

1 May 2018
66-ZB-H200-ASI-19036

Ms. Lorenda Ward
Investigator In Charge
National Transportation Safety Board
490 L'Enfant Plaza, SW
Washington DC 20594-003

Subject: Boeing Submission for Ameristar MD-83 N786TW Runway Overrun
Following a Rejected Takeoff at Ypsilanti, Michigan – 8 March 2017

Reference: NTSB Tech Review Meeting, 4 April 2018

Dear Ms. Ward,

As requested following the reference technical review, please find attached the Boeing submission on the subject accident. Per your request we are sending this electronic version to your attention for distribution within the NTSB.

We would like to thank the NTSB for giving us the opportunity to make this submission. If you have any questions, please don't hesitate to contact us.

Best regards,



Robert J. McIntosh
Director, Product Safety

Enclosure: Boeing Submission to the NTSB for the subject accident





Submission to the
National Transportation Safety Board
for the

**Ameristar Air Cargo MD-83 N786TW
Runway Overrun Following A
Rejected Takeoff at
Ypsilanti, MI
8 March 2017**

**The Boeing Company
1 May 2018**



INTRODUCTION

On March 8, 2017, about 1452 eastern standard time (EST), Ameristar Air Cargo, Inc. dba Ameristar Charters flight 9363, a Boeing MD-83, N786TW, ran off the end of runway 23L after executing a rejected takeoff at Willow Run Airport (YIP), Ypsilanti, Michigan. All 110 passengers and 6 crewmembers evacuated the airplane. One passenger was reported to have received a minor injury. The airplane sustained substantial damage (no post-crash fire occurred). The airplane, which had been flown to YIP 2 days before the accident, was operating under the provisions of 14 *Code of Federal Regulations* (CFR) Part 121 as an on-demand charter flight and was destined for Washington Dulles International Airport (IAD), Dulles, Virginia. Daytime visual meteorological conditions prevailed at the time of the accident.

Submission Abstract

- The Boeing Company, as the airplane's manufacturer, is an invited party to the investigation and provides technical and operational assistance to the National Transportation Safety Board (NTSB) in their investigation.
- The conclusions presented in this submission are based on factual information received from the NTSB, Boeing expertise, the use of analytical tools, and a methodical investigation process.
- The takeoff was rejected because the airplane would not rotate for takeoff in response to control column input. The over-centering of the right elevator geared tab inboard push rod links and actuating crank caused the elevator to jam trailing edge down, which prevented the airplane from responding to the control column input.
- Analysis and laboratory testing determined the over-center condition was initiated when the airplane was parked and exposed to winds affected by a nearby hanger. The hanger caused turbulent dynamic vertical winds to impact the airplane's elevators with sufficient downward force to cause the over-center condition.
- Boeing is investigating potential methods to prevent takeoff attempts by DC-9, MD-80, and 717 airplanes with elevators jammed trailing edge down. Boeing has initiated the Airlines for America Lead Airline process to request operator input.
- During evacuation of the airplane, an evacuation slide did not inflate as a cable was not properly retained in an inflation valve pulley. The evacuation slide manufacturer updated the Component Maintenance Manual to ensure the cable will be retained in the pulley.



BOEING ASSISTANCE WITH THIS INVESTIGATION

The National Transportation Safety Board (NTSB) is conducting the investigation into this Ameristar Air Cargo MD-83 accident. Assisting the NTSB in their investigation are the Federal Aviation Administration (FAA), Ameristar Air Cargo, Boeing, and other designated parties.

As the manufacturer of the MD-83 airplane, Boeing's specific role in this investigation has been to provide technical information regarding the airplane design, manufacture and operation to assist the NTSB.

Furthermore, the NTSB requested that all parties submit proposed findings to be drawn from the factual information established during the course of the investigation. Boeing has responded to the NTSB request with this document, which:

- Provides an assessment of the factual information and other pertinent data.
- Identifies knowledge gained from the investigation.
- Identifies conclusions and recommendations supported by the knowledge gained from the investigation.

BOEING ASSESSMENT

The Boeing assessment of the accident is based upon the facts as documented in the NTSB's factual reports. These reports are observations of the airplane and accident site, post-accident examination of airplane systems and components, flight data recorder data, flight crew interviews, a wind model analysis, and laboratory testing.

WEATHER

At 1153 EST, YIP reported: *wind from 260° at 35 knots with gusts to 50 knots, visibility 10 statute miles or greater, sky clear below 12,000 feet above ground level (agl), temperature of 11° Celsius (C) and a dew point temperature of -11°C, altimeter setting of 29.81 inches of mercury; Remarks: station with a precipitation discriminator, peak wind from 260° of 55 knots occurred at 1139 EST, sea level pressure of 1009.5 hectopascals (hPa), temperature of 10.6°C and dew point temperature of -10.6°C.*¹

At 1253 EST, YIP reported: *altimeter setting of 29.79 inches of mercury; Remarks: station with a precipitation discriminator, peak wind of 46 knots from 240° occurred at 1156 EST, sea level pressure not available, over last 3 hours pressure decreased (was steady or increasing then decreased, or was decreasing then decreased more rapidly) by 1.2 hPa, maintenance needed on the system.*²

At 1353 EST, YIP reported: *altimeter setting of 29.77 inches of mercury; Remarks: station with a precipitation discriminator, sea level pressure not available, maintenance needed on the system.*³

At 1453 EST, YIP reported: *altimeter setting of 29.80 inches of mercury; Remarks: station with a precipitation discriminator, sea level pressure not available, maintenance needed on the system.*⁴

¹ NTSB Meteorology Group Chairman's Factual Report, dated 18 December 2017, page 7

² NTSB Meteorology Group Chairman's Factual Report, dated 18 December 2017, page 7

³ NTSB Meteorology Group Chairman's Factual Report, dated 18 December 2017, page 7

⁴ NTSB Meteorology Group Chairman's Factual Report, dated 18 December 2017, page 7



SEQUENCE OF EVENTS

The flight crew interviews indicate a pre-flight inspection and a flight control rollout check were performed by the flight crew prior to the accident.

