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

Performance Study

Specialist Report
Marie Moler

A. ACCIDENT

Location:	Memphis, Tennessee
Date:	February 5, 2014
Time:	0015 CST, 0615 UTC
Airplane:	EMB145, N802HK
NTSB Number:	DCA14FA058

B. GROUP

No vehicle performance group was formed.

C. SUMMARY

On February 5, 2014, about 0015 Central Standard Time (CST), N802HK, an Embraer S.A. EMB-145EP, operated by Trans States Airlines LLC as a Title 14 CFR Part 121 scheduled domestic passenger flight to Memphis International Airport (MEM), Memphis, Tennessee, landed hard on runway 36R. Instrument meteorological conditions prevailed at the time of the accident and an instrument flight rules flight plan was filed. The right wing struck the ground and the airplane incurred substantial damage. There were no injuries to the three flight crew members or the 50 passengers aboard. The flight originated from Houston, Texas, the previous day about 2022 CST.

D. PERFORMANCE STUDY

The aircraft was equipped with a flight data recorder (FDR) and cockpit voice recorder (CVR). Radar data of the aircraft flight was provided to the NTSB and is used in this report. Times are coordinated with and reported in the recorded UTC of the radar data (CST = UTC – 6 hours). The radar data used in the study are secondary returns from an Airport Surveillance Radar (ASR) at Memphis International Airport (MEM) (ASR-9). These data have an inherent uncertainty of ±2 Azimuth Change Pulses (ACP) = ± (2 ACP) x (360º/4096 ACP) = ±0.176° in azimuth, ±50 ft in altitude, and ±1/16 NM in range.

Airplane Ground Track, Altitude, Airspeed, Attitude, and Control Input

The aircraft first approached Memphis International Airport at approximately 0550 UTC before abandoning the landing attempt and executing a go-around. At 0606 UTC, the aircraft turned again onto final for runway 36R at MEM. One second before touchdown (marked as weight on wheels) the aircraft experienced a sudden roll that resulted in the right wing impacting the ground. The aircraft's flight path during the first approach, go-around, and final approach are shown in Figure 1.

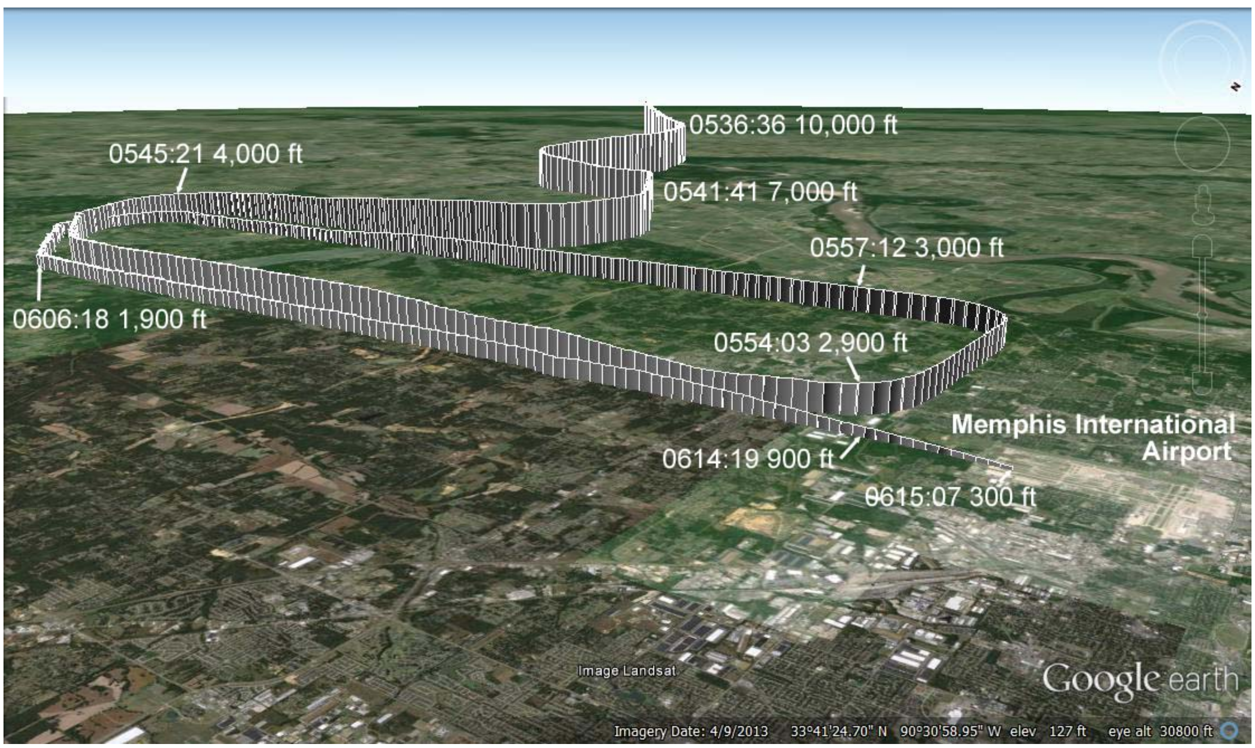

Figure 1. Aircraft radar track with selected times and altitudes marked.

