Saab-Scania SF340B, G-LGNG

AAIB Bulletin No: 8/2004	Ref: EW/C2003/09/03	Category: 1.1
INCIDENT		
Aircraft Type and Registration:	Saab-Scania SF340B, G-LGNG	
No & Type of Engines:	2 General Electric CT7-9B turboprop engines	
Year of Manufacture:	1992	
Date & Time (UTC):	12 September 2003 at 1554 hrs	
Location:	Kirkwall Airfield, Orkney	
Type of Flight:	Public Transport (Passenger)	
Persons on Board:	Crew - 3	Passengers - 36
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Aft fuselage ventral strakes scraped	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	38 years	
Commander's Flying Experience:	2,904 hours (of which 1,714 were on type)	
	Last 90 days - 134 hours	
	Last 28 days - 45 hours	
Information Source:	AAIB Field Investigation	

Synopsis

The aircraft landed at Kirkwall and soon after touchdown the nose attitude reduced slightly and then began to rise to the point where the ventral strakes contacted the runway. A detailed check of the cargo loading revealed that the passenger baggage weight exceeded that stated on the loadsheet by 215 kg and that the aircraft's centre of gravity had been beyond the aft limit. Analysis of the Flight Data Recorder (FDR) showed that the aircraft touched down at V_{ref} -20 kt, at a higher than normal pitch attitude with the elevator in a position that was commanding further nose up pitch; the FDR also showed that nose up pitch trim had been used from the beginning of the flare to the point of touchdown. In accordance with normal procedures, the power levers were retarded from FLIGHT IDLE toward GROUND IDLE just after touchdown. The investigation concluded that the lower than normal de-rotation after touchdown had been caused by a combination of the high landing pitch attitude, the elevator position and the aft centre of gravity position. The major contributors to the nose up pitch change was the negative thrust generated at GROUND IDLE power in combination with the aft centre of gravity. The inability of the crew to lower the nose using full nose down elevator was due to a

reduction in elevator effectiveness caused by a combination of low speed and a change in airflow over the elevators caused by negative thrust.

History of the flight

This narrative is based upon information provided by the flight crew, witnesses to the event, and relevant data from the Flight Data Recorder (FDR).

The aircraft was scheduled to fly a passenger service from Aberdeen, Aberdeenshire, to Kirkwall in the Orkney Islands, departing at 1450 hrs. This was the third flight of the day for the flight crew who had previously flown a round trip from Aberdeen to Sumburgh, the return leg of which had been in G-LGNG. Before departing Aberdeen, the commander was presented with a computerised loadsheet which he checked and signed, having satisfied himself that the weight and balance calculations shown were correct. Departure was delayed slightly, awaiting passenger boarding, and the aircraft pushed back at 1505 hrs. The first officer was the handling pilot and she noticed nothing unusual during the taxi or the takeoff but, during the initial climb, she felt that the aircraft was out of trim. Neither of the pilots considered this to be particularly unusual and the first officer re-trimmed the aircraft before raising the flaps. The aircraft functioned and handled normally for the remainder of the climb, cruise and initial descent. When approaching Kirkwall, the first officer dis-engaged the autopilot and positioned the aircraft on a downwind leg for Runway 27.

At 1,800 feet agl, the landing gear was selected DOWN and at about 1,500 feet agl the flaps were set to 15°. A short time later the flaps were selected to 20°. The aircraft continued to handle normally and the first officer turned the aircraft on to base leg. Shortly thereafter she requested flaps 35° and, immediately after they had been set, the first officer stated that she had "run out of [nose down] trim". However, after discussion with the commander they concluded that the aircraft was controllable and, in particular, they noted that elevator control was still available. After establishing the aircraft on the final approach at about 700 feet agl the crew discussed whether to return the flap to 20° but, having satisfied themselves that the aircraft was still controllable with control authority in all axes, they decided to continue the approach to land.

