Havarikommisjonen for Sivil Luftfart og Jernbane HSLB

REPORT

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Date: 01 Nov 2004
SL Report: 40/2004

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.
This investigation is limited in its extent. For this reason, the AIBN has chosen to use a simplified report format. The report format indicated in the ICAO annex 13 is only used when the scope of the investigation makes it necessary.

All times given in this report is local time (UTC + 2), if not otherwise stated.

Aircraft information:		
- Type and reg.:	Airbus A321-232, OY-KBK	
- Manufacturing year:	2001	
- Engines:	IAE V2530-A5	
Operator:	Scandinavian Airlines	
Radio call sign.:	SK 473	
Date and time:	Thursday 4 September 2003, at approx. 1735	
Location:	Oslo Airport Gardermoen (ENGM)	
Type of occurrence:	Incident, early rotation on take-off	
Type of flight:	Commercial scheduled flight	
Weather conditions:	METAR ENGM 041520 UTC: 17004KT 120V220 9999 FEW045 SCT200 21/07 Q1022 NOSIG=	
Light conditions:	Daylight	
Flight conditions:	VMC	
Itinerary:	IFR	
No. of persons onboard:	2 pilots, 4 members of cabin crew and 165 passengers	
Injuries to persons:	None	
Damage to aircraft:	None	
Other damage:	None	
Flight Crew:	Commander	Flight Officer
- Sex and age:	Male, 47	Male, 42
- Licence:	ATPL-A (Swedish)	ATPL-A (Swedish)
- Flying experience:	Total of 10,804 flying hours, of which 291 hours on the A321	Total of 6,003 flying hours, of which 192 hours on the A321
Information sources:	Report from the commander and the company's own investigation report (IR03-04303), report from the Airbus Integration Test Centre and the AIBN's own investigations	

FACTUAL INFORMATION

During preparations prior to take-off on route SK 473 from Gardermoen (ENGM) to Kastrup (EKCH) on 14 September 2003, the flight crew in the cockpit established that the data link by which the aircraft's ACARS[1] usually communicates, was not working. They were therefore not able to calculate their take-off data in the normal way, and made radio contact with the company's air traffic management department (OSLND-T) at Gardermoen to obtain assistance. The aircraft was of the type A321.

The Duty Flight Operation Officer at OSLND-T said that he was not in a position to assist the crew. He explained this by saying that the portable computer that was necessary for the task was out of service. The captain then requested that the person concerned should get in touch with the dispatch office in Copenhagen (CPHOW) to have the calculations made there. The captain read the information about take-off weight, runway and current weather on the radio, so that the Flight Operation Officer would be able to pass these on to Copenhagen. The take-off weight (TOW) was 76.4 tonnes.

The Flight Operation Officer explained to AIBN that he noted down the values, but that he only passed on the relevant details about the runway in use, wind and QNH by telephone to CPHOW. As his reason for doing this, he stated that in Copenhagen they actually had access to everything except the runway in use via computer systems. According to his explanation, the next contact with CPHOW was when he received a fax with the completed results of the calculations.

The explanations from the people involved disagree as regards the values that were exchanged. The Flight Operation Officer in Oslo maintains that erroneous values must have been entered by mistake in the calculations that were made in Copenhagen. The person at CPHOW who took the telephone call has declared that the take-off weight from Oslo was given as 60 tonnes. He has also declared that he made telephone contact again before he carried out the calculations, since he reacted to the fact that the take-off weight was low. According to the person at CPHOW, however, the Flight Operation Officer in Oslo maintained that 60 tonnes was the correct figure, and the calculations were then based on 60 tonnes. The result of the 'Take-off Data Calculations' were faxed to the Oslo office a few minutes later.

The Flight Operation Officer called up the crew on SK 473 by radio and read off the values on the fax from CPHOW. The flight crew has explained that they both took notes while they listened to the radio announcement. The captain read all of the values back and got confirmation that they had been correctly understood. The First Officer also overheard this communication. They reflected on the fact that V_1 was low, but they were satisfied that the values were correct since the read-back had been confirmed. The First Officer entered the speeds V_1, V_R and V_2, and Flex[2] into the FMGC (Flight Management Guidance Envelope Computer). The FMGC on the A321 does not suggest default values for the speeds based on the take-off weight that is entered into the system, which is what the Flight Management Computer (FMC) on SAS aircraft of the type Boeing 737 does, for example.