The flight crew prepared for take-off and calculated V-speeds (V_1 , V_R , V_2) using “Normal Thrust Takeoff” (as specified by the operator, Ameristar, as policy for KYIP runway 23L), a 10 kts headwind, and a take-off weight of 146,600 lbs. The V-speeds for this configuration were 139 kts, 142 kts, and 150 kts, respectively. However, the flight crew chose to increase V_R to 150 kts to allow for more control during take-off in the presence of windshear.⁵

The NTSB’s performance analysis provided the following rejected takeoff sequence of events:

Event	Time, EST hr:min:sec	Relative Time (sec)	Distance, ft	Groundspeed (airspeed), kts
Begin take-off roll	14:51:29	0	0	0 (not recorded)
Initial control column input	14:51:56	27	3000	120 (138)
Significant control column input	14:52:01	32	4100	140 (151)
Peak left elevator deflection	14:52:06	37	5450	160 (165)
Brakes applied	14:52:08	39	5850	163 (173) ~ maximum speed
Control column released	14:52:09	40	5900	162 (172)
Spoilers deployed	14:52:10	41	6400	155 (170)
Thrust reversers	14:52:13 to 14:52:15	44 to 46	6900 to 7300	138 (161) to 118 (142)
End of the runway	14:52:15	46	7450	112 (135)
Off paved surface	14:52:16	47	7650	100 (121)
End of good data	14:52:24	55	8600	40 (64)

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Once the airplane came to rest, an evacuation was initiated. During the evacuation, the evacuation slide at Door-1 Right did not inflate. The evacuation slides at Door-1 Left, Door- 2 Left, and the Aft Tailcone exit inflated properly.

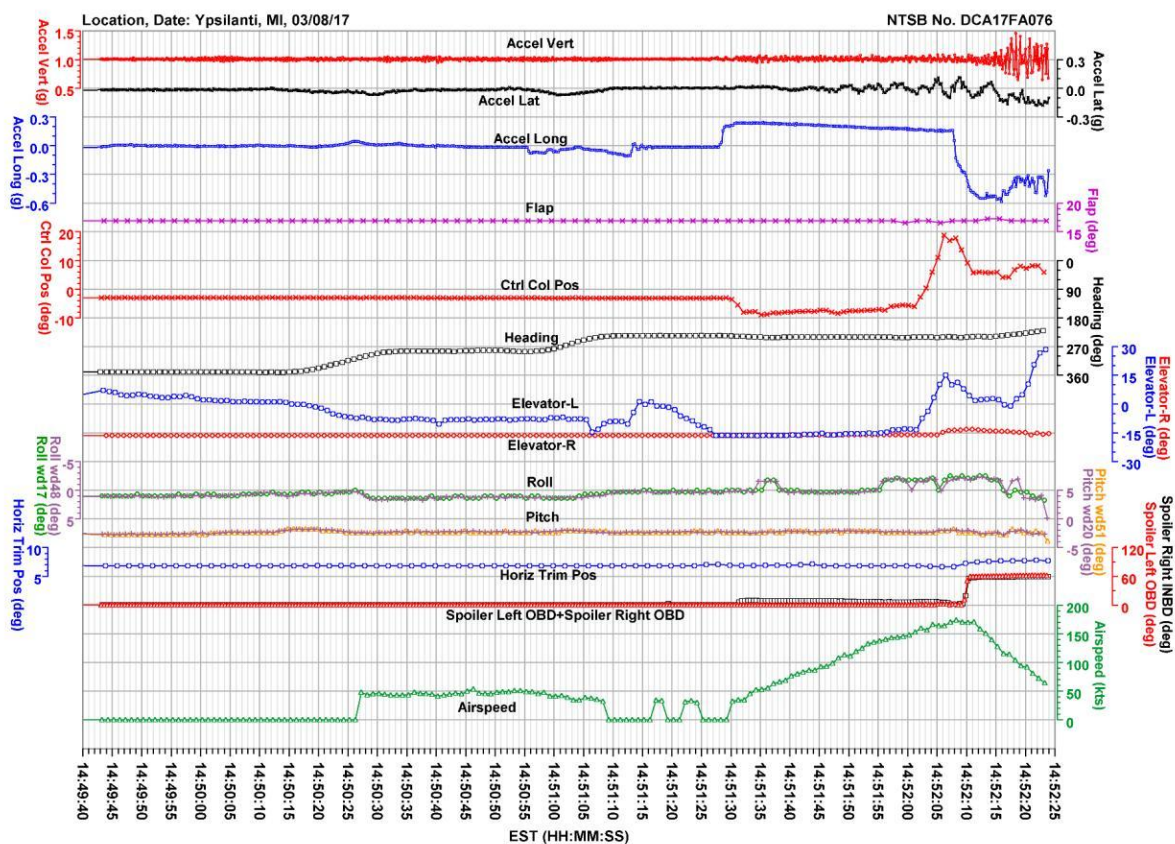
⁵ NTSB Performance Study Specialist’s Report, Not Dated, pages 9-10

⁶ NTSB Performance Study Specialist’s Report, Not Dated, page 14

FLIGHT DATA RECORDER INFORMATION

The following plot of some FDR parameters shows the left elevator was moving as the airplane was taxiing and during the takeoff roll. Additionally, the left elevator appears to have responded normally to the control column input that was initiated during the takeoff roll at approximately 14:52:01 EST. The right elevator did not appear to move from the elevator's trailing edge down limit of approximately 16.5 degrees, as the airplane was taxiing and during the initial takeoff roll. At approximately 14:52:01 EST, the right elevator only moved approximately 3 degrees trailing edge up, in response to the control column input.

