BY WAYNE ROSENKRANS

Moment of Truth

Rigid adherence to procedures for takeoff weight, center of gravity and stabilizer trim setting reduces the likelihood of uncommanded or delayed rotation.

When the U.S. National Transportation Safety Board (NTSB) in July 2008 issued three safety recommendations about mistrim takeoff, one was remarkable for its scope. It urged the U.S. Federal Aviation Administration (FAA) to encourage all operators of the Bombardier Challenger series to provide pilot training to "emphasize the importance of proper stabilizer trim setting," including type-specific mistrim-takeoff characteristics identified in the accident investigation.[1] The status of the recommendations (*ASW*, 9/08, p. 10) — based on findings of a Challenger 600 departure overrun accident at Teterboro (New Jersey, U.S.) Airport in February 2005 (*ASW*, 3/07, p. 30) — was "open — awaiting response," as of late January.

In the accident, the captain rejected the takeoff when the airplane did not rotate immediately at rotation speed (V_R) and the airplane overran the runway. The probable cause was "the flight crew's attempt to take off with the center of gravity (CG) well forward of the forward takeoff limit, which prevented the airplane from rotating at the expected rotation speed."[2]

Some aspects of the Teterboro accident were unique, others were not. The recommendations open an opportunity for all operators, not just those using the Challengers as specified by the NTSB, to reassess their training. "Pilots are less likely to attempt a takeoff with a mistrimmed stabilizer if they are made aware of the importance of the proper takeoff stabilizer trim setting on these particular airplanes and have directly experienced the delay in rotation associated with mistrim-takeoff conditions in a flight simulator," the NTSB said.

Preventing, recognizing and responding to mistrim takeoffs — as opposed to drills on pitch trim runaways and other equipment failures — ideally would emerge from risk-identification processes within the safety management system of any commercial jet operator. If an operator does not have sufficient events to study, voluntary

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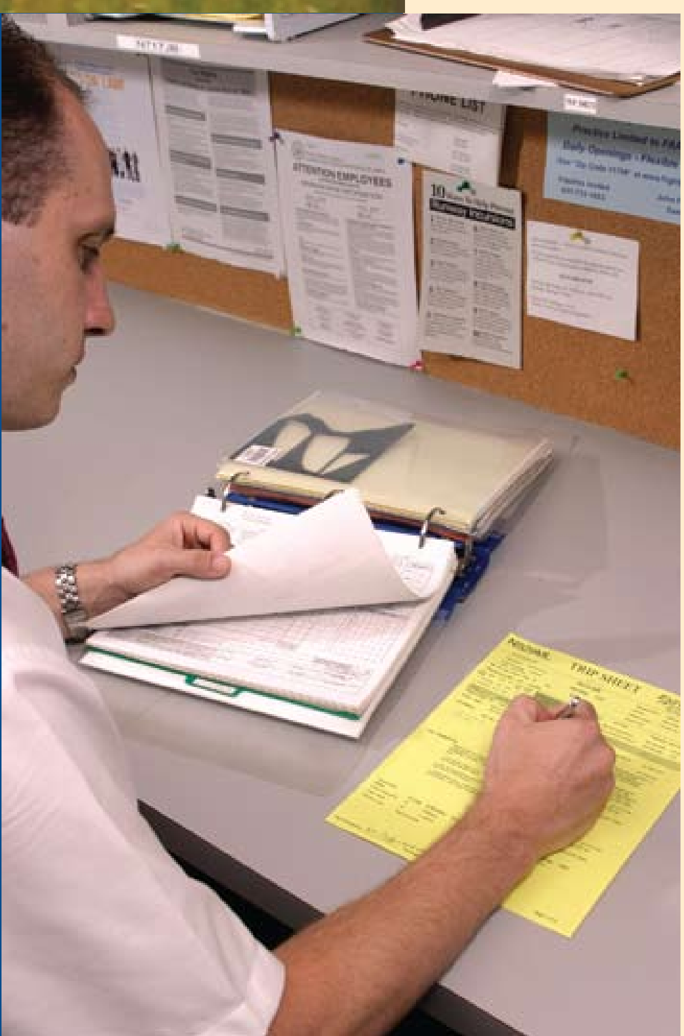
reports from U.S. air carrier pilots since the Teterboro accident could be a starting point for considering factors that have caused uncommanded early rotations, delayed rotations and failures to rotate. The reports also suggest potential subject areas suitable for checking pilot awareness, safety responsibilities of others in the load control system and follow-up to system-level safety threats identified by company pilots.

