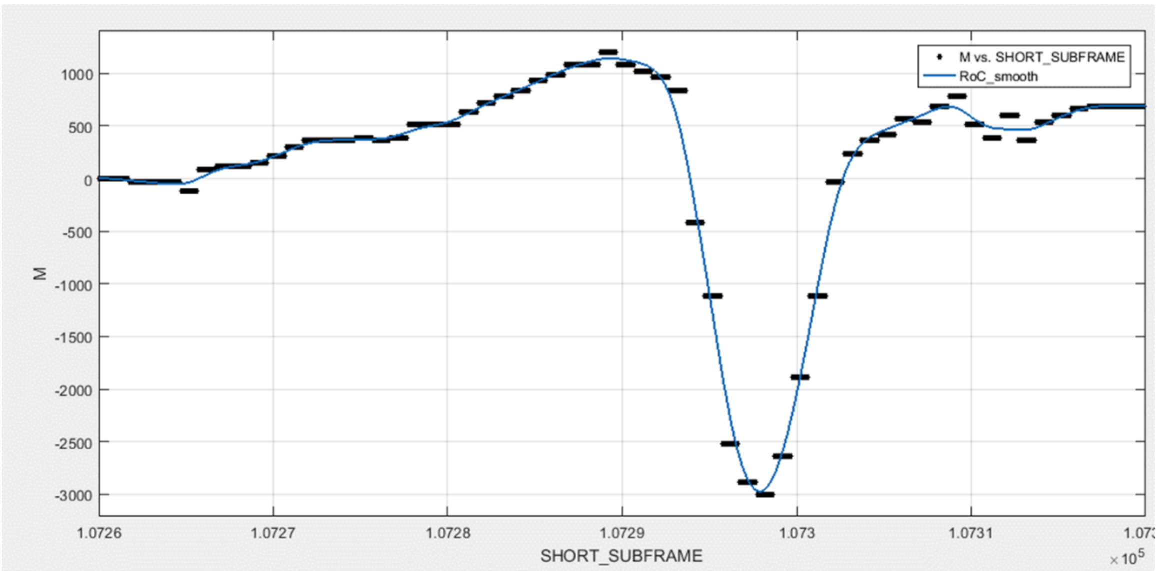


**Figure 4, Example: Re-sampled Flight Data (Derived Rate of Climb)**

# 4 Theory – Total Aircraft Pitching Moment

In order to assess the static and dynamic stability, modelling of the total aircraft pitching moment is needed and individual contributions of all major components are required, not simply tail lift + wing lift (Figure 5).

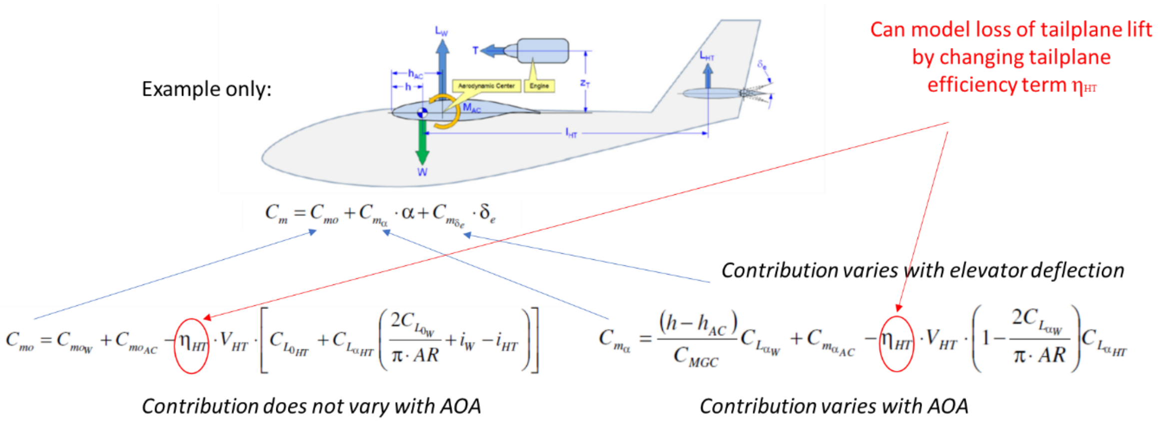


**Figure 5, Total Aircraft Pitching Moment Theory (Adapted from Gudmundsson,2)**

The total aircraft pitching moment is given by:-

$$C_m = C_{mo} + C_{m_\alpha} \cdot \alpha + C_{m_{\delta_e}} \cdot \delta_e$$

**(Equation 1)**

Where:-

$$C_{mo} = C_{mo_W} + C_{mo_{AC}} - \eta_{HT} \cdot V_{HT} \cdot \left[ C_{L_{0HT}} + C_{L_{\alpha HT}} \left( \frac{2C_{L_{0W}}}{\pi \cdot AR} + i_W - i_{HT} \right) \right]$$

**(Equation 2)**

And:-

$$C_{m_\alpha} = \frac{(h - h_{AC})}{C_{MGC}} C_{L_{\alpha W}} + C_{m_{\alpha AC}} - \eta_{HT} \cdot V_{HT} \cdot \left( 1 - \frac{2C_{L_{\alpha W}}}{\pi \cdot AR} \right) C_{L_{\alpha HT}}$$

**(Equation 3)**

Where $\eta_{HT}$ = tailplane efficiency (0>1).

Thus, the contributions to the pitching moment fall into two major categories (2):-

- Contributions that do not vary with angle of attack ( (Equation 2);
- Contributions that do vary with angle of attack ((Equation 3)

The tailplane ($\eta_{HT}$) can be used to model the degradation of lift due as a result of tailplane icing.

Classical theory shows that for positive static stability the following condition must be true:-

$$\frac{dC_m}{dC_\alpha} < 0 \qquad \textbf{(Equation 4)}$$

Thus, a negative slope represents positive static stability – the aircraft returning to the trimmed flight condition after a disturbance.

# 5 Modelling of a Generic Business Jet

Due to the lack of available published stability and control derivatives and performance data for the for the specific aircraft make/model, a generic business jet model of similar characteristics was used. For reasons of expediency, stability and control derivatives for this generic business jet were determined using a commercial aircraft design package enabling rapid parametric analysis to be conducted in a range of flight conditions.
The results obtained are therefore 'generic' and should be used with this in mind. They represent likely trends in stability due to effects of tailplane icing and are estimates only.