The flight data recorder captured several prior flights and activities between flights. For the prior flight, both elevators were moving as expected.⁷



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⁷ NTSB Performance Study Specialist's Report, Not Dated, page 15

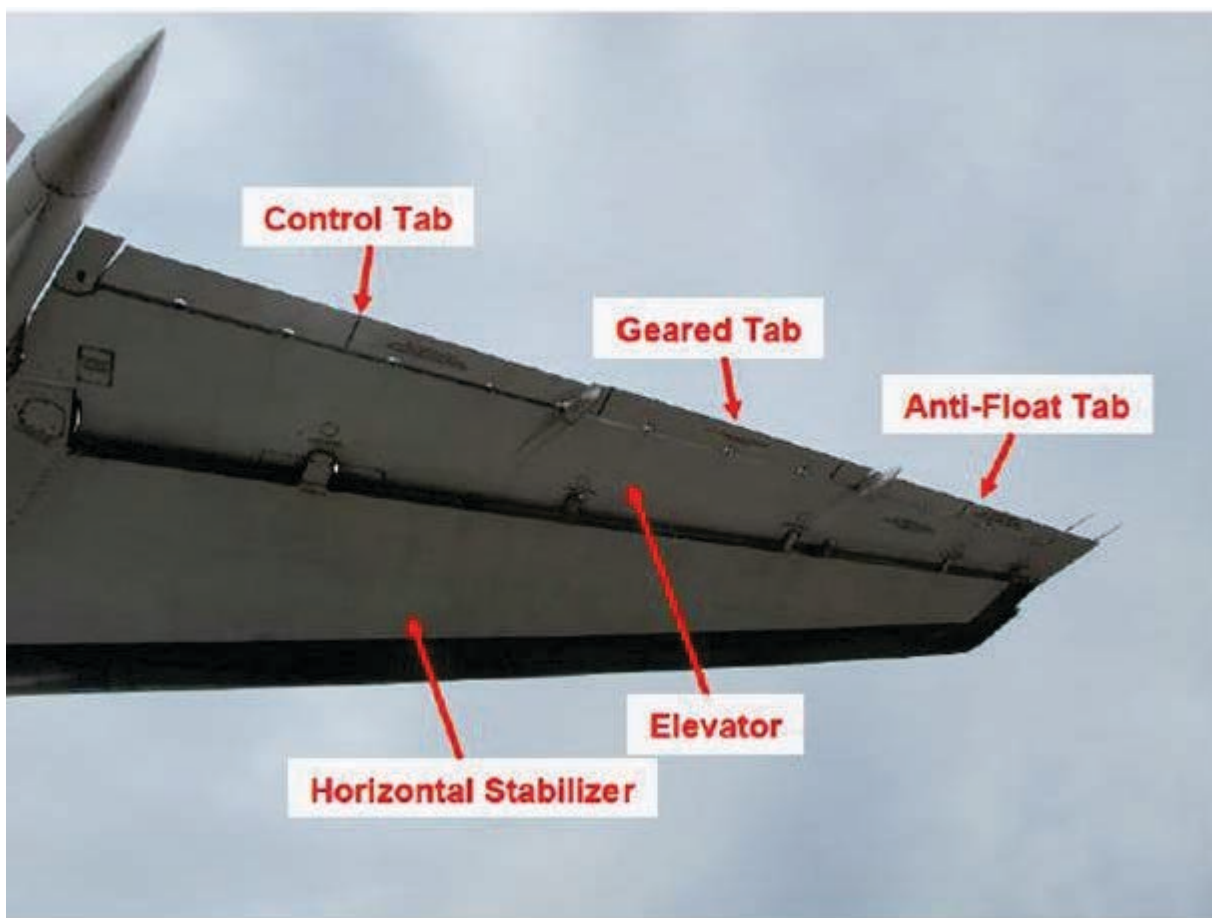
⁸ NTSB Flight Data Recorder Specialist's Report, dated 10 January 2018, page 6

AIRPLANE SYSTEMS AND STRUCTURES

Elevator Control System

MD-80 Elevator Control System Description

The left and right elevators provide longitudinal control about the pitch axis of the aircraft. Each elevator is attached to the rear spar of the horizontal stabilizer at six hinge locations. Each elevator can travel 27° trailing edge up and 16.5° trailing edge down. Mechanical stops limit movement of the elevator in both the trailing edge up and trailing edge down direction. The elevator control surfaces are mechanically controlled and operated by aerodynamic forces created by control surfaces which consist of control tabs, geared tabs and anti-float tabs. The control tabs are operated by the control columns in the cockpit and the control columns do not directly move the elevator surface. On the ground the elevators are free to move independently within the confines of the mechanical stops.⁹