The speed over the threshold was 113 kt (the nominated threshold speed, V_{ref}) but, as the first officer flared the aircraft for landing, she remarked "this does not feel normal". Nevertheless, the touchdown was uneventful and close to the normal touchdown point, with the thrust levers being retarded from FLIGHT IDLE towards GROUND IDLE just after touchdown. Shortly after landing, when both power levers were brought back to below the FLIGHT IDLE stop, the nose began to rise rapidly. The stall warning activated and despite both pilots applying full nose down elevator, the nose continued to rise until the crew lost sight of the horizon. An eyewitness in the ATC control tower considered that the landing attitude and touchdown appeared normal, but the nose wheel had remained clear of the ground and then began to rise. The crew considered carrying out a go-around, but with the stall warning activated and doubts about the aircraft's controllability they decided to remain on the runway. After a "few seconds" at the maximum attitude reached, the power levers were advanced to the FLIGHT IDLE stop and the aircraft's nose pitched downwards. Following de-rotation and the selection of REVERSE, the crew were able to bring the aircraft to a halt about 350 metres from the end of the runway. Neither the crew nor the eyewitness were aware that the strakes under the rear of the aircraft had scraped the runway during the incident. The aircraft came to a halt in an unusually high nose attitude and the crew had to confirm with ATC that the nose wheel was contacting the ground. The commander decided to disembark some rear-seated passengers and the hold baggage before taxiing to the ramp.

The passenger bags were weighed after landing and were found to be 215 kg more than shown on the loadsheet. A further weight and balance calculation was then made using the actual weights and distribution found. This revealed that the aircraft had been 85 kg over maximum take-off weight, the maximum load for baggage compartment C2 (see below) had been exceeded by 45 kg and the aircraft had operated with the centre of gravity (CG) position beyond the aft limit.

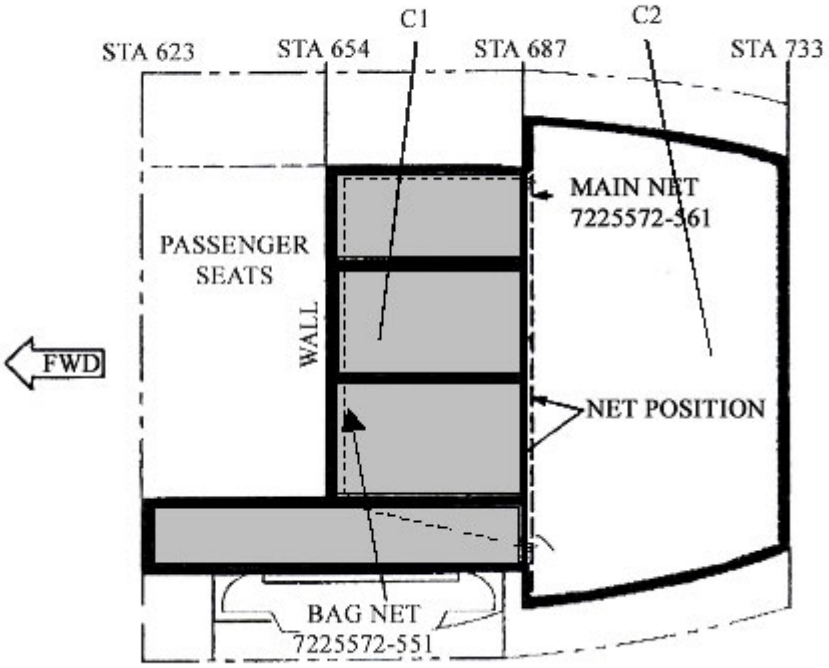
Aircraft configuration

G-LGNG is a Saab 340B with a seating capacity of 36. There are two cargo compartments, C1 and C2, located to the rear of the passenger cabin and both can be accessed via a large cargo door on the left of the aircraft. Passenger baggage is not containerised and is normally loaded loose into each compartment. The maximum load for unsecured cargo in C1 is 510 kg, while the maximum load permitted in C2 is 385 kg; the maximum combined load for C1 and C2 is 860 kg. G-LGNG was unique in the operator's fleet in that hold C1 was 'L' shaped to permit a row of passenger seats to be positioned aft of fuselage Station 623, Figure 1. The aircraft in the rest of the operator's fleet had rectangular C1 holds that extend from Station 623 to Station 687. Thus, although the maximum load for C1 and the maximum combined load are slightly reduced in G-LGNG, the position of the CG for a fully laden aircraft is likely to be further aft in G-LGNG than in the other aircraft in the operator's fleet.

