National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: July 12, 2011

In reply refer to: A-11-68 and -69

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

On July 27, 2010, about 1138 local time, a Boeing MD-11F equipped with General Electric CF6-80C2 engines, German registration D-ALCQ, operated by Lufthansa Cargo as flight 8460, caught fire after a hard landing at King Khalid International Airport, Riyadh, Saudi Arabia (RUH). The airplane bounced twice, experiencing a strong pitch up after the second hard touchdown, followed by strong nose-down pitch forces and vertical loads at the third and final touchdown that caused the fuselage to rupture. The two pilots, who were the only airplane occupants, were transported to the hospital with injuries. The airplane was destroyed. The flight was a scheduled cargo flight from Frankfurt, Germany, (FRA) to RUH.[1]

The accident flight departed FRA about 0516 local time (0316 coordinated universal time), 2.5 hours later than originally scheduled due to minor maintenance issues. The accident flight was the first time the captain and first officer had flown together. The captain decided that the first officer, who had been employed with Lufthansa Cargo for 7 months and had not flown into RUH before, would fly the leg because he believed it would be an easy leg appropriate for the first officer. The flight crew stated in postaccident interviews that cruise flight and approach to RUH were uneventful. The first officer indicated during interviews that he completed the approach briefing about 25 minutes before landing, calculating that he would use a flap setting of 35º, target 72 percent N_1 rpm on final approach, expect a pitch attitude of about 4.5º on final approach, and commence the flare about 40 feet above ground level (agl).[2] The flight was radar vectored to the instrument landing system of runway 33L, and the first officer flew the approach with a planned V_{ref} of 158 knots. Convective conditions prevailed, with a temperature of 39º C (about 102º F) and winds at 15 to 25 knots on a heading closely aligned with the landing runway.

[1] The General Authority of Civil Aviation of Saudi Arabia is conducting the investigation of this accident. In accordance with the provisions of Annex 13 to the Convention on International Civil Aviation, the National Transportation Safety Board is participating in the investigation representing the State of Manufacture and Design, and the German Federal Bureau of Aircraft Accident Investigation (Bundesstelle für Flugunfalluntersuchung) is participating representing the State of Registry and the Operator.

[2] The first officer used a table provided by Lufthansa Cargo to calculate these values.

Both crewmembers indicated that they were aware of the high density altitude and expected a slight increase in landing distance as a result.

The first officer reported that he sensed that the airplane's sink rate was increasing at 80 feet, but he retarded the thrust levers at 50 feet, in accordance with Lufthansa Cargo standard procedure. He did not attempt to advance the thrust levers before touchdown. The first officer stated that he believed he had started the flare at 30 to 40 feet, but recorded flight data showed that a pull on the control column was initiated between 15 and 30 feet agl, at which time the sink rate decreased only slightly, to about 780 feet per minute.

The cockpit voice recorder captured, at 10 foot intervals, automated aural announcements from 50 feet to initial touchdown that did not decrease in frequency as would be expected during a normal flare as the airplane approached the ground. The captain, who was the pilot monitoring, did not call out the high sink rate or call for a go-around, as suggested in the Lufthansa Cargo Operating Manual. The captain later reported that, for a split second, he thought the first officer should flare but that he was satisfied when the first officer did flare. The captain said that he could not take action in time before the touchdown, which was measured at 2.1 G.

Following the initial touchdown, the aircraft bounced about 4.7 feet off the runway and the nosewheel touched down a second time at 3.0 G. After the second touchdown, the aircraft reached a pitch attitude of 13°, and a third touchdown, on the main gear, exceeded 4 G. Flight data indicated that two large forward and aft control column inputs were made between the first touchdown and the third and final touchdown.

Reporting his recollection of events after the initial touchdown, the first officer described the nose as "coming up and down" and said he did not have a clear recollection of what happened after that. The captain stated that "what came after touchdown was shocking" and "much beyond [his] experience." He said that strong movement of the nose was unexpected and that the pitch attitude was higher than the maximum allowable and outside of his comfort zone.

The fuselage fractured just aft of the wings following the third touchdown in the landing sequence. A fire developed in the mid fuselage area of the airplane after the tail section of the fuselage had been severed. The main landing gear remained in the extended position, but the nose landing gear folded backwards. The airplane departed the runway and came to rest about 180 feet left of the runway. The pilots evacuated the airplane after it came to a stop and the airplane was substantially consumed by fire.