The aircraft design software package used to estimate stability & control derivatives used basic aircraft geometry for the 'generic' business jet (Figure 6) to be defined. This differed from the accident aircraft in the following characteristics: -

- Different wing planform
- Different wing aerofoil section
- Different MTOW/CG Range

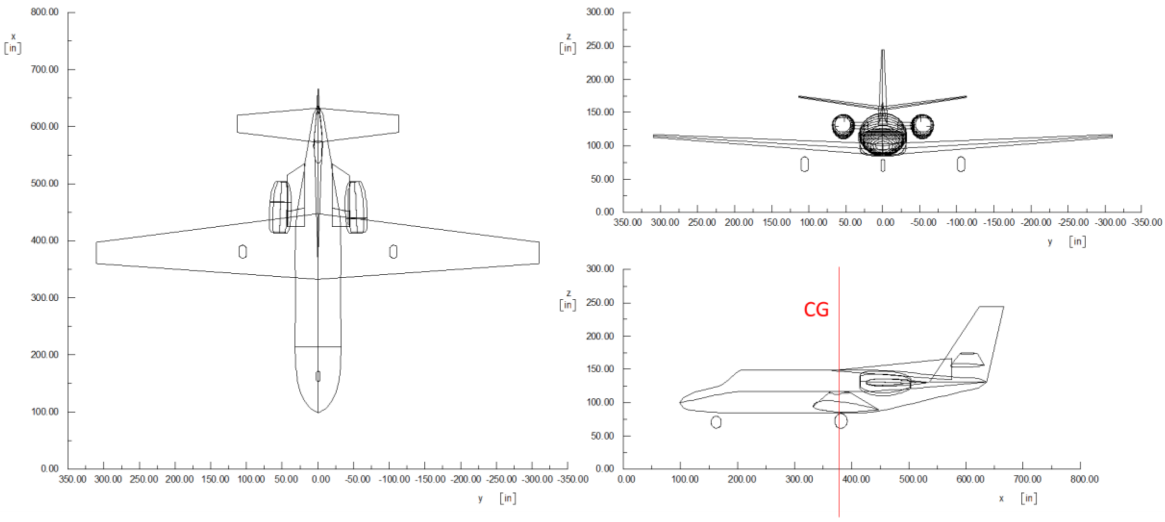


**Figure 6, Generic Business Jet Geometry**

Known flight characteristics at the time of the event were used to determine flight condition, these being: -

- V = 204 kts
- Flap = 7 degrees

- Mass & Balance = Low Mass/Aft CG
- T = 29F
- H = 4,000 ft press height

Using the available 'generic business jet' geometry and given flight conditions, the commercial aircraft design software was used to estimate stability and control derivatives for a range of conditions.

# 6 Modelling Results

This section presents results obtained using the commercial software package for the modelling of static and dynamic stability of a given 'generic business jet' in a range of conditions.

## 6.1 Static Stability

For the 'generic business jet', using the given flight condition of V= 204 KTAS, H = 4,000 ft pressure height, T = 29F, aft CG/low MTOM with flap = 7 degrees, the variation of pitching moment with angle of attack was obtained for a range of horizontal tailplane efficiency ($\eta_{HT}$) from 1 (100% efficient) to 0.1 (10% efficient) to simulate the effects of icing on the aircraft tailplane (Figure 7). The results show that the gradient ($\frac{dC_m}{dC_\alpha}$) decreases as the horizontal tailplane efficiency decreases, hence aircraft static stability also decreases as horizontal tailplane efficiency decreases.

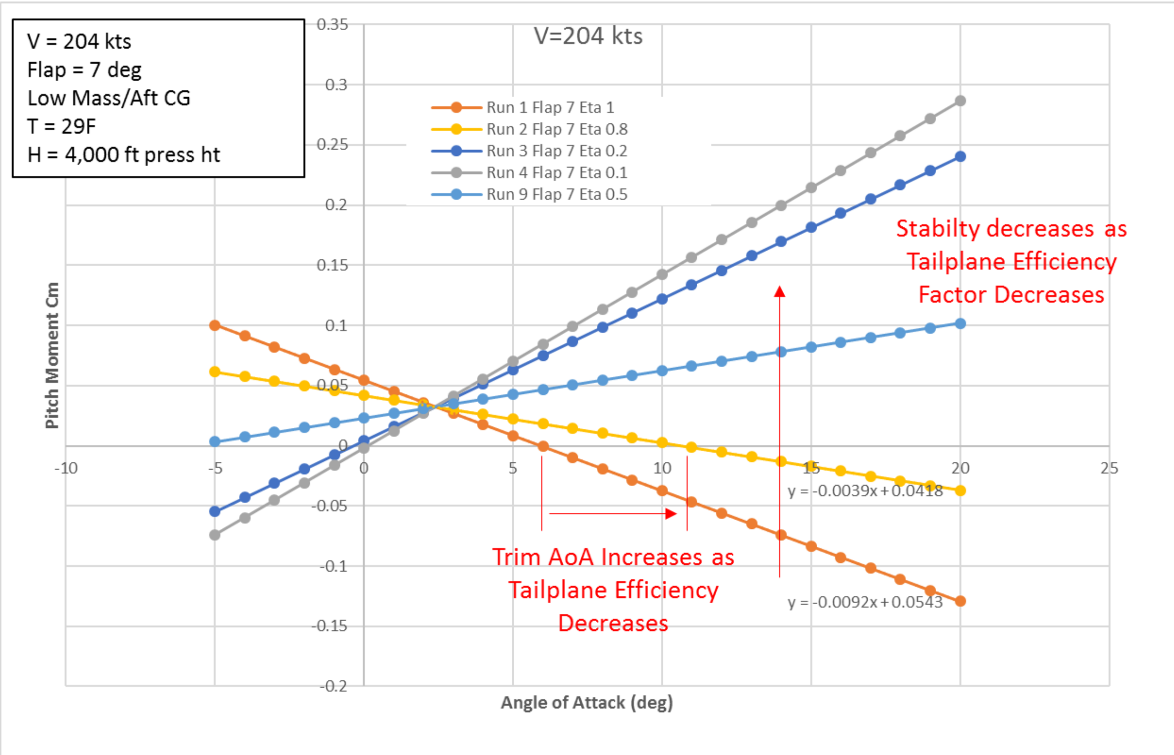


**Figure 7, Pitching Moment vs AoA with Varying Tailplane Efficiency Factor**

The results also show that the angle of attack for trimmed flight conditions increases as tailplane efficiency decreases. A cross-plot of horizontal tailplane efficiency versus stick-fixed static margin (Figure 8) suggests that static margin decreases as the horizontal tailplane efficiency decreases and that the aircraft is neutrally (statically) stable when the horizontal tailplane efficiency is approximately 0.68 for the 'generic business jet' model in given flight conditions.

