National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: July 17, 2009

In reply refer to: A-09-55 through -60

The Honorable J. Randolph Babbitt
Administrator
Federal Aviation Administration
Washington, D.C. 20591

On September 19, 2008, about 2353 eastern daylight time, a Bombardier Learjet 60 (Learjet 60), N999LJ, operated by Global Exec Aviation, overran runway 11 while departing Columbia Metropolitan Airport, Columbia, South Carolina.[1] The pilot, copilot, and two of the four passengers were killed; the two other passengers were seriously injured. The aircraft was destroyed by postcrash fire. Visual meteorological conditions prevailed, and an instrument flight rules flight plan was filed for the 14 *Code of Federal Regulations* (CFR) Part 135 nonscheduled domestic passenger flight to Van Nuys, California.

According to witness interviews and the cockpit voice recorder (CVR) transcript, the beginning of the takeoff roll appeared normal. However, sparks were observed as the airplane traveled along the runway. The airplane then continued beyond the runway and through the approximately 1,000-foot runway safety area and, beyond that, struck airport lighting, navigation facilities, a perimeter fence, and concrete marker posts. The airplane then crossed a roadway and came to rest when it struck an embankment across the road from the airport.

Postaccident examination of markings and tire debris indicated that the right outboard tire failed first because of underinflation, followed by failures of the other tires.[2] Examination of the engines revealed evidence consistent with high thrust in both engines and indicated that the thrust reversers were stowed when the airplane hit the embankment.

The National Transportation Safety Board's (NTSB) investigation of this accident is ongoing. However, on the basis of preliminary findings, the NTSB is concerned about safety

[1] More information about this accident, DCA08MA098, is available on the National Transportation Safety Board's website at <http://www.ntsb.gov/ntsb/query.asp>.

[2] During the investigation, the NTSB found evidence that the accident airplane's tires were underinflated. Review of tire fragments revealed that there was extensive heat damage within the tire construction; excessive weight (overflexure) of the rubber created the heat. No evidence of excessive brake heating was found. The tires are being separately addressed.

issues involving inadvertent stowage[3] of the thrust reversers. In March 2009, Learjet published a Federal Aviation Administration (FAA)-approved temporary flight manual (TFM) change in procedures, which described improved methods for quickly recognizing and handling situations when inadvertent stowage occurs. However, the NTSB is concerned that Learjet 60 pilots are not sufficiently trained to recognize that a failure could occur during takeoff as well as landing phases of flight and could subsequently result in the loss of system logic control requirements for maintaining deployed thrust reversers during a rejected takeoff. The design of the Learjet 60 thrust reverser system (and potentially similarly designed systems for Raytheon Hawker 1000 business jets) is also of concern to the NTSB. Information supporting six recommendations to address these safety issues is discussed below.

Design of Learjet 60 Thrust Lever System

Review of the CVR revealed that the first indication of tire damage occurred after the airplane had passed V_1[4] and that flight crew actions were consistent with a decision to reject the takeoff.[5] The Learjet 60 rejected takeoff procedure calls for the pilot to reduce thrust to idle, deploy the reverse levers, and then increase thrust while in reverse. A sound spectrum analysis of the CVR indicated that the engine power was reduced and then increased to about 80 percent of maximum power, consistent with the pilot following the rejected takeoff procedure.

On most transport-category airplanes, including the Learjet 60, to deploy the thrust reversers, the pilot first moves the engine power levers to idle then pulls the reverse levers upward. The levers' upward deflections determine how much reverse thrust is created. In Learjet 60 airplanes, there is no mechanical or cable-actuated connection between the reverse levers and the engine thrust reversers. When the reverse levers are raised, an electrical signal commands the thrust reversers to go to a reverse thrust position. The system must meet certain requirements before the thrust reversers will move to a reverse thrust position; for example, the air/ground sensor squat switches, located on the main landing gear, must indicate that the airplane is on the ground (by detecting weight on wheels). The electronic engine controls have no ability to automatically return the reverse levers to the idle positions and do not reduce the thrust if the system control logic requirements for keeping the thrust reversers deployed are no longer being met. In addition, the thrust reversers are designed to fail to the stowed position to allow forward thrust and prevent reduction of pilot control in flight.

The wiring for the accident airplane's right squat switch was routed along the right main landing gear strut between the right tires. Glass from the adjacent landing light and evidence of a broken hydraulic hose were found among the first tire fragments, and data on the CVR indicated

[3] Although this situation is referred to as "inadvertent" stowage, it is not the result of any crew-commanded action.

