National Transportation Safety Board
Office of Research and Engineering
Washington, D.C. 20594

Performance Study

Specialist Report
Marie Moler

A. ACCIDENT

Location:	Ypsilanti, Michigan
Date:	March 8, 2017
Time:	1452 EST
Airplane:	Boeing MD-83, N786TW
NTSB Number:	DCA17FA076

B. GROUP

No vehicle performance group was formed.

C. SUMMARY

On March 8, 2017, about 2:52 p.m. eastern standard time (EST), Ameristar Air Cargo Inc. 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. (The MD-83 was manufactured by McDonnell Douglas, which merged with Boeing in August 1997.) All 109 passengers and 7 crewmembers evacuated the airplane via emergency escape slides. One passenger was reported to have received a minor injury. The airplane sustained substantial damage (no postcrash fire occurred). The airplane, which had been flown into YIP 2 days before the accident, was operating under the provisions of 14 Code of Federal Regulations 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.

PERFORMANCE STUDY

The aircraft was equipped with a flight data recorder (FDR) and cockpit voice recorder (CVR). The FDR recorded acceleration, airspeed, altitude, attitude, engine, and control parameters. The FDR did not record latitude or longitude, and the universal time recorded was offset from the true value. The FDR contained data for a previous take-off and landing which are discussed in *Elevator position in earlier FDR data*.

Tire scrub marks on the runway surface, witness marks in the grass and dirt beyond the end of runway 23L, and the airplane's final resting location were surveyed using an Aeryon Labs Inc Sky Ranger unmanned aircraft system (UAS), courtesy of the Michigan State Police.

Weight and Balance

Maximum take-off weight for the airplane is 160,000 lbs. The flight crew calculated a take-off weight of 145,076 lbs and a center of gravity (cg) at 11.7%. The crew used a weight of 146,600 lbs to calculate cg limits as 3.7% forward and 22.1% aft. After the accident, the baggage was weighed [1] and found to be 1,300 lbs heavier than estimated by the crew. The actual take-off weight was therefore calculated to be 146,400 lbs and the cg was calculated to be 10.4%.

Weather Observations

The last officially reported weather at YIP was at 1153 EST with a two-minute average wind from 260° at 35 knots with gusts to 50 knots. Weather observations from the airport were not available at the time of the accident due to power outages. The meteorology report [1] discusses the high winds on the day of the accident; a working anemometer on the airport at the time of the accident reported a two-minute average wind magnitude of 24 kts, a two-minute average wind direction of 248° (255° magnetic), and a maximum instantaneous wind magnitude over the previous 10 minutes of 37 kts.

Ground Marks

Runway 23L is 7543 ft long and 150 ft wide[1]. The first clear tire marks on the accident runway were 5,956 ft from the beginning of the runway and were from the tires on the left main gear (Figure 1). Marks from the right main gear tires were 6,650 ft from the beginning of the runway. The airplane traveled off the end of runway 23L slightly left of centerline (see Figure 1 and Figure 2). The airplane continued to track to the left as it traveled 950 ft across the grass before coming to rest after crossing a raised airport perimeter road.

[1] The 2016 Jeppesen 20-9A chart, used at the time of the accident, referenced in the Operations Factual Report [1] reports the runway width as 161 ft. However, the 2018 Jeppesen chart reports the width to be 150 ft and a measurement taken using the current satellite imagery confirms the width of runway 23L was 150 ft.

Figure 1. End of runway 23L, left and right main gear tire marks are highlighted green and red, and the airplane's final position can be seen.

Figure 2. Threshold of runway 23L/5R and main gear tire marks on pavement.

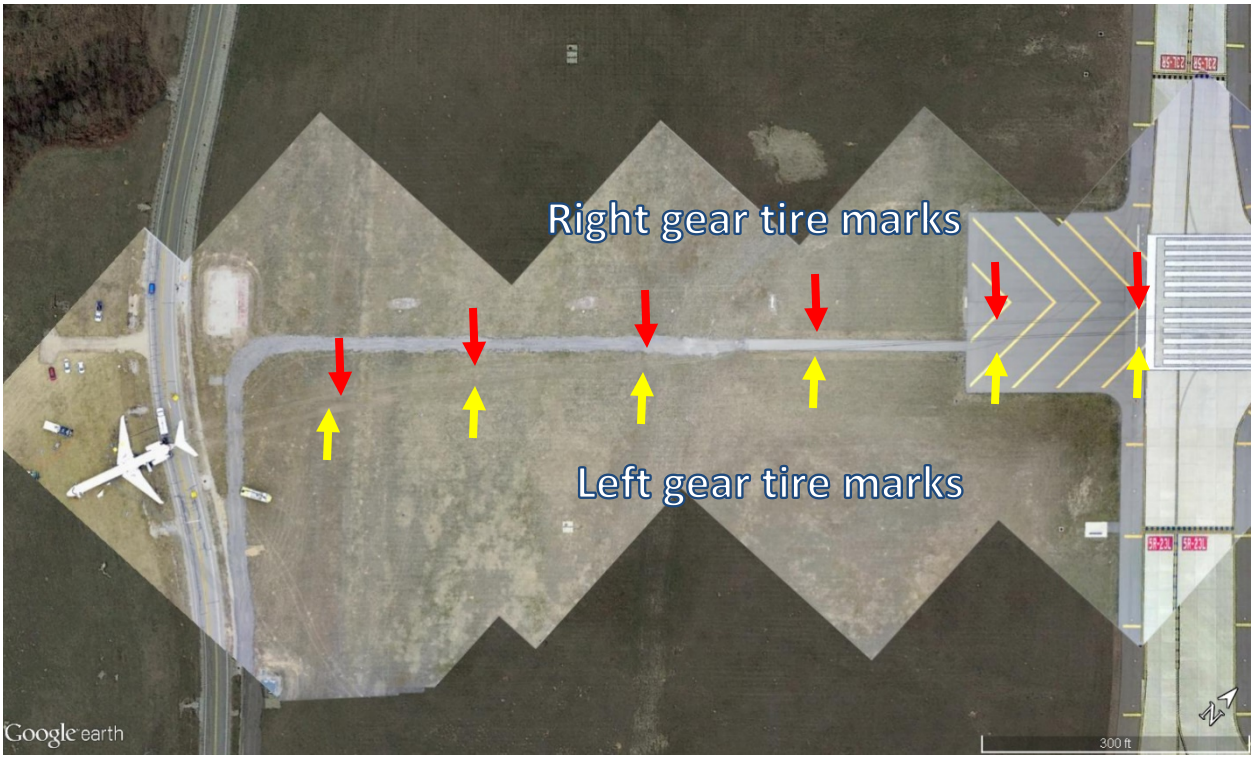

Figure 3. End of runway 23L, ground marks, and airplane final location.

Recorded Data

The accident airplane overran runway 23L after unsuccessfully attempting take-off. The FDR did not record latitude and longitude, so the airplane's path to 23L was determined using heading data. The recorded heading showed that the airplane traveled along taxiway E1 to runway 27 to access runway 23L (Figure 4 and Figure 5).