The table below shows the values based on the incorrect TOW of 60 tonnes and the values for actual TOW, 76.4 tonnes.

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[1] AIRINC Communication Addressing and Reporting System

[2] Reduced take-off thrust that can be used to conserve the engines when the take-off weight is lower than the maximum under prevailing conditions

	TOW = 60.0 tonnes	TOW = 76.4 tonnes	Difference
Take-off decision speed, V_1	118 kt	151 kt	33 kt
Rotation speed, V_R	127 kt	156 kt	29 kt
Initial climb-out speed, V_2	131 kt	159 kt	28 kt

Flex 50 was the actual maximum permissible reduction of engine output at 76.4 tonnes, while Flex 56, which was a maximum reduction at 60 tonnes, was used.

The First Officer was flying the aircraft during take-off. He noticed that the aircraft's response during rotation was sluggish. ('sloppy'). As soon as they were airborne, they were able to see that the selected speed for V_2 (Magenta speed bug) was lower than it should have been, since it was within the red area on the 'speed tape' (see fig. 1).

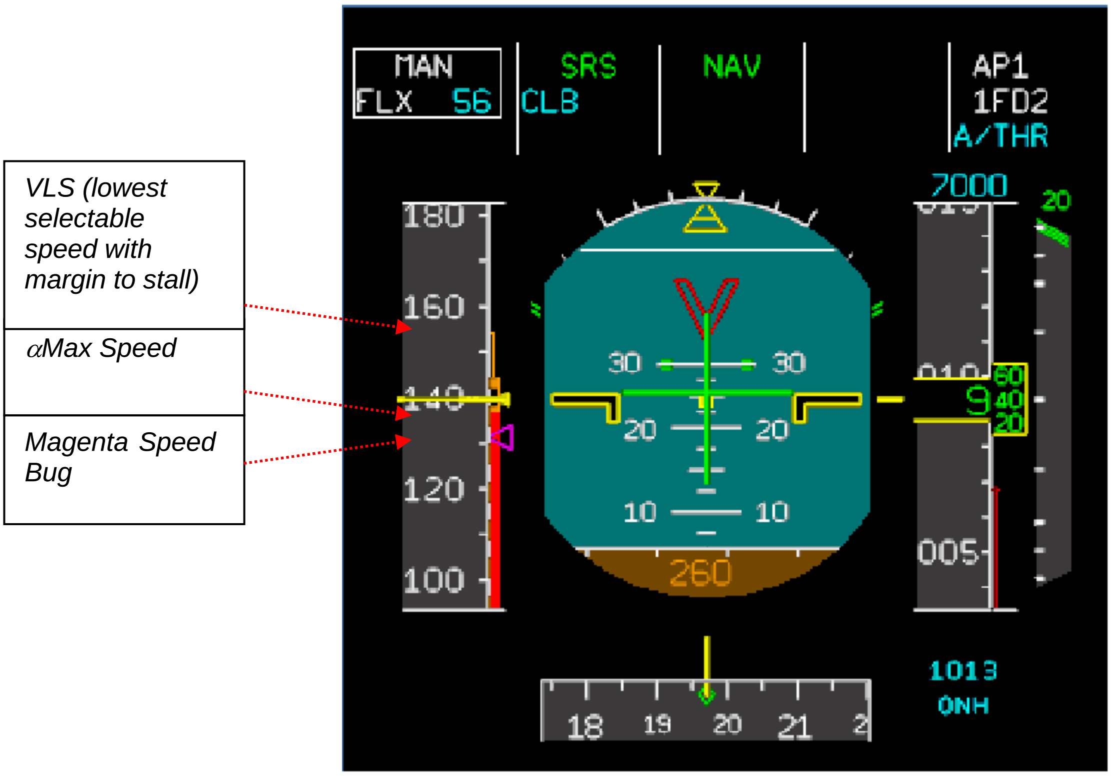

Fig. 1 Illustration of the Flight Management Guidance Envelope Computer (FMGC)

The flight crew chose to accelerate to 250 kt. The climb out of Gardermoen continued without problem or abnormal indications of any kind. However, the crew did not feel satisfied with what had happened and started to make their own investigations once they landed at Copenhagen. It was then discovered that the take-off calculations were based on a take-off weight of 60 tonnes, without it having been accurately clarified where or how the error had occurred.

