

**SERIOUS INCIDENT**

<b>Aircraft Type and Registration:</b>	Airbus A330-243, G-OJMC	
<b>No &amp; Type of Engines:</b>	2 Rolls-Royce RB211 Trent 772B-60 turbofan engines	
<b>Year of Manufacture:</b>	2002	
<b>Date &amp; Time (UTC):</b>	28 October 2008 at 0426 hrs	
<b>Location:</b>	Sangster International Airport, Montego Bay, Jamaica	
<b>Type of Flight:</b>	Commercial Air Transport (Passenger)	
<b>Persons on Board:</b>	Crew - 13	Passengers - 318
<b>Injuries:</b>	Crew - None	Passengers - None
<b>Nature of Damage:</b>	None	
<b>Commander's Licence:</b>	Airline Transport Pilot's Licence	
<b>Commander's Age:</b>	47 years	
<b>Commander's Flying Experience:</b>	14,500 hours (of which 3,000 were on type) Last 90 days - 170 hours Last 28 days - 40 hours	
<b>Information Source:</b>	AAIB Field Investigation	

**Synopsis**

Due to an error in the takeoff performance calculations, incorrect takeoff speeds were used on departure. On rotation, the aircraft initially failed to become airborne as expected, causing the commander to select TOGA power. The aircraft then became airborne and climbed away safely. Whilst the investigation could not identify the exact source of the error, deficiencies were revealed in the operator's procedures for calculating performance using their computerised performance tool.

A study of previous takeoff performance events showed that the number and potential severity is sufficient to warrant additional safeguards to be identified by industry and to be required by regulators.

Two Safety Recommendations are made.

**History of the flight**

The crew reported for duty at 0245 hrs UTC (2145 hrs local) at Sangster International Airport, Jamaica for the flight to the UK. The flight crew consisted of a commander, a co-pilot and a supernumerary pilot, who was an A330 line captain and also a qualified A320/A321 training captain.

During the pre-flight preparation, the flight crew were unable to locate the aircraft's performance manual. As a result, at about 0400 hrs UTC (2300 hrs local in Jamaica, 0400 hrs local in UK), the commander contacted the operator's flight dispatch department in the UK by mobile telephone, requesting that the figures be calculated using the Airbus Flight Operations Versatile Environment (FOVE) computerised system. The dispatcher taking the call in the UK and the commander

reported that the telephone reception had been good and that communications had been clear. Information was passed by the commander to the dispatcher in order for the performance figures to be calculated using the FOVE system and these figures were then read back to the commander. The telephone was then handed to the operating co-pilot to repeat this process as a cross-check. The commander and co-pilot stated that they both received the same takeoff performance figures and that these were entered into the Flight Management Guidance System (FMGS).

The remainder of the pre-flight preparation was completed without incident and all three pilots briefed for the departure from Runway 07. The brief included a review of the performance figures entered into the FMGS, none of which the three pilots considered abnormal for the aircraft's planned weight.

Takeoff was commenced at 0426 hrs UTC with the commander acting as handling pilot. The aircraft appeared to accelerate normally and the co-pilot made the standard calls as the aircraft passed through 100 kt and then  $V_1/V_R$ . The commander was surprised by how close the calls had followed on from each other. On hearing the co-pilot call 'rotate' he pulled back on his sidestick and pitched the aircraft to about 10° nose up but stated that the aircraft 'did not feel right' and instinctively selected TOGA power. The aircraft then became airborne and climbed away.

Having completed the after-takeoff checks the crew discussed the incident and decided to check the takeoff performance figures by reference to the generic performance data contained in the FCOM 2 Manual carried on the flight deck. This revealed significant differences in the performance data derived from the manual to that used for the takeoff.

The flight continued without further incident and, during the final descent, the aircraft's performance manual was found. It had been incorrectly stowed amongst some navigation charts.

### **Airport information**

The Montego Bay / Sangster International Airport has one runway designated 07/25. Takeoff Run Available (TORA) for Runway 07 is 2,663 m with an Accelerate/Stop Distance Available (ASDA) of 2,724 m and an upslope of 0.03%.