At about 0545 UTC, the aircraft descended from 7,000 to 4,000 ft mean sea level (MSL), as shown in Figure 2. At 0553 when the go-around was initiated, the aircraft was at an altitude of about 2000 ft (runway 36R is at an elevation of 250 ft MSL). The aircraft climbed to 3,000 ft during the go-around before returning to 2,000 ft and maintaining that altitude for approximately 12 minutes.

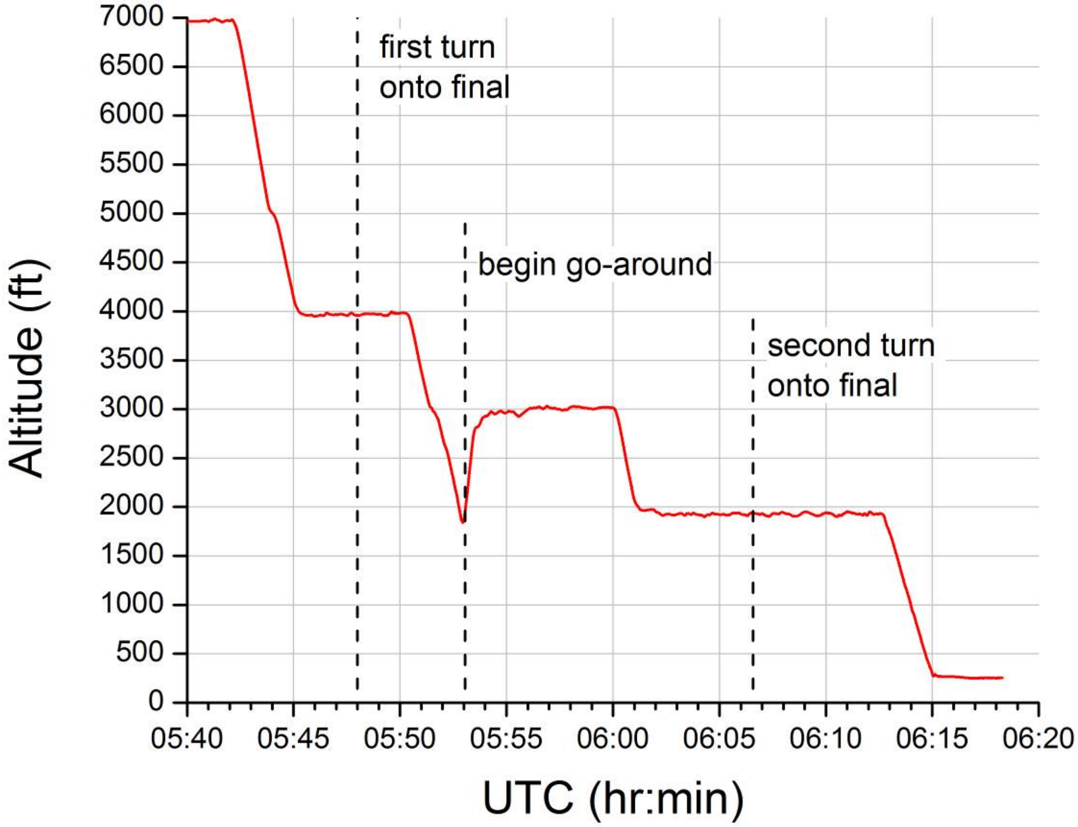

Figure 2. Aircraft altitude (MSL) with the times for the initial turn onto final, the go-around, and the second turn onto final marked.

The aircraft's recorded indicated airspeed during the go-around was between 170 and 180 kts (see Figure 3). During the final descent to the runway, the aircraft's speed reduced to 130 kts. The autopilot (AP) was disconnected at 0614:35, about 300 ft above the runway and less than 30 seconds before touchdown. Embraer Standard Operating Procedures (SOP) guidance for instrument landing system (ILS) landings allows the autopilot to remain on until 200 ft above the ground [1]. Weight on wheels was recorded at 0615:03.