[4] V_1 is the takeoff decision speed or critical engine failure speed. Following a failure of the critical engine, V_1 is the minimum speed in the takeoff at which the pilot can continue takeoff and achieve the required height above the takeoff surface within the takeoff distance. V_1 is also the maximum speed in the takeoff at which the pilot must take the first action (for example, apply brakes, reduce thrust, deploy speed brakes) to stop the airplane within the accelerate-stop distance.

[5] The tires began to fail just as the first officer said, "V_1." In addition, during the investigation, the NTSB learned about an FAA test pilot of a Learjet 55 who rejected a takeoff after multiple tires failed at V_1; the pilot reported that he made the decision because he was afraid that the engines would ingest numerous large tire pieces that were being thrown past the cockpit windows.

that a squat switch circuit went to the "air" mode during the accident sequence.[6] These findings are strong indications that the squat switch wiring was probably damaged when the tires failed. Thus, with the loss of the on-ground signal, the system would have moved both thrust reversers to the stowed position (the position in which the accident airplane's thrust reversers were found). Accordingly, the engines would have provided forward thrust commensurate with the angle of the thrust lever position commanded by the pilots, even though the reverse levers were in the reverse position.

The only way to reduce forward thrust under these abnormal circumstances is to move the reverse levers to the stowed position. However, moving the reverse levers to the stowed position would be counterintuitive to a pilot who was trying to reject a takeoff by applying maximum reverse thrust. Initially, flight crewmembers trying to slow the airplane would likely think that they are receiving the reverse thrust that they commanded until they realize that the airplane is not slowing. Therefore, the NTSB recommends that the FAA require Learjet to change the design of the Learjet 60 thrust lever system in future-manufactured airplanes so that the reverse lever positions in the cockpit match the positions of the thrust reverser mechanisms at the engines when the thrust reversers stow. Once design changes are developed per Safety Recommendation A-09-55, the NTSB recommends that the FAA require Learjet 60 operators to retrofit existing airplanes so that the reverse lever positions in the cockpit match the positions of the thrust reverser mechanisms at the engines when the thrust reversers stow.

Learjet 60 Thrust Reverser Indications

Normally, six lights[7]—three for each engine—will illuminate on the forward instrument panel to indicate the status of the thrust reversers (see figure). Each bottom light (TR ARM) is green and indicates that prerequisites for reverse thrust exist, such as the availability of hydraulic pressure to deploy the engine thrust reversers. Two of the conditions that trigger the TR ARM lights and that would be apparent to the pilots were that (1) the squat switches sense that the aircraft is in ground mode, and (2) the engine power levers are in the idle positions. The TR ARM lights denote that the reverse levers can be moved upward if the pilot elects. Because these lights are normally on when the engines are at the idle position on the ground and go out whenever the engine power levers are moved to and from idle, the pilot can become conditioned to these lights going on and off during normal taxi.

When the reverse levers are raised to the DEPLOY position, hydraulic pressure unlocks the engine thrust reverser doors, and, subsequently, two amber lights (TR UNLOCK) will illuminate to indicate that both thrust reverser doors are unlocked. When the amber TR UNLOCK lights illuminate, the green TR ARM lights extinguish. After the engine thrust reverser doors are fully deployed, two white lights (TR DEPLOY) illuminate, and the amber TR UNLOCK lights extinguish.

[6] A nose gear steering disconnect tone was heard on the CVR, which was an indication that the squat switch went to air mode. The alert was advisory, under the conditions in this accident; no pilot action was needed.

[7] On Learjet 60 airplanes, indicator lights for the left thrust reverser are located on the left side of the instrument panel (in front of the pilot), and lights for the right thrust reverser are on the right side (in front of the copilot).

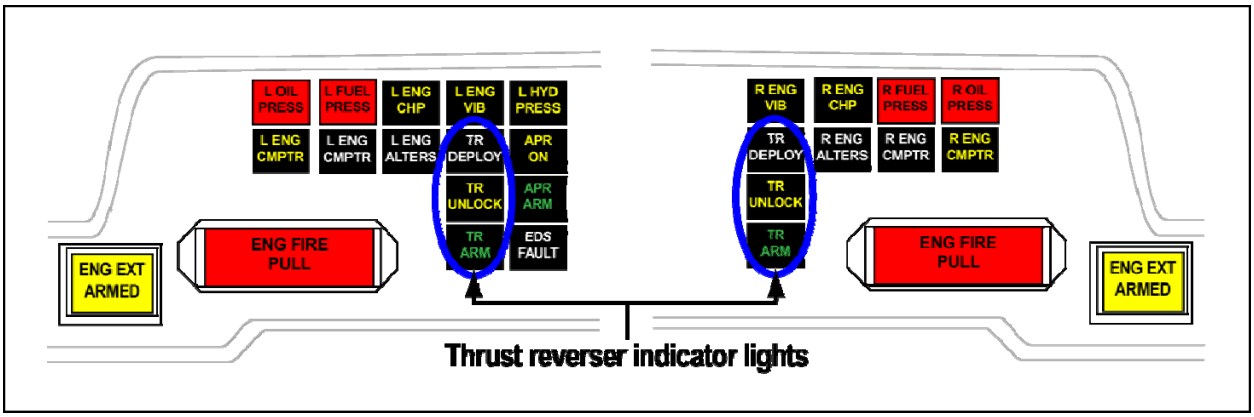

Figure. Diagram of a Learjet 60's lights on the main annunciator panel.
Source: Flight Safety International Learjet 60 Pilot Training Manual, Volume 1, Revision 1.