Industry-developed training aids for this narrowly focused subject may be sparse, but resources such as the *Airplane Upset Recovery Training Aid, Revision 2* <www.flightsafety.org/upset_recovery.html> and detailed guidance from airframe manufacturers on subjects such as tail-strike prevention cover out-of-limit CG and takeoff trim safety issues (see "Attitude Adjustment," p. 34).

Mistrim takeoff, as used by the NTSB, refers to "a takeoff configuration in which the CG is at one limit of its allowable range, but the stabilizer position is set at the green band limit [a range of indications of the horizontal stabilizer position displayed to the flight crew] corresponding to the opposite CG limit." The green band indicates the range in which acceptable handling qualities can be expected during takeoff rotation and climb, and that normal flight operations will remain within the allowable longitudinal range of CG travel.



Guidance on tail strikes from Boeing Commercial Airplanes, for example, describes possible effects of a mistrim takeoff. "A mistrimmed stabilizer occurring during takeoff is not common, but is an experience shared at least once by almost every flight crew," said one article for operators. "It usually results from using erroneous data, the wrong weights or an incorrect CG. Sometimes the information presented to the flight crew is accurate, but it is entered incorrectly either to the flight management system (FMS) or to the stabilizer itself. In any case, the stabilizer is set in the wrong position."[3]

One defense before takeoff — often the last chance to identify the error and correct the condition — is for skeptical pilots to challenge whether the numbers on the final weight manifest or load sheet make sense. Vigilance for any stabilizer trim setting inconsistent with prior experience of what is normal for the same weight range enables crews to catch errors early, Boeing said. An airplane that has been trimmed nose-up substantially more than required may pitch up during takeoff at nearly twice the recommended rate of 2 degrees to 3 degrees per second and may leave the runway without control input from the pilot flying.

Pilots, dispatchers and loading supervisors may understand that flight tests for airplane certification include mistrim takeoffs at the forward and aft CG limits, but this has led some personnel to overestimate the safety margins. The NTSB recently has been concerned about a less-known phenomenon not quantified currently in flight testing: unusual, but characteristic, delays in airplane rotation in response to nose-up control input.

U.S. Federal Aviation Regulations Part 25, for transport airplane certification, specify that during "reasonably expected variations" from takeoff procedures — including over-rotation and out-of-trim conditions — a flight crew must not experience unsafe flight characteristics or a "marked increase"[4] in the scheduled takeoff distances in the airplane flight manual. Revisions have been in process for about six years, however, and changes that would define safely acceptable delays in rotation at V_R have been proposed by the European Aviation Safety Agency in concert with the FAA.

One example of guidance prepared in response to earlier NTSB calls for pilot training on mistrim takeoff was FAA Advisory Circular 120-85, *Air Cargo Operations*, published in June 2005.

U.S. National Transportation Safety Board

This Bombardier Challenger 600 pitch-trim position indicator is similar to one examined in the Teterboro crash.

NTSB safety recommendation A-98-44 had said that the FAA should "require all … Part 121 air carriers to provide flight crews with instruction on mistrim cues that might be available during taxi and initial rotation, and require air carriers using full flight simulators in their training programs to provide flight crews with special purpose operational training that includes an unanticipated pitch mistrim condition encountered on takeoff."

