National Transportation Safety Board

Washington, DC 20594

Safety Recommendation

Date: April 2, 2014

In reply refer to: A-14-004 through -007

The Honorable Michael P. Huerta
Administrator
Federal Aviation Administration
Washington, DC 20591

We are providing the following information to urge the Federal Aviation Administration (FAA) to take action on the safety recommendations issued in this letter. These recommendations address landing accidents involving McDonnell Douglas MD-11 airplanes. The recommendations are derived from the National Transportation Safety Board's (NTSB) investigation of several MD-11 hull loss accidents. As a result of these investigations, the NTSB has issued seven recommendations, four of which are addressed to the FAA. Information supporting these recommendations is discussed below.

Background

The NTSB is aware of at least 13 MD-11 hard landing accidents that occurred between 1994 and 2010.[1] For example, on July 31, 1997, an MD-11 operated by Federal Express (FedEx) made a hard landing at Newark International Airport, Newark, New Jersey, causing the main landing gear and a wing spar to fracture and the airplane to roll over. The captain, first officer, and three passengers received minor injuries, and the airplane was destroyed by impact forces and a postcrash fire.[2]

The NTSB determined that the probable cause of this accident was the captain's overcontrol of the airplane during the landing and his failure to execute a go-around from a destabilized flare. As a result of the accident, the NTSB issued 12 recommendations to the FAA on August 25, 2000, to reduce the risk of accidents with similar circumstances.

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[1] The MD-11 received FAA certification in November 1990. In addition to the 13 accidents, the NTSB investigated an April 1993 MD-11 hard landing incident that resulted in minor airplane damage and no crewmember or passenger injuries. For more information about this incident, see LAX93IA198 on the NTSB's website, which can be accessed at http://www.ntsb.gov/.

[2] *Crash During Landing, Federal Express, Inc., McDonnell Douglas MD-11, N611FE, Newark International Airport, Newark, New Jersey, July 31, 1997*, Aircraft Accident Report NTSB/AAR-00/02 (Washington, DC: NTSB, 2000), which can be accessed at the NTSB's website.

These recommendations addressed pilot training, airplane design, flight control software, and MD-11 certification requirements.[3]

In addition, in accordance with the provisions of Annex 13 to the Convention on International Civil Aviation, the NTSB participated in several foreign MD-11 accident investigations as the representative of the state of manufacture and design, including the following:

- In August 1999, a China Airlines MD-11 made a hard landing at Hong Kong International Airport, Lantau, Hong Kong, causing the right main landing gear to collapse, the right wing to separate, and the airplane to roll and yaw uncontrollably to the right. Three people died, 50 people were seriously injured, and 139 people received minor injuries. The airplane sustained "severe impact and some [postcrash] fire damage."[4]

- In March 2009, a FedEx MD-11 made a hard landing at Narita International Airport, Narita, Japan, causing the airplane to bounce "repeatedly" and the left wing to break and separate from the airplane. The two flight crewmembers died, and the airplane was destroyed by impact forces and a postcrash fire.[5]

- In July 2010, a Lufthansa Cargo MD-11 made a hard landing at King Khalid International Airport, Riyadh, Saudi Arabia, causing the aft fuselage to rupture and the nose gear to collapse. The captain received minor injuries, and the first officer received serious injuries. The airplane was destroyed by impact forces and a postcrash fire.[6]

On July 12, 2011, while the Narita and Riyadh investigations were still underway, the NTSB issued Safety Recommendations A-11-68 and -69 to the FAA. These recommendations addressed the need for improved recurrent training and operational guidance for MD-11 pilots.[7] The NTSB believed that the actions described in those recommendations would provide near-term improvements to reduce the risk of MD-11 landing accidents. The recommendations in

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[3] For more information, see Safety Recommendations A-00-92 through -103 at the NTSB's website. The response history for these recommendations can be accessed using the safety recommendation database at the NTSB's website.

[4] *Report on the Accident to Boeing MD11 B-150 at Hong Kong International Airport on 22 August 1999*, Aircraft Accident Report 1/2004 (Hong Kong: Civil Aviation Department, 2004), which can be accessed at http://www.cad.gov.hk/reports/main1.pdf.

[5] *Crash During Landing, Federal Express Corporation, McDonnell Douglas MD-11F, N526FE, Narita International Airport, March 23, 2009*, Aircraft Accident Investigation Report AA2013-4 (Tokyo, Japan: Japan Transport Safety Board, 2013), which can be accessed at http://www.mlit.go.jp/jtsb/eng-air_report/N526FE.pdf.