Figure 1: Saab 340B Aft Cargo Hold Layout

Figure 1 Saab 340B Aft Cargo Hold Layout

Note: Valid only for configurations with passengers aft of STA 623.

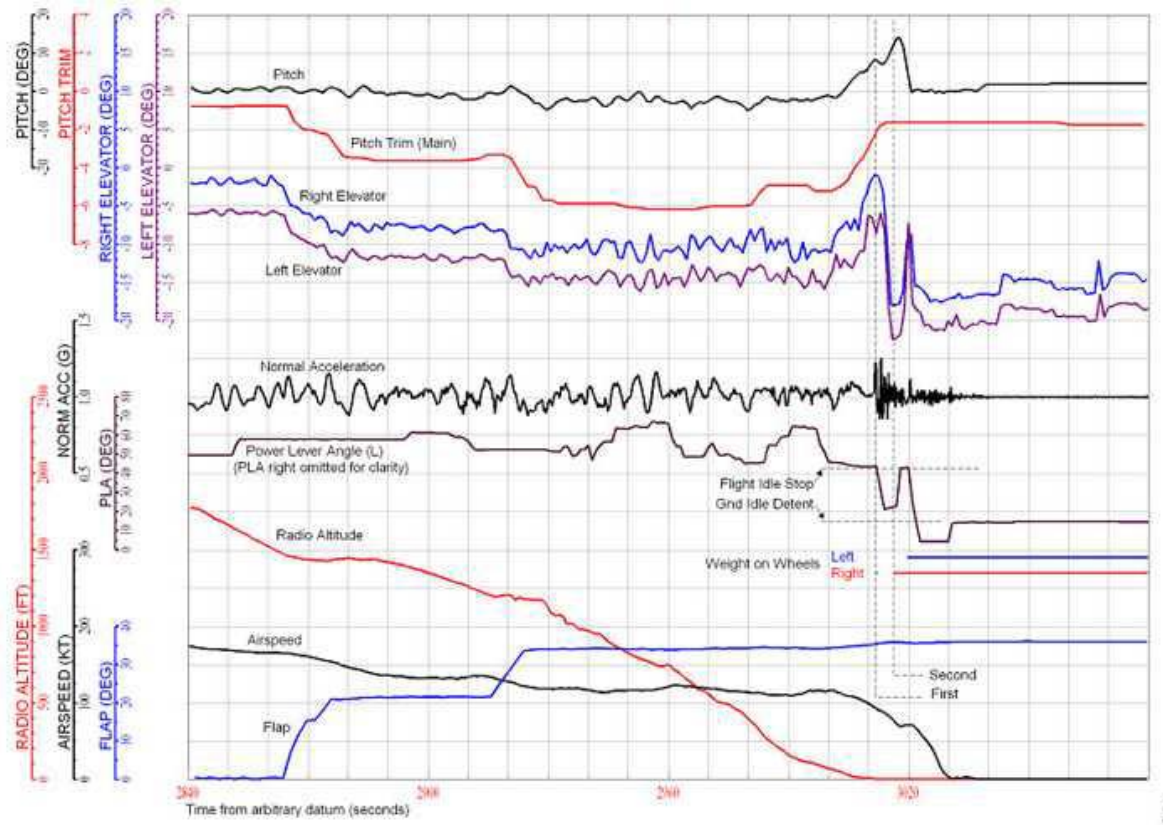


Flight Recorders

The flight data recorder fitted to the aircraft at the time of the event had been removed and sent to an approved maintenance organisation for replay. It was this organisation that provided data printouts to the AAIB for further assessment. A constant difference of approximately 5° was observed between the recorded values of left and right elevator position and it was considered that this was due to the set-up of the relevant aircraft sensors and not because of a difference in actual surface position.