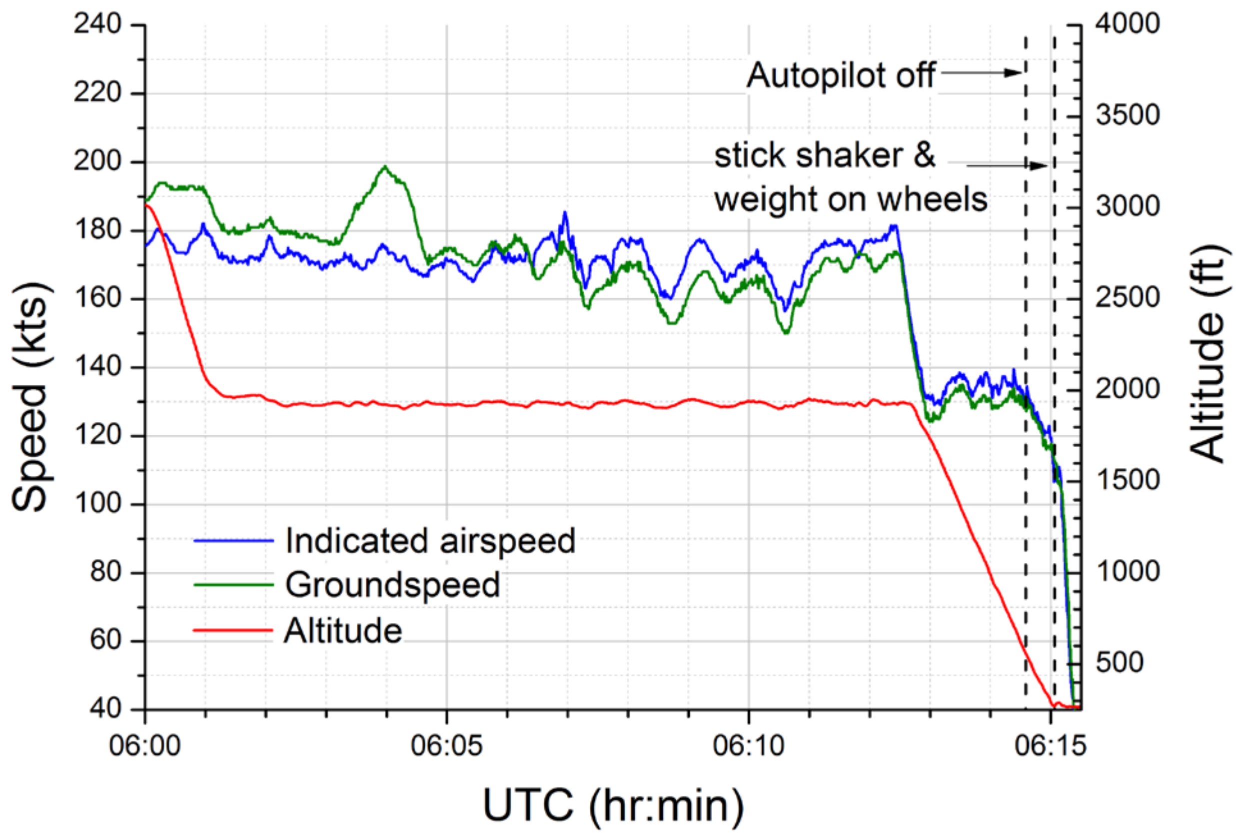

Figure 3. Aircraft airspeed, groundspeed, and altitude for the final 15 minutes of flight.

Just before 0615:00 the aircraft began to roll quickly to the right (Figure 4). At 0615:02, the stick shaker activated. The aircraft's maximum roll attitude, which coincided with the stick shaker activation, was 28° right wing down. The pilot was making substantial left wheel inputs to counteract the right roll, but the roll was ultimately stopped by the right wing impacting the ground. The aircraft rolled back to near wings level as it landed.

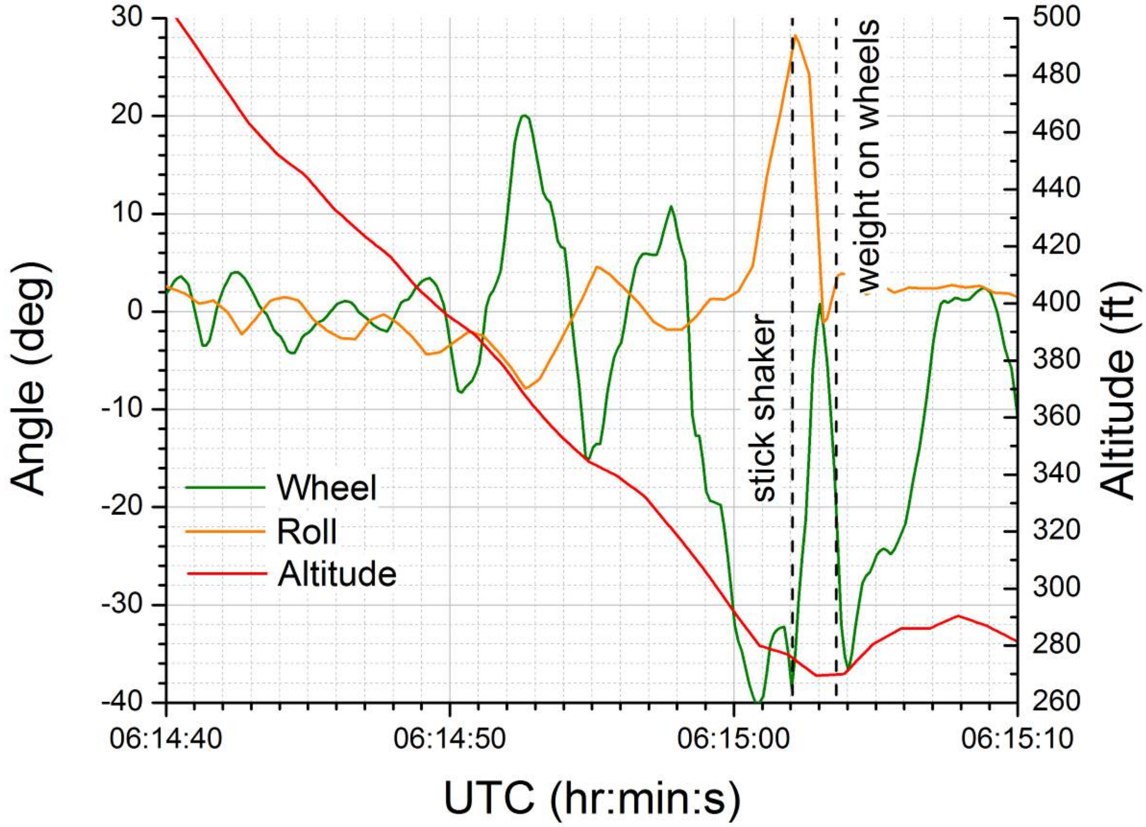

Figure 4. Aircraft wheel input, roll, and altitude for the end of the flight.

