Safety in Numbers

Correct V speeds rely on valid takeoff performance parameters.

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REPORTS

Tied Up in Knots

Take-off Performance Calculation and Entry Errors: A Global Perspective

Australian Transport Safety Bureau (ATSB). Aviation Research and Analysis Report AR-2009-052. 97 pp. <www.atsb.gov.au/publications/2009/ar2009052.aspx>. 2011.

During takeoff from Montego Bay, Jamaica, the Airbus A330-243 seemed at first to accelerate as expected on an October 2008 flight to London. "After passing 100 kt, the first officer called 'V_1' and 'V_R,'" the report says. "The captain was surprised by the quick succession of these calls. The first officer called 'rotate' and the captain pulled back on the sidestick. When [he did] so, the aircraft did not appear to feel right and the captain immediately applied TO/GA [takeoff/go-around] thrust."

Following completion of the "After Takeoff" checklist, the crew compared the takeoff performance figures against those specified in the flight crew operating manual. They discovered significant discrepancies.

Takeoff weight was given by the dispatcher as 120,000 kg (264,555 lb); the actual takeoff weight was 210,183 kg (463,374 lb). The error led to incorrect V speeds. Instead of the correct 136 kt, V_1 was called at 114 kt. Rotation should have occurred at 140 kt, but took place at 125 kt.

That crew recovered from the error. Not every flight crew is so fortunate in the case of mistaken data calculation or data entry in the cockpit (see, "Absence of Reasonableness," p. 12). The report describes 20 international and 11 Australian accidents and incidents, called occurrences, in which "the calculation and entry of erroneous takeoff parameters, such as aircraft weights and V speeds were involved. … [The report] provides an analysis of the safety factors that contributed to the international occurrences and suggests ways to prevent and detect such errors."[1]

The report is organized as follows:

- Defining takeoff performance parameters, the methods used by airlines for calculating and entering the parameters, typical errors that sometimes result and the consequences.

- A brief summary and analysis of occurrences resulting from takeoff calculation and entry errors involving Australian

aircraft from 1989 to June 2009. Another chapter provides detailed descriptions of similar occurrences involving non-Australian aircraft during the same period.[2]

- A safety factor analysis of the non-Australian-aircraft occurrences, using the ATSB's investigation analysis model.

- Discussion of ways to minimize some of the common causal factors.

Takeoff performance parameters include reference speeds, or V speeds. The aircraft's takeoff weight (TOW) and zero fuel weight (ZFW) are critical for determining the V speeds. In addition, the report says, reduced-thrust takeoffs are commonly conducted to save wear and tear on the engines; those takeoffs require that an "assumed" or "flex" air temperature higher than the actual ambient temperature be factored in.

"Different airlines use, and different aircraft types require, different methods for calculating and entering takeoff performance parameters," the report says. "These may be performed manually or be automated; they may be performed by the crew using performance manuals, the flight management system (FMS), the flight management computer (FMC) or a laptop computer; or remotely by the use of the aircraft communications addressing and reporting system (ACARS)."

Typical errors, the report says, include these:

The ZFW is inadvertently used instead of the TOW; the numbers for a weight are transposed — for example, 324,000 kg becomes 234,000 kg; V speeds are incorrectly entered in the system manually; takeoff data are not updated to reflect a change in conditions, such as ambient temperature; the wrong value is selected from the load sheet or takeoff data card. And there are other ways of messing up the takeoff performance parameters.

If such errors are not caught and fixed, dire consequences may result: tail strike; reduced acceleration or climb rate — the aircraft feels

"sluggish"; degraded handling; rejected takeoff; runway overrun; overweight takeoff; reduced obstacle clearance; and other dangerous possibilities.

For Australian occurrences, the specific takeoff performance parameter error was identified in 10 of the 11 cases. "Of these 10, half were related to errors involving V speeds," the report says. "This was followed by aircraft weights, accounting for three occurrences. Of this, two were related to the ZFW and one related to the aircraft's TOW. There were two occurrences where an erroneous flex temperature was used."

The action, or inaction, that led to the erroneous takeoff performance parameters was identified in all 11 occurrences. Data entered incorrectly or not updated accounted for three occurrences each. Using the wrong manual or the wrong figure happened in two occurrences each. In one instance, the data were not checked after a change in flight conditions.

The type of device or aircraft system involved was identified in 10 occurrences. "The most prevalent was the FMC, accounting for just over a quarter of the occurrences," the report says.

An operational or environmental change — for example, a switch from a published instrument departure procedure to a visual departure — was associated with six occurrences, requiring the crew to check, change and/or update the parameters previously calculated.

Six of the 11 occurrences had an effect on flight, including reduced performance on takeoff, a rejected takeoff, a tail strike and application of TO/GA thrust.

The data from the 20 non-Australian occurrences offered a counterpoint to those that took place in Australia.

"While half of the Australian occurrences analyzed … involved the incorrect calculation or input of V speeds, they accounted for only four of the 20 international occurrences," the report says. "The incorrect calculation or input of weight parameters accounted for the greatest

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proportion, with 16 occurrences, of which 14 were related to the aircraft's TOW and two involved the fuel on board weight."

In 11 non-Australian occurrences, or more than half, *wrong data* were entered — for example, entering the ZFW instead of the TOW, or using the TOW from the previous flight. In four cases, the data were correct but the *entry* was wrong.

"The most common devices involved in the calculation or entry of erroneous takeoff performance parameters related to aircraft documentation and the laptop computer, accounting for six and five occurrences respectively," the report says. "Documentation errors included using the wrong weight to determine the V speeds from aircraft performance charts, using the wrong chart or not taking into account certain flight conditions when determining the maximum permitted TOW."