### **Reduced thrust takeoff**

Certain aircraft can optimise the engine thrust used during takeoff by using less than the maximum thrust available. This reduces engine wear whilst providing sufficient power to achieve takeoff under the prevailing conditions. On Airbus aircraft this is referred to as 'FLEX'. The takeoff power is adjusted by entering an artificial outside air temperature (OAT) into the FMGS. The OAT is calculated from the aircraft configuration and airport weather conditions, and is referred to as the 'FLEX temperature'. When the throttle levers are advanced to the FLX/MCT (FLEX / Maximum Continuous Thrust) position, the autothrottle system commands the reduced thrust. The higher the FLEX temperature used, the lower the thrust generated.

### **Operator's FOVE takeoff performance calculation procedure**

Each of the operator's Airbus aircraft carried a performance manual containing tabulated data which allowed the crew to determine takeoff performance. Flight crews were also able to contact the operator's dispatch office, based in the UK, to request performance data calculated using the FOVE system. As this gives more accurate performance figures it is generally used on occasions where takeoff performance is more limiting.

Instructions and procedures on the use of the FOVE computer system were contained in the operator's Flight Support Procedures Manual. This manual was intended for use by ground staff only. Flight crews were not provided with a comparable written procedure documenting their role in obtaining FOVE performance figures from their dispatch office.

The FOVE system required the user to input aircraft data, including the takeoff weight, weather conditions and runway information, prior to it computing the relevant performance data. The calculated data produced included the  $V_1$ ,  $V_R$  and  $V_2$  speeds as well as any permitted reduction in takeoff thrust, expressed as the FLEX temperature. It was also capable of calculating the aircraft's Green Dot<sup>1</sup> speed. The aircraft's FMGS also calculates the Green Dot speed independently of the performance figure provided by FOVE, and so this could be used as a gross error check, provided that the same takeoff parameters were input to both systems. The function to calculate the Green Dot speed had, for an unknown reason, been disabled on this operator's FOVE system and they had no procedure requiring the FOVE-generated Green Dot speed to be passed to crews.

In addition the system displayed any specific takeoff emergency procedures required for the departure being used. However, the operator's procedure did not specify the requirement to pass any emergency turn procedures to the crew as part of the performance calculation process as this information should be available to the crew in the onboard performance manual. In this event, the crew of G-OJMC could not find this manual.

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**Footnote**

<sup>1</sup> The single engine target speed in the clean configuration, being approximately the best lift to drag ratio speed.

The procedure published in the operator's Flight Support Procedures Manual required the dispatcher to obtain the input figures from the crew and enter them into the FOVE computer. Once the performance figures had thus been computed he would then read back the input figures to one of the crew members as a crosscheck, followed by the performance figures. He would then request to speak to the other crew member and would in turn hand the FOVE computer over to the other dispatcher on duty for the whole process to be repeated.

If the dispatcher was on duty on his own he was required to contact the duty pilot, who had his own FOVE computer, to carry out the second calculation. In this way two independent sets of performance figures were generated using two sets of input data. Once the entire procedure was complete the two pilots compared the performance figures they had independently obtained and, provided they were consistent, these were then entered into the FMGS.

The dispatcher logged the input information and performance output on a logsheet, which was retained as a record. However, there was no standard method or requirement for the flight crew to record either the performance figures or the information used to derive it as part of the flight documentation.

The FOVE procedure did not appear in any flight crew documentation. A flight crew air safety report, raised in August 2008, questioned the procedure for cross-checking performance data, because the procedure was alleged to be open to interpretation. The report was passed to the relevant department for comment but none had been received at the time of this incident.

### FOVE performance calculation

The telephone conversations were not recorded and it has not been possible to determine exactly what information was passed between the crew and dispatcher. Two dispatchers were on duty at the time, but only one was in the dispatch office when the call was made and only he processed the data. He did however speak with both pilots and confirmed the input data and performance data with each.

The data recorded by the dispatcher in the FOVE performance log are shown in Table 1.

As noted above a takeoff mass (TOM) of 120,800 kg was recorded on the performance log, although the true TOM recorded on the aircraft's loadsheet was 210,183 kg. When recalculated using the correct TOM, this gave the following output conditions shown in Table 2.