Among the details that the captain included in his report:

"… to me it is a mystery that I as a commander being responsible for the safety of the A/C do not have a possibility to onboard the A/C make check of T/O calculations, ref. the 'old' Gross Weight Charts in case this happens again."

The company's general, non-type-specific documentation (Operations Manual (OM) sub-para. 2.4.1.2) contains the following statement:

"The actual T/O weight shall always be checked against a valid max T/O weight calculation, normally made by ACARS TODC or handheld computer. As an alternate means, Gross Weight Charts (GWC) may be used."

The following quotation is taken from the company's documentation concerning Take-off data calculation A321 (Flight Crew Operations Manual (FCOM) sub-para. 2.02.90):

"On SAS Airbus aircraft, all takeoff data calculations are performed by using a takeoff data computer program (TODC). In order to calculate optimum takeoff weights and speeds and due to the complexity involved in performing a manual calculation, no GWC is provided. The software program is designed to give maximum takeoff weight for different conditions and maximum thrust reduction for a given actual takeoff weight. All calculations are based on JAA regulations."

The documentation that is included onboard the SAS A321 contains 'Quick Reference' tables for take-off (FCOM 2.02.40), but nothing is laid down about using these for manually calculating take-off data. Immediately after this incident, the company issued the following announcement to their pilots:

"TAKEOFF DATA CALCULATION:
IF ACARS TODC IS U/S, USE LAPTOP IF ON BOARD OR REQUEST CALCULATION FROM CPHOW. ALWAYS HAVE CPHOW READ BACK THE INPUT AS WELL AS THE OUTPUT FOR COMPARISON OF ACTUAL DATA. ON DRY RUNWAY, ALSO CHECK THE RESULT TO BE REASONABLE WHEN COMPARED WITH FCOM 2.02.40"

The loss of the datalink did not lead to a significantly increased workload for the personnel in the air traffic management department in Oslo. In such circumstances, only the company's Airbus aircraft will be in need of assistance with take-off calculations. The rest of the fleet has formal backup systems onboard. As regards the operational stability of systems running ACARS, information from SAS indicates this to be well over 99 %, on an annual basis. During the period August/September 2003, however, a new version of the software for the datalink part was being installed and, in connection with this, the system was out of service several times for periods lasting 1-2 hours.

The AIBN transmitted data from the flight data recorder to Airbus for analysis. The data indicated that the nose wheel had left the ground immediately after the control stick was moved backward through the equivalent of 8° 'aircraft pitch up'. Rotation took place at around 140 kt. The left main undercarriage left the ground at a pitch of 9° and, at 11° 'pitch up', the right main undercarriage also left the ground. According to Airbus, this produced a ground clearance/margin for 'tailstrike' of 0.6 ft (18 cm). Ground clearance at 60 tonnes TOW and the same 'inputs' would have been 4 ft (122 cm). According to FCOM, tailstrike occurs at 11° 'pitch up'.

The wrong take-off weight also led to the calculation of the location of the centre of gravity being wrong (23.3 % instead of 29 %), and the horizontal stabiliser was therefore not optimally adjusted for take-off. (1.32° nose up instead of 0.4° nose down).

The relevant Minimum Control Speed on Ground, V_{MCG}, was lower than the 'false' V_1 of 118 kt. The stall speed (V_S) for a take-off weight of 76.4 tonnes is 128 kt.

The duty Flight Operation Officer at OSLND-T had many years of relevant professional experience. He was trained and gained his licence as a 'flight operation officer' in Sweden in 1977. He had been given general training in the use of a laptop and the current TODC program but, in his everyday work, the need for these skills seldom arose.

Just after this incident, the company's own investigation board carried out a test in which they concluded that the Flight Operation Officer concerned did not have sufficient knowledge and proficiency as regards take-off calculations for Airbus. The same was true for several of the department's employees. The internal board also reported that at the time of the incident it was not clear which services the various support departments should perform for the flight crews.

The company has explained that, in future, flight crews should contact CPHOW directly when assistance is required regarding take-off calculations. However, a new training programme has also been held on T/O Data Calculations for the OSLND-T department employees, since the intention is that they should be able to assist in cases when the flight crews are unable to make contact with CPHOW.

The company's own investigation report contains six recommendations covering the training of personnel in support functions, assessing an individual's qualifications, clarifying the support departments' responsibilities and clarification as regards methods of carrying out take-off calculations. They also recommended carrying out an assessment as to whether an alternative procedure for calculating take-off data ought to be included in the documentation onboard.