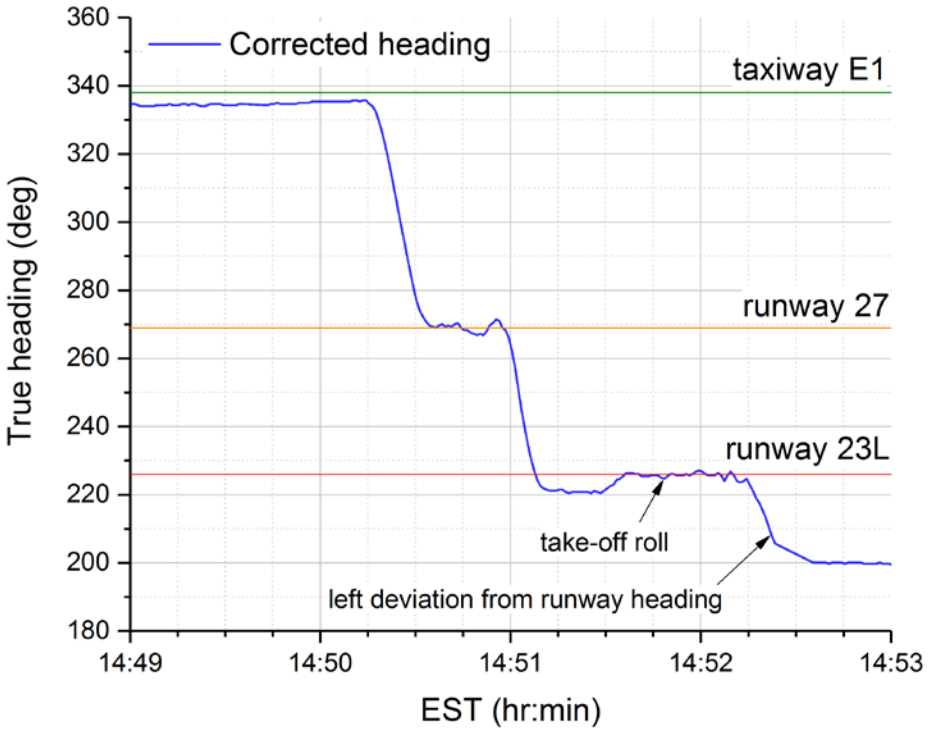

Figure 4. Airplane heading before take-off roll and related taxiway and runway headings.

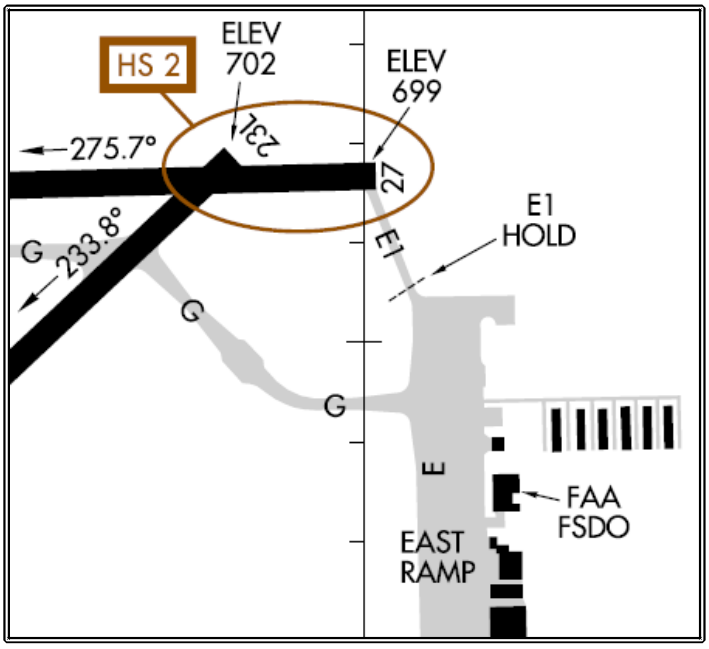

Figure 5. Excerpt from Willow Run (YIP) Airport Diagram. Magnetic variation is 7.1° west.

Integration of accelerometer data

Figure 6 shows the portion of the accelerometer data associated with the attempted take-off. The aircraft began accelerating at 14:51:29 when the longitudinal acceleration increased from near zero to over 0.2 g's. The aircraft accelerated as it moved down the runway until 14:52:08 when the longitudinal acceleration began to drop, reaching a maximum deceleration of -0.54 g's by 14:52:12. At 14:52:15 the vertical load factor became much noisier and the airplane heading began to move to the left. At 14:52:24 the recorded data abruptly stopped, and it was determined that this time was when the airplane struck the raised perimeter road. Recording of the accelerometer data began again 11 seconds later, with the load factors being nearly constant (lateral and longitudinal load factors near zero, and vertical load factor near 1 g) consistent with the airplane at rest.

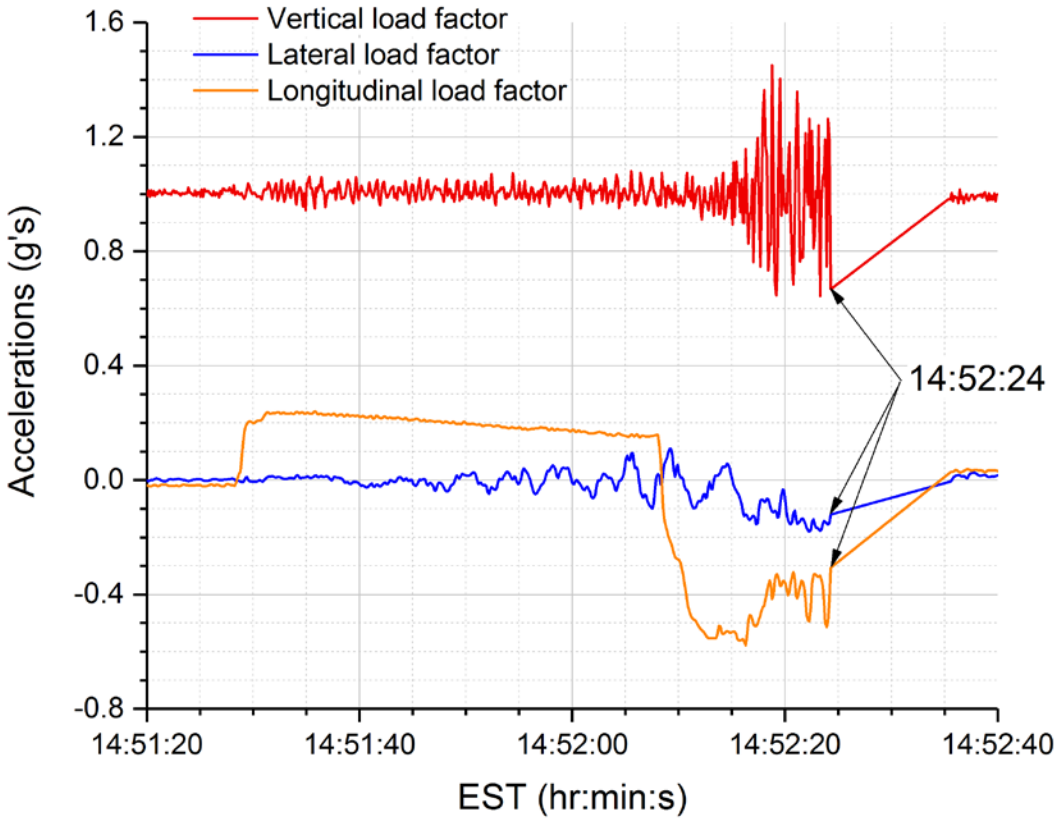

Figure 6. Airplane load factors during the accident ground roll.