The FDR channels recording the control surface positions of rudder, aileron, and elevator were all determined to be non-functional [2]. This study reports the recorded pilot input of wheel, column, and rudder pedal and assumes that the control surfaces track the pilot input.

The aircraft's load factors were recorded and are shown in Figure 5. Only the longitudinal load factor showed a marked change just before touchdown, consistent with the final slowing of the aircraft. The vertical load factor stayed reasonably steady and did not indicate a full aircraft aerodynamic stall.

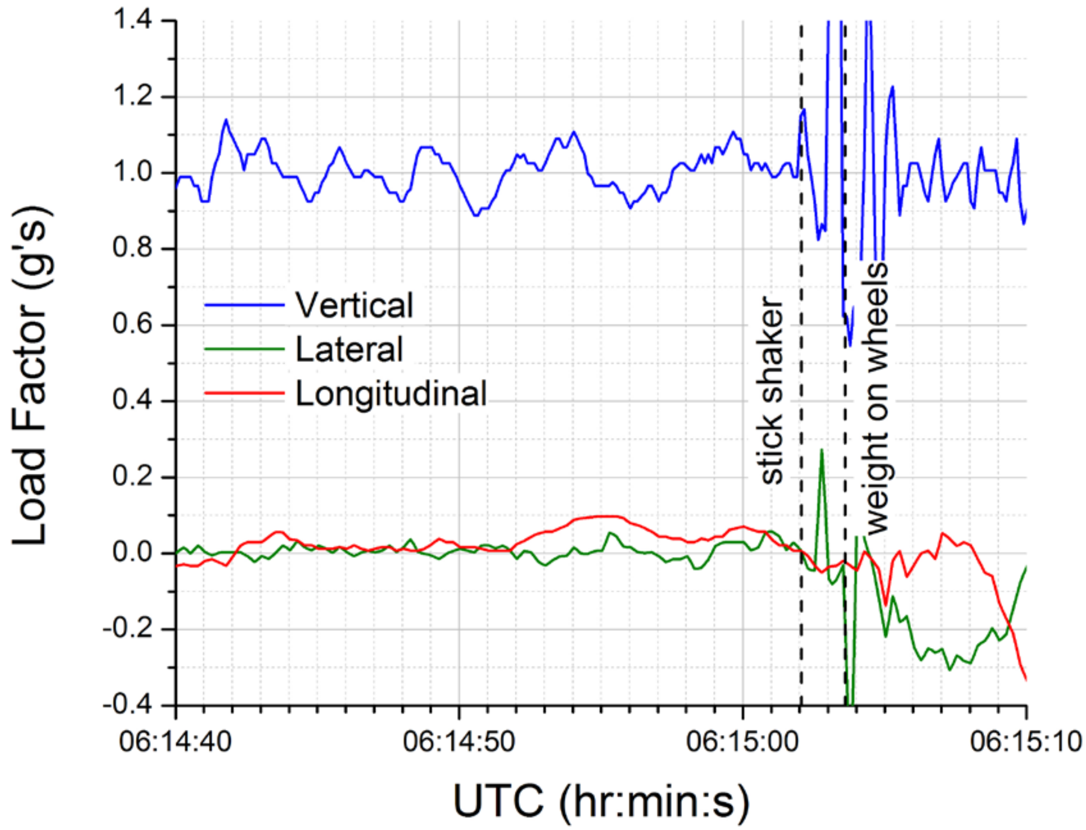

Figure 5. Aircraft vertical, lateral, and longitudinal load factors for the end of the flight.

The stick shaker activated when one of the aircraft's two angle of attack (AoA) sensors reached 15° and the indicated airspeed was 113 kts as shown in Figure 6. The stick shaker activation point was not listed, but the Embraer 145 Flight Manual records that the stick pusher will activate at 105 kts for gear down, flaps 45°, and a weight of 41,100 lbs [4].