Elevator Control Tab

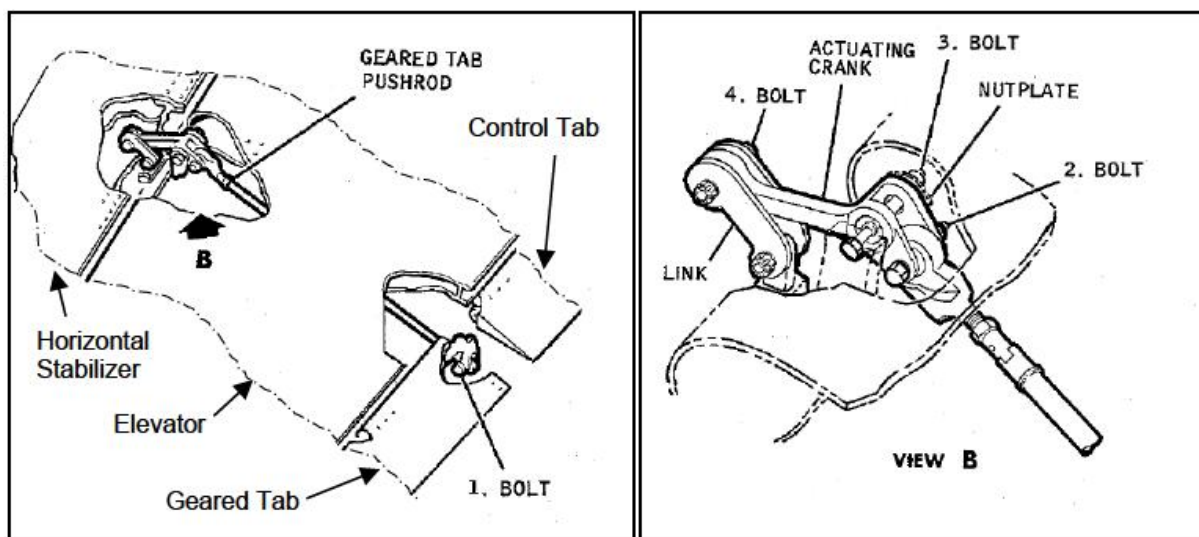
The control tab on each elevator's trailing edge is deflected by mechanical inputs from the captain or first officer's control column. When the elevator control tab is deflected, the aerodynamic forces will move the elevator surface. When the control column is pushed forward, commanding an aircraft nose down direction, the control tab will deflect in a control tab trailing edge up direction and the resultant aerodynamic forces will move the elevator surface in a trailing edge down direction. The movements of the tab and surface are opposite if the control column is pulled aft for an aircraft nose up command.

⁹ NTSB Systems Group Chairman's Factual Report, dated 05 February 2018, page 10

If 10° or more of control tab movement is required to move the elevator trailing edge down, a hydraulically operated elevator power control system will activate and drive the elevator in a trailing edge down direction. The control tabs for the left and right elevator are interconnected below the cockpit floor via the control columns, but the left and right elevator surfaces are not interconnected.¹⁰

Elevator Geared Tab

The geared tab provides aerodynamic assistance to the control tab to deflect the elevator. The geared tab drive linkages are directly connected to the horizontal stabilizer rear spar at two places approximately in line with the inboard and outboard ends of the geared tab. The connection to the horizontal stabilizer rear spar consists of an eye bolt, two links, and an actuating crank. Each geared tab pushrod connects to a crank fitting on the geared tab. The geared tab movement directions are identical to the control tab movement but based on elevator surface movement, not control column input.¹¹



Maintenance Manual Excerpt of Gear Tab Components

Elevator Anti-Float Tab

The anti-float tab is the outer most elevator tab. The anti-float tab prevents down-float of the elevator when the horizontal stabilizer position is greater than 10° aircraft nose-up. The anti-float tab is mechanically connected to the horizontal stabilizer and movement is driven by the stabilizer position. The anti-float tab will remain faired with the elevator when the stabilizer position is less than 10° aircraft nose-up.¹²

Elevator Damper

Each elevator has a damper installed to the leading edge of the elevator and connected to the horizontal stabilizer rear spar. The damper prevents elevator flutter during flight and dampens rapid movement of the elevator caused by gusty winds when the aircraft is on the ground.¹³

¹⁰ NTSB Systems Group Chairman's Factual Report, dated 05 February 2018, page 12

¹¹ NTSB Systems Group Chairman's Factual Report, dated 05 February 2018, pages 12-13

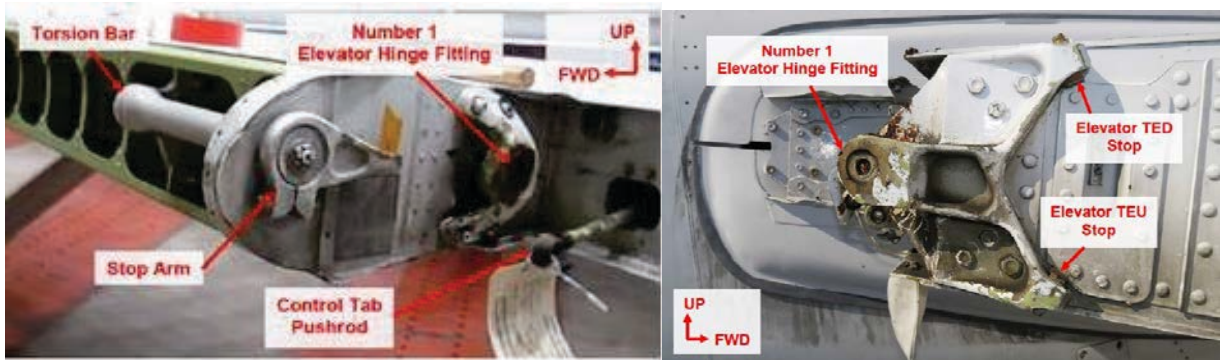
¹² NTSB Systems Group Chairman's Factual Report, dated 05 February 2018, page 13

¹³ NTSB Systems Group Chairman's Factual Report, dated 05 February 2018, page 11

Elevator Stop, Stop Arm and Torsion Bar

Elevator travel is typically limited to 27° trailing edge up and 16.5° trailing edge down by mechanical stops on the horizontal stabilizer. The elevator contacts the stop via a stop arm and torsion bar arrangement mounted in the leading edge of the elevator near the root. The torsion bar is attached to a structural rib in the elevator to distribute increased loading due to an increase of force on the stop arm when the elevator is in contact with the elevator stops. The torsion bar passes through the closeout rib via a bearing to allow for torsion bar rotation.¹⁴

One function of the stop arm and torsion bar arrangement is to assist the elevator dampers in preventing damage to the elevator and/or horizontal stabilizer due to high winds while the airplane is on the ground. The spring action of the arrangement is intended to absorb the energy created by a gust driving an elevator to its stops, before airplane damage occurs.