Another indication of the importance of such training is the FAA's January 2009 proposed rule on new training requirements[5] for pilots and other professions, which includes awareness criteria for pilots to "experience the pitch handling qualities of the aircraft with runaway stabilizer or runaway pitch trim, and pitch mistrim during takeoff or landing and during cruise flight" and to "observe the effects of early versus late detection and deactivation or correction." Pilots also would have to practice the procedures for recovery prescribed in the flight crew operating manual. Evaluation of performance would require that pilots in training "confirm that the aircraft trim and wing high-lift devices are configured properly."

The FAA also has focused on auxiliary performance computers (APCs), sometimes called auxiliary performance laptop computers, encompassing in part processes, procedures and computer proficiency underlying the data for setting stabilizer trim for takeoff.[6] Guidance in this information for operators also will "cause operators to review those procedures and related training to ensure their adequacy, if APC is to be used in the operator's approved weight and balance control system."

A forthcoming FAA advisory circular for the on-board aircraft weighing system (OBAWS)[7] on some large transport airplanes — which provides flight crews a continuous display of the aircraft total weight and other safety-critical information whenever the airplane is on the ground — also could enable training developers to cover the recognition of discrepancies that result in out-of-trim takeoff and CG out of limits.

Rotation Surprises

Causal factors in the Teterboro crash already were familiar. The NTSB had investigated the March 2001 rejected takeoff of an Airbus A320.[8] "The flight crew reported that, during the takeoff roll at an airspeed of about 110 kt, the nose of the airplane began to lift off the runway," a safety recommendation letter said. "In a post-accident interview, the captain stated that he continued the takeoff to [computed V_R of 143 kt] but, because he believed the airplane pitch was uncontrollable, he initiated a rejected takeoff. The airplane then became airborne and climbed a few feet. … The flight crew had incorrectly set the trim for the trimmable horizontal stabilizer at minus 1.7 degrees UP (airplane nose up [ANU]). This setting resulted in a pitch-up trim condition. The proper trim setting, 1.7 degrees DN (airplane nose down), would have resulted in a correct trim condition for the way the airplane was loaded."

In the letter about the A320, the NTSB cited similar factors in the April 2000 rejected takeoff of another A320, which simulations showed would have been controllable if the takeoff had continued. In this earlier event, the nose also had begun to lift off below the computed rotation speed. The airplane had been loaded with an aft CG, and the flight crew inadvertently had set the trimmable horizontal stabilizer at minus 2.2 degrees UP rather than the correct setting of 2.0 degrees DN.

Review of U.S. National Aeronautics and Space Administration Aviation Safety Reporting System (ASRS) reports about events in 2005–2008 suggests flight crew training subjects and issues to consider in refining aircraft weight and balance control systems. Most fit the same few categories mentioned in the 1990s by Boeing.

The first officer of a 747 discovered before takeoff that the final weight manifest showed takeoff gross weight 98,700 lb (44,770 kg) less than the correct figure, an error later attributed to a dispatcher's miscalculation. "I was lucky to pick up on the error because the takeoff gross weights were significantly different, and the trim required on the final weight manifest was significantly different from the trim required in the flight management computer [FMC]. The final weight trim was 4.4 units and the FMC said [it should have been] 5.5 units, a difference of 1.1. … It appears there is no safety check between the flight plan, fuel boarded and the final weights. … There is no fleet standard operating procedure or guidance given in the airplane flight manual to help catch this error. If there is, then it is not being effectively taught in training and not being used during line operations. I routinely watch most 747-400 first officers on the line set the trim based on what the final weight paperwork says, and never cross-check the FMC."[9]

A 757 flight crew quickly recognized an incorrect trim setting while accelerating for takeoff. "We had a load of military personnel with their duffel bags," the captain said. "Percent mean aerodynamic chord [MAC] was forecast to be 28.8 with 8,190 lb [3,715 kg] in the front [baggage] pit. … Trim was 3.7 units [ANU] during the takeoff roll, and at [V_R] it took an extraordinary amount of control force to rotate. I had to trim the aircraft in the rotation to help get off the ground. … The final weights calculation indicated [that the actual required takeoff] trim had been 4.2 units with 4,380 lb [1,987 kg] loaded in the front pit, and percent MAC was 25. Basically, the front pit weight fell off 4,000 lb [1,814 kg] from planned, and the trim moved aft from 3.7 to 4.2 units with a full airplane. Unlikely. These were bad numbers — from where, I don't know."[10]