According to the captain, he had not completed the company's "Bounced Landing Recovery Procedure" training, but he had been trained to maintain 7.5º of pitch when recovering from a bounced landing. The first officer had completed the bounced landing recovery training along with his initial training in 2010. A one-time course, Lufthansa Cargo's bounced landing recovery training was developed based on the company's experiences with hard landings, as well as those of other MD-11 operators. During the simulator session, an instructor demonstrates a hard landing and the trainee takes control, maintains 7.5º of pitch, and applies go-around thrust to recover. The company's MD-11 chief flight instructor stated that the simulator was limited in its ability to capture the true sensation of a bounced landing, and the head of flight operations

said that, while bounced landing training was positive training, it may still be difficult for a pilot to recognize a bounce in a real aircraft.

The NTSB is also participating in the investigation of another MD-11 landing accident, in which both pilots were fatally injured. The accident involved FedEx flight 80, a 14 *Code of Federal Regulations* Part 121 international cargo flight that crashed while landing at Narita International Airport, Narita, Japan, on March 23, 2009. The airplane was destroyed by impact forces and postcrash fire.[3] Similar to Lufthansa Cargo flight 8460, data captured from the flight data recorder (FDR) and the localizer surveillance camera show that FedEx flight 80 bounced after touching down initially on the right main landing gear and subsequently bounced once more before the left wing of the airplane fractured and the airplane rolled over to the left and caught fire. The vertical acceleration at initial touchdown was 1.63 G followed by acceleration as high as 3.06 G when the airplane touched down on the nose landing gear following the last bounce. The Japan Transport Safety Board investigation of this accident is also ongoing.

Although it is not uncommon for jet transport aircraft to experience a small skip or bounce during landing, since it was entered into service in 1990, the MD-11 has had at least 14 events of such severity that the aircraft sustained substantial damage, including 4 events that were complete hull losses (see table). Seven of these events have taken place in the last 2 years. The number and severity of these events raise concerns that MD-11 flight crews are not effectively trained to recognize and arrest high sink rates during landing or to properly control pitch attitude following a hard landing.

Table. MD-11 Bounced and Severe Hard Landings Resulting in Substantial Aircraft Damage (1993–2010)

Date	Airport	Operator	Event
4/30/1993	Los Angeles	Delta Air Lines	Bounced hard landing
8/19/1994	Chicago	Alitalia	Landing bounce and porpoise
7/31/1997	Newark	FedEx	Wing spar break and rollover
8/22/1999	Hong Kong	China Airlines	Wing spar break and rollover
5/22/2000	Taipei	Eva Air	Hard landing and go around
11/20/2001	Taipei	Eva Air	Bounce and nose landing gear (NLG) strike
6/7/2005	Louisville	UPS	Hard NLG strike
3/23/2009	Narita	FedEx	Wing spar break and rollover
6/3/2009	Urumqi	China Cargo	Hard landing and tailstrike
9/6/2009	Khartoum	Saudi Arabian Airlines	Hard landing
9/13/2009	Mexico City	Lufthansa Cargo	Hard landing and NLG strike
10/20/2009	Montevideo	Centurion	Hard landing and main landing gear collapse
7/27/2010	Riyadh	Lufthansa Cargo	Hard landing and fuselage failure
9/22/2010	Kabul	World Airways	Hard NLG strike

Regarding normal landing procedures, the Boeing MD-11 Flight Crew Operating Manual (FCOM), dated August 15, 2010, states that the sink rate in the flare should be 2 to 4 feet per second (fps) and that MD-11s are certified to be able to land at maximum landing weight at a sink rate of 10 fps (600 feet per minute), with an ultimate sink rate of 12.3 fps. Boeing defines

[3] The Japan Transport Safety Board is conducting the investigation of this accident. In accordance with the provisions of Annex 13 to the Convention on International Civil Aviation, the NTSB is participating in the investigation representing the State of Manufacture and Design and the State of the Operator.

hard landings that exceed 12.3 fps or that involve "rapid" derotation[4] after the initial touchdown as severe. The Boeing MD-11 FCOM states the following concerning bounced landing recovery:

> If the aircraft should bounce, hold or re-establish a normal landing attitude and add thrust as necessary to control the rate of descent. Avoid rapid pitch rates in establishing a normal landing attitude. **Caution: tail strikes or nosewheel structural damage can occur if large forward or aft control column movements are made prior to touchdown.** [Emphasis in original]

Avoiding high sink rates at touchdown requires pilots to manage energy by applying appropriate combinations of power and pitch, and operators employ certain techniques to assist pilots in determining when to flare. Lufthansa Cargo, for example, provides a table in its MD-11 training information for landing that guides pilots when to commence the flare based on gross weight, temperature, and pressure altitude. UPS instructs its pilots that airspeed trend vector may be a useful tool, while FedEx (operator of the largest MD-11 fleet) suggests that aural altitude calls and radar altimeter may also be useful. Although the pilot monitoring also has a role in recognizing and responding to high sink rates (for example, calling out the sink rate and calling for a go-around), the ability to appropriately judge when to initiate the flare is a fundamental pilot skill that is learned in training and checked periodically.

A few of the hard landing events listed in the preceding table provide examples of MD-11 flight crews' failure to avoid high sink rates at touchdown. The captain of China Air flight CI642, which landed hard at Hong Kong International Airport on August 22, 1999, allowed a high sink rate to develop and then attempted to counteract it using a large elevator input, resulting in destructive force on the structure at touchdown. The accident report[5] stated that "the [c]ommander did not react to override the early retardation of the thrust levers and apply thrust to counteract the increasing rate of descent in the flare." Preceding the June 9, 2009, severe hard landing of Saudi Arabian Airlines flight 983 in Khartoum, Sudan, the aircraft's enhanced ground proximity warning system "sink rate" alert sounded below 100 feet agl and continued to touchdown, which the FDR recorded as 3.06 G. The captain of Lufthansa Cargo flight 8240, which experienced a severe hard landing at Mexico City, Mexico, on September 13, 2009, did not begin the flare until 20 feet agl; the sink rate was approximately 1,020 feet per minute during the last 5 seconds before touchdown. The initial touchdown was about 2.7 G.

Regarding derotation, the Boeing MD-11 FCOM indicates that after touchdown the pilot flying should "fly [the] nosewheel to the runway" but does not prescribe a rate.[6] Following the March 23, 2009, event at Narita International Airport, FedEx conducted a study of 6,300 MD-11 landings and determined that derotation rates averaged about 1º per second. During the Riyadh accident landing, FDR data show that during the first bounce, the aircraft pitched down 6° in 2 seconds, which is 3° per second, and during the second bounce the aircraft pitched down 14º in

[4] Derotation is the act of lowering the nosewheel to the runway following main gear touchdown.

[5] For more information, see *Report on the Accident of Boeing MD-11 B-150 at Hong Kong International Airport on 22 August 1999*, Aircraft Accident Report 1/2004 (Hong Kong: Civil Aviation Department of Hong Kong, 2004).

[6] Section 2.3.30 "Supplementary Operation," in the Lufthansa Cargo Operating Manual also does not specifically prescribe derotation rates, stating only that "pitch attitude and sink rate cannot be examined in due time."

3 seconds, which is approximately 4.7º per second. After the initial touchdown, the captain's manual control inputs were excessive, exacerbating the airplane's pitch excursion.

As with excessive sink rate, rapid derotation has been a major factor in many MD-11 landing accidents. For example, the NTSB found during the investigation of the July 31, 1997, accident involving FedEx flight 14 at Newark, New Jersey, that the captain initiated a rapid nose-down elevator input within 0.5 second following initial touchdown, resulting in a second touchdown that exceeded the airplane's design structural limits. An NTSB performance study of the June 7, 2005, accident involving UPS flight 6971 in Louisville, Kentucky, found that the pilot flying moved the control column forward sharply following the initial touchdown, reducing pitch angle from 5º nose up to 1º nose down in about 1.5 seconds, reducing load factor to 0.3 G[7] and inducing a touchdown on the nosewheel of 2.5 G.