Elevator Stop, Stop Arm and Torsion Bar

DC-9 and 717 Elevator Control Systems

The DC-9 and 717 have elevator control systems similar to the MD-80 and utilize control tabs and geared tabs. Only the MD-80 has anti-float tabs incorporated.

Elevator On-Site Observations

From the ground, when viewed from behind, the left elevator was in a trailing edge up position and the right elevator was in a trailing edge down position. Flight control continuity for the elevator system was established by exercising the control column in the cockpit from both the pilot and copilot's side to the control column stops in both the aircraft nose up and aircraft nose down directions. The left and right control tabs responded with movement in the appropriate directions.¹⁵

A lift was used to inspect the elevators and attempts were made to move the elevators by hand. The right elevator could not be moved by hand from its trailing edge down position. The left elevator moved freely when moved by hand to the stops in the trailing edge up and trailing edge down direction.¹⁶

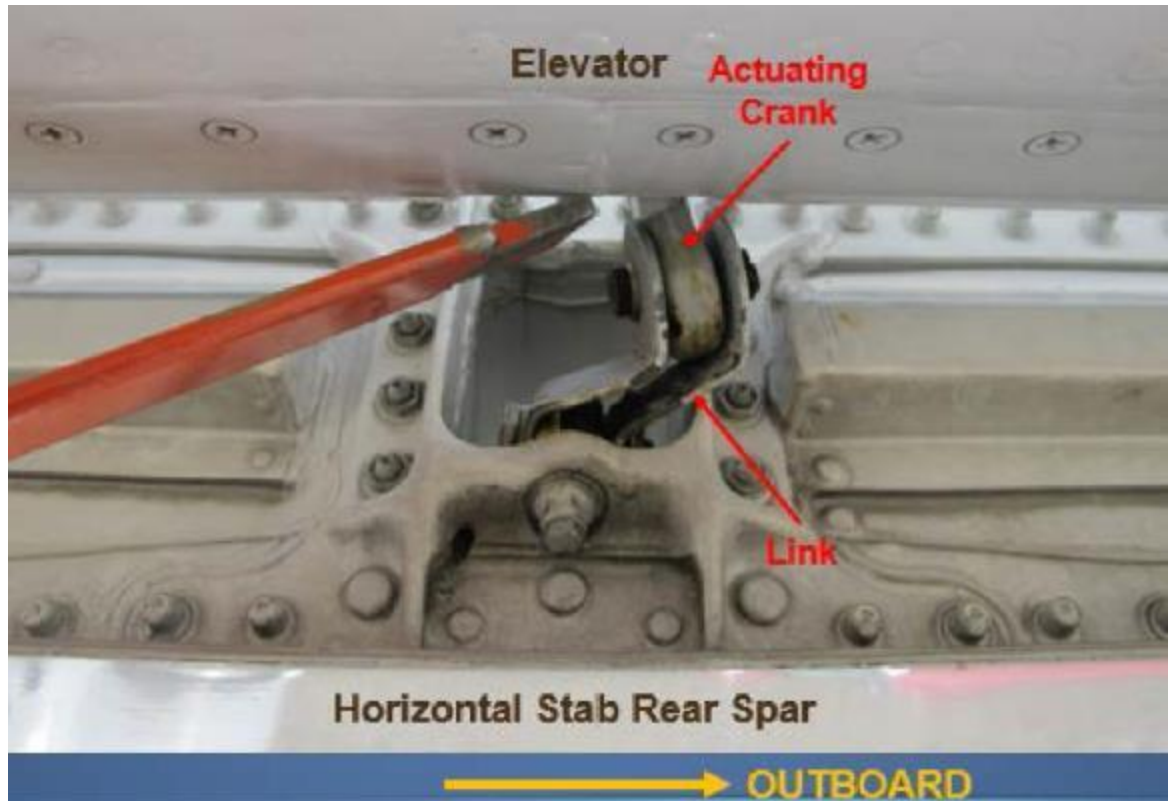
¹⁴ NTSB Systems Group Chairman's Factual Report, dated 05 February 2018, page 13

¹⁵ NTSB Systems Group Chairman's Factual Report, dated 05 February 2018, page 17

¹⁶ NTSB Systems Group Chairman's Factual Report, dated 05 February 2018, page 17

A visual examination of the tab hinges and control linkages found that the inboard right geared tab links and actuating crank were damaged and in an over-centered position. The two links and the actuating crank arm were bent in an outboard direction.¹⁷

The damaged links and associated attachment hardware were removed. After the links were removed, the right elevator was free to move, by hand, within the confines of the elevator stops.¹⁸



Inboard right hand geared tab attachment at horizontal stab rear spar as found (orange bar used by group to point to damaged links)