Input Conditions		Output Conditions	
Date	28 October	Flex	63°
A/C reg	G-OJMC	V1	114 kt
Runway	07	VR	114 kt
Wind	0 kt	V2	125 kt
OAT	27°C	Config	2
QNH	1015	Perf limit wt	236,893 kg
TOM	120,800 kg		
Config	Optimal		
Air Conditioning	Off		
Anti ice	Off		
Rwy cond	Dry		
Thrust option	TOGA		

**Table 1**

Flex	50°
V <sub>1</sub>	136kt
V <sub>R</sub>	140kt
V <sub>2</sub>	147kt
Config	2
Perf limit wt	236,893kg

**Table 2**

## Duty periods

### *Flight crew*

The commander had ended an eight-day period of leave on 24 October during which he had been attending to a sick family member. He was at home on standby on 25 October, but was not called.

The operating co-pilot had returned from a long-haul trip on 22 October. He then had three days off.

The supernumerary pilot had been off on 22-23 October. The following day he had attended a two hour office meeting at his home base and was at home on standby on 25 October, but was not called.

All three crew members had flown out to Jamaica on the 26 October. The flight had departed the UK at 0938 hrs UTC (0938 hrs local) and had arrived at 1945 hrs UTC (1445 hrs local). The commander and co-pilot operated the flight and the training captain had positioned on the same aircraft as a passenger.

The return flight was due to depart at 0005 hrs UTC (1905 hrs local) on 28 October but, due to the delayed arrival of the inbound flight, the departure was rescheduled for 0400 hrs UTC (2300 hrs local). The crew was notified of this change at about 1530 hrs UTC (1030 hrs local).

### *Dispatcher*

The dispatcher had been off sick from 22-24 October. He had then worked from 0700 hrs UTC to about 1730 hrs UTC on 25 October. He next reported for duty at 1850 hrs UTC on 27 October for a planned 12 hour shift. From a subsequent interview it was apparent that he had not fully recovered from his period of sickness when he returned to work.

## Electronic flight bags (EFBs)

With the advent of 'less paper' and 'paperless' cockpits came a variety of devices which allow flight crews to access documentation and information electronically. In 2003, the JAA issued Technical Guidance Leaflet (TGL) 36<sup>2</sup> which provides guidelines to cover airworthiness and operational criteria for the approval of EFBs.

An EFB is defined in TGL 36 as:

*'An electronic display system intended primarily for flight deck or cabin use. EFB devices can display a variety of aviation data or perform basic calculations (e.g. performance data, fuel calculations etc.)'*

Under these guidelines, the operator's FOVE system was classified as a Class 1 hardware and Type B software EFB. Such a configuration does not require airworthiness approval but TGL 36 outlines an operational approval process to ensure the fidelity and reliability of the system, which should be undertaken with the appropriate airworthiness authority. Included in this operational approval process are details of the flight crew training required, and procedures for crosschecking of data entry.

Work is in progress to supersede TGL 36 with an EASA Acceptable Means of Compliance (AMC 20-25). As of July 2009, this was still in draft form and the Notice of Proposed Amendment (NPA) action under the EASA rulemaking procedures is pending.

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### Footnote

<sup>2</sup> JAA Temporary Guidance Leaflet No 36 – *Approval of Electronic Flight Bags (EFBs)*.

## Recorded Information

Due to the length of the flight between Montego Bay and the UK, the Cockpit Voice Recorder (CVR) had been overwritten. However, the Flight Data Recorder (FDR) had recorded over 53 hours of operation and captured the incident flight.

The recording started with the aircraft taxiing to Runway 07, arriving at the threshold at around 04:26:25 hrs. Just prior to takeoff, the FDR recorded a gross weight of 210,338 kg, CG position of 30% Mean Aerodynamic Chord (MAC) and a FLEX temperature of 63°C. The slats and flaps were extended in CONF 2 and the air conditioning packs were selected to OFF for takeoff.