[6] *MD-11F, King Khalid International Airport – Riyadh, Kingdom of Saudi Arabia, Abnormal Runway Contact, July 27, 2010*, Aircraft Accident Report (Jeddah, Saudi Arabia: General Authority of Civil Aviation, 2012), which can be accessed at http://www.bfu-web.de/EN/Home/homepage_node.html.

[7] For more information, see Safety Recommendations A-11-68 and -69 at the NTSB's website. The letter includes a table that lists the 13 MD-11 hard landing accidents between 1994 and 2010. The response history for these recommendations can be accessed using the safety recommendation database at the NTSB's website. Safety Recommendation A-11-68 is discussed later in this letter.

this letter are aimed at providing longer term solutions for further reducing the risk of MD-11 landing accidents.

Possible Factors Contributing to MD-11 Hard Landing Accidents

MD-11 hard landing accidents have frequently involved a pilot's late or ineffective flare and/or mismanagement of bounced landings, which can cause the airplane to porpoise.[8] This sequence of events could be particularly hazardous in the MD-11 because overloading of the main landing gear in the vertical direction could cause the main wing spar to fracture and the airplane to subsequently roll over.[9] The NTSB's review of an online aerospace information database found that the MD-11 had the highest rate of hard landing events (5.63 per 1 million flight cycles) among the 27 large western-built transport-category airplanes for which data were available as of August 2012.[10] The NTSB reviewed data from multiple MD-11 hard landing accidents that resulted in hull losses (with and without fatalities) and identified factors that might have contributed to the severity of these hard landing accidents, including the following:

- the MD-11's high landing speed, which increases the difficulty of a properly timed and executed flare because it must be initiated within a narrow timeframe;
- the airplane's geometry, which places the cockpit far ahead of the center of gravity and the main landing gear, reducing pilot awareness of wheel-ground contact;
- the MD-11's automatic reduction of thrust during the landing flare, which could lead to a delay in adjusting thrust or pitch overcontrol during landings with excessive sink rates; and
- the airplane's use for long-range cargo flights, which reduces the opportunities for pilots to maintain landing proficiency compared with transport-category pilots who do not fly such routes.

Each factor, by itself, is not sufficient to account for the relatively high MD-11 hard landing rate because other large transport-category airplanes are affected by some of the same factors.[11] However, the interaction of all of these factors might increase the MD-11's

[8] "Porpoising" refers to the series of upward and downward motions that occur when a bounced landing is not properly recovered, On September 26, 2005, the NTSB issued Safety Recommendation A-05-30, which asked the FAA to "require all 14 *Code of Federal Regulations* [CFR] Part 121 and 135 air carriers to incorporate bounced landing recovery techniques in their flight manuals and to teach these techniques during initial and recurrent training." On November 5, 2013, the FAA issued a final rule, titled "Qualification, Service, and Use of Crewmembers and Aircraft Dispatchers" (78 *Federal Register* 67800, November 12, 2013) with an effective date of March 12, 2014. The final rule includes a requirement that Part 121 pilots undergo bounced landing recovery training in a simulator.

[9] As indicated in the Newark report, the MD-11 main landing gear was designed to break from the wing (fuse) under drag overload conditions. However, at the time that the MD-11 was certified, there was no FAA requirement for main landing gear fusing during overloading in the vertical direction.

[10] For more information, see the Ascend Online fleet data, which can be accessed at www.ascendworldwide.com.

[11] For example, the Boeing 747 has higher landing speeds than the MD-11 at high weights. Airbus A320 manual landings also involve manual control of pitch and roll with the autothrottles engaged, and the A320 has neutral pitch

susceptibility to a late flare, a bounced landing, and improper column inputs by the pilot after a bounce, which could lead to overload of the main gear and the potential for catastrophic structural overload, a hull loss, and injuries and/or fatalities. These factors are discussed in more detail below.