SURVIVAL FACTORS

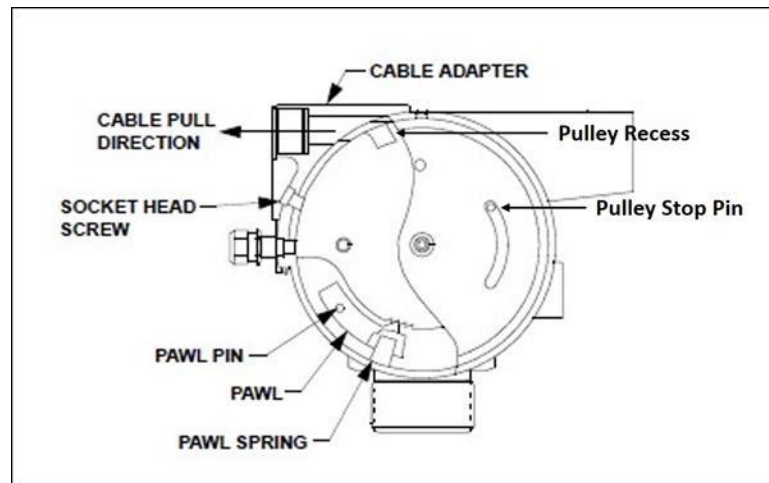
Door-1 Right Evacuation Slide

The operation of the evacuation slide inflation valve is based on a 'ball type' valve design. On the valve assembly, a pulley is used to turn the internal ball from a closed position to a fully open position when release of the inflation gases from the reservoir is required to inflate the evacuation slide. When the inflation valve is rigged for use, the inflation cable is inserted into the pulley housing and wound onto the pulley as the valve is moved from an open position to a closed position. With the valve closed and the inflation cable in place, the reservoir is then charged with the appropriate amount of compressed gas. The Reservoir and Valve Assembly (RVA) is then connected to the evacuation slide and the system is packed. When the evacuation system is deployed, the packed slide releases below the aircraft door. The inflation

¹⁷ NTSB Systems Group Chairman's Factual Report, dated 05 February 2018, page 19

¹⁸ NTSB Systems Group Chairman's Factual Report, dated 05 February 2018, page 21

cable is manually pulled, which rotates the pulley in the inflation valve to the open position, releasing the inflation gas into the slide assembly and inflating the evacuation slide.¹⁹



Inflation valve

The evacuation slide was evaluated at the manufacturer's facility and it was noted the slide had partially deployed during the evacuation with no evidence of gas flow from the RVA into the slide. The RVA was inspected and found with a fully charged reservoir with the valve pulley in the closed position. The manual inflation release cable (pulled by the flight attendant during the evacuation) was located inside the shipping box. The cover plate on the valve's internal mechanism was removed to reveal the pulley, pulley recess, lock pin and pawl.²⁰ The valve was re-assembled, and the valve release cable was installed by rotating the pulley to the 'valve open' position, inserting the cable ball end of the cable into the pulley recess, and then rotating the pulley back to the 'valve closed' position.²¹ A 'floor run' inflation of the slide assembly was performed by withdrawing the valve release cable from the RVA. The slide successfully inflated.²²

The RVA was removed from the slide. The inflation valve was disassembled to simulate the potential for incorrectly installing the valve release cable assembly. The investigation revealed that the cable ball could be retained inside the housing without actually engaging the pulley recess.²³ If the cable ball is not engaged in the pulley recess, it is possible the valve will not open to inflate the evacuation slide when the manual release cable is pulled. The evacuation slide manufacture has made modifications to the Component Maintenance Manual valve testing procedures to ensure the cable ball is retained in the pulley recess in revision #29, dated July 14, 2017.²⁴

¹⁹ NTSB Survival Factors Group Chairman's Factual Report, dated 02 April 2018, page 11

²⁰ NTSB Survival Factors Group Chairman's Factual Report, dated 02 April 2018, page 12

²¹ NTSB Survival Factors Group Chairman's Factual Report, dated 02 April 2018, page 13

²² NTSB Survival Factors Group Chairman's Factual Report, dated 02 April 2018, page 13

²³ NTSB Survival Factors Group Chairman's Factual Report, dated 02 April 2018, page 13

²⁴ NTSB Survival Factors Group Chairman's Factual Report, dated 02 April 2018, page 16



RESEARCH AND ANALYSIS

MD-80 Ground Gust Certification and Service Experience

The applicable certification basis for the Model DC-9-83 was the FAA's 14 CFR Part 25 Airworthiness Standards, effective February 1, 1965, including Amendments 25-1 through 25-40, effective May 2, 1977, with some exceptions and special conditions.²⁵

FAR 25.415 provides certification requirements concerning on-ground gust conditions an airplane's control system must withstand. The gust value specified by FAR 25.415 in the CFR Part 25 Airworthiness Standards, effective February 1, 1965, was approximately 52.1 knots; however, the MD-80 was designed to a gust value of 65 knots. For the purpose of design and certification, it was assumed the gusts were horizontal.

Both the MD-80 Flight Crew Operating Manual (FCOM) and the MD-80 Aircraft Maintenance Manual (AMM) direct the accomplishment of aircraft control systems inspections on airplanes that experience winds or gusts in excess of 65 knots while on the ground. The Ameristar MD-83 accident is the first event Boeing has been notified of where a DC-9, MD-80, or 717 elevator was jammed due to on-ground wind gusts below 65 knots, since the DC-9 entered service in 1965.

A December 1999 event was reported to Boeing of an MD-83 successfully rejecting a takeoff after an elevator had jammed trailing edge down due to damaged links and a damage actuating crank at the horizontal stabilizer end of a geared tab outboard pushrod. While the airplane was parked prior to the attempted takeoff, it was exposed to gusty tailwinds with speeds up to 70 knots. The crew witnessed the aircraft control surfaces striking their respective stops with considerable force and requested a flight controls inspection. At that time, the AMM required an operational check of the controls after high wind exposure, but did not provide details on how to perform the check. Following the event, Boeing updated the AMM to require MD-80 elevators' freedom of movement be validated by moving the elevators by hand. Boeing also updated the FCOM's Exterior Inspection Procedure to caution flight crews that airplanes suspected of being exposed to winds over 65 knots are susceptible to elevator jamming and inspections in accordance with the AMM are required. Additionally, Boeing issued a Flight Operations Bulletin to advise flight crews of the event and the update to the FCOM.