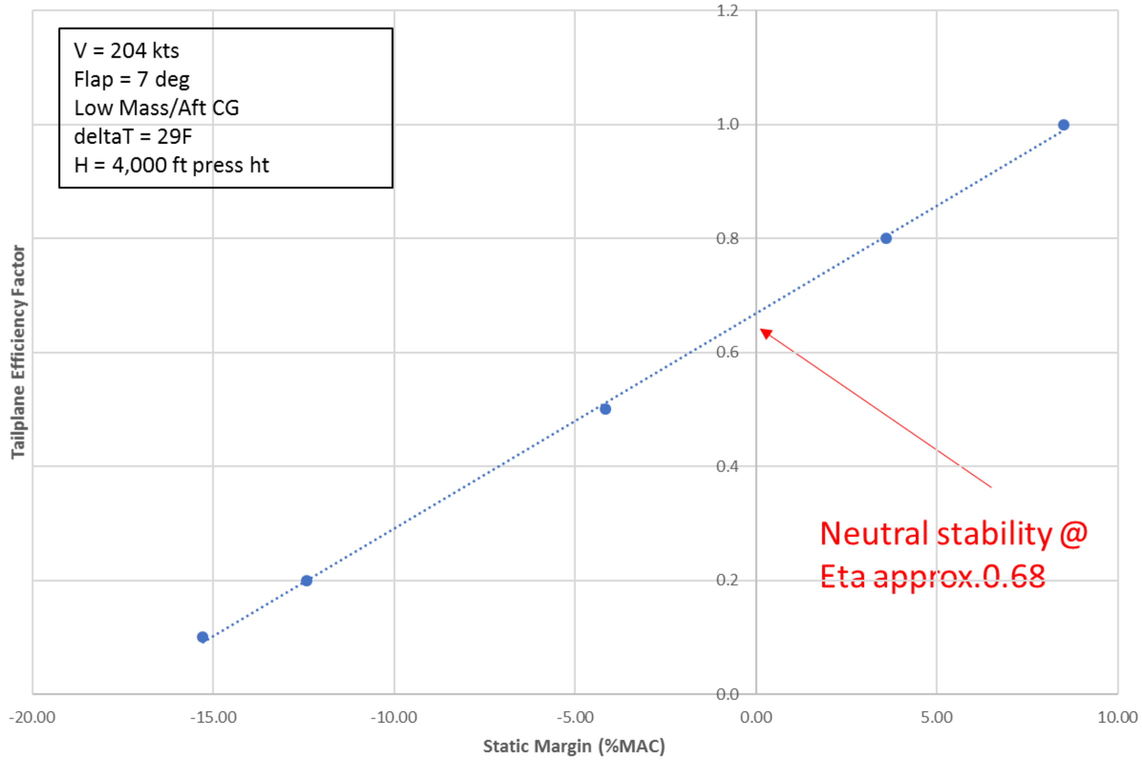


**Figure 8, Tailplane Efficiency Factor vs Static Margin**

A further plot of elevator deflection versus horizontal tailplane efficiency (Figure 9) suggests that increasing UP elevator (-ve deflection) is required to maintain trimmed flight as the horizontal tailplane efficiency decreases. The range of elevator deflection for the 'generic business jet' model was 20 degrees UP and 15 degrees DOWN. The results suggest that as horizontal tailplane efficiency decreases below approximately 0.2 (20%), there is insufficient UP elevator to maintain trimmed flight.

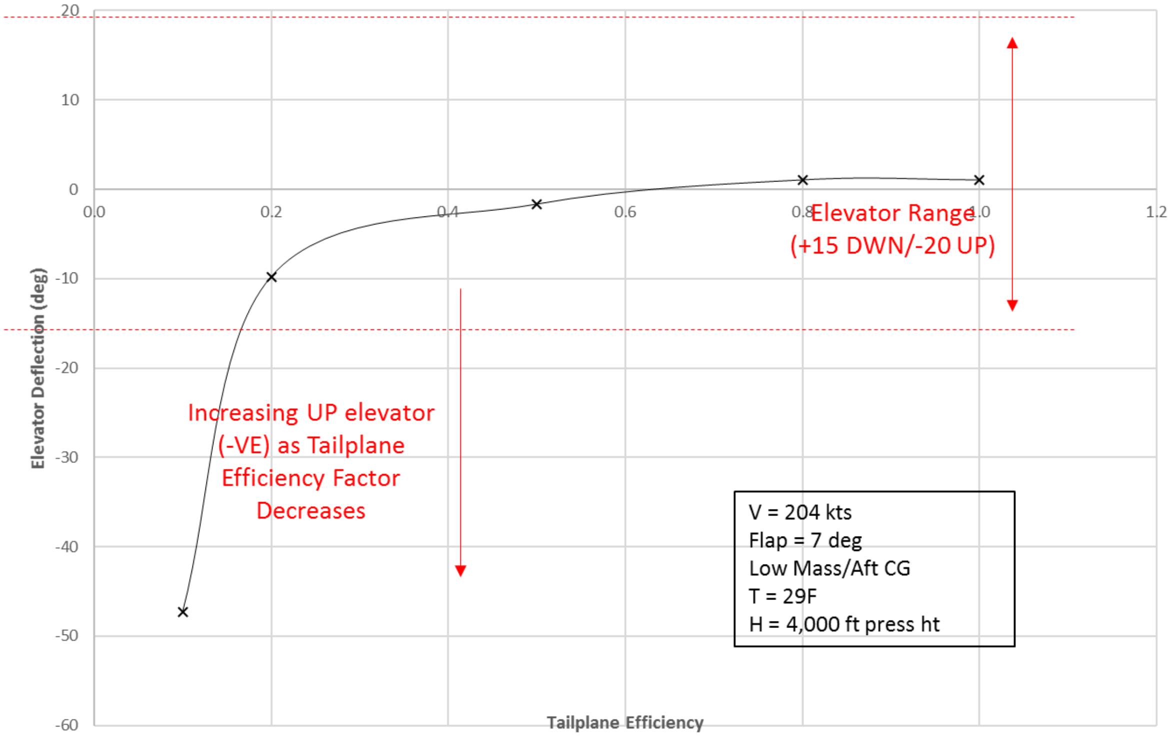


**Figure 9, Elevator Deflection vs Tailplane Efficiency**

## 6.2 Summary of Static Stability Analysis

Using known theory and a commercial aircraft design software for a given 'generic business jet model' suggests that:-

- Static stability decreases as Tailplane Efficiency Factor decreases
- Static margin decreases as Tailplane Efficiency Factor decreases
- Neutral static stability at approx. 68% Tailplane Efficiency Factor
- Negative static stability at 20% Tailplane Efficiency Factor
- Increasing UP elevator (-VE) is required to compensate as Tailplane Efficiency Factor Decreases

# 7 Dynamic Stability

Having established the trimmed flight condition and static stability of the 'generic business jet' the dynamic analysis was undertaken to consider the effects of small disturbances (perturbations) such as turbulence (external) or control inputs (internal).

Before conducting the dynamic analysis, the aircraft, the system of notation and axes were defined using the 'right-hand rule' (Figure 10). State variable, control inputs and matrix/vector notations were defined: -