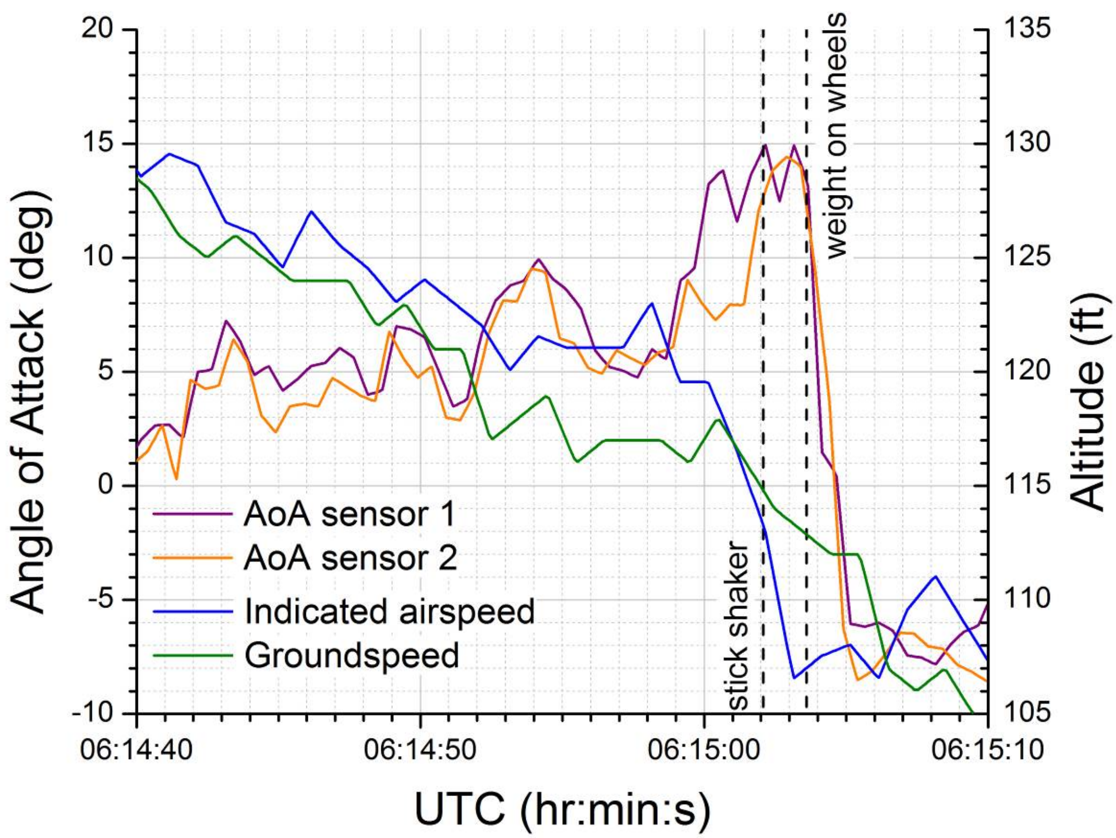

Figure 6. Aircraft angle of attack (AoA), indicated airspeed, and groundspeed prior to and after stick shaker activation.

Figure 7 (which time correlates with Figure 4 and Figure 6) shows the rudder pedal movement during the final roll event and touchdown. The CVR and post-accident pilot statements showed that the pilots thought that the sudden right roll was caused by a rudder hard over [3]. Embraer confirmed that the rudder pedals would move if the rudder surface, the rudder trim, or the yaw damper move. The rudder pedal movement did not show evidence of a larger rudder surface deflection.

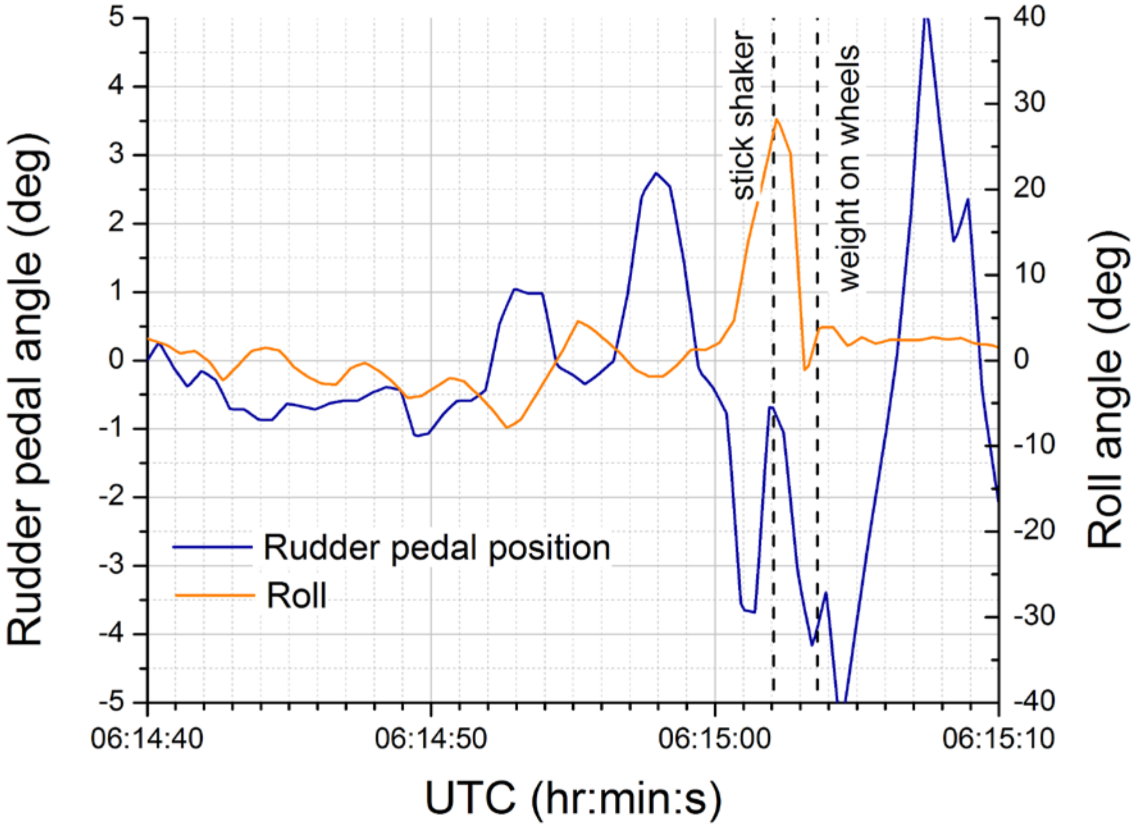

Figure 7. Rudder pedal application for final moments of flight.