Since latitude and longitude were not recorded, the recorded longitudinal acceleration was integrated to determine the airplane's groundspeed and ground track during the take-off roll. The longitudinal acceleration was found to have a -0.02 g's bias when the airplane was stopped. The integration was started at 14:51:20, when the longitudinal acceleration was at zero and the brakes were on (Figure 7). When the brakes were released at 15:51:28 the airplane began to accelerate.

The longitudinal acceleration was positive until 14:52:08 when the brakes were applied and the acceleration quickly became negative. Spoiler and thrust reverser deployment will be discussed later in *Take-off Attempt*.

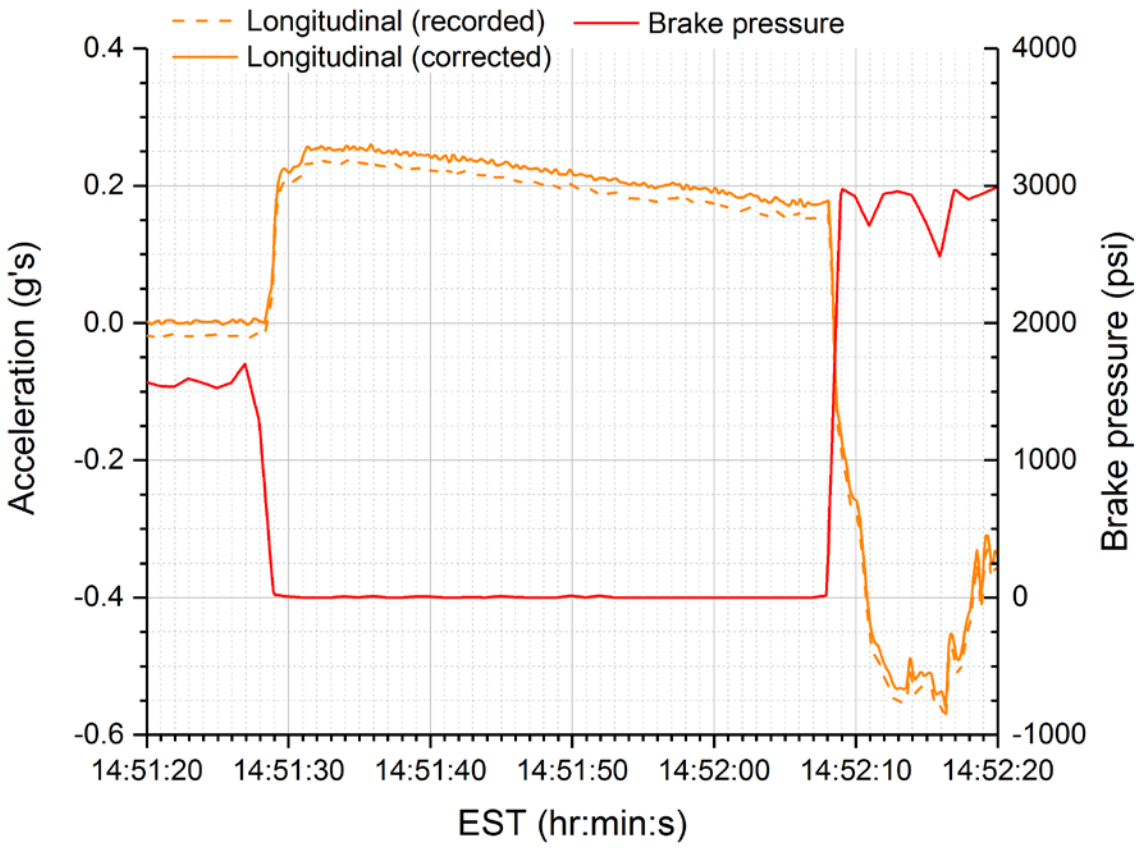

Figure 7. Longitudinal acceleration and brake pressure.

Figure 8 shows the recorded longitudinal acceleration and the integration results. The longitudinal acceleration increased from zero to over 0.2 g's at 14:51:29. The groundspeed steadily increased until 14:52:08 when it achieved a maximum speed of 163 kts. The integration was stopped at 14:52:24 when the acceleration data became discontinuous. The calculated groundspeed was 40 kts when the airplane impacted the perimeter road at 14:52:24.

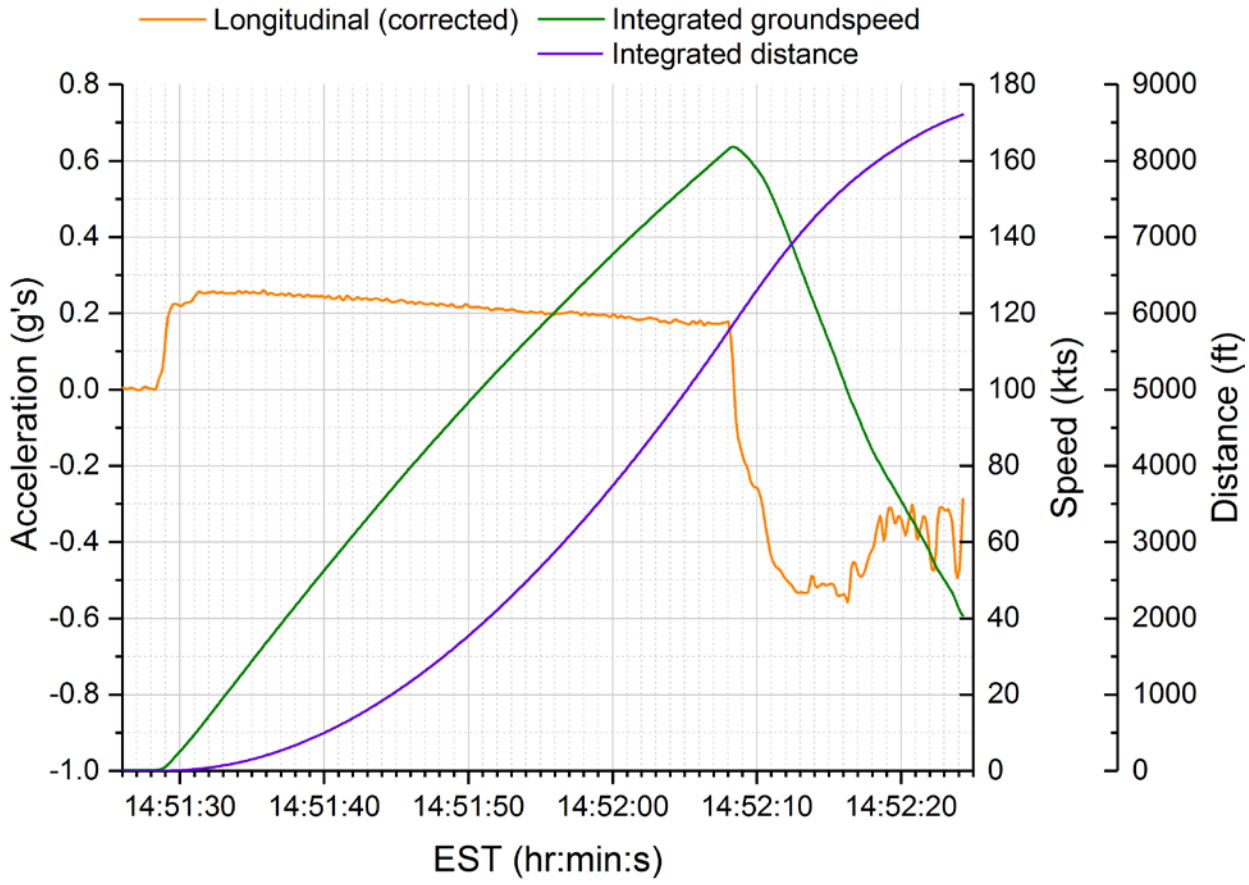

Figure 8. Integration of longitudinal acceleration to groundspeed and distance.