Takeoff commenced after the aircraft was lined up, with the thrust levers advanced to the FLX/MCT position and the commander's side stick pushed forward to around 4 degrees (maximum travel is  $\pm 16$  degrees) to command a slight nose-down pitch. Both engines increased to 82%  $N_1$  and the aircraft began accelerating, achieving a longitudinal acceleration of around 0.16g.

Data presented in Figure 1 shows recorded aircraft parameters plotted with respect to the G-OJMC's estimated position on the runway. As the aircraft latitude and longitude was only recorded every four seconds, position on the runway was established by integrating the longitudinal acceleration and assuming that the aircraft started rolling at the runway threshold.

As the aircraft accelerated through an airspeed of 116 kt, over a two second period, the commander pulled back on the sidestick to  $-14.8^\circ$  to command the aircraft to pitch up. Figure 1 shows this command was then reduced to  $-10.6^\circ$  and then back up to  $-15.5^\circ$  over the next second. The nose gear left the ground three and a half seconds

after the pitch up command began, at an airspeed of 125 kt. The commander then reduced the sidestick position to around  $-9^\circ$  pitch up command but the aircraft pitch attitude continued to increase.

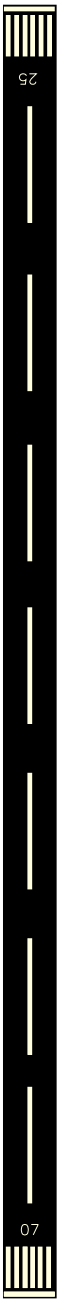
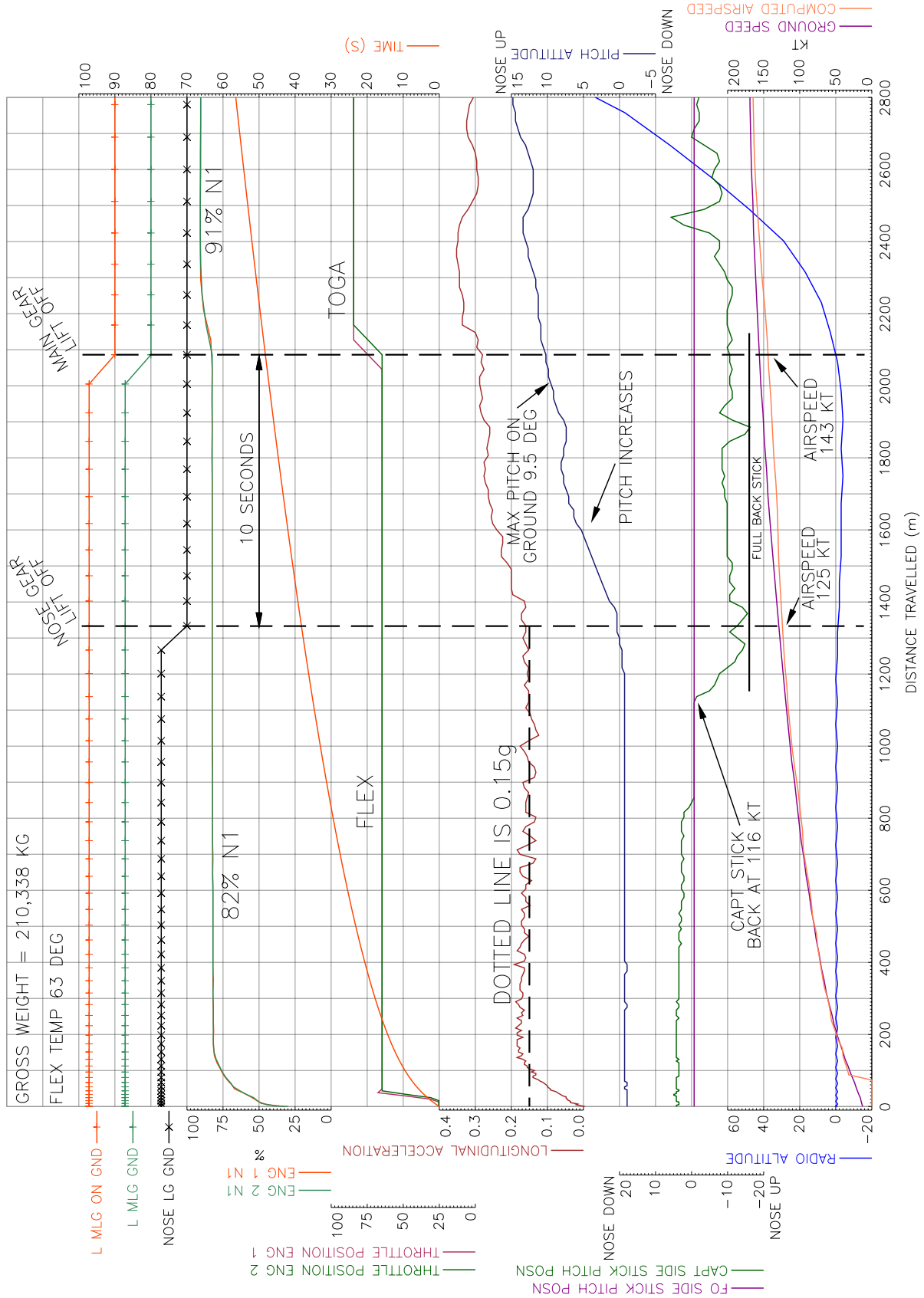
Ten and a half seconds after the initial pitch up command, as the aircraft accelerated through 138 kt, the main landing gear was still on ground and the commander applied a further pitch up command by pulling fully back on the sidestick to  $-16.3^\circ$ . Two seconds later as pitch attitude increased further, the main landing gear squat switches registered that the main gear had extended. The pitch attitude at this time was  $10.2^\circ$ , airspeed 143 kt and the approximate runway distance covered was 2,086 m. Maximum aircraft pitch attitude on the ground with the main gear compressed was recorded as  $9.5^\circ$  nose-up.