Weather Observations and Icing

The official weather prior to the accident reported by Automatic Terminal Information Service (ATIS) at 0554 UTC at Memphis International Airport was wind from 280° at 10 kts, tower visibility 1/2 mile, ceiling overcast at 400 ft, temperature 1°C, dew point temperature -1°C, and an altimeter setting of 29.95 inHg. Surface visibility was 8 miles and the three hour precipitation was 0.10 in [5].

The next METAR after the accident at 0654 UTC was wind from 290° at 19 knots, tower visibility 1/2 mile, ceiling overcast at 400 feet, temperature 1°C, dew point temperature -1°C, altimeter 29.99 inHg. Winds aloft data, shown in Table 1, is from an Aircraft Meteorological Data Relay (AMDARS) equipped aircraft that landed at 0627 UTC and should be considered an estimate of the wind affecting the aircraft.

Table 1. Winds at the approximate time of the accident.

Altitude (ft)	Wind Direction (°)	Wind Magnitude (kts)
600	288	11
1280	280	19
1440	273	20
1980	277	24
2499	291	23
2820	300	23
3860	288	24
3980	289	25
3990	289	25
4260	289	25
4590	290	26
4781	268	26
5600	262	34

While on the approach heading, the aircraft experienced a crosswind with a magnitude of 24 kts when at 1,900 ft dropping to 10 kts on the final portion of the approach as shown in Figure 8. The crosswind data in this figure is calculated using the data from Table 1.

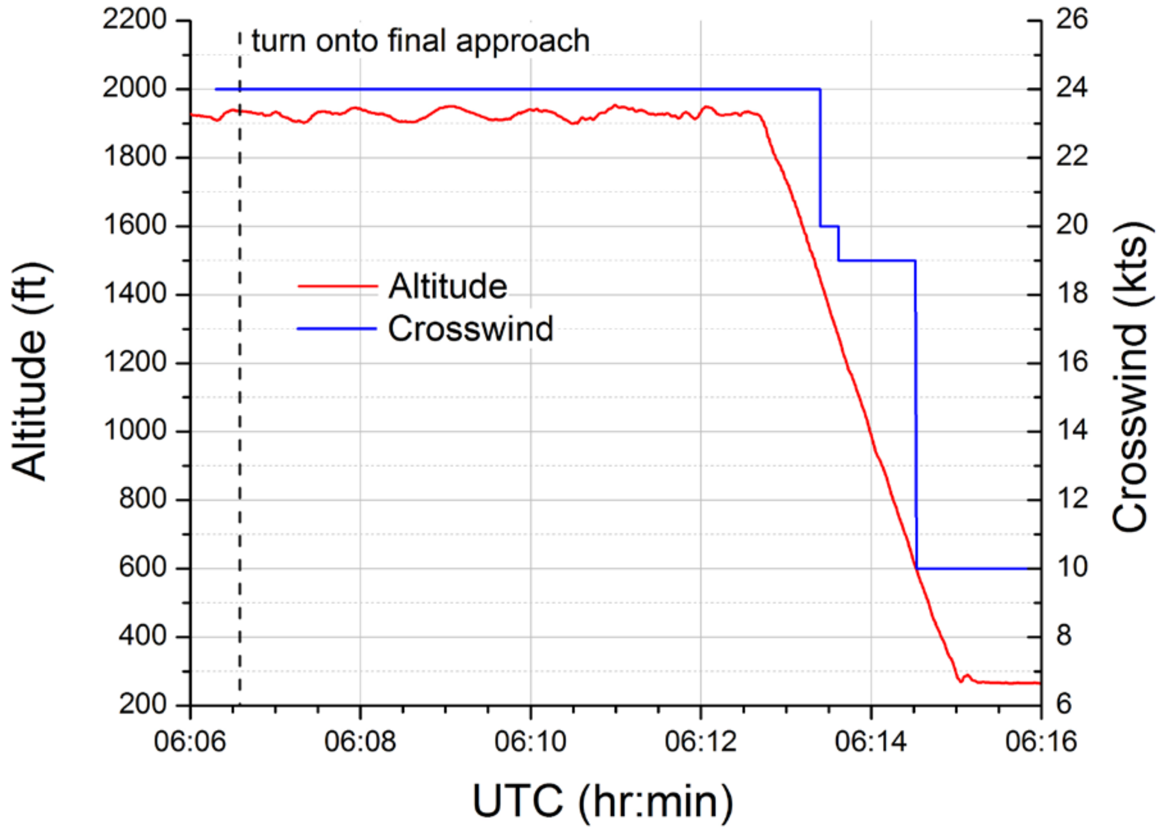

Figure 8. Altitude and crosswind component during final approach. Crosswinds are calculated using aircraft heading and the AMDARS wind data from Table 1.

The NTSB Meteorology Factual Report states that the icing charts from the National Center for Atmospheric Research (NCAR) for 0600 UTC in the region of MEM indicated an increasing probability of trace to light icing conditions between 1,000 and 2,000 ft above ground level (AGL) with the probability between 50 to 70%. The charts for 0700 UTC (the next available time period) depicted light icing conditions below 3,000 feet AGL with the probability increasing to 85%. Figure 9, below, compares the aircraft's altitude with the icing probabilities discussed above. Note that the charts indicated an increasing probability of icing at increasing altitudes during the time while the airplane was executing the go-around.