The integrated groundspeed showed the airplane covering 8,600 ft of ground during the attempted take-off. Matching 8,600 ft of travel from the airplane's final location along the ground marks and then down the runway results in the ground roll shown in Figure 9. This is consistent with the taxiing discussion from Figure 4 and Figure 5.

Figure 9. Accident ground roll.

The beginning of the ground roll line in Figure 9 is about 80 ft from the threshold of runway 23L. The integrated distance will be used throughout this report to reference where an event occurred during the ground roll. Zero feet on this scale refers to the beginning of the ground roll when the airplane's speed was zero.

Headwinds were calculated from the recorded airspeed and integrated groundspeed (Figure 10). Airspeed measurements are less reliable when the airplane is on the ground and the wind calculations reflect the headwind component only, but the calculated winds were consistent with what had been reported that day.

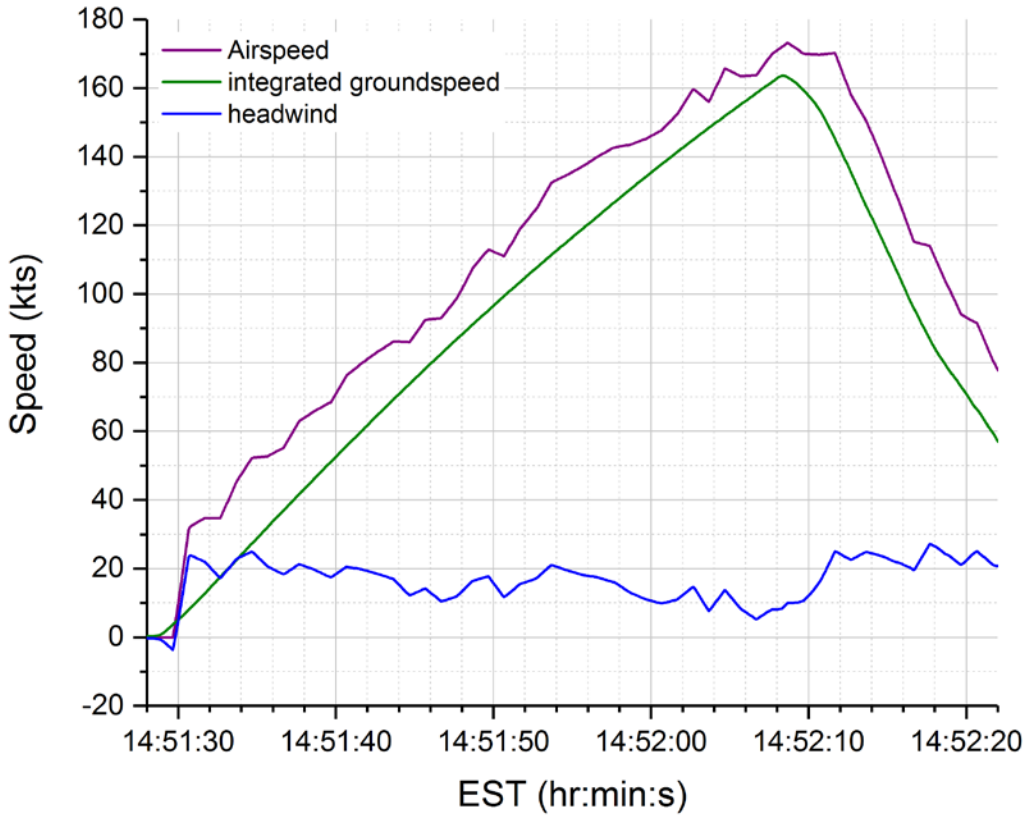

Figure 10. Accident recorded airspeed, integrated groundspeed, and calculated headwind component.

Take-off Attempt

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 [2].

Figure 11 and Figure 12 show the recorded airspeed and the crew's attempt to rotate the airplane for take-off. At 14:51:56 (about 3,000 ft down the runway) and about 138 kts of airspeed, the control column was pulled back slightly from a non-dimensional value of -7 to -5.5[2]. The airplane's left elevator follows the control input and moves from a position of -15° trailing edge down to -13° trailing edge down. The right elevator does not change and stays at approximately -16° trailing edge down. At 14:52:01 a large control column input was made (151 kts and 4100 ft down the runway) to a non-dimensional 18.5 and the left elevator moves to a position near 15° trailing edge up. After 14:52:05 the right elevator moves to -13° trailing edge down, but no more. The airplane does not respond in pitch and does not rotate. Figure 11 also includes selected CVR comments between the captain and check airman [3].

From the beginning of the large control column input at 14:52:01 to the peak left elevator deflection is about five seconds. The control colum stays at the maximum input for another three seconds before being released. During these eight seconds the airplane travels 1,800 ft down the runway (from 4,100 to 5,900 ft).

[2] A reliable data conversion for the control column FDR parameter was not available. What is shown is non-dimensionalized, but demonstrates the trend.

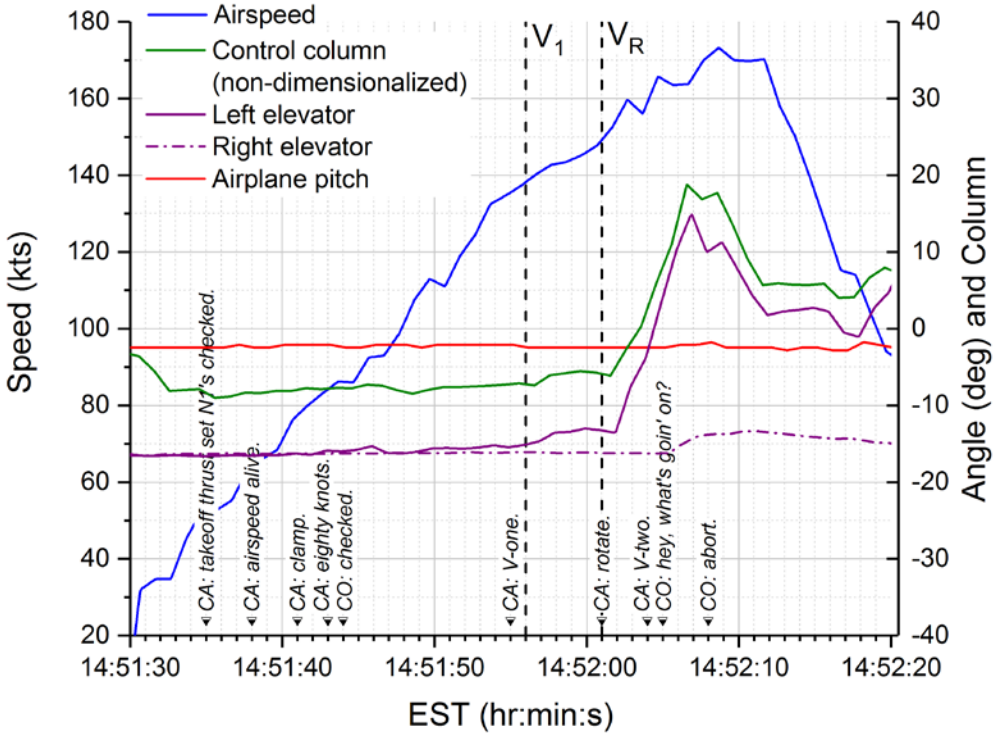

Figure 11. Accident recorded airspeed, control column, elevators, and pitch versus time. CO indicates comments from the captain. CA indicates comments from the check airman.