In recent years, the accident investigation authorities in Scandinavia have investigated several incidents involving incorrect take-off calculations or errors in the basic data. For example, the SAS Boeing 767 at Kastrup on 28 August 1998 and 24 August 1999, and in Chicago on 24 March 2000. (Ref. reports 49/99 and 21/00 from Denmark's Accident Investigation Board http://www.havarikommissionen.dk/sw13901.asp). There have also been several cases of incorrect loading and incorrect loading documentation. (Ref. AIBN Report: 15/2002, 56/2001, 27/2000).

The incident with the SK 473 has similarities with an accident that occurred in Auckland, New Zealand, on 12 March 2003. An aircraft of the type Boeing 747 from Singapore International Airlines experienced 'tail strike' during take-off after having started rotation at too slow a speed. In this case, the calculations were incorrectly carried out, with a take-off mass that was 100 tonnes too low. One of the recommendations in this report deals with the potential for developing automated functions on the aircraft, to allow unreasonable take-off data to be detected. The recommendation from the Transport Accident Investigation Commission in New Zealand, dated 24 October 2003, is directed at Boeing:

> *"… Implement an FMS software change on all various Boeing aircraft models that ensures any entries (such as V speeds and gross weight) that are mismatched by a small percentage are either challenged or prevented."*

The following is an extract from the preliminary response from Boeing dated 17 November 2003:

"This event is another example of incorrect takeoff speeds, which has previously been identified by Boeing as an issue for the industry. The common feature among these cases is that the takeoff speeds used by the crew are inappropriate to the specific operating conditions (actual weight, runway length, etc). The error or errors leading to the incorrect speed can happen at various points along the computational path, which consists of both manual and automated operations. In all cases, the results are the same - a takeoff is attempted with rotation at an inappropriate speed. The consequential risks to the airplane (tail strike, overweight takeoff, increased runway length, reduced manoeuvre margin to stall, reduced climb gradient, etc) are the same regardless of the specific error that led to the incorrect V speeds. Boeing is working to ensure that adequate and appropriate defences are in place to reduce the possibility that such errors are made or propagated."
…

"The recommended software check would be ineffective in preventing a large proportion of incorrect takeoff speed events - those in which an incorrect weight is entered into the FMC…"
…

"Boeing will continue to examine the safety recommendation in the context of the broader issue regarding incorrect takeoff speeds. As the work progresses, we will determine whether changes to existing FMS installations may be warranted. Separately, we will also determine if such new features should be included in new FMS installations. At this point, no schedule has been set for the completion of our examination."

(Ref. Report 03-003 TAIC New Zealand http://www2.taic.org.nz/InvDetail.aspx?InvNo=03-003).

COMMENTS FROM THE ACCIDENT INVESTIGATION BOARD

This incident joins the series of incidents in which errors have occurred in take-off calculations without this being detected by the crew prior to take-off. The error had no serious consequences. Without the crew's curiosity and willingness to report, the error would have gone unnoticed, and the knowledge could not have been used in proactive flight safety work.

The safety margins are reduced if there is an error in the take-off calculations. If there had been an engine failure, this type of error could have had catastrophic consequences. In such a situation, the margins are much smaller than otherwise, so it is of the greatest importance that the take-off calculations should be correct and that the presumed airspeeds are maintained. The official requirement is that each take-off within this category of aviation should be planned with engine failure occurring at the most inopportune moment. However, it is highly improbable that this would indeed occur. If take-off is based on incorrect take-off calculations, the usual consequences would be, as Boeing describes, 'tail strike', overweight, increased rolling distance, reduced margin for manoeuvre in relation to stalling, reduced gradient of climb etc.

SK 473 was close to sustaining a 'tail strike'. Engine output was reduced by more than is permitted in the regulations, making the rolling distance probably longer and the altitude during departure lower than presumed. Immediately after take-off, the margin to stall speed was less than presumed. As soon as the aircraft became airborne, the automatic controls contributed to making it clear that the selected airspeed for the climb was too low. The crew reacted rapidly and correctly when they saw that the selected departure airspeed (V_2) was below the 'α max speed'. The situation was dealt with by the crew making the aircraft accelerate to a considerably higher speed. This was not a problem under the pertaining conditions, with both engines operational.