As the aircraft became airborne, the thrust levers were advanced to the TOGA position and the recorded engine  $N_1$  increased to 91%. Aircraft pitch attitude continued to increase until, at a radio altitude of 40 feet and  $13.4^\circ$  pitch up, the commander pushed the sidestick forward to  $5.6^\circ$ . By 50 feet radio altitude, the aircraft had covered an estimated distance of approximately 2,500 m since the start of the takeoff roll.

## Aircraft performance

With the lower aircraft acceleration provided by a lower thrust from the engines, the aircraft will require more runway length to achieve a given speed than if the engines were producing full thrust. With more runway used up, the distance available in the event of a rejected takeoff is then reduced.

Using a 63°C FLEX temperature and takeoff weight of 210.4 tonnes, the aircraft manufacturer calculated that in the event of a rejected takeoff at  $V_1$  with all engines operative, the required Accelerate-Stop Distance (ASD)



**Figure 1**  
Relevant G-OJMC FDR Parameters

would have been 1,828 m. In wet conditions this would have increased to 2,082 m.

### Previous occurrences and studies

#### *Transportation Safety Board (TSB) of Canada, 9G-MKJ investigation*

On 14 October 2004, an aircraft registered 9G-MKJ attempted to take off from Runway 24 at the Halifax International Airport. The aircraft overran the end of the runway for a distance of 825 feet, became airborne for 325 feet, and then struck an earth bank, killing all on board. The accident was investigated by the Transportation Safety Board (TSB) of Canada whose report<sup>3</sup> included in its conclusions that it was likely that an incorrect aircraft weight was used to generate takeoff performance data. This resulted in incorrectly calculated takeoff speeds and a thrust setting which was too low to enable the aircraft to takeoff safely for the actual aircraft weight.