Boeing Wind Model Analysis

The NTSB provided Boeing weather history data for the period of time Ameristar's MD-83 was parked in Ypsilanti prior to the aborted takeoff. The NTSB also provided drone collected data representing the physical characteristics of structures and terrain in the vicinity of the ramp where Ameristar's MD-83 was parked in Ypsilanti. Boeing was asked to use the information provided by the NTSB to perform a wind model analysis to determine the wind conditions experienced by Ameristar's MD-83 while it was parked, prior to the subject event.²⁶ In this analysis, a period of variable wind magnitudes, directions, and gusts were simulated over the structures and terrain sampled by the NTSB's drone. Although the results of this simulation cannot be verified and error margins are unknown, it is believed that the results presented herein represent a plausible scenario of the complex wind flow pattern that may be generated downwind of a hangar and other structures.²⁷

²⁵ NTSB Systems Group Chairman's Factual Report, dated 05 February 2018, page 67

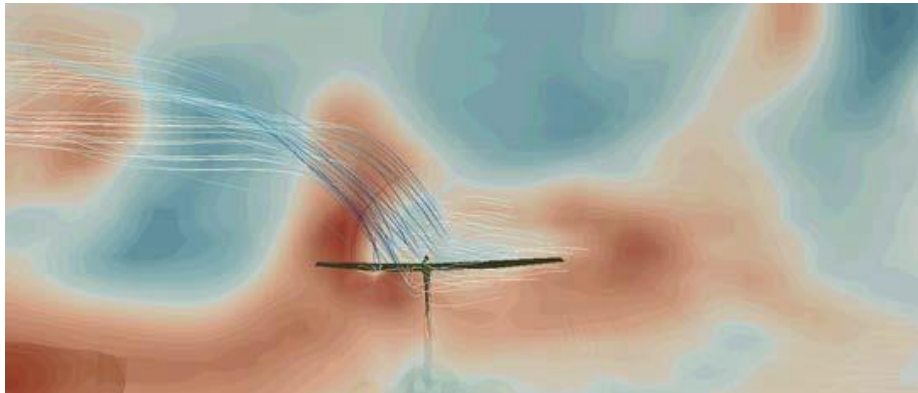
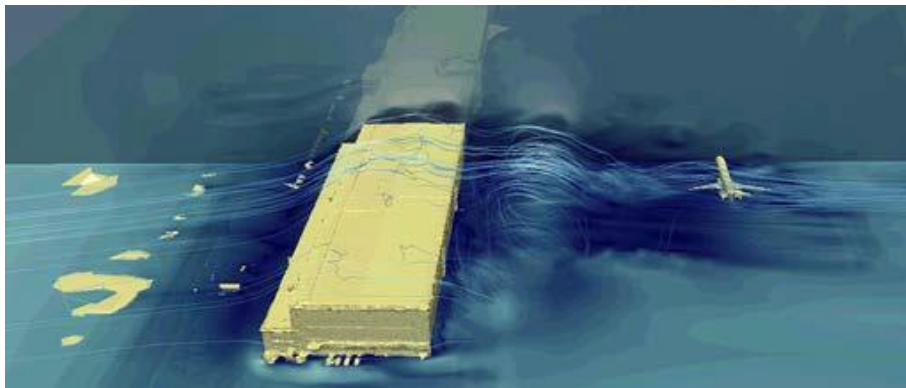
²⁶ NTSB Meteorology Group Chairman's Factual Report, dated 18 December 2017, Attachment 7, Boeing Letter

²⁷ NTSB Meteorology Group Chairman's Factual Report, dated 18 December 2017, Attachment 7, page 1

The final mesh used for the model wind simulation was a blend of the combined NTSB drone mesh data inserted into a 500 X 500 m flat plane and an MD-83 model provided by Boeing. The MD-83 model was positioned based on the location where Ameristar's MD-83 was parked prior to the event. The NTSB provided the location where the airplane was parked.

In the model, the boundary condition wind speeds varied with time. Wind direction varied from roughly 240 to 260 degrees at magnitudes of 37-40 knots with gusts to 55 knots. These wind conditions were provided by the NTSB and represent the March 8, 2017 ASOS wind observations, from 11:37-11:39 EST.

The following figures from the simulation show that over time, the structure affected the predominantly horizontal wind flow and caused varying magnitudes of turbulence with dynamic vertical (both up and down) wind components to impact the airplane's tail.



Elevator Deflection Analysis

Boeing performed an analysis to determine the amount of elevator trailing edge down deflection that is required to actuate the elevator's geared tab inboard push rod to a point that would cause its forward end's links and actuating crank to go to an over-center condition and eventually allow for the damage noted on the accident airplane. Boeing determined the elevator has to travel 4.5 degrees beyond the point where the elevator's stop arm makes contact with the elevator trailing edge down stop.

Boeing also determined the amount of elevator trailing edge up deflection required to actuate the elevator's geared tab inboard push rod to the a point that would cause its forward end's links and actuating crank to go to an over-center condition. Boeing determined the elevator has to travel 22 degrees beyond the point where the elevator's stop arm makes contact with the elevator trailing edge up stop. Physical restrictions present in the control system prevent elevator deflection of this magnitude.

LABORATORY TESTING

The left and right elevator assemblies, including their tabs, were removed from the accident airplane for laboratory testing. It was found that the right elevator's torsion bar was free to rotate and the left elevator's torsion bar was not free to rotate. If a torsion bar is not free to rotate, its elevator's deflection will be limited to a point where the stop arm contacts a stop, so it cannot deflect far enough to cause a geared tab's links and actuating crank to go to an over-center condition.

The elevators were mounted on a Boeing provided MD-80 horizontal stabilizer, which was secured on a fixture attached to the test facility's floor, so the effects of horizontal loads on the elevators could be evaluated.