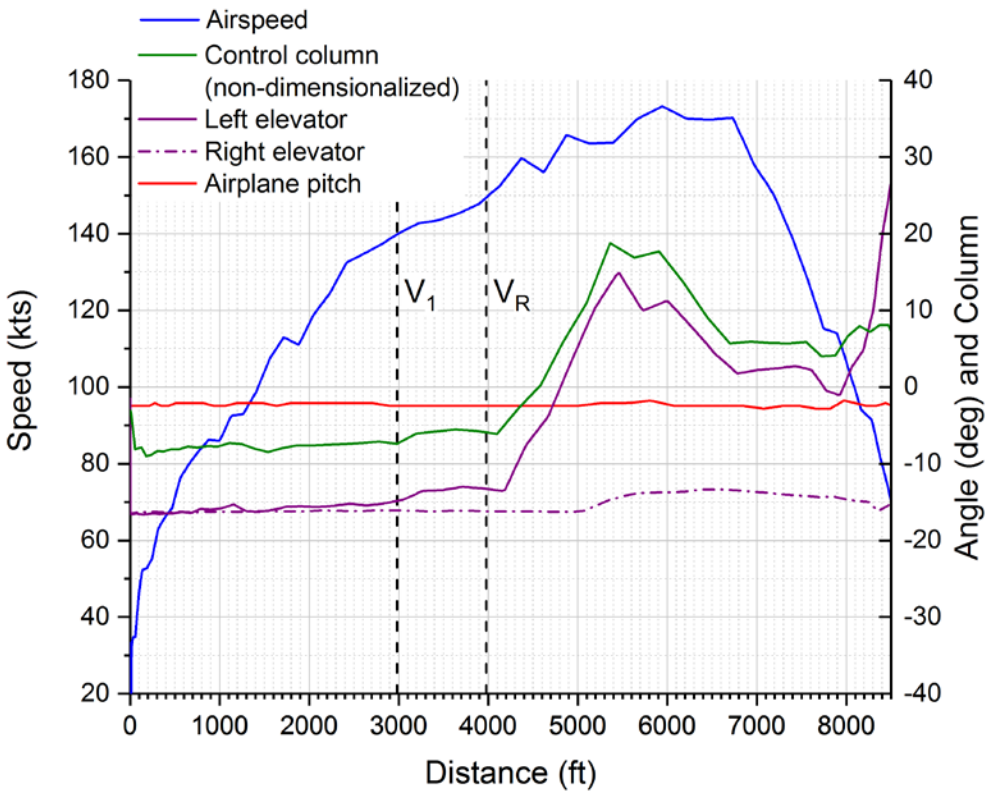

Figure 12. Accident recorded airspeed, control column, elevators, and pitch versus distance.

Figure 13 shows the prior take-off from Lincoln, Nebraska on March 5th for comparison. At an airspeed of about 140 kts, at about 22:37:36, the control column moved from a non-dimensional value of -3.5 to 5 over the course of five seconds. Both elevators responded by going from -10° trailing edge down to 3° trailing edge up. The airplane responded at 22:37:39 (within about 3 seconds) as the pitch increased from a recorded -2° to 15°.

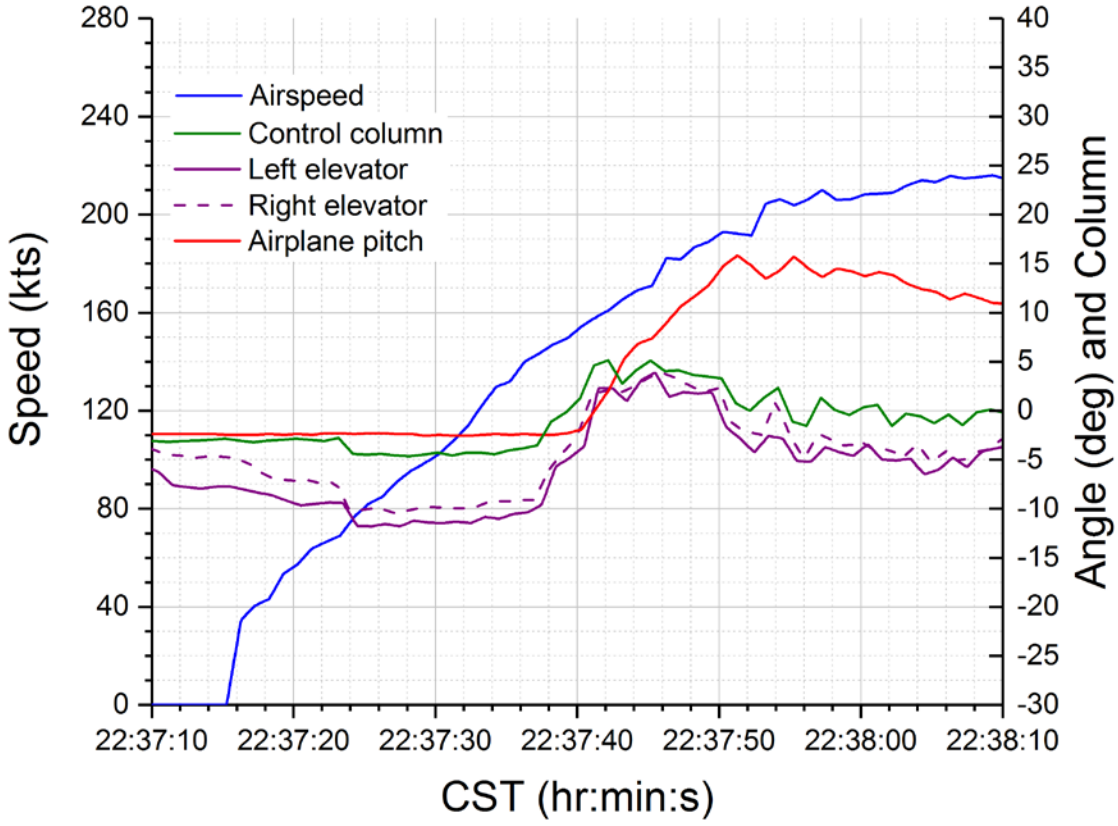

Figure 13. Prior take-off recorded airspeed, elevators, and pitch versus time.

The maximum groundspeed for the accident take-off was 163 kts (173 kts airspeed) and the airplane began to decelerate as soon as the brakes were applied at 14:52:08 (Figure 14). Spoilers were deployed at 14:52:10 and thrust reversers were deployed between 14:52:13 and 14:52:15. Figure 15 shows the braking actions versus distance and include the ground mark locations relative to the integrated distance. The first evidence of tire scrub marks, the end of the runway, and the end of the paved surface are marked. The first tire mark was 5,956 ft down the runway; 1,780 ft from the end of the paved surface. The airplane's ground speed was 100 kts when it left the paved surface.