In contrast to the Australian occurrences, all of the international occurrences affected flight. Eleven led to a tail strike, and four resulted in reduced takeoff performance. Five of the occurrences resulted in collision with an obstacle or terrain.[3] Changed operational and environmental conditions were found to have been present in nine occurrences.

The researchers conducted a safety factor analysis of the non-Australian occurrences.[4] "A total of 131 contributing safety factors were identified from the 20 accidents and incidents," the report says. "Of these, 39 percent were related to individual actions." This was followed by risk controls, or "what could have been in place to reduce the likelihood or severity of problems at the operational level," in 31 percent and local conditions in 28 percent.

Under the heading of individual actions, 50 were aircraft operation actions by the flight crew. In order of frequency, the report says, they included "monitoring and checking," "assessing and planning," "using equipment," "communicating and coordinating (internal)," and "communicating and coordinating (external)."

Of the 131 safety factors, 41 were identified as risk controls. "Of these, 46 percent were related to problems with the usability or availability of aircraft equipment, and 37 percent involved problems with the design, delivery or availability of procedures, checklists or work instructions used by operational personnel," the report says.

The most common local condition identified was "task experience or recency, accounting for 31 percent of all local conditions. This refers to situations where an individual did not have a sufficient amount of total or recent experience to conduct the task appropriately. This also includes being unfamiliar with a task or procedure, and negative transfer influences from other aircraft types or flights."

While cautioning that no single solution exists, the report offers suggestions for minimizing the risk.

The report recommends an independent calculation or cross-check of the takeoff performance data by a second crewmember; having procedures for when the primary aircraft system used to calculate parameters is unavailable; and clearly delineating the responsibilities of each crewmember.

"Where more than one system is available for calculating takeoff performance parameters, system manufacturers and airlines should consider provisions for cross-checking the data between both sources," the report says. "For example, the V speeds automatically calculated by the FMC may be entered into the handheld performance or laptop computer and compared with those values calculated by the computer."

Improved design of tools and materials could help avoid miscalculation or mis-entry, the report suggests: "Flight plans and takeoff data cards should be designed so that all of the relevant performance figures have a designated location. … Performance data such as the TOW or ZFW should be presented clearly and unambiguously to reduce the possibility of the wrong figure being selected."

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An airline's crew rostering practices should ensure that every crew includes a captain or first officer who is highly experienced in type, the report says.

If airline and cockpit procedures fail to "trap" erroneous takeoff parameters, it becomes all the more important to detect degraded takeoff performance in time to reject the takeoff safely. The report quotes an investigation by the Transportation Safety Board of Canada, which "recognized that despite over 30 years of industry effort, there is no acceptable 'in cockpit' defense that provides crews with the necessary information to indicate that the aircraft performance is insufficient to safely execute the takeoff."

Although takeoff performance monitoring systems have been the subject of research and experimentation, "solutions put forward have been too complex and demanding on the pilots," the report says. "A simple system that confirms that the takeoff is progressing as required is needed, one that is as easy to read and understand as the fuel gauge in a car."

Runway distance-remaining signs (RDRS), also known as "distance to go" markers, enable pilots to compare actual versus expected acceleration before rotation. Such markers have been in military use for years, but have not been adopted in civil aviation, the report says. It adds that the U.S. Federal Aviation Administration (FAA) currently recommends that the system be installed on runways used by jet aircraft, and the Air Line Pilots Association, International has urged the FAA to make RDRS compulsory at all U.S. airports with public transport aviation. "However, neither the International Civil Aviation Organization nor the Civil Aviation Safety Authority, Australia, require or recommend airport operators to install RDRS at the side of runways," the report says.

In conclusion, the report says, "Despite advanced aircraft systems and robust operating procedures, accidents will continue to occur during the takeoff phase of flight. [During takeoff] there are limited time and options available to the flight crew for managing abnormal situations such as insufficient airspeed. … The results of this study, and those from other related research, have recognized that these types of events occur irrespective of the airline or aircraft type, and that they can happen to anyone; no one is immune. While it is likely that these errors will continue to take place, as humans are fallible, it is imperative that the aviation industry continue to explore solutions, firstly to minimize the opportunities for takeoff performance parameter errors from occurring and secondly, to maximize the chance that any errors that do occur are detected and/or do not lead to negative consequences." ✈

Notes

1. The examples of takeoff performance parameter errors were limited to aircraft with a maximum capacity of more than 38 seats or a maximum payload of 4,200 kg (9,259 lb). Accidents and incidents involving Australian-registered aircraft were sourced from the ATSB's safety database. Sources for data on non-Australian-registered aircraft included the International Civil Aviation Organization, the Ascend World Aircraft Accident Summary and the Transportation Safety Board of Canada.

2. The actual number of erroneous takeoff performance parameter events was probably greater, the report says. The database did not include errors that were discovered and corrected before takeoff, and other occurrences that involved no damage would normally not be reported.

3. The accident at Melbourne, Victoria, in March 2009 — the subject of the cover story on p. 12 — damaged ground equipment. In this report, the consequence of that occurrence is categorized as a tail strike rather than a collision with an obstacle.

4. A safety factor is "an event or condition that increases safety risk. In other words, it is something that, if it occurred in the future, would increase the likelihood of an occurrence, and/or the severity of the adverse consequences associated with an occurrence." Safety factor analysis of the 11 Australian occurrences could not be undertaken because of limitations in the data.