The flight crew of an A320 rejected a takeoff at about 80 kt. "Final weights had the trim set at 38.3 percent MAC," the report said. "Once takeoff power was added, I immediately noticed a strong nose-up tendency. … With the control stick full down to maintain directional control via the nosewheel, I elected to accelerate a bit to see if relative airflow over the horizontal stabilizer would help alleviate this tail-heavy scenario. After about 70 kt, I was hesitant to neutralize the stick because [I felt that] the nosewheel was going to lift off the ground. I knew the CG was aft because the trim setting was unusual although within the limits on paper. … The aft limit for this was 1,672 units and the aircraft was actually loaded to 1,680 units. When [we asked the loading agent] about the out-of-range number, we were told, 'There is slop built into the limits.'"[11]

Takeoff performance of a McDonnell Douglas MD-80 surprised the flight crew, and a load audit was ordered at the destination. "During the takeoff roll at rotation, the aircraft would not rotate — very heavy [control forces] and extra long takeoff roll," the report said. "Fuel and passenger load were spot on [according to the audit results]. Freight was listed at 198 lb [90 kg], I believe. They unloaded 13 crates out of the mid-cargo area. … Assuming 900 lb [408 kg] each, that comes to almost 12,000 lb [5,443 kg] different than reported [to the flight crew], approximately 6,000 lb [2,722 kg] over maximum zero fuel weight. … This was a potentially deadly error. Good airmanship on the part of the first officer prevented disaster. The station manager … should be held accountable."[12]

Other ASRS reports include post-takeoff revision of final weight manifests, sometimes by thousands of pounds; flight crew complaints about load planners' apparent ignorance of the takeoff safety consequences of errors on final weight manifests; flight crew error in departing before receiving the final weight manifest; flight crew input of zero fuel weight data instead of actual takeoff gross weight data; count discrepancies of more than 100 passengers on some flights; errors in identifying which passengers are children; discontinuation of procedures that had required crewmembers to cross-check the actual passenger count; miscommunication of bag counts; failure to account for ballast fuel in load planning; and load-planning computation errors confusing kilograms and pounds.

Notes

1. NTSB. Safety Recommendations A-08-48, -49 and -50. July 17, 2008.
2. NTSB. "Runway Overrun and Collision, Platinum Jet Management, LLC, Bombardier Challenger CL-600-1A11, N370V, Teterboro, New Jersey, February 2, 2005." Aviation Accident Report NTSB/AAR-06/04, 2006.
3. Boeing. "Tail Strike Avoidance." *Aero*. October 1998.
4. In U.S. and European terminology for airworthiness certification, marked increase means any amount greater than 1 percent of the scheduled takeoff distance.
5. FAA. "Qualification, Service, and Use of Crewmembers and Aircraft Dispatchers; Proposed Rule." *Federal Register* Volume 74 (Number 7), p. 1280. January 12, 2009.
6. FAA. "Weight and Balance Control Methods: Auxiliary Performance Computer." Information for Operators, InFO 08031. May 16, 2008.
7. An OBAWS uses strain-sensing transducers in each main wheel and nosewheel axle, a weight and balance computer, and indicators that show the takeoff gross weight, the CG location in percent of MAC and attitude.
8. NTSB. Letter regarding safety recommendations A-02-06 and A-02-07 to FAA Administrator Jane F. Garvey. April 15, 2002.
9. NASA ASRS report no. 754690, September 2007.
10. NASA ASRS report no. 731902, March 2007.
11. NASA ASRS report no. 796177, July 2008.
12. NASA ASRS report no. 694610, April 2006.