Experience shows that incorrect take-off calculations often have different origins, so there are multiple opportunities for making errors in this safety-critical operation. Ideally, technology ought to be developed that would eliminate all opportunities for making errors. If it is not possible to realise this in full, the technology must contribute as far as possible to reducing the probability of an error occurring and spreading. To achieve the necessary degree of security, there has to be interplay between operator and system. Training, good procedures and possibilities for checking results are central elements in this.

The recommendation to Boeing in conjunction with the aforementioned accident in Auckland reflects the thinking on further development of the technology, whereas the response illustrates the challenges facing the manufacturers. The AIBN is also aware that the Airbus is working on the same set of problems. The AIBN has received the following relevant details about the programme of this year's safety conference for Airbus customers:

"One of the topics will address the tail strike issue, taking into account a few examples, amongst them a take-off with a wrong Vr resulting from an error in the take-off weight.

Amongst the preventive actions we are taking:
- Training aids such as video and Flight Crew Operation Briefing Note. The objective is to reinforce pilot awareness on all factors that could contribute to tail strike.
- Depending on the a/c type we are also studying the possibility to provide tail strike indication to the crew and pitch limit indicator. However these design features will not solve by themselves all the possible factors. This is why the key preventive actions are to reinforce pilot awareness."

The purpose behind not providing the crew of A321s with documentation for carrying out manual take-off calculations was to reduce the probability of error. The intention was good, therefore, but at the time of the incident SAS had not established an alternative satisfactory standby solution in case the primary system failed. Laptops are not brought along on ordinary scheduled flights, and the aircrews had to improvise when the datalink failed. The probability of errors occurring is high when verbal information is being transmitted via several links. It is then all the more important for the crew to have the opportunity to check the final result. In reality, SAS had neither made preparations for an alternative procedure, nor provided crews with the training and guidelines for verifying the results.

A contributory cause of the fault going unnoticed was that the aircrew on the SK 473 had little experience of the aircraft type in question when the incident occurred. Gradually, as people gain experience on an aircraft type, they gain a better basis on which to judge whether the results of take-off calculations are reasonable. The fact that the crew did not ask questions, despite the fact that they reacted to the speeds being low, may be explained by what is known within psychology as 'confirmation bias'. People expect the answer to be correct and focus on arguments which support this, while disregarding factors that indicate otherwise, because of this expectation. The error would most probably have been detected if the display on the FMGC had suggested ‘default’ take-off speeds in relation to the take-off weight entered into the system, as on the Boeing 737. Such a considerable discrepancy, as in this case, would have been a clear sign that something was wrong, and that new calculations should be undertaken.

The company’s own investigation report proposes improvements within several areas of the organisation to prevent any recurrence. The AIBN agrees with the conclusions of this report, and recommends that the Norwegian Civil Aviation Authority ensures that the recommendations are properly assessed.

SAFETY RECOMMENDATIONS[3]

The internal SAS investigation team has provided recommendations both to the air traffic management department and the company’s flight operations department aimed at preventing incorrect take-off calculations occurring in future. The recommendations cover the training of personnel in support functions, assessing an individual’s qualifications, clarifying the support department’s responsibilities and clarification as regards methods of carrying out take-off calculations. AIBN recommends that the Norwegian Civil Aviation Authority should assess the company’s monitoring of these recommendations. (SL Recommendation no. 46/2004).

APPENDIX: Recommendations from SAS Investigation Team

[3] The Ministry of Transport and Communications forwards safety recommendations to the Norwegian Civil Aviation Authority and/or other involved ministries for evaluation and monitoring, see Norwegian Regulations regarding public investigations of accidents and incidents in civil aviation, § 17.

4. RECOMMENDATIONS

4.1 OSLND-T shall train involved personnel in calculating T/O data and the understanding of the figures being calculated.
Action: OSLND-T

4.2 OSLND-T shall review and assure TCM's qualifications.
Action: OSLND-T

4.3 Flight Operations shall establish an alternate procedure for calculating T/O data for when the data link is not operational.
Action: STOOF

4.4 Flight Operations shall consider adding material for manual calculation of T/O data in FCOM.
Action: STOOF

4.5 Flight Operations shall state whether data in FCOM 2, 2.02 can be used for T/O data calculations.
Action: STOOF

4.6 Flight Operations shall state what kind of services the different traffic support departments should provide.
Action: STOOF