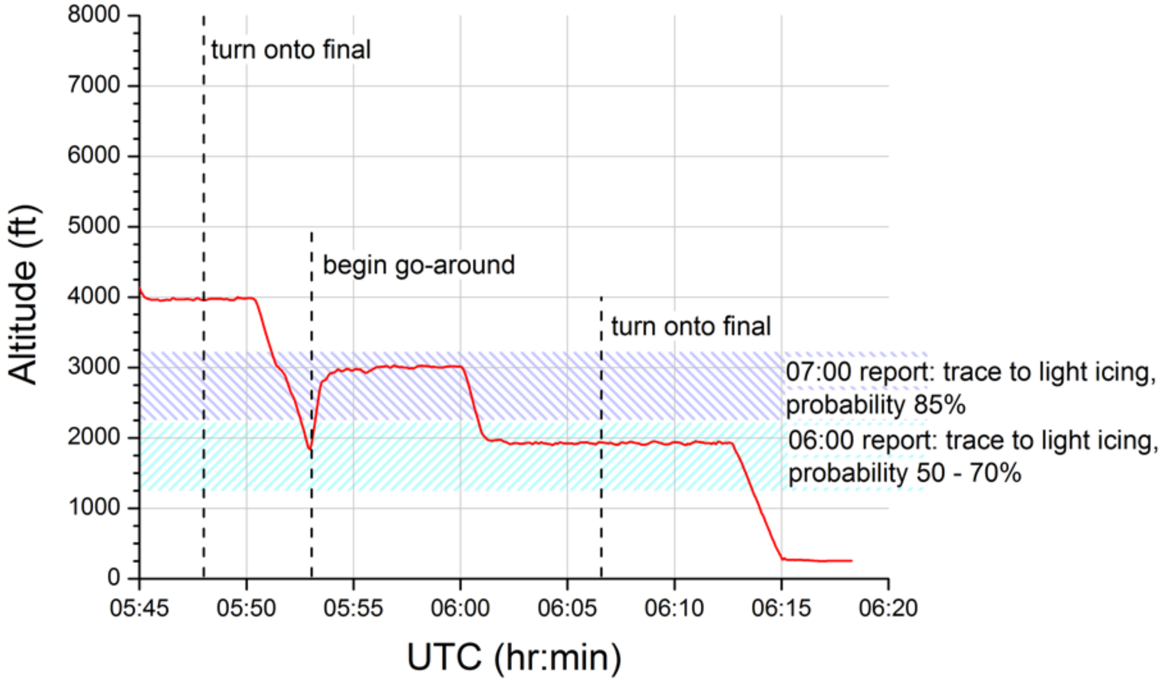

Figure 9. Aircraft altitude with various flight points marked. Includes NCAR icing probabilities for 0600 UTC in blue and 0700 UTC in purple.

Due to the go-around, the aircraft spent an additional 19 minutes of time in an altitude region with an increased probability of icing. Upon landing at MEM, ice buildup on the leading edge of the wings was discovered and photographed (shown in Figure 10). The aircraft's automatic icing protection system did not activate and was not on during its approach into MEM.

Figure 10. Ice on the leading edge of the aircraft wing shortly after landing.

Ice buildup can cause aerodynamic stall as the ice disrupts airflow across aircraft lift surfaces. Buildup of ice on the leading edge can cause air flow to separate and lift to be lost across the whole or a portion of the wing.

Aerodynamic Simulation of Aircraft

Embraer provided the NTSB with a simulation of the accident flight using their aerodynamic model of the EMB-145. The goal of the simulation was to quantify the rolling moment needed to match the aileron input and bank angle during the flare portion of the flight. While the simulation did show some differences between the simulation aileron and elevator inputs and the accident flight control surfaces, the discrepancies were small enough that they could have been due to the unavailable exact crosswind and side slip angle data. The simulation did not show a noticeable loss in roll authority or change in flight characteristics during the accident flight. This indicates that the build-up of ice on the leading edge of the aircraft did not degrade flight control by an appreciable degree during the aircraft's approach.

E. CVR OVERLAY

The CVR paraphrasing from the flight was overlayed with the latitude and longitude from the radar track and is shown in Figure 11 [3]. The figure shows the time of the paraphrased comment and if it was spoken by the first officer (FO) or the captain (CA), who was the pilot flying. Not all of the cockpit conversation is shown in the figure. The selected comments focus on the discussion between the captain and first officer about capturing the localizer (also referred to as the 'signal' or 'nav mode'), the autopilot (abbreviated AP for space), and icing. The first approach was aborted due to failure to capture the localizer as the aircraft approached the runway. The pilots continue to discuss the localizer during the second approach.