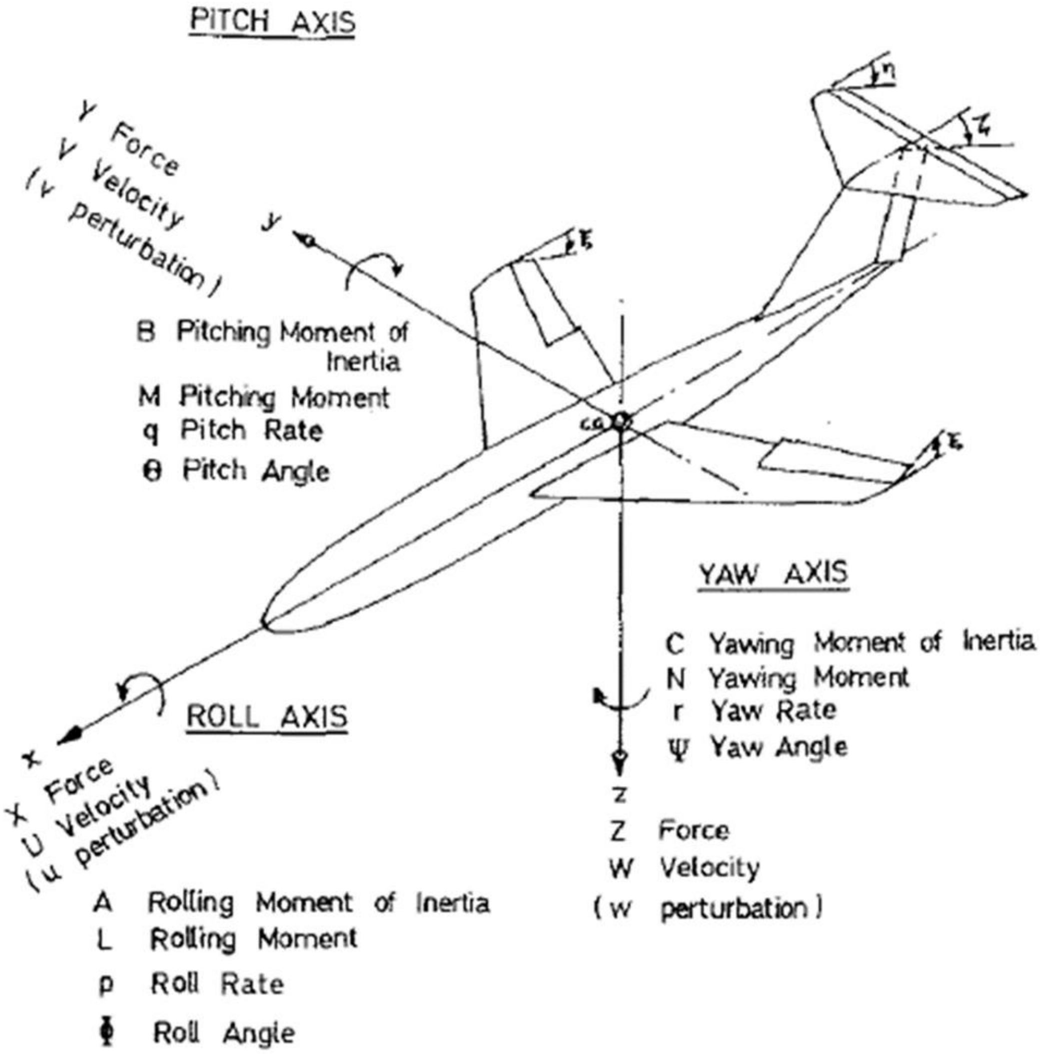


**Figure 10, Aircraft Notation & Axes**

State variables:

U = Longitudinal Speed in X-body axis

W =Vertical speed in Z-body axis (Pointing downwards)

q = Pitch rate

θ = Pitch angle

Control inputs:

η = Elevator deflection

τ= Throttle input

Matrix/vector notations in bold

**A**: State Matrix, depends on stability derivatives and setpoint condition

**B**: Input matrix, depends on control derivatives and actuator layout

**X**: State vector, components are u, w, q, θ

**u**: Control input vector, Components are η, τ

## 7.1 MIMO (Multiple Input Multiple Output) Aircraft longitudinal state space model

Systems with more than one input and more than one output are known as Multi-Input Multi-Output systems (MIMO). Systems that have only a single input and a single output are defined (SISO). The aircraft in longitudinal and pitching motion maybe modelled using a state-space model. The longitudinal aircraft dynamics, linearised about the setpoint (V= 204 KTAS, θ = 24 degrees pitch), can be written as a state space model:-

$$\dot{\mathbf{X}} = \mathbf{A}_{\text{long}}\mathbf{X} + \mathbf{B}_{\text{long}}\mathbf{u} \qquad \textbf{(Equation 5)}$$

with:

$$\mathbf{X} = \begin{bmatrix} u \\ w \\ q \\ \theta \end{bmatrix}, \ \mathbf{u} = \begin{bmatrix} \eta \\ \tau \end{bmatrix}$$

$u$: X axis speed, $w$ : Z axis speed.

$q$: pitch rate, $\theta$: pitch, $\eta$: elevator deflection, $\tau$: Throttle command.

Using matrix notation, the state transition and control matrices are given by:

```
A= [XTu+Xu              Xw                  Xq-m*We               -g*cos(theta0);
    Zu/f                Zw/f                (Zq+U1)/f             g*sin(theta0)/f;
    MTu+Mu+Mwd*Zu/f     Mw+MTal/U1+Mwd*Zw/f Mq+Mwd*(Zq+U1)/f      -wd*g*sin(theta0)/f;
    0                   0                   1                     0];
```

**u = [elevator, throttle]** (Throttle history known, elevator history is not)

```
B=[ Xel              XT;
    Zel/f            0;
    Mel+Mwd*Zel/f    0;
    0                0]
```

**Alternative model if u = [elevator, flap, throttle]**

```
B1= [Xel                Xflap                  XT;
     Zel/f              Zflap/f                0;
     Mel+Mwd*Zel/f      Mflap+Mwd*Zflap/f      0;
     0                  0                      0];
```

**(Equation 6)**

The elements of matrix **A** are stability derivatives describing the effect of state variables on forces and moments. The elements of matrix **B** are control derivatives representing the effects of elevator and throttle commands on the body referenced forces and moments.

Note: The '**B1**' type model requires computation of flap aerodynamic parameters, which are not available. The simulations were generated by computing the **A** and **B** for different tailplane stall efficiency settings.

**Transfer functions from elevator to pitch**

Using this matrix method, transfer functions were derived using Matlab to determine the relationship between Input: Elevator Deflection (η) and Output: Pitch Angle (θ).

For the given flight condition V = 204 KTAS, H = 4,00 ft pressure height, low mass/aft CG, T= 29F an flap = 7 degrees:

The elevator to pitch transfer function with 100% horizontal tailplane efficiency was:

```
-17.39 s^2 - 52.13 s - 1.128
---------------------------------------------
s^4 + 5.521 s^3 + 12.5 s^2 + 0.3387 s + 0.2689
```

**(Equation 7)**

Decreasing the horizontal tailplane efficiency to 50% results in the following transfer function:

```
-8.736 s^2 - 26.17 s - 0.6315
------------------------------------------------
s^4 + 4.226 s^3 - 0.03886 s^2 + 0.0396 s + 0.1132
```

**(Equation 8)**

The negative coefficient (-0.03886) in the denominator for Equation 8 is linked to an unstable pole and the pitch response to elevator commands is therefore unstable when horizontal tailplane efficiency is reduced to 50%.

## 7.2 Short Period Oscillation (SPO) & Long Period Oscillation (LPO)

For model validation purposes, the longitudinal dynamics were analysed by excitation of the Short Period (Figure 11) and Long Period (Figure 12) modes using the eigenvectors (specific to modes) of **A** to specify initial conditions. The variables simulated were relative changes (variations with respect to a trim condition). Zero value indicates the initial trimmed flight condition and all angles are in radians.