High Landing Speed

Landing approach speeds for the MD-11 (which are as high as 186 knots for one variant in a normal landing configuration) are among the fastest for transport-category airplanes. These speeds can be even higher in high or gusty wind conditions due to the use of wind additives, which can increase approach speeds by up to an additional 20 knots. The airplane's high approach speeds can increase the difficulty of the landing flare because it must be initiated when the airplane is descending between 50 and 30 feet above the runway. For example, with a standard 3º glidepath, MD-11 airplanes traveling at nominal airspeeds on short final (from about 158 to 175 knots) would have vertical speeds ranging from about 840 to 930 feet per minute; thus, the pilot would have to initiate the flare within about 1.4 seconds after the 50-foot callout. The pilot would then continue to make flare control inputs to achieve and hold the proper landing attitude (about 7º of nose-up pitch). This relatively short response window leaves little margin to accommodate any delays in flare initiation by the pilot.

The Hong Kong, Narita, and Riyadh MD-11 accidents involved delayed flares. For example, for the Riyadh and Narita landings, the pilot response times for initiating the flare after the 50-foot callout were about 1.8 and 2.0 seconds, respectively.[12] Delayed response times could result from pilot factors, including fatigue, or environmental conditions, including challenging wind conditions (which were present during the Narita landing). Such conditions can affect a pilot's ability to anticipate the proper timing of the flare by occupying the pilot's attention with the need to make frequent control inputs to maintain the desired aim point, especially when transitioning from a crab to a sideslip in a crosswind. The Newark MD-11 accident involved a destabilized flare in which the pilot's control inputs were not effective from flare initiation to touchdown.

A delayed or an improperly executed flare maneuver in the MD-11 appears to be an early link in the chain of events that could lead to a bounced landing. One way to reduce the possibility of a delayed or an improperly executed landing flare is to provide assistance to the pilot (in addition to the aural cues provided by the 50-, 40-, and 30-foot callouts) to promote flare initiation at the appropriate time and help ensure the proper pitch control inputs during the maneuver. This additional help could be provided as a redundant cue presented visually on a heads-up display (HUD). FedEx has installed HUDs on the captain's side of the cockpit in all of the company's MD-11 airplanes. The HUDs present a flare cue as a horizontal line that rises up in the captain's field of view. The captain tracks this line with the airplane symbol by increasing pitch until the proper landing pitch attitude is attained.

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stability in normal mode. The Boeing 747-800 and 777-300 cockpits are farther ahead of the center of gravity than the MD-11 cockpit. The Boeing 747, 767, and 777 and the Airbus A300 are also used for long-range cargo flights.

[12] The report on the Narita accident indicated that the flare was likely delayed until the airplane descended to 20 feet radio altitude. The Riyadh report stated that a late flare was initiated between 23 and 31 feet above the runway.

The NTSB concludes that a cue to promote flare initiation as the desired pitch changes from an approach attitude to a landing attitude could help improve the timing and performance of this landing task. As a result, the NTSB recommends that the FAA work with Boeing to (1) assess the effectiveness of flare cueing systems to assist MD-11 pilots in making timely and appropriate inputs during the landing flare, (2) provide a formal report on the findings of the assessment, and (3) if the assessment shows that flare cueing systems could be useful to MD-11 pilots, provide copies of the report to all US operators of MD-11 airplanes and encourage them to install such a system on these airplanes.

Airplane Geometry

The MD-11, a derivative of the DC-10 airplane, was made longer by extending the fuselage forward of the wing an additional 100 inches; as a result, the cockpit is well ahead of the airplane's center of gravity and main landing gear. If the airplane bounces during a landing, the airplane could pivot about its center of gravity, which could cause the cockpit and the main landing gear to move in opposite vertical directions and at different rates and thus provide misleading motion cues to a pilot during a bounce. As a result, a pilot might not be able to determine whether the main landing gear was in contact with the ground and whether the gear, if it was not contacting the ground, was ascending or descending.

The disconnect between the motion of the cockpit and the motion of the main landing gear when the airplane rotates about its center of gravity could cause a pilot to make inappropriate control column inputs under certain conditions. For example, a pilot normally makes pitch control inputs to de-rotate the airplane after touchdown.[13] However, these inputs would be inappropriate in the MD-11 during a bounce because they could exacerbate the bounce.

Improved pilot awareness of wheel-ground contact could reduce the possibility of a pilot-exacerbated bounce and increase the likelihood that a pilot would properly react to this situation with a promptly initiated go-around maneuver. One way to promote such awareness is a bounce cueing system, such as the one currently being developed by Lufthansa Cargo and Boeing. This system, referred to as an on-ground awareness system, would illuminate a cyan indicator light in the cockpit to signal that the main landing gear has left the ground so that the pilot could take the appropriate remedial action.