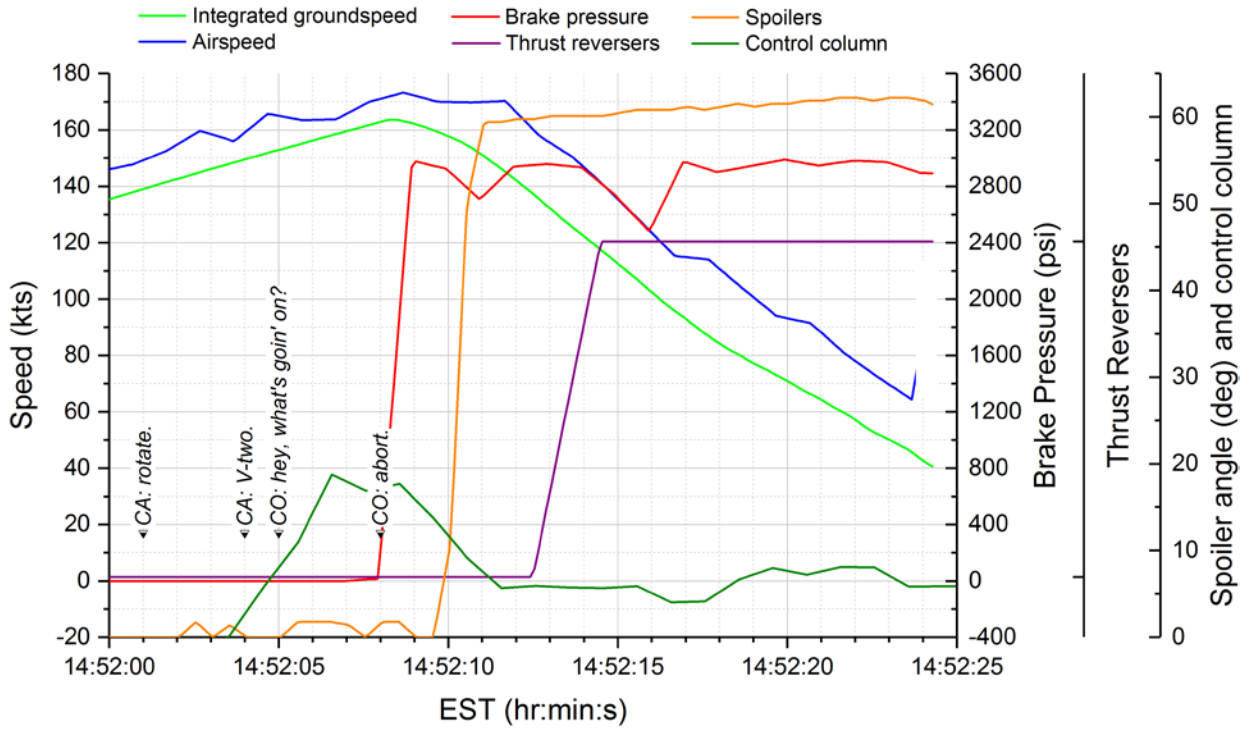

Figure 14. Accident braking versus time. CO indicates comments from the captain. CA indicates comments from the check airman.

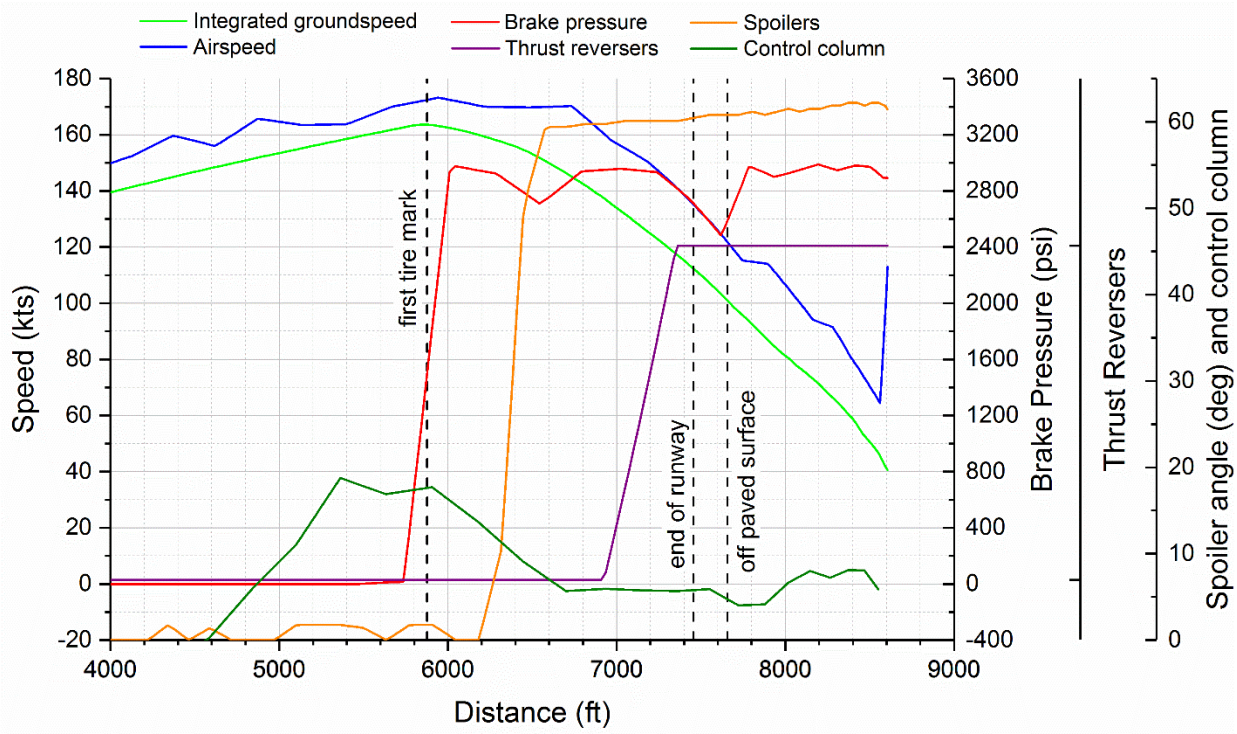

Figure 15. Accident braking versus distance.

Table 1 shows the time, location, and the groundspeed and airspeed of each take-off roll event.

Table 1. Take-off roll events

Event	Time, EST hr:min:s	Time from zero, s	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)

Elevator position in earlier FDR data

The flight data recorder captured several prior flights and activities between flights. Figure 16 shows the prior take-off and the landing at Ypsilanti and the movement of the elevator. The weather on March 5th in Lincoln Nebraska thirty minutes before take-off was winds from 170° at 22 kts, gusting to 32 kts. The wind activity was consistent with the movement of the floating elevators in the time before take-off. When the airplane landed in Ypsilanti, Michigan at 0100 EST the winds were reported from 110° at 3 kts. The much calmer winds were consistent with the much smaller movements in the elevators during taxi. For the prior flight, both elevators were moving as expected.