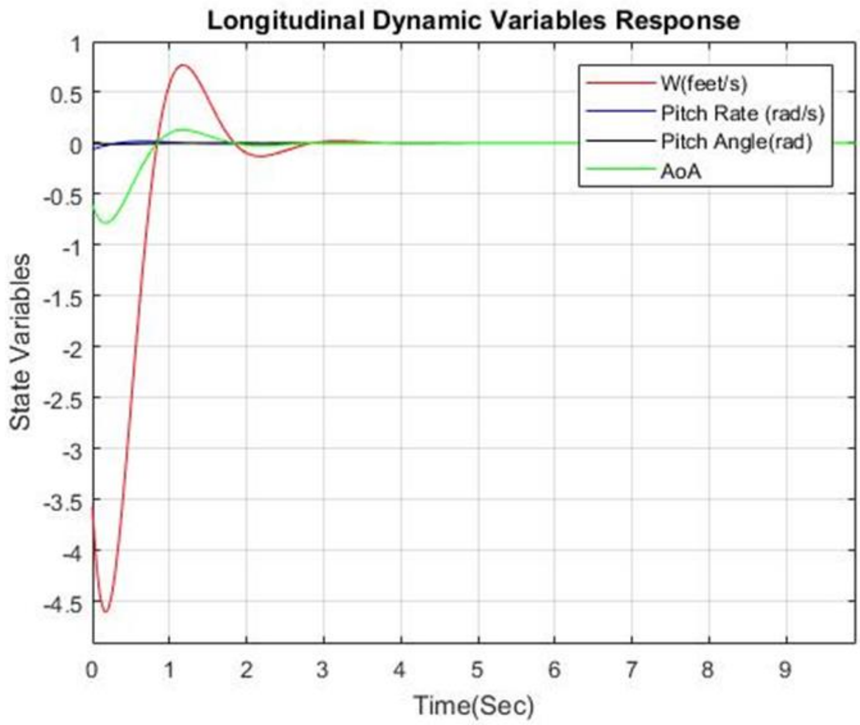


**Figure 11, Short Period Oscillation (SPO) with 100% Horizontal Tailplane Efficiency**

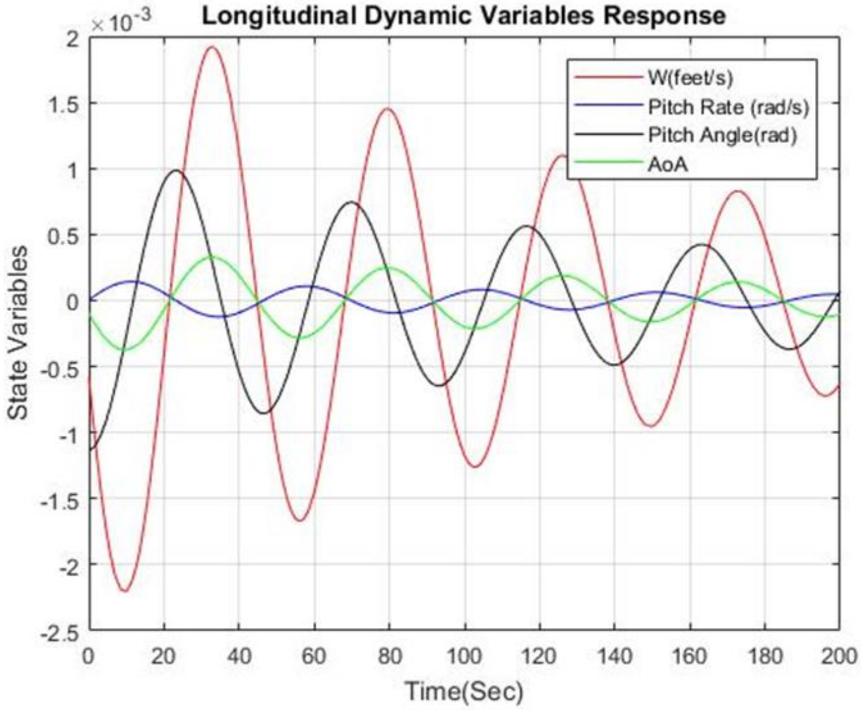


**Figure 12, Long Period Oscillation (LPO) with 100% Horizontal Tailplane Efficiency**

The results show that for a horizontal tailplane efficiency of 100% the aircraft is statically and dynamically stable with heavy and moderate damping for the SPO and LPO respectively. In addition, the model was independently verified by comparing results to a reduced order model (see Appendix A).

When the efficiency is reduced to 80%, the response for the LPO is also stable although with less damping of oscillations than the 100% efficiency case (Figure 13). The results of the dynamic stability are in agreement with those of the static stability analysis.

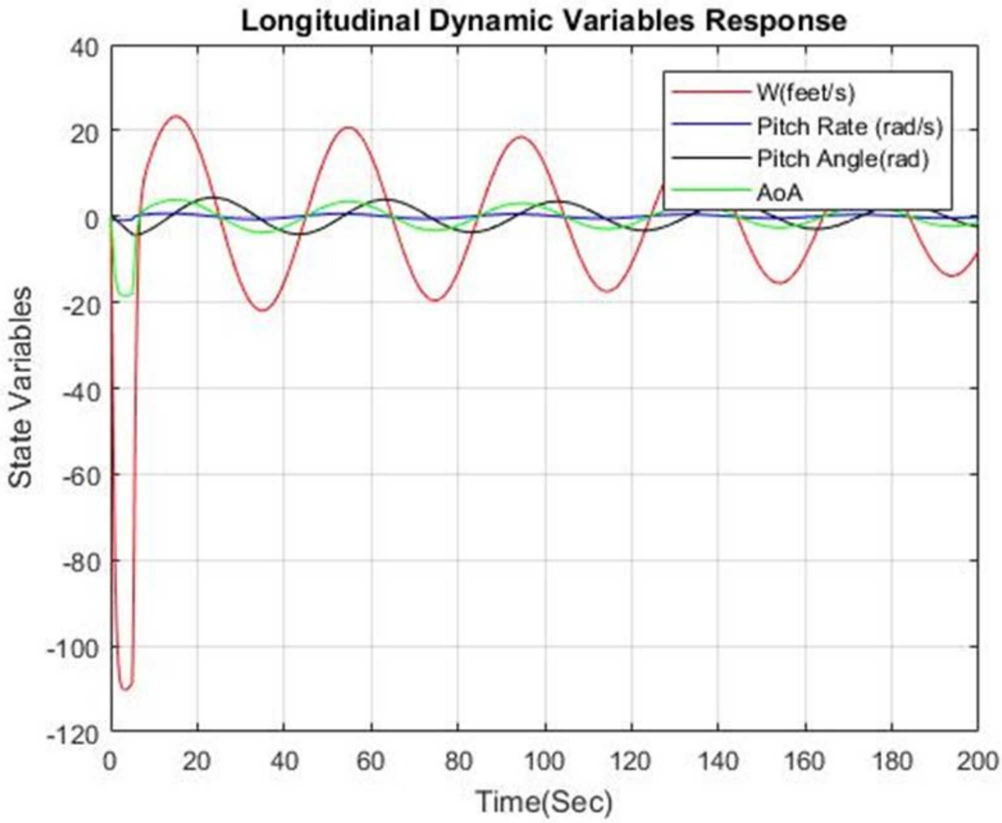


**Figure 13, Long Period Oscillation (LPO) with 80% Horizontal Tailplane Efficiency**

## 7.3 The Effects of Flap Retraction

The effects of flap retraction were simulated using a Simulink Switching Model. This model enables the dynamic analysis to account for changes in stability & control derivatives as a result of flap configuration changes. Stability & control derivatives were determined for the 'generic business jet' model using the commercial aircraft design software as before. Transfer functions were estimated for four different conditions (Table 1) using the Switching Model (Figure 14).