Because a pilot's visual attention is focused primarily on the runway environment during touchdown, it would be beneficial if a bounce cueing system included an aural or a tactile indication of a bounce in addition to a visual indication. The NTSB concludes that a bounce cueing system could allow MD-11 pilots to more effectively control the airplane after a bounced landing by providing the pilots with a cue when the main landing gear is not in contact with the ground. Therefore, the NTSB recommends that the FAA work with Boeing to (1) assess methods for providing weight-on-wheels cueing to MD-11 pilots to enhance pilot awareness of bounced landings and facilitate proper pilot reaction and effective control inputs when bounced landings occur, (2) provide a formal report on the findings of the assessment, and (3) if the assessment shows that the weight-on-wheels cueing methods could be useful to MD-11 pilots, provide

[13] During de-rotation, the pilot lowers the nosewheel to the runway after main gear touchdown.

copies of the report to all US operators of MD-11 airplanes and encourage them to provide a means for weight-on-wheels cueing for these airplanes.

Automatic Thrust Reduction During Flare

Normal landings for the MD-11 are flown with the throttles controlled automatically and pitch and roll controlled manually by the pilots. During a flare, the throttles begin to automatically move back as the airplane reaches a height of 50 feet above the runway, and they reach idle at 30 feet above the runway. Although this automatic thrust reduction can help ease workload during a high workload phase of flight, pilots need to maintain awareness of throttle movements. Pilots typically maintain such awareness by "guarding" the throttles (that is, placing their hands on the throttles to follow along with throttle movement) and intervening as necessary to adjust thrust during the landing if the sink rate were to increase close to the ground due to changing wind conditions or if other flightpath changes were to occur. However, any delay in inputting necessary thrust commands could lead to a suboptimal touchdown, which could increase the risk of a bounce.

Safety Recommendation A-11-68 asked the FAA, among other things, to require Boeing to revise its MD-11 *Flight Crew Operating Manual* (FCOM) to reemphasize the importance of "using proper pitch attitude and power to cushion excess sink rate in the flare." This recommendation was issued in part as a result of the NTSB's concerns that MD-11 flight crews were not effectively trained to recognize and arrest high sink rates during landing. In a November 8, 2012, letter to the NTSB, the FAA indicated its concerns that adding power during the flare could introduce "additional hazards" that could cause the airplane to land long and fast and without automatic ground spoiler extension. The FAA also stated that the flare capability of the MD-11 airplane was sufficient to keep the sink rate from causing an accident (as long as the flare was initiated between 50 and 30 feet above the runway) even with a descent rate as high as 18 feet per second and a flight crew that did not advance the throttles during the landing.[14]

The NTSB acknowledges the FAA's concern about the risk of "additional hazards" that adding power during the flare could introduce, even with the safety margins that were incorporated into the MD-11 landing distance tables, given that the landing distances were based on the automatic reduction of thrust at a height of 50 feet above the runway and the automatic and immediate extension of the ground spoilers. However, it is important to reduce the possibility that an MD-11 pilot might attempt to correct a high sink rate with excessive pitch inputs, which could destabilize a flare and lead to a bounced landing. The NTSB concludes that brief power increases to arrest an excessive sink rate during a flare should be factored into MD-11 landing performance data. It should be possible to quantify the effect on the airplane's landing performance of brief power increases to correct an excessive sink rate to determine how to mitigate the additional hazards identified by the FAA. Therefore, the NTSB recommends that the FAA work with Boeing to (1) evaluate the effect of brief power increases on simulated

[14] On May 15, 2013, Boeing issued Temporary Revision 2-1042 to the MD-11 FCOM, which revised the landing characteristics and techniques information to "mitigate hard landings and an improper bounced recovery with clear direction on how to ensure that a stable approach and a successful and uneventful landing [are] executed." In a June 27, 2013, letter to the FAA, the NTSB stated that, if the changes in Boeing's temporary revision were fully incorporated into the FCOM, the intent of Safety Recommendation A-11-68 would be satisfied. As a result, the NTSB classified the recommendation "Open—Acceptable Response."

MD-11 landing distances, (2) adjust the values in published MD-11 landing distance tables accordingly, and (3) provide the adjusted values to MD-11 operators.