The report also stated that:

*'Once the take-off began, the flight crew did not recognize that the aircraft's performance was significantly less than the scheduled performance until they were beyond the point where the take-off could be safely conducted or safely abandoned.'*

As a consequence of this accident, TSB Canada issued a number of recommendations including recommendation A06-07:

*'the Board recommends that:*

*The Department of Transport, in conjunction with the International Civil Aviation Organization, the Federal Aviation Administration, the European Aviation Safety Agency, and other regulatory organizations, establish a requirement for transport category aircraft to be equipped with a take-off performance monitoring system that would provide flight crews with an accurate and timely indication of inadequate take-off performance.'*

The Canadian Department of Transport (Transport Canada) was the only organisation required to respond to this recommendation from the TSB. Their response was:

*'It is agreed that if a Take-off Performance Monitoring System could be designed to function as intended, it could provide a significant safety benefit, however in order for Civil Aviation Authorities to establish a requirement for aircraft to be equipped with a take-off performance monitoring system, an acceptable system would have to exist. Transport Canada is not aware of any certified system that is available at this time to meet this recommendation.'*

Transport Canada also cautioned that such a system may create a greater hazard through spurious warnings resulting in unnecessary high-speed rejected takeoffs and stated that such a system would have to demonstrate a high reliability.

Since the initial response, work has progressed between Transport Canada and the TSB with Transport Canada forming a cross-disciplinary project team. Objectives of

### Footnote

<sup>3</sup> Transportation Safety Board of Canada Aviation Investigation Report No A04H004,



this team include establishing what remains to be done before a certifiable Takeoff Performance Monitoring System (TPMS) could be made available, consulting with industry to gauge their interest in a TPMS solution, and working with industry to bring about a certifiable system. By April 2009, none of these objectives had been achieved and progress was limited.

In response to the 9G-MKJ accident report, the JAA issued a Safety Information Circular (SIC)<sup>4</sup> highlighting the importance of crosschecking EFB output, independent calculation and gross error checks. It also detailed suggested improvement to EFBs to prevent incorrect data from previous flights being used.

#### *AAIB G-OOAN investigation<sup>5</sup>*

During takeoff out of Manchester Airport on the 13 December 2008 a Boeing 767, registration G-OOAN, suffered a tailstrike. After dumping fuel, the aircraft safely returned to Manchester. Takeoff speeds had been calculated using a computer-based tool, into which the crew had inadvertently entered the Zero Fuel Weight instead of the aircraft takeoff weight, a difference of 54.4 tonnes. Subsequent takeoff speeds were in the order of 20 kt lower than they should have been.

During the takeoff, the commander delayed the  $V_1$  call by 10-15 kt due to a “sluggish” acceleration which he felt was due to the aircraft being heavier than calculated.

#### *Australian Transportation Safety Board (ATSB) A6-ERG investigation*

On the 20 March 2009, during takeoff from Melbourne Airport in Australia an A340-500, registration A6-ERG, suffered substantial tailstrike damage. It also damaged

some lights and the instrument landing system at the airport. The preliminary report<sup>6</sup> issued by the ATSB detailed that a takeoff weight 100 tonnes lower than the actual aircraft takeoff weight was inadvertently used by the flight crew during takeoff performance calculations. The result was the use of a thrust setting and takeoff speeds lower than that required for the actual aircraft weight and a tailstrike occurred during rotation.

#### *CAA Mandatory Occurrence Report (MOR) data*

A search of the CAA MOR database for performance related incidents during takeoff covering the ten-year period prior to this incident revealed 26 relevant events.

- Eight cases related to the aircraft being significantly heavier than the loadsheet figure used to calculate the performance.
- Four cases involved aircraft performance being calculated remotely from the aircraft, the incorrect figure then being passed to the crew prior to departure via ACARS. These cases did not involve a system of crosschecking between the crews and those carrying out the calculations.
- Four cases involved deficiencies in performance and airfield charts intended for use in calculating aircraft performance. These were all identified prior to takeoff, although it is not known whether they were used to produce erroneous data during previous flights.
- Three cases identified failings in the design of the Flight Management Computer (FMC) on one aircraft type which allowed the commander’s and co-pilot’s FMCs to display

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#### **Footnote**

<sup>4</sup> JAA SIC No 7, 15 August 2006.

<sup>5</sup> AAIB Report EW/G2008/12/05, July 2009 Bulletin.

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#### **Footnote**

<sup>6</sup> ATSB report AO-2009-012, Issued 30<sup>th</sup> April 2009.

different figures. This was discovered when a weight change was programmed into one FMC which was not then reflected in the other.