If, during a rejected takeoff, there were an inadvertent thrust reverser stowage due to loss of the requirements for maintaining reverse thrust, the following indications would occur:

- The white TR DEPLOY light(s) would extinguish,
- The amber TR UNLOCK light(s) would illuminate momentarily, and
- The green TR ARM light(s) would blink momentarily.[8]

The only indication available to the pilots that the cockpit reverse levers and engine thrust reversers were not in agreement would be the pilots' comprehension that neither of the TR DEPLOY lights was illuminated while the reverse levers were in the positions normally associated with reverse thrust. The NTSB concludes that, during a rejected takeoff, which requires quick and concentrated pilot actions, it may be difficult for a pilot to recognize the significance of the absence of reverse thrust indicator lights.

In the March 2009 TFM revision, Learjet expanded its rejected takeoff procedure by advising that, if none of the engine annunciator lights for both reversers is illuminated, the reversers have stowed. Additionally, a note was added to clarify the normal sequencing of the annunciator lights when thrust reversers are deployed. The NTSB is concerned that Learjet 60 airplanes still do not provide sufficient cues for pilots to be able to quickly recognize an inadvertent thrust reverser stowage (and resultant forward thrust) and then make timely decisions and act on them. In addition to having a system in which the reverse lever position matches the engine thrust reverser position, similar, more modern airplanes have a visual indication that informs the flight crew (especially the nonflying pilot whose hand most likely is not on the lever) that the reversers have inadvertently stowed. Therefore, the NTSB recommends that the FAA require Learjet to develop and install improved aural or visual cues on future-manufactured Learjet 60 airplanes that would allow pilots to recognize an inadvertent thrust reverser stowage

[8] The MASTER CAUTION light may illuminate momentarily if the MASTER CAUTION is not inhibited during takeoff; inhibiting the MASTER CAUTION light is a normal part of the Learjet 60 takeoff procedure.

in a timely manner. Once improved aural or visual cues are developed per Safety Recommendation A-09-57, the NTSB recommends that the FAA require Learjet 60 operators to install those cues on existing Learjet 60 airplanes.

Inadvertent Thrust Reverser Stowage Procedure

During initial certification of Learjet 60 airplanes, Learjet developed an abnormal procedure in the event of an inadvertent thrust reverser stowage. Following a January 14, 2001, Learjet 60 accident,[9] Learjet amended the procedure; it is now an emergency procedure titled "Inadvertent Stow of Thrust Reverser After a Crew-Commanded Deployment." The procedure, located in the Learjet 60 Crew Checklist and in the Quick Reference Handbook (QRH), states in part:

> *INADVERTENT STOW OF THRUST REVERSER AFTER A CREW-COMMANDED DEPLOYMENT*
>
> *1. Maintain control with rudder, aileron, nose wheel steering & brakes*
>
> *2. Both Thrust Reverser Levers……STOW*[10]

Steps 1 and 2 listed above are contained in a hatched box in the QRH indicating that the steps are to be performed by memory.

The March 2009 TFM revision for Learjet 60 airplanes added a warning to this procedure and to the rejected takeoff procedure; the warning advises Learjet 60 operators that a damaged squat switch could potentially cause inadvertent thrust reverser stowage. The warning also describes engine power lever movements and light indications on the cockpit panel and on the engine indication system panel that result from the damaged squat switch and states that, if a damaged squat switch (or its failures) causes inadvertent thrust reverser stowage resulting in forward thrust, then the thrust reverser levers must be stowed immediately.