Long-Range Flying

Because the MD-11 is a medium- to long-haul wide-body airplane used predominantly for international cargo flights, MD-11 pilots obtain relatively less landing experience per hour of flying compared with other transport-category airplane pilots who do not fly long routes.[15] Pilot landing skills can degrade over time when not used on a regular basis, and it is possible that the existing standards for landing currency for all pilots (typically three landings in 90 days) do not provide MD-11 pilots with sufficient opportunities to maintain their skills in timing the initiation of the flare and making appropriate control inputs during the flare.

According to FAA Order 8900.1, *Flight Standards Information Management System*, flight standardization boards (FSB) are established for large turbojet airplanes to determine the requirements for pilot type ratings, develop minimum training recommendations, and ensure initial flight crewmember competency in accordance with FAA Advisory Circular 120-53, "Crew Qualification and Pilot Type Rating Requirements for Transport Category Aircraft Operated Under 14 CFR Part 121." This information is then provided to the FAA's Air Transportation Division for approval and is used afterward by principal operations inspectors as guidance in approving operator training, checking, and currency programs. An FSB was convened to address the training, checking, and currency requirements for pilots operating the MD-10 and MD-11 airplanes under Part 121.[16] The FSB issued a report on its findings in May 2000, and the report was revised in January 2009 to incorporate training, checking, and currency requirements for operating MD-10 and MD-11 airplanes equipped with HUDs and enhanced flight vision systems.[17]

FAA Order 8900.1 also states that, in the event of an accident, "FSB members may be consulted on training or crewmember competency issues involving aircraft assigned to the board." Given that 13 hard landing accidents involving the MD-11 occurred during a 16-year period and that many of these accidents involved a pilot's late or ineffective flare and/or mismanagement of bounced landings, the NTSB concludes that additional landing experience beyond the current requirement of three landings every 90 days might help MD-11 pilots consistently make the appropriate control inputs during the landing flare. As a result, the NTSB recommends that the FAA reconvene the MD-10/MD-11 FSB to determine whether currency requirements should be strengthened for MD-11 pilots.

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[15] This statement also applies to pilots of other airplanes used predominantly for long-range international flights. However, compared with the MD-11, the hard landing accident rates for those airplanes are lower, which could indicate that pilots of those airplanes are not typically performing a late or an ineffective flare.

[16] An MD-10 is a DC-10 that has been retrofitted with an advanced-technology flight deck. According to Boeing, the retrofit allows, among other things, a two-person flight crew (instead of a three-person flight crew as with the DC-10) and commonality with the MD-11.

[17] For more information, see the MD-10/MD-11 FSB's January 2009 report, which can be accessed at http://fsims.faa.gov/wdocs/fsb/md-10-md-11%20fsb%20rev1.pdf.

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

> Work with Boeing to (1) assess the effectiveness of flare cueing systems to assist MD-11 pilots in making timely and appropriate inputs during the landing flare, (2) provide a formal report on the findings of the assessment, and (3) if the assessment shows that flare cueing systems could be useful to MD-11 pilots, provide copies of the report to all US operators of MD-11 airplanes and encourage them to install such a system on these airplanes. (A-14-004)
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> Work with Boeing to (1) assess methods for providing weight-on-wheels cueing to MD-11 pilots to enhance pilot awareness of bounced landings and facilitate proper pilot reaction and effective control inputs when bounced landings occur, (2) provide a formal report on the findings of the assessment, and (3) if the assessment shows that the weight-on-wheels cueing methods could be useful to MD-11 pilots, provide copies of the report to all US operators of MD-11 airplanes and encourage them to provide a means for weight-on-wheels cueing for these airplanes. (A-14-005)
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> Work with Boeing to (1) evaluate the effect of brief power increases on simulated MD-11 landing distances, (2) adjust the values in published MD-11 landing distance tables accordingly, and (3) provide the adjusted values to MD-11 operators. (A-14-006)
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> Reconvene the MD-10/MD-11 flight standardization board to determine whether currency requirements should be strengthened for MD-11 pilots. (A-14-007)

The NTSB has also issued three safety recommendations to Boeing.

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

The NTSB is vitally interested in these recommendations because they are designed to prevent accidents and save lives. We would appreciate receiving a response from you within 90 days detailing the actions you have taken or intend to take to implement them. When replying, please refer to the safety recommendations by number. We encourage you to submit your response electronically to correspondence@ntsb.gov.

[Original Signed]

By: Deborah A.P. Hersman,
Chairman