- Three cases were due to engine problems resulting in reduced thrust being available, but which were not necessarily reflected in specific warnings to the crew.
- Two cases resulted from ice accretion causing degraded performance.
- One case was due to the crew misinterpreting Minimum Equipment List (MEL) performance requirements as a result of a technical failure.
- One case was due to the crew entering incorrect data into the FMC.

#### *Study into performance errors at takeoff*

In 2008, the BEA<sup>7</sup> issued a report titled '*Use of Erroneous Parameters at Takeoff*'<sup>8</sup> which was instigated after two serious incidents in France involving early rotation and a subsequent tailstrike on takeoff. Both events were caused by use of incorrect aircraft weight at takeoff with consequential incorrect calculations of thrust and takeoff speeds. The effect in each case was that the aircraft attempted to take off using incorrect performance parameters.

The report included analyses of the accident involving 9G-MKJ and of a further 11 incidents involving tailstrikes or crew perceptions of a reduced performance on takeoff.

Conclusions of this report included the fact that errors relating to takeoff data are frequent and that the use of the appropriate aircraft weight is a key factor in calculation of the correct takeoff parameters. Time pressure and interruptions as the departure time approached were cited as common factors in contributing to errors. In several of the cases, crews perceived abnormal aircraft behaviour during the takeoff and took action.

#### **Takeoff performance monitoring systems**

Once the takeoff data has been calculated and programmed into an aircraft's flight management system, no additional takeoff performance monitoring is undertaken by the aircraft while accelerating down the runway. In the case of G-OJMC and in a number studied in the BEA report, the flight crew suspected that the takeoff performance was abnormal and took action.

The concept of TPMS has been the subject of a number of studies. The systems operate on the principle of monitoring aircraft acceleration and comparing it against the expected acceleration for the given aircraft configuration and airfield conditions. Beyond this, dynamic systems, using aircraft position and the remaining runway available, can continuously calculate whether sufficient runway remains available for safe takeoff or for a safe rejected takeoff. Such a system could help flight crews decide if the takeoff performance is somehow abnormal.

Concerns have been raised with such systems that spurious warnings may lead to unnecessary high-speed rejected takeoffs with their associated risks. However, the benefits of such a system are the ability to provide a timely alert in the event of unexpected takeoff performance and that its calculations could be made independent of data entered by flight crews.

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#### **Footnote**

<sup>7</sup> Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile, the French equivalent of the AAIB.

<sup>8</sup> Use of Erroneous Parameters at Takeoff, DOC AA 556/2008, May 2008, available on the BEA website.

### **Airbus developments**

The aircraft manufacturer confirmed that, as part of ongoing system improvements, studies are underway looking at improvements to the FMGS to help prevent flight crews entering erroneous takeoff data. These improvements include identifying out-of-range weight entries and takeoff speeds, and are designed to capture incorrect crew entries prior to takeoff. The manufacturer has recently certified a system known as 'Brake to Vacate' (BTV) on the A380. The primary function of this system is to be able to stop the aircraft next to a pilot-selectable runway exit after landing. This system also includes a function which monitors aircraft performance during deceleration with respect to runway position. If insufficient runway remains using a calculated deceleration profile, the flight crew are advised and the system will automatically apply maximum braking. Currently the BTV function is available only during rollout following a landing and not during a rejected takeoff.

### **EASA activities**

As part of this investigation, the EASA was contacted to obtain its views and current thinking on the topic of TPMS. Their response was that no direct work into such systems was underway. However, they were extremely forthcoming about future developments in EFB standards, recognising the continued improvements in sophistication and increased use of such devices. Also recognised were the safety implications of erroneous takeoff parameter input and the need for robustness in both EFBs and operational procedures.

Separately, as part of the EASA Rulemaking programme<sup>9</sup>, work is underway into ascertaining the 'real' weight and

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#### **Footnote**

<sup>9</sup> EASA 4-year Rulemaking Programme 2009-2012 items OPS.036 (a) and (b).

balance of aircraft with a view to reducing the number of accidents and incidents involving incorrect load data and loading.