Following its investigation of the FedEx flight 14 accident at Newark, the NTSB issued Safety Recommendation A-00-93 to the Federal Aviation Administration (FAA) addressing the need for pilot training on these concepts:

> Convene a joint government-industry task force composed, at a minimum, of representatives of manufacturers, operators, pilot labor organizations, and the FAA to develop, within 1 year, a pilot training tool to do the following: provide a syllabus for simulator training on the execution of stabilized approaches to the landing flare, the identification of unstabilized landing flares, and recovery from these situations, including proper high sink rate recovery techniques during flare to landing, techniques for avoiding and recovering from overcontrol in pitch before touchdown, and techniques for avoiding overcontrol and premature derotation during a bounced landing.

The NTSB classified this recommendation "Closed—Acceptable Action" on October 22, 2002, based on the issuance of an appendix to Advisory Circular 120-71, "Standard Operating Procedures for Flight Deck Crew Members," and the issuance of Flight Standards Information Bulletins for Air Transport (FSAT) 00-08 and 00-12, which addressed stabilized approaches and approach and landing accident reduction. In its response to Safety Recommendation A-00-93, the FAA stated that, although FSAT 00-12 discussed the ground spoiler knockdown feature of the DC-10 and MD-11, the guidance in the appendix and FSATs was generic rather than airplane type-specific. The FAA also stated that the recommended task force would not be any more effective in developing type-specific training than the airplane certification team.

Despite the corrective action taken in response to Safety Recommendation A-00-93, MD-11 crews continue to have difficulty in judging the flare maneuver and in making appropriate pitch and power changes after hard landings; four of the eight events that occurred after the recommendation was closed involved U.S. operators. The frequency of MD-11 hard landing accidents suggests that generic guidance on these concepts is not sufficient or effective. As the investigative agency representing the state of manufacture of the MD-11 airplane, the NTSB continues work to evaluate the factors that contribute to these accidents. However, the

[7] A FedEx tailstrike awareness training module indicates that unloading the wing prior to touchdown reduces the weight bearing capability of the main landing gear.

NTSB believes that enhanced operational guidance and recurrent training will provide near-term improvements that reduce the risk of MD-11 landing accidents. Therefore, the NTSB recommends that the FAA require Boeing to revise its MD-11 FCOM to reemphasize high sink rate awareness during landing, the importance of momentarily maintaining landing pitch attitude after touchdown and using proper pitch attitude and power to cushion excess sink rate in the flare, and to go around in the event of a bounced landing.

The NTSB notes that, following the Narita accident, FedEx instituted recurrent simulator training for bounced landing recovery for all its MD-11 pilots but other U.S. operators of MD-11s (such as Centurion and World Airways) currently do not provide any bounced landing recovery training. Accurately simulating the dynamics of a bounced landing is difficult, but hands-on training provided in a flight simulator is the best way to train for this type of event. Moreover, to increase the likelihood that the appropriate procedures will be used when circumstances require and to maintain proficiency, MD-11 flight crews should be required to take simulator training in bounced landing recovery on a recurring basis. Therefore, the NTSB recommends that, once Boeing has completed the revision of its FCOM as recommended in Safety Recommendation A-11-68, the FAA require all MD-11 operators to incorporate the Boeing-recommended bounce recognition and recovery procedure in their operating manuals and in recurrent simulator training.

Therefore the National Transportation Safety Board makes the following recommendations to the Federal Aviation Administration:

> Require Boeing to revise its MD-11 Flight Crew Operating Manual to reemphasize high sink rate awareness during landing, the importance of momentarily maintaining landing pitch attitude after touchdown and using proper pitch attitude and power to cushion excess sink rate in the flare, and to go around in the event of a bounced landing. (A-11-68)

> Once Boeing has completed the revision of its MD-11 Flight Crew Operating Manual as recommended in Safety Recommendation A-11-68, require all MD-11 operators to incorporate the Boeing-recommended bounce recognition and recovery procedure in their operating manuals and in recurrent simulator training. (A-11-69)

In response to the recommendations in this letter, please refer to Safety Recommendations A-11-68 and -69. 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 secure mailbox. 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).

Chairman HERSMAN, Vice Chairman HART, and Members SUMWALT, ROSEKIND, and WEENER concurred in these recommendations.

[Original Signed]

By: Deborah A.P. Hersman
Chairman