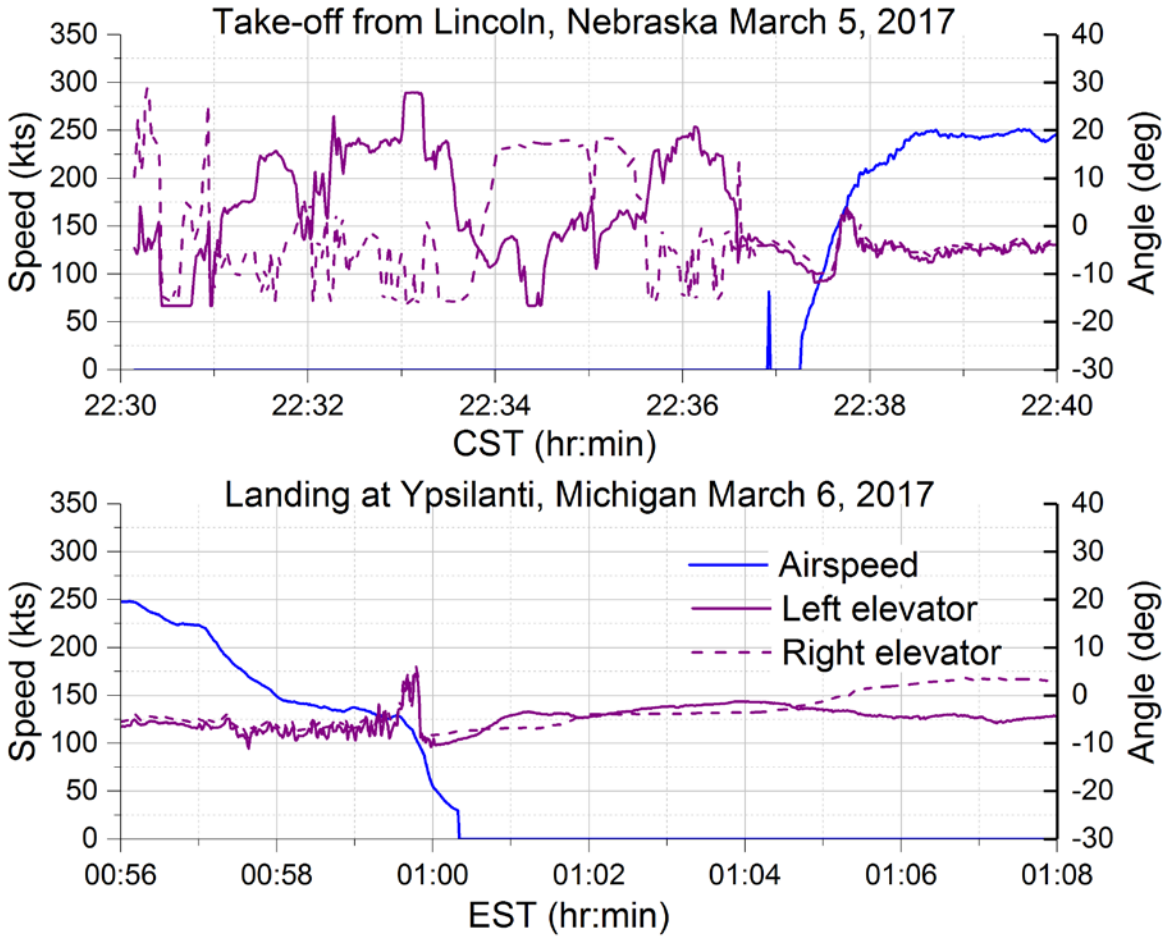

Figure 16. Airspeed and elevator positions for prior take-off and landing.

Figure 17 shows the elevator movement from the taxing after the flight March 6th, a routine maintenance check later March 6th, and the initial powering on of the airplane on March 8th. It was not until March 8th that the right elevator came to be in its trailing edge down position. Throughout the day May 8th, the right elevator remained full trailing edge down while the left elevator moved in the strong winds.

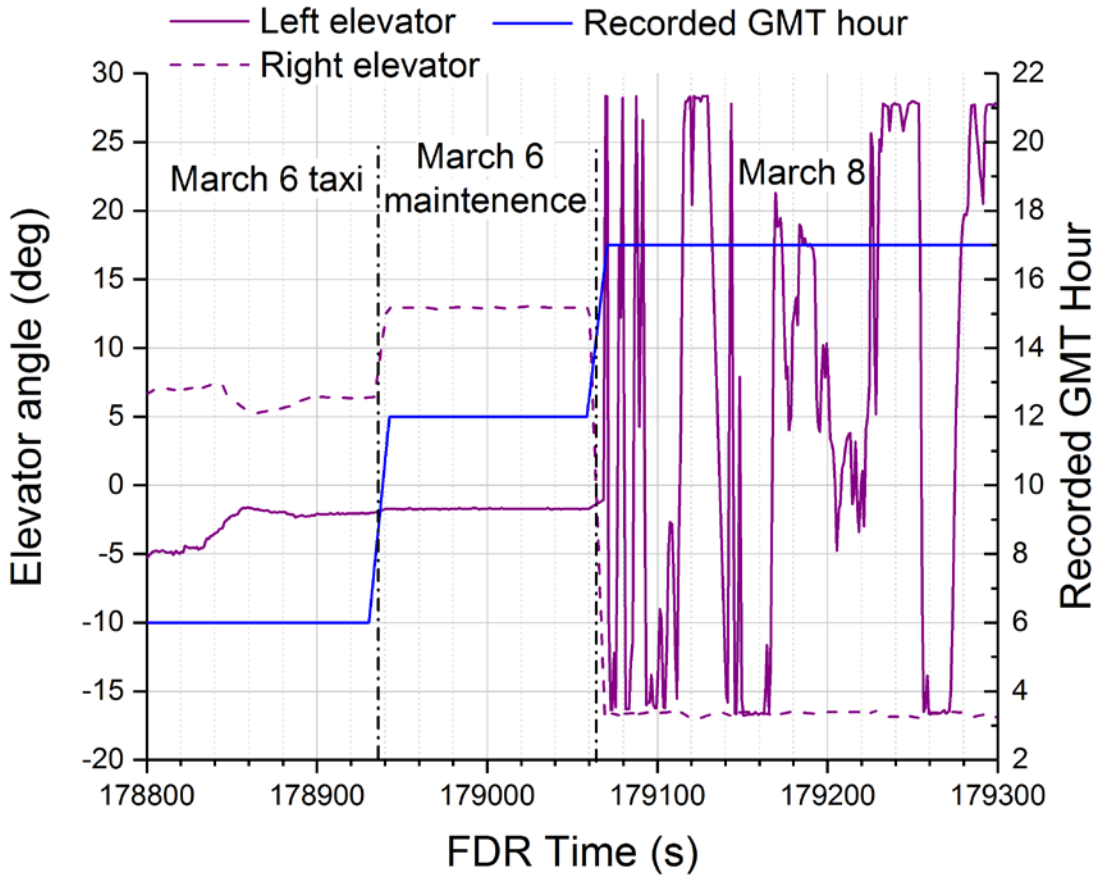

Figure 17. Elevator position and recorded GMT hour versus FDR time.

Stopping Distances

Of interest was when the crew would have had to begin braking to stop before the end of the runway. The deceleration profile of the groundspeed from the accident was shifted earlier until a point was found where the airplane would stop while still on the runway (Figure 18 and Figure 19). It was determined that the crew would have had to start braking before the 5,000 ft mark to come to a stop while still on the runway. At this point (14:52:04 during the accident roll, four seconds and 800 feet before the accident braking point), the airplane's airspeed was 164 kts and groundspeed was 151 kts. The control column input had begun three seconds earlier and the left elevator was only just reaching a neutral position and had not yet moved to be trailing edge up. During the earlier successful take-off the airplane was only just beginning to respond in pitch at this same point.