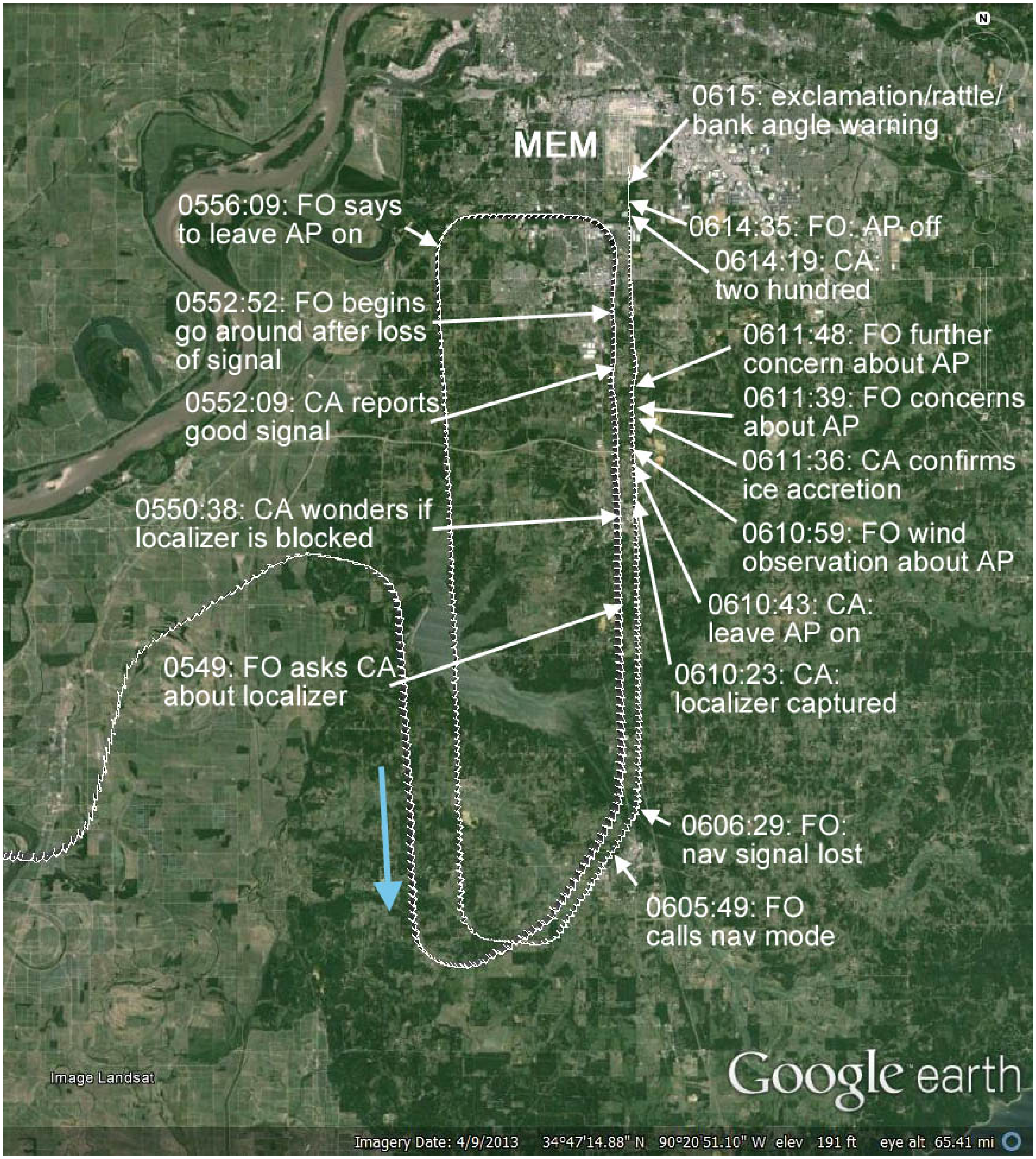

Figure 11. CVR paraphrasing overlay of go around and landing. FO denotes first officer speaking and CA denotes comments by the captain (flying pilot). Autopilot is abbreviated AP for space.

The pilots discussed the autopilot and possible ice accretion between 0610 and 0612 as shown in Figure 11. They also commented that the autopilot seemed to having trouble with the wind, but decided to leave the autopilot on.

F. CONCLUSIONS

An Embraer S.A. EMB-145EP experienced a sudden right roll just before landing resulting in a wing strike and substantial damage. The right roll was not commanded by the pilots as the wheel position did not correspond with the roll. The record of the rudder pedal position was not consistent with the roll being initiated by excessive rudder deflection. During a full aerodynamic stall the vertical load factor would drop due to the loss of lift, but the vertical load factor stayed between 0.9 and 1.1 g until after the roll event.

The surface crosswinds during the aircraft's final approach were recorded to be 10 kts with no recorded gusting conditions. The weather data does not support a sudden wind gust to have caused the sudden roll.

Correlating icing charts from the time of the accident with the aircraft's altitude showed that the aircraft spent an additional 19 minutes of time due to the go-around in an altitude region with an increased probability of icing. The pilots discussed ice accretion during the final approach and photographs of the aircraft shortly after landing show a build-up of ice on the leading edge of the wing. The automatic icing protection system did not activate and the aircraft's de-icing systems were not on during the approach and landing.

While the aircraft had a definite build-up of ice on the leading edge of the wings, the vertical load factor record did not indicate that the aircraft experienced a full aerodynamic stall. The simulation performed by Embraer also did not provide evidence of measurable degradation of control authority during the approach. However, ice could cause the aircraft to roll by creating enough flow separation on one wing for it to lose lift without the initial ice build-up affecting the control of the aircraft in a measurable way.

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G. REFERENCES

1. Embraer EMB145 Standard Operation Procedures Manual.
2. Flight Data Recorder Factual Report, National Transportation Safety Board
3. Cockpit Voice Recorder Factual Report, National Transportation Safety Board
4. Embraer EMB145 Flight Manual. Section 5-69: Stall Speed (Stick Pusher Speed)
5. Meteorology Factual Report, National Transportation Safety Board