**Table 1, Switching Conditions**

| Condition | Tailplane Efficiency Factor | Flap |
|---|---|---|
| 1 | 100% | 0 deg |
| 2 | 100% | 7 deg |
| 3 | 20% | 0 deg |
| 4 | 20% | 7 deg |

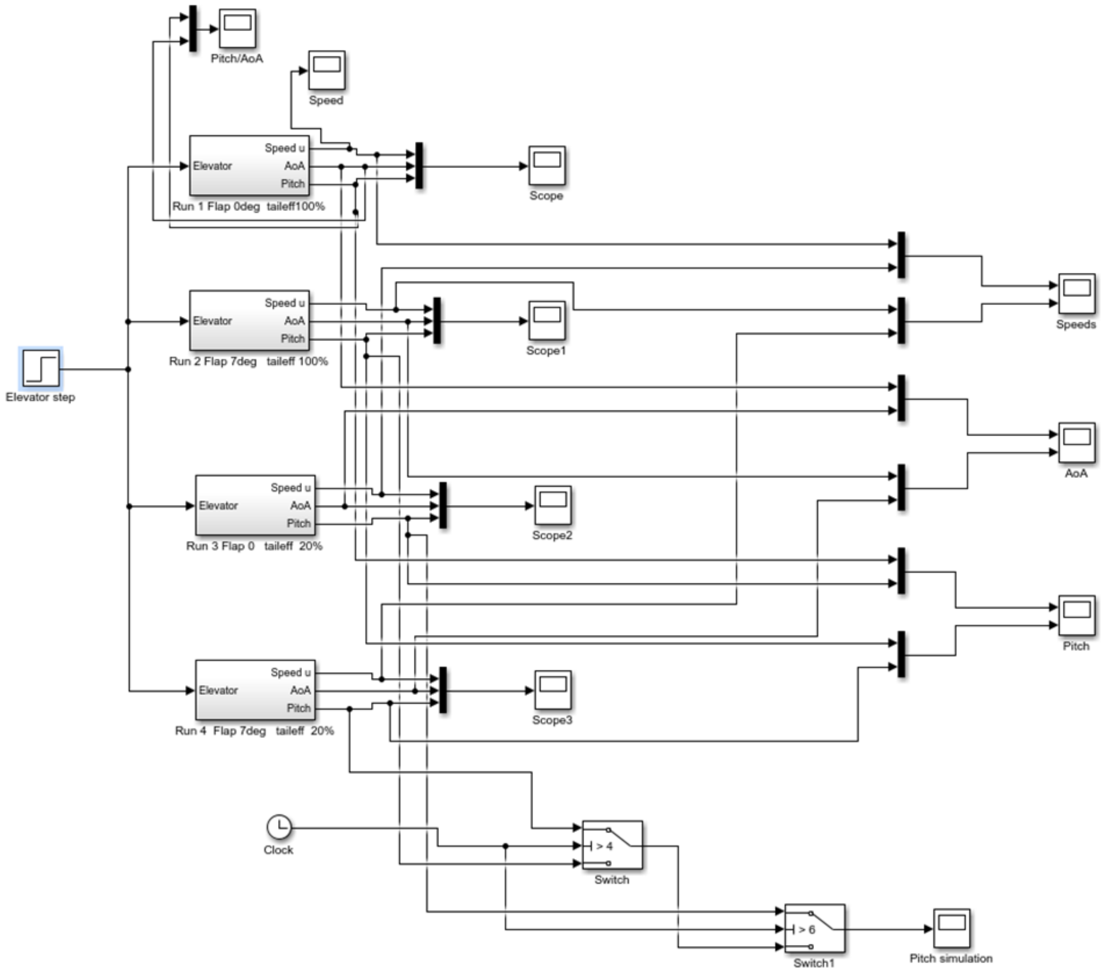


**Figure 14, Simulink Switching Model**

Figure 15 shows the results of a flap retraction following a tailplane stall. Initially, the tailplane efficiency is 100% and the flap angle is 7 degrees. At t=4 seconds, a tailplane stall is applied by a step reduction of 50% to horizontal tailplane efficiency, which destabilises the system response. The aircraft pitches down (-30 degrees) within 2 seconds. At t= 6 seconds, the retraction of flaps from 7 degrees to 0 degrees helps initially, but not sufficiently to stabilise the response with only 50% tailplane efficiency.

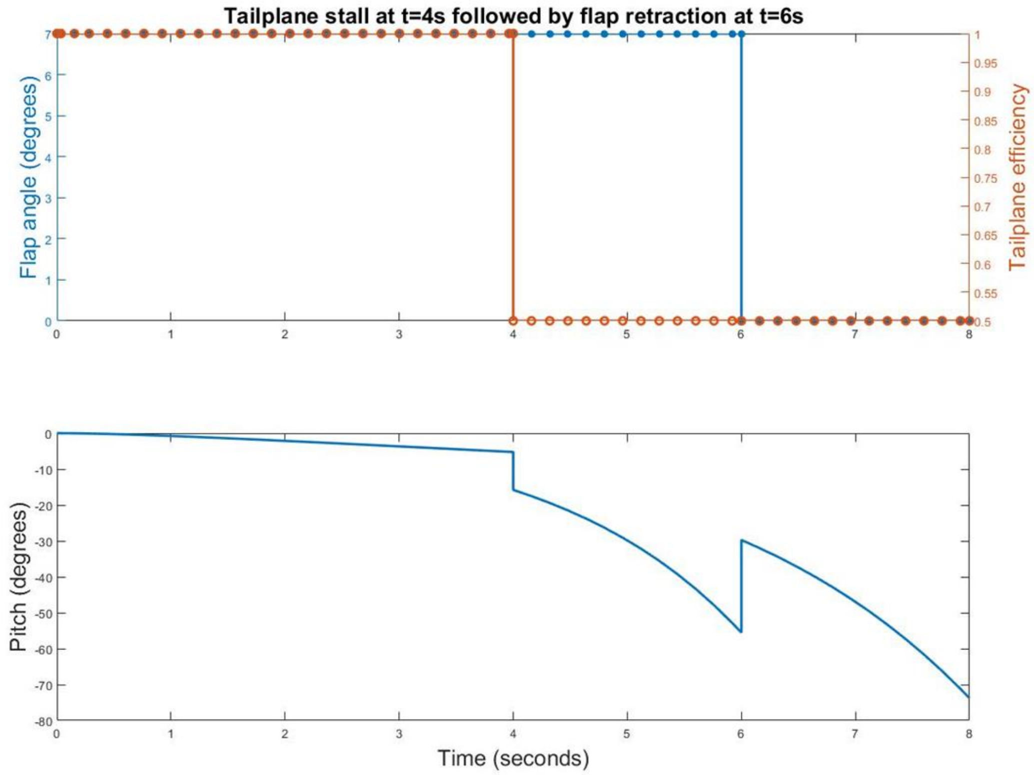


**Figure 15, Pitch Response with Tailplane Stall then Flap Retraction**

The effect of tailplane efficiency on the initial response to a 1 second elevator impulse is shown in figure 16. At 100% horizontal tailplane efficiency, a large 20deg elevator down during 1 second is needed to initiate a large magnitude but stable phugoid response, which is shown during the first 20 seconds for comparison purposes (Figure 16). At 50% efficiency, a 1 second 2-degree elevator down input destabilises the system with oscillations and at 20% efficiency, 1-degree elevator down is sufficient to produce very fast divergence without oscillations.