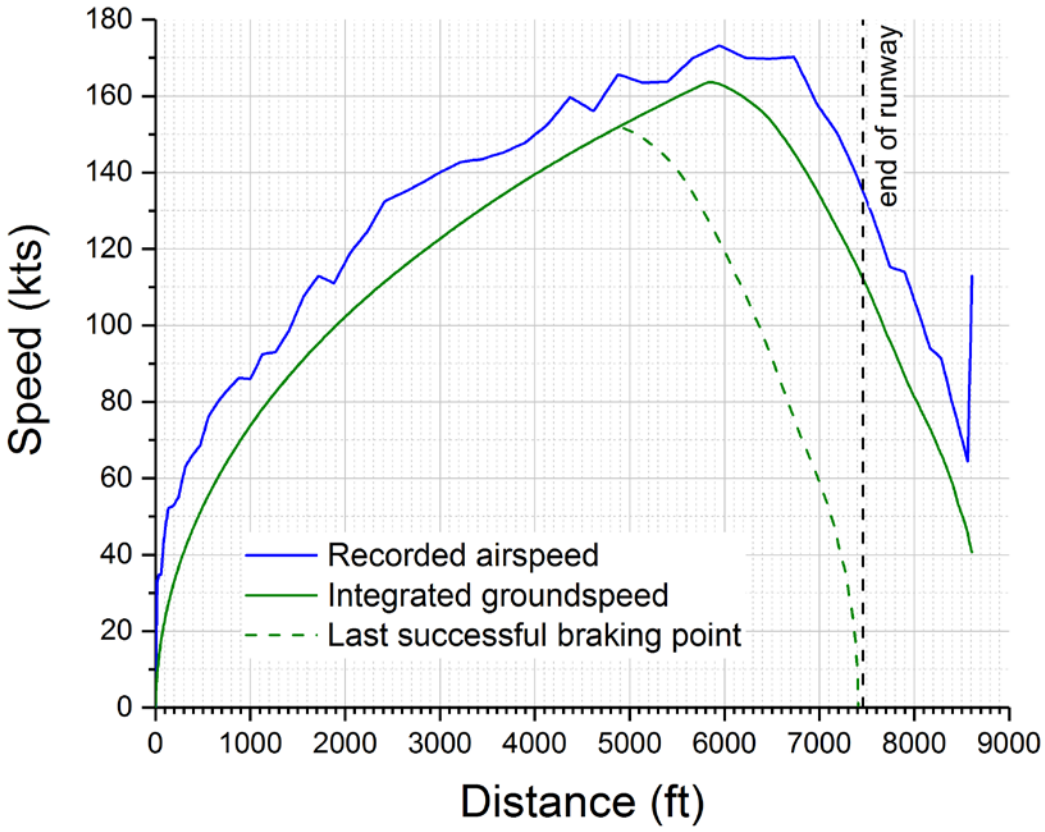

Figure 18. Accident airspeed and groundspeed and groundspeed of last successful braking point versus distance.

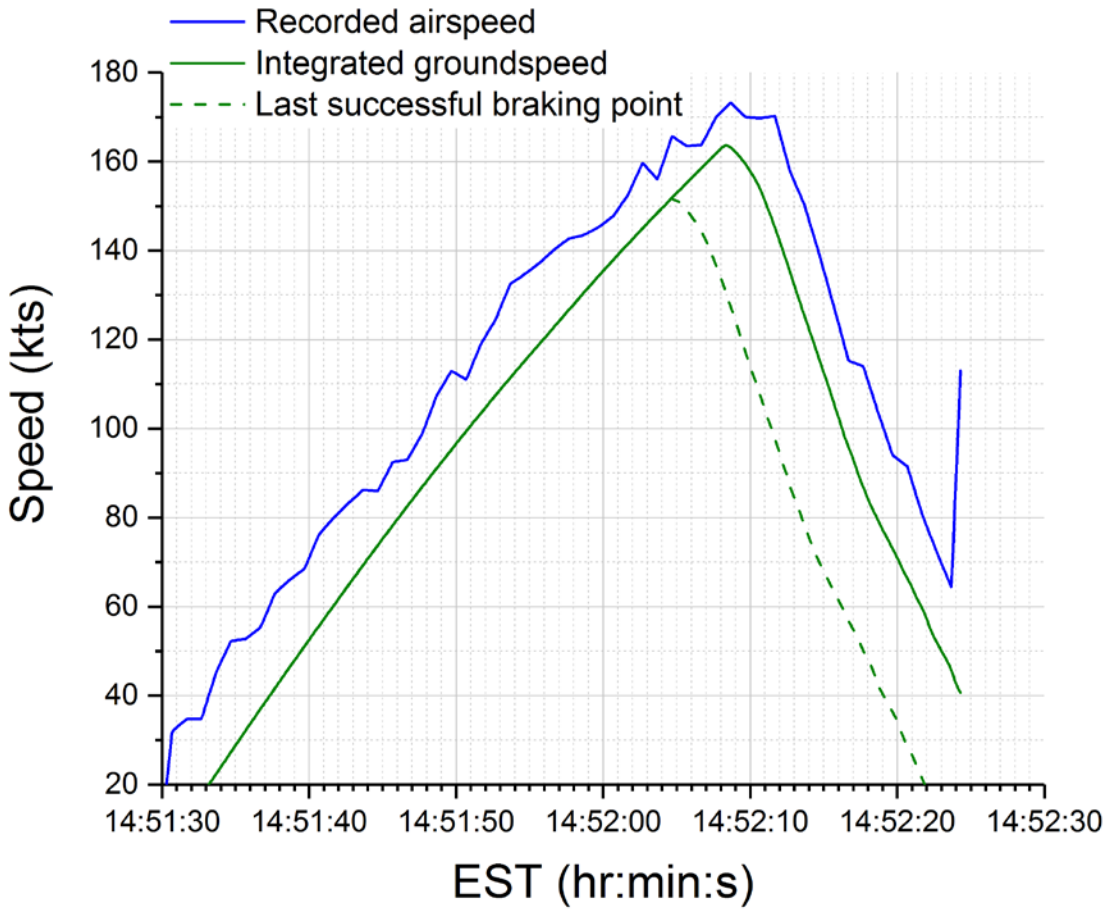

Figure 19. Accident airspeed and groundspeed and groundspeed of last successful braking point versus time.

D. CONCLUSIONS

The airplane began its take-off roll at 14:51:29 and, in 32 s and 4,100 ft, accelerated to an airspeed of 151 kts (140 kts groundspeed). At 14:52:01 a large control column input was applied for five seconds, but only the left elevator deflected up to 15° while the right elevator moved from -15° to -13° (trailing edge down). The airplane did not pitch up in response to the control column input.

At 14:52:08, seven seconds after the column input, the brakes were applied. The airplane's groundspeed at brake application was 163 kts and it was 5,850 ft down the runway with 1,800 ft of paved surface left ahead. Spoilers and thrust reversers were deployed and the airplane decelerated, but it left the paved surface at a groundspeed of 100 kts. The airplane continued across the grass and over a raised access road before coming to a stop.

Assuming the same deceleration profile as the accident, the crew would have had to start braking before the 5000 ft mark, when the airplane's groundspeed was 151 kts, to come to a stop while still on the runway. However, this would have only been three seconds after the column input, and based on prior take-offs, the airplane's lack of rotational response would not yet have been apparent.

While the right elevator behaved as expected on the prior flight and during earlier maintenance on May 6th, it was in its full trailing edge down position when the FDR was powered on May 8th, the day of the accident. The left elevator showed movement in the high winds, but the right elevator stayed in the same -15° position before take-off, only moving to -13° during the take-off.

Marie Moler
Specialist – Airplane Performance
National Transportation Safety Board

E. REFERENCES

1. Meteorology Group Chairman's Factual Report, DCA17FA076, National Transportation Safety Board. 2018.
2. Operations Group Chairman's Factual Report, DCA17FA076, National Transportation Safety Board. 2018.
3. Cockpit Voice Recorder Group Chairman's Factual Report, DCA17FA076, National Transportation Safety Board. 2018.