After this accident, investigators interviewed numerous pilots and instructors and found that the Inadvertent Stow of Thrust Reverser procedure was included during initial training on the airplane. However, pilots and instructors said that the inadvertent stowage scenario was usually taught during landing phases rather than during takeoff phases. Another example of damaged squat switch wiring causing inadvertent thrust reverser stowage on takeoff occurred in June 1998. According to a voluntary pilot report submitted to the National Aeronautics and

[9] On January 14, 2001, a Learjet 60 registered to and operated by Ark-Air, Inc., collided with deer shortly after touchdown at Troy Municipal Airport, Troy, Alabama, continued down the runway with tires smoking, veered off the right side of the runway, and impacted a ditch before bursting into flames. According to the pilots, the engine thrust reversers failed to operate when engaged. A sound spectrum study conducted by the NTSB indicated that engine thrust increased from 82.4 to 90.4 percent during the landing rollout and that the thrust reversers experienced an inadvertent stowage. Examination of the landing gear found all three gears collapsed and deer fur lodged in the squat switch on the left main landing gear. More information about this incident, ATL01FA021, is available on the NTSB's website at <http://www.ntsb.gov/ntsb/query.asp>. As a result of this event, Learjet changed the squat switch circuitry to prevent inadvertent thrust reverser stowage after an airplane had taken off and flown, but the design change did not prevent an inadvertent stowage from occurring during a rejected takeoff.

[10] Moving both thrust reverser levers to stow would reduce commanded thrust to idle.

Space Administration's aviation safety reporting system, in the June 1998 event, the engine thrust reverser system was rendered inoperative due to damage to the squat switch system. In this event, a Learjet 60 experienced a failure of both right main tires during takeoff from Washington Dulles International Airport, Chantilly, Virginia. The tire failure resulted in the disintegration of the right main brake assembly, which severed the hydraulic lines and electric connections to the antiskid system and the squat switch system. The NTSB concludes that training for inadvertent stowage of thrust reversers during only landing phases is insufficient to prepare pilots for this situation during rejected takeoff, when the airplane has greater acceleration energy. Therefore, the NTSB recommends that the FAA require that all Learjet 60 pilots receive training, for takeoff as well as landing phases of flight, on recognizing an inadvertent thrust reverser stowage, including the possibility that the stowage can occur when the requirements for deploying thrust reversers are not fully met, such as when the air/ground sensor squat switch circuits are damaged. Pilots must be aware that this can result in forward thrust even when the reverse levers are in the reverse thrust position.

Similarly Designed Raytheon Hawker 1000 Engine Installation

The NTSB is aware that the engine installation for Raytheon Hawker 1000 business jets shares numerous similarities with the engine installation for Learjet 60 airplanes. Both airplane models use Pratt & Whitney PW305 engines and have similarities in the electronic engine controls, thrust reverser systems, and indications. Because of the similarities, the NTSB recommends that the FAA evaluate the design of the thrust reverser controls and indications in Raytheon Hawker 1000 business jets for potential thrust reverser failure modes that are similar to those identified in Learjet 60 airplanes and implement necessary changes.

Therefore, the National Transportation Safety Board recommends that the Federal Aviation Administration:

> Require Learjet to change the design of the Learjet 60 thrust lever system in future-manufactured airplanes so that the reverse lever positions in the cockpit match the positions of the thrust reverser mechanisms at the engines when the thrust reversers stow. (A-09-55)
>
> Once design changes are developed per Safety Recommendation A-09-55, require Learjet 60 operators to retrofit existing airplanes so that the reverse lever positions in the cockpit match the positions of the thrust reverser mechanisms at the engines when the thrust reversers stow. (A-09-56)
>
> Require Learjet to develop and install improved aural or visual cues on future-manufactured Learjet 60 airplanes that would allow pilots to recognize an inadvertent thrust reverser stowage in a timely manner. (A-09-57)
>
> Once improved aural or visual cues are developed per Safety Recommendation A-09-57, require Learjet 60 operators to install those cues on existing Learjet 60 airplanes. (A-09-58)

Require that all Learjet 60 pilots receive training, for takeoff as well as landing phases of flight, on recognizing an inadvertent thrust reverser stowage, including the possibility that the stowage can occur when the requirements for deploying thrust reversers are not fully met, such as when the air/ground sensor squat switch circuits are damaged. (A-09-59)

Evaluate the design of the thrust reverser controls and indications in Raytheon Hawker 1000 business jets for potential thrust reverser failure modes that are similar to those identified in Learjet 60 airplanes and implement necessary changes. (A-09-60)

In response to the recommendations in this letter, please refer to Safety Recommendations A-09-55 through -60. If you would like to submit your response electronically rather than in hard copy, you may send it to the following e-mail address: correspondence@ntsb.gov. If your response includes attachments that exceed 5 megabytes, please e-mail us asking for instructions on how to use our Tumbleweed secure mailbox procedures. To avoid confusion, please use only one method of submission (that is, do not submit both an electronic copy and a hard copy of the same response letter).

Acting Chairman ROSENKER and Members HERSMAN, HIGGINS, and SUMWALT concurred with these recommendations.

[Original Signed]

By: Mark V. Rosenker
Acting Chairman