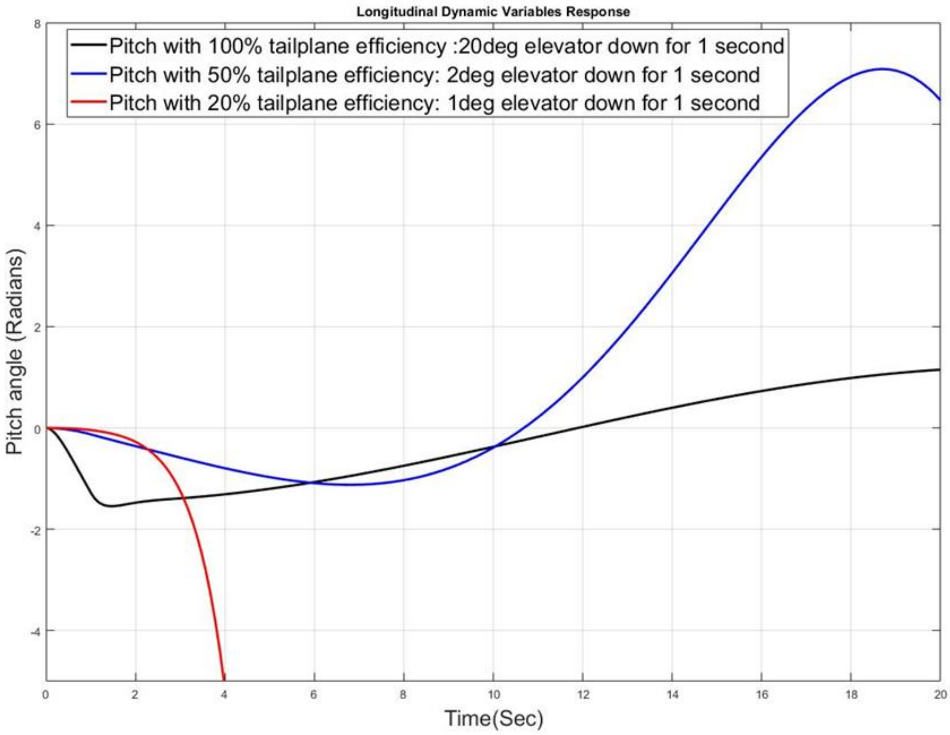


**Figure 16, Pitch Response with Varying Tailplane Efficiency and Elevator Inputs**

Load factor changes with 1 second elevator down commands for varying horizontal tailplane efficiencies were also presented (Figure 17). With 100% efficiency, load factor remains very close to 1 with a small elevator command, as expected. With 50% tailplane efficiency, load factor is reduced but changes are small. Major changes to load factor are however obtained with 20% tailplane efficiency and **negative G** is quickly reached in this case. This is believed to be closer to the conditions during the flight incident.

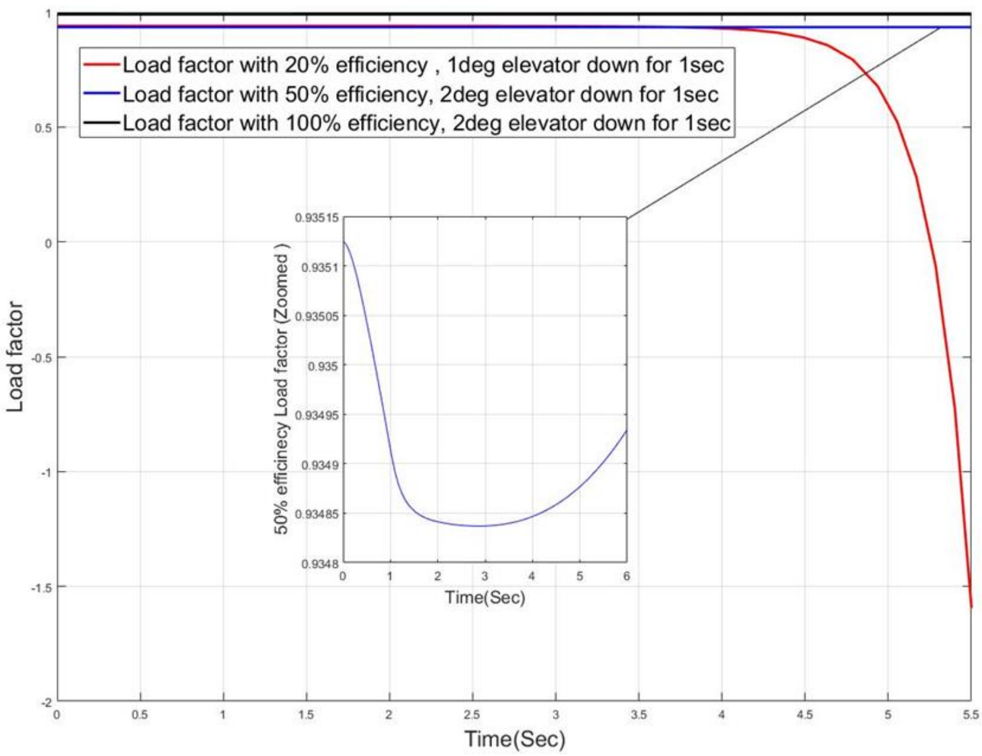


**Figure 17, Load Factor with Varying Tailplane Efficiency and Elevator Inputs**

## 7.4 Summary of Dynamic Stability Analysis

Theory using a generic business jet model (illustrative only) suggests that:-

- The aircraft pitch response to elevator commands is unstable when Tailplane Efficiency is 20%
- Flap retraction helps initially, but not sufficiently to stabilise the response with 20% tailplane efficiency
- A tailplane stall destabilises the system response

# 8 Conclusions

The aim of this study was to provide further insight into Loss of Control Inflight (LoC-I)/Upset events in icing conditions. The main objective was to identify the probable characteristics of a LOC-I/upset event due to tailplane icing for a 'generic business jet'. The lack of available stability, control and aerodynamic data for a specific aircraft make/model resulted in a 'generic business jet' model being used for all analyses. Therefore, it has not been possible to replicate exact aircraft dynamics as evidenced by FDR data using modelling & simulation techniques. Flight data analysis and weather reports were used to determine flight conditions to be assessed, static and dynamic stability was assessed using established flight dynamics theory and modelling.

The modelling and 'what-if' trends analysis does however illustrate similar trends to the recorded flight data, particularly in the case of a severe tailplane stall. The degradation/severity of tailplane aerodynamic characteristics due to icing was simulated using an assumed reduction in Tailplane Efficiency Factor and classical theory supported by a commercial aircraft design software package.
The results are applicable only for short time periods after a given disturbance since:

- A linearised flight model was used about a trimmed flight condition
- No pilot control inputs were available (e.g. yoke pitch/roll, rudder)
- No external (environmental) disturbance data were available (e.g. turbulence)

The results demonstrate that the 'generic business jet' aircraft used in the analysis is statically and dynamically stable when horizontal tailplane efficiency is greater than 80%. When horizontal tailplane efficiency is reduced to 20% (simulating a 'tailplane stall'), the aircraft is statically and dynamically unstable, smaller and shorter elevator commands produce large pitch responses and negative 'G' may be quickly reached within a short time period.

## Appendix A – Model Verification

The following table was used for model verification. In a correct model, the state space based modal characteristics (Damping ratio, natural frequency of each mode) are meant to be close to the theoretical values, although not exactly the same because reduced order models are based on approximations. This is the case in this analysis.

**Table A1, Model Verification**

| | Mode damping ratio, natural frequency from full state space model | Theoretical damping ratio, natural frequency from reduced second order mode approximations |
|---|---|---|
| Damping ratio SPO | 0.5180 | 0.4298 |
| Natural frequency SPO | 3.6029 | 3.6269 |
| Damping ratio LPO | 0.0445 | 0.0593 |
| Natural frequency LPO | 0.1348 | 0.1349 |

## Appendix B– Effects of Complete Loss of Tailplane (Indicative Only)

For preliminary insight into the loss of tailplane effectiveness a commercial flight simulation package and generic business jet flight model was used (Figures B1 & B2). A (negative) nose down pitching moment was observed with negative 'G' as a result of simulated total loss of the tailplane (Figure B3).