The incident flight, Figure 2

Figure 2: Selected parameters recorded during the landing



Selected parameters recorded during the landing
(Accident to G-LGNG on 12 Sept 2003 at Kirkwall

Figure 2

Settings of 15° of flap and a pitch trim of -1.0° had been selected prior to the departure. At an airspeed of 113 kt nose-up elevator was applied and pitch attitude began to increase at a rate of just over 3.5°/sec. Less nose up elevator was applied and, by 34 feet agl, pitch attitude stabilised at approximately 13.7°.

As the aircraft climbed from 400 feet agl to 700 feet agl and with no change in elevator position, nose down pitch trim was applied with the recorded values changing from -1.0° to -4.0° over this period. Pitch attitude reduced to about 7.5° nose up. Flaps were selected to up and nose up trim was applied to bring the setting back to -1.0°. Later, during the cruise at FL125 with an airspeed of 225 kt, a stable pitch trim setting of -1.7° was recorded.

The remainder of the cruise and initial descent were uneventful. At 1,500 feet agl and 165 kt, the crew selected flap 15° followed almost immediately by flap 20° and commenced a right turn from 127°M towards the runway heading of 271°M. More nose down trim (-3.6°) and nose down elevator were applied to maintain a level pitch attitude. At 1,200 feet agl with the selection of flap 35°, further nose down trim (to a setting of -6.1°) and nose down elevator were applied. The aircraft became established on the extended runway centreline at 450 feet agl with an approximate airspeed of 115 kt.

At 400 feet agl a small amount of nose up trim (change from -6.0° to -4.9°) and a slight increase in nose down elevator was applied.

At 69 feet agl the power levers were moved toward FLIGHT IDLE and engine power reduced to 10-15% torque, the flare was initiated and airspeed began to reduce from 115 kt. Progressive application of nose up trim at an average rate of 0.32°/sec (normal operating rate 0.4°/sec) was recorded during the touchdown sequence. Less nose down elevator was also applied and the pitch attitude of the

aircraft increased from -2.0° to +8.4° by the time that the first contact with the runway surface was made. At this first contact the pitch trim setting was increasing through -2.4°. An airspeed of 93 kt and a normal acceleration peak of 1.2g was recorded. Both power levers were retarded below the FLIGHT IDLE stop to within 4° of the ground idle detent.

Pitch attitude momentarily reduced before increasing sufficiently for the oleos to extend (and possibly for the aircraft to become momentarily airborne) for a period of less than three seconds. Elevator position progressively changed to full nose down during this period whilst pitch trim stabilised at -1.6°. By the time of the second and final touchdown/oleo compression, pitch attitude had increased to 13.4° nose up. One second later, pitch attitude reached a maximum nose up value of 14.06° and this is considered to be when the rear of the aircraft contacted the ground. Airspeed at that time had decayed to 71 kt. Both power levers were then advanced to the FLIGHT IDLE stop (42°) for several seconds, the aircraft began to pitch forward and the nose gear made contact with the runway three seconds later, with less nose down elevator being applied to reduce the rate of de-rotation. REVERSE was selected and the remainder of the rollout was uneventful; the aircraft was brought to a halt on the runway.

A comparison was made with data recorded during another landing. Although similar relative elevator movements were recorded during the flare there was no evidence of nose up pitch trim change.

Baggage loading

Detailed comparison of the actual weight of loaded baggage compared with the weights entered on the loadsheet revealed a number of discrepancies. It was clear that in some cases, notably where baggage for a group had been 'pooled' or where baggage had been interlined from a connecting service, 'Baggage Standard Mass' of 11 kg per bag had been used rather than actual weights. With actual baggage weights varying from 4.2 kg to 32.2 kg, this practice was responsible for some of the undocumented load. There was also some evidence that baggage weights had been estimated rather than measured, possibly in an effort to speed up the check-in process.