Overview of accident aircraft elevators on test stand at test facility

The hinge moment forces corresponding to varying values of horizontal winds impacting an MD-80's elevator were calculated and weights were used to simulate these downward horizontal wind loads impacting the elevator mounted on the horizontal stabilizer in Boeing's test facility.



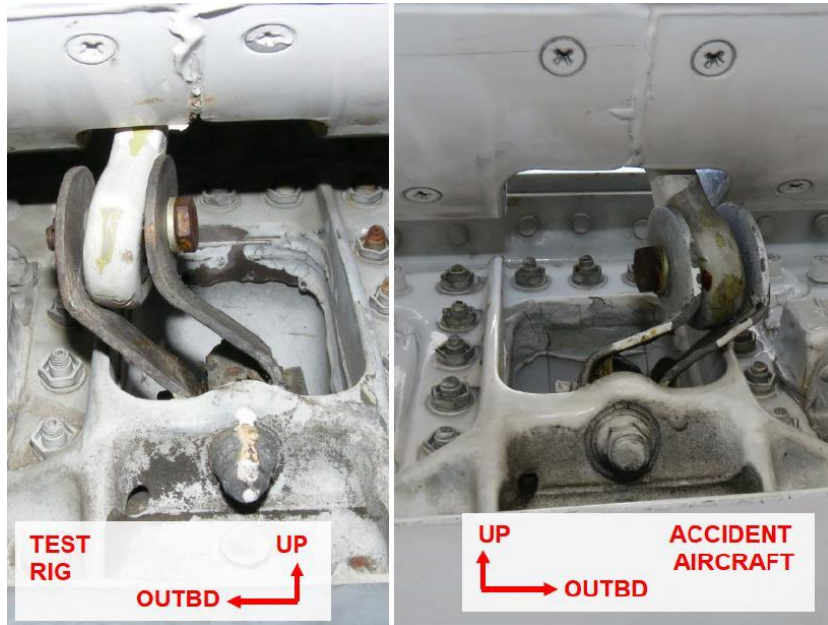
Weights Simulating Horizontal Wind Gust Loads

It was noted during testing that when weights representing gusts of 60 knots and greater were dynamically applied to the elevator, the torsion bar would continue to rotate after the elevator stop arm contacted the elevator stop, and the geared tab's inboard links and actuating crank would travel to an over-center condition. To simulate the dynamic wind conditions, the elevator was positioned full trailing edge up before a simulated downward wind load was applied.



Inboard geared tab link and actuating crank position compared to elevator position

It was also found that if the links and actuating crank were in an over-center condition and an upward force was applied to the elevator, such as that caused by the force of the control tab on the elevator when the column is pulled for takeoff rotation, the links and crank would bend in a similar fashion to the links and crank found during the post-accident inspection of the accident airplane.



Side by Side comparison of test results with accident aircraft damage after upward force application

KNOWLEDGE GAINED DURING THE INVESTIGATION (Findings)

The following knowledge gained is pertinent to drawing conclusions:

- A rejected takeoff was initiated at approximately 173 knots, 34 knots beyond V₁, because the airplane would not rotate for takeoff in response to control column input.
- The airplane did not rotate because the right elevator was jammed trailing edge down by the over-centering of its geared tab inboard push rod links and actuating crank, at the horizontal stabilizer end of the pushrod.
- The DC-9 and 717 elevator control systems are similar to the MD-80, and are susceptible to elevator jamming by the over-centering of a geared tab inboard push rod links and actuating crank, at the horizontal stabilizer end of the pushrod.
- The pre-flight control check cannot detect that an elevator is jammed by the over-centering of its geared tab inboard push rod links and actuating crank, at the horizontal stabilizer end of the pushrod, because the elevator's control tab remains free to move when the control column is moved fore and aft.
- Winds gusts of approximately 55 knots occurred while the airplane was parked near a structure prior to the attempted takeoff. The structure affected the wind and turbulent dynamic vertical wind components resulted.



- Laboratory testing simulating dynamic vertical wind loads on an MD-80 elevator duplicated the over-centering of, and damage to, the geared tab's inboard push rod's links and actuating crank.
- The left elevator did not jam because its torsion bar was not free to rotate within its bearing. This prevented the elevator from traveling to the point where a link and actuating crank over-center condition could occur.
- The MD-80 elevator's trailing edge up travel is limited to a point that prevents the over-centering of a geared tab's links and actuating crank that could cause an elevator to become jammed trailing edge up.
- During evacuation of the airplane, the Door-1 evacuation slide did not inflate because a ball at RVA end of the cable was not properly retained in the inflation valve pulley. The evacuation slide manufacturer updated the Component Maintenance Manual to ensure the cable ball is retained in the pulley recess
- With the exception of the right elevator and the Door-1 evacuation slide, the airplane's systems and structures performed as expected during the accident sequence.

CONCLUSIONS

Boeing believes that the evidence supports the following conclusions for the accident:

This accident resulted from a jammed right elevator caused by the over-centering of the elevator's geared tab inboard push rod links and actuating crank, at the horizontal stabilizer end of the pushrod. The over-center condition was initiated by forces imparted on the elevator by dynamic vertical winds, while the airplane was parked near a structure that affected the local high winds.

BOEING ACTIONS

As a result of this investigation, Boeing has:

- Boeing issued a Multi-Operator Message to provide operators details of the event, including the over-centering of and damage to the geared tab hardware and the wind conditions the airplane was exposed to while parked near a structure. Boeing also reinforced the importance of inspecting airplanes that have been potentially exposed to high winds or gusts while on the ground.
- Boeing is investigating potential methods to prevent takeoff attempts by DC-9, MD-80, and 717 airplanes with elevators jammed trailing edge down. Both preflight procedures and airplane modifications will be evaluated. Boeing has initiated the Airlines for America lead airline process to receive operator input.