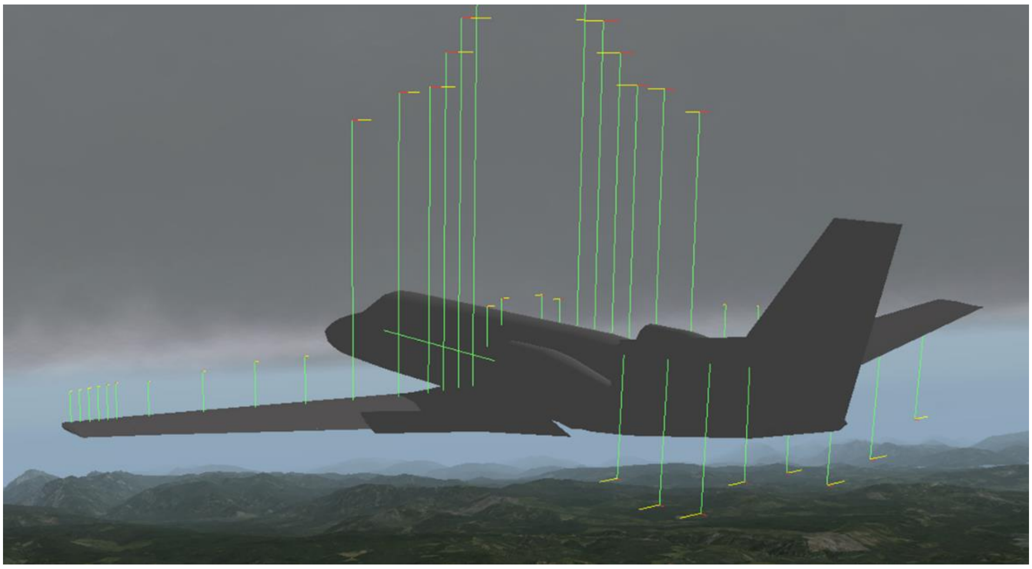

**Figure B1, Aircraft with Tailplane (-ve) Lift**

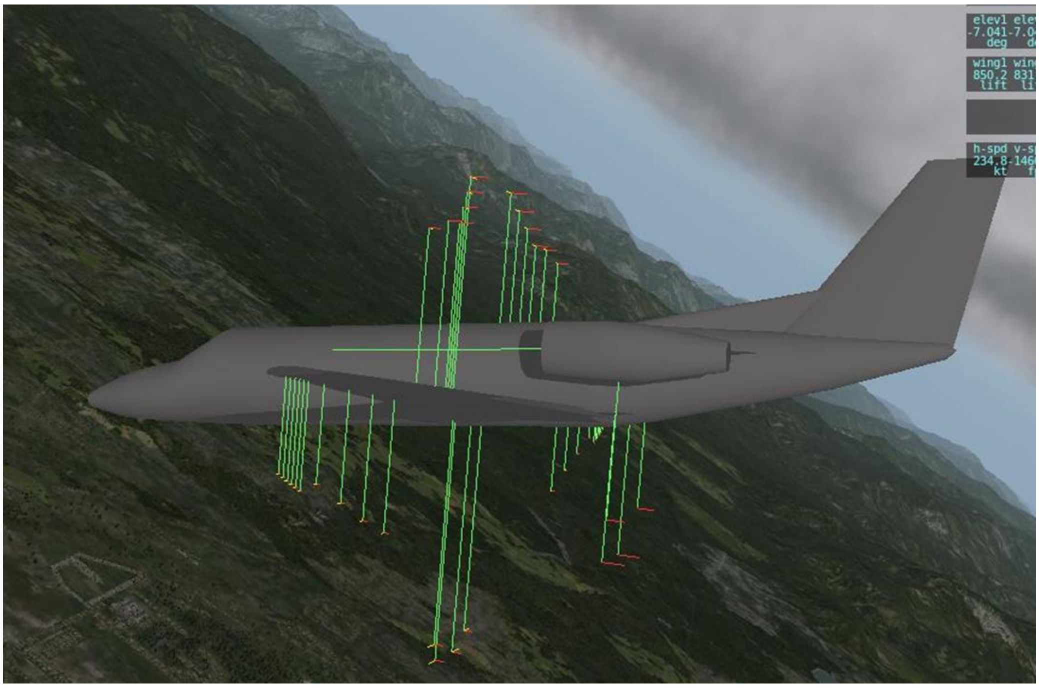

**Figure B2, Aircraft without Tailplane (-ve) Lift**

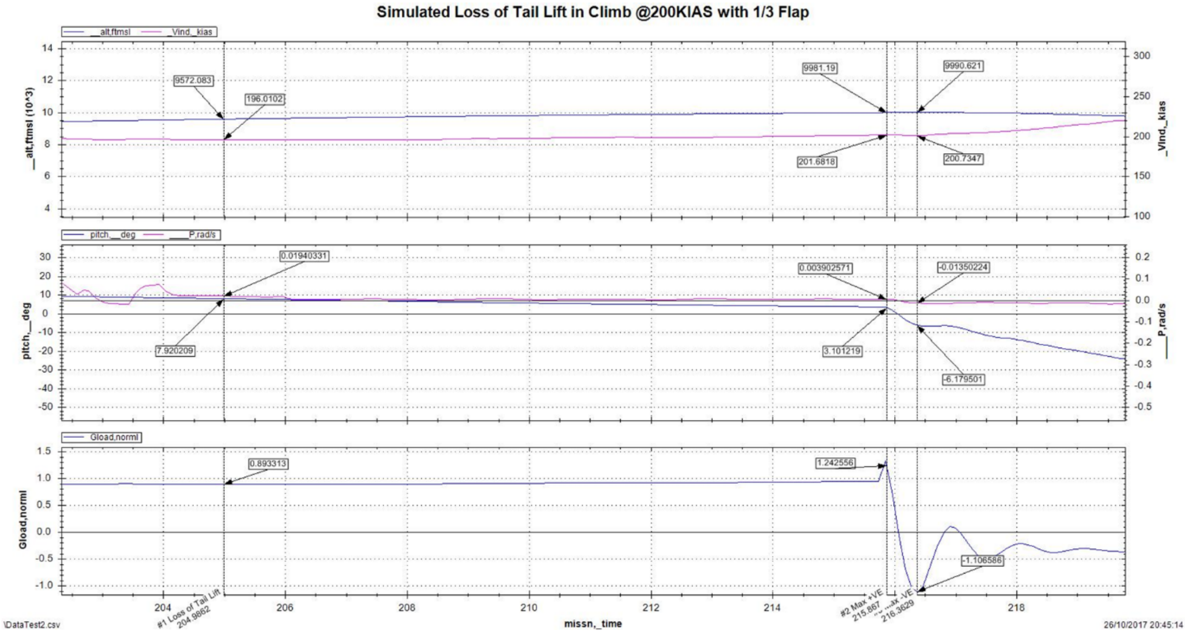


**Figure B3, Normal 'G' before/after Tailplane Loss Max 1.24G/ Min -1.11G (Indicative only)**

# References

[1] Cook, (2013), Flight Dynamics Principles, 3rd Edition, Elsevier, Oxford, UK

[2] Gudmundsson (2014), General Aviation Aircraft Design, Elsevier, Oxford, UK