There were also discrepancies in the loading of the baggage. The load control officer had produced a Loading Instruction (LI) which indicated to the baggage loading staff where the bags should be located in the aircraft holds. The LI issued for the accident flight required 30 of the 43 bags to be loaded in hold C1 and the remainder to be loaded in C2. Unfortunately the computer software that produced the LI did not fully recognise the limited volume of hold C1 on G-LGNG. When the loading staff came to put the baggage on the aircraft there was a lack of space in hold C1 and so the aircraft was loaded with 23 bags in hold C1 and 20 in hold C2. There was no attempt to re-calculate the trim after this change in loading and, indeed, since the baggage tags did not provide individual baggage weights it was not possible for the ramp loading staff to calculate the trim change. Some time later a number of suit carriers and oversize cabin baggage were loaded in hold C1. Thus, the actual loading of the aircraft was 294 kg in hold C1 and 430 kg in hold C2, compared to the loadsheet which showed 338 kg in hold C1 and 171 kg in hold C2. This mis-loading placed the CG position 13 units aft of the aft CG limit of 64 units. (For reference, the forward CG limit at the aircraft's landing weight was 23.5 units.)

Aircraft Information

The manufacturer's Aircraft Operations Manual (AOM) provides the following information regarding a (normal) landing:

> *'The approach should follow a 2.5-3 degree glide path angle. With an aiming point approximately 1,000 feet down the runway.....*
>
> *Stabilize speed on final and trim for that speed. .....Start to bleed off speed at approximately 50 feet above the runway.*

Flare should be initiated when the main gear is a few feet above the runway; it is accomplished by raising the nose 5-6 degrees from the approach attitude, ie for all normal cases the flare touchdown attitude should be 4-5 degrees nose up. When initiating the flare, gently reduce power to flt idle. Immediately after touchdown retard PLs (Power Levers) to gnd idle.

Do not cause the aircraft to float just above the runway by increasing nose up attitude during flare as this increases the landing distance and may result in tail strike.....

A nose up attitude in excess of 10 degrees at or after touchdown may cause the tail to contact the ground'.

The operator's training staff provide the following additional advice on landing technique:

Aim to cross the threshold at approximately 50 feet.

Advisory datums at threshold:

1. *Vref*
2. *50 feet agl*
3. *Circa 20% torque*

Torque settings of less than 20% produces significant discing effect and excessive rate of descent.

The manufacturer provided the following information about the aircraft's landing characteristics:

- The pitch attitudes at which the rear ventral strakes contact the ground are 13° with the landing gear oleos compressed and 15° with the oleos extended.
- If the AOM recommended landing technique is used the normal touchdown speed is V_{ref} -5 kt.
- The manufacturer's engineering simulator indicated that, on the accident flight, the elevator position at touchdown provided a nose up pitch demand.
- On touchdown the aircraft has a natural tendency to de-rotate from the landing attitude due to the effects of wheel spin up and the vertical reaction of the landing through the landing gear about the CG. On the accident landing, the higher than normal nose attitude and the aft CG combined to provide a slight nose up pitching moment at touchdown.
- Full Ground Idle thrust at 86 kt (the speed at which the thrust levers came closest to the Ground Idle position during G-LGNG's landing) provides 1,600 lbs of negative thrust per engine while Flight Idle at the same speed provides about 400 lbs of negative thrust per engine. The negative thrust provides a nose up pitching moment and reduces elevator effectiveness due to airflow effects over the elevator.

A check of the aircraft's engineering records revealed that there had been no previous problems with the aircraft pitch trim.

Discussion

The principle event in the sequence of events leading to this accident was the mis-loading of the aircraft in Aberdeen. As a result of loading errors, the aircraft was 215 kg above the declared weight on the loadsheet, and departed Aberdeen 85 kg above the maximum authorized take-off weight. The baggage in the cargo hold was not loaded in accordance with the LI and the maximum load for hold C2 was exceeded by 45 kg. As a result of these errors the aircraft's longitudinal CG position was beyond the aft CG limit for both takeoff and landing.