### **Analysis**

#### *Operational factors*

Whilst it has been determined that the crew used incorrect performance speeds and thrust setting for the takeoff, it has not been possible to determine the exact cause of the error. It is apparent that the operator's procedures were not followed in full, and that the operator's FOVE system had been set up in such a way that an important crosscheck designed into the system was not available to those using it.

The crew were all able to describe the normal range of takeoff speeds and FLEX temperatures they would expect to see for such a takeoff, the figures actually used falling some way outside this range. The crew were, in theory, well-rested although there had been disruption to the flight's departure time. It is likely that the mental performance of all those involved would have been affected by being at a low point in their circadian rhythm at the time of making the performance calculations. However, these circumstances are not exceptional for crews, especially on long-haul flights where time differences will be a factor.

The crew were unable to explain why they did not recognise that the figures they used were outside the expected range, and it is considered possible that other crews, especially those less experienced or less rested, might be expected to make a similar oversight.

As a result of this incident the operator has reconfigured its FOVE system to incorporate the Green Dot calculation function. They have revised the ground staff instructions to include this function and to ensure pilots

are passed any emergency turn information. A notice has also been issued to flight crews notifying them of the FOVE procedure to be used, including the need to crosscheck the Green Dot speed calculated by FOVE with that calculated by the aircraft's FMGS.

### **Aircraft performance**

With an incorrect aircraft weight entered into FOVE, the calculated  $V_1$  and  $V_R$  speeds were too low for the takeoff at Montego Bay. In terms of available runway length, the effect of using an incorrect FLEX temperature was less significant as calculation demonstrated that, in this instance, sufficient runway was available for takeoff even at the lower thrust setting. In addition, despite taking longer to accelerate, the lower  $V_1$  speed would have allowed sufficient runway remaining should a rejected takeoff have been necessary.

The FDR shows a rotation speed of 116 kt which, for this aircraft configuration, meant that insufficient lift was available to allow the aircraft to lift off and accounted for the sluggish aircraft rotation recognised by the commander. As the main landing gear left the runway, the aircraft was accelerating through 138 kt towards the correct  $V_R$  of 140 kt and the selection of TOGA thrust increased that acceleration.

A tailstrike was avoided in this event as aircraft pitch attitude reached a maximum of  $9.5^\circ$  whilst the main landing gear shock absorbers were compressed;  $11.5^\circ$  of pitch would have been required for the tail to contact the runway.

### **Takeoff performance monitoring**

Throughout the course of this investigation, numerous other takeoff incidents, similar to G-OJMC, were identified. These incidents occurred despite having procedural safeguards in place, such as independent

crosschecking. The number of incidents of this type has been recognised by the aircraft manufacturer and the EASA who have embarked on projects to reduce the likelihood of incorrect takeoff parameters being used.

All current improvement work focuses on EFB procedural robustness and reducing the probability of incorrect data being input into flight management systems before takeoff. However, once this takeoff data has been input, no additional independent analysis is performed on-board to establish whether that data is consistent with the aircraft configuration and airfield conditions.

In a number of the cases, flight crews successfully identified some kind of performance abnormality during takeoff. However, this may not always be the case due to a number of factors including high crew workload, the range of aircraft operating conditions and subtle margins of under-performance. This was the case during the 9G-MKJ incident in Canada which ended up in fatal injuries being sustained by all on board.

A system which actively monitors takeoff performance can add an additional safety net, independent of data input by flight crews. However, despite being identified as having a positive impact, little or no progress has been made in the development of takeoff performance monitoring systems in recent years. Such a system would require a high level of maturity before being introduced to avoid unnecessary and potentially unsafe crew actions.

As a consequence, the following recommendations are made:

#### **Safety Recommendation 2009-080**

It is recommended that the European Aviation Safety Agency develop a specification for an aircraft

takeoff performance monitoring system which provides a timely alert to flight crews when achieved takeoff performance is inadequate for given aircraft configurations and airfield conditions.

**Safety Recommendation 2009-081**

It is recommended that the European Aviation Safety Agency establish a requirement for transport category aircraft to be equipped with a takeoff performance

monitoring system which provides a timely alert to flight crews when achieved takeoff performance is inadequate for given aircraft configurations and airfield conditions.