The operator's investigation found that a number of factors had contributed to the loading errors. In particular, the use of Baggage Standard Mass for baggage weights, the possibility that baggage weights had been estimated rather than weighed and the difficulty in ensuring that interline baggage had been correctly weighed and entered into the computer load system, were identified as possible causal factors. The overweight situation was further exacerbated by the practice of providing loading instructions that distributed the baggage by pieces rather than by weight. Since the accident, the operator has put in place a number of procedures to prevent a re-occurrence. The importance of using actual baggage weight has been emphasised to all staff. Software improvements have been introduced that help ensure interline bags are weighed on departure and the weights are entered into the loading computer, and a baggage distribution system based on weight has been introduced. However, although the aircraft was operated with the CG position beyond the aft limit there were other factors that also contributed to the tail scrape.

The FDR showed that at 69 feet radio altitude the power levers were moved towards FLIGHT IDLE at a speed of about 115 kt and that torque reduced to 10-15%. Both pilots recalled that the aircraft "crossed the threshold" at the correct V_{ref} of 113 kt, and the FDR confirmed that the aircraft was at 113 kt at 50 feet agl. However, the movement of the power levers towards FLIGHT IDLE at 69 feet agl was well before the point recommended by the AOM and resulted in a torque setting below that recommended by the operator's training staff.

Furthermore, the landing flare, which the AOM recommends should be *'initiated when the main gear is a few feet above the runway',* commenced at about 50 feet radio altitude. Coincident with the elevator input to increase the pitch attitude for the landing flare, the pitch trim, which by this stage was not fully nose down, started to run in the nose up sense. As a result of these factors, the aircraft eventually touched down with a pitch attitude of 8.3° nose-up (4-5° recommended) at a speed of V_{ref} minus 20 kt.

The first officer cannot remember using pitch trim during the landing flare and stated that she was not in the habit of using pitch trim to assist the flare. However, the average rate of nose up pitch trim movement recorded by the FDR indicates that the pitch trim was not activated continuously and that therefore there was probably more than one activation of the trim switch from the beginning of the flare to touchdown. This may indicate that the trim was used intentionally rather than inadvertently. The elevator position broadly increased in line with the increase in pitch trim possibly indicating that the trim was driving the elevator. The aircraft would have remained largely in trim throughout the speed reduction during the landing flare, and this would have deprived the pilot of normal landing flare control forces. This may partly account for the higher than normal pitch attitude and for an elevator position that was commanding further nose up pitch at touchdown. It may also account for the first officer's sense that the aircraft did not "feel normal". The reason why nose up trim was used during the flare has not been established but it is possible that the forward stick position as a result of the aft centre of gravity position may have been a factor.

After touchdown a number of factors mitigated against normal de-rotation. The manufacturer stated that the higher than normal touchdown pitch attitude in combination with the aft CG resulted in a slight nose up pitching moment when the main landing gear touched down. In addition, the manufacturer's engineering simulator indicated that the elevator position at touchdown was commanding a pitch up. On the other hand, wheel spin-up would have caused a nose down reaction. The combined effect of these factors meant that the nose attitude decreased only by about half a degree.

Shortly thereafter in accordance with published procedures, the power levers were selected from FLIGHT IDLE toward GROUND IDLE. The resultant increase in negative thrust created a nose up pitching-moment, which in combination with the aft centre of gravity, caused the pitch attitude to increase. The crew selected full nose down elevator immediately; however, by the time the elevator reached full nose down travel, elevator effectiveness had been reduced by the combined effects of low speed (about 80 kt) and the change in airflow over the elevators caused by the negative thrust. As a result the elevators did not have the authority to reduce the pitch attitude which increased to the point

where the ventral strakes touched the runway. The pitch attitude eventually reduced shortly after the power levers had been returned to the FLIGHT IDLE position.

The crew had discussed returning the flaps to 20°, a certified landing flap position, for the landing but decided to retain flap 35°. The control column, with flap 20° set, would have been further aft than with the flaps at 35°, and the lesser flap position would have provided a greater margin of trim and elevator control. With the benefit of hindsight, the use of the lesser flap position might have been preferable.

Since the accident, the operator has brought the attention of its flight crews to the hazards of using trim in the flare and plans to include the use of trim in the flare as a data point when a Flight Data Management Programme is introduced.