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Mr. Dennis Jones
NTSB Office of Aviation Safety Major Investigations AS-10
490 L'Enfant Plaza
Washington D.C., 20594

Subject: Boeing Performance Analysis – Southwest (SWA) 737-700 N753SW Nose Landing Gear Collapse on Landing, LaGuardia, New York, 22 July 2013

References: (a) E-mail, 06 December 2013, NTSB to Boeing, same subject
(b) E-mail, 01 January 2014, Boeing to NTSB, same subject

Dear Mr. Jones::

In support of the National Transportation Safety Board's investigation into the subject event, Boeing was provided Flight Data Recorder (FDR) raw data from the event airplane. We have completed an analysis of that data and it is enclosed with this letter.
The related plots were submitted as attachments to Reference (b)

The information included with this correspondence is for the use of the NTSB and participants supporting official accident investigation activities.

The information included with this correspondence is controlled under the US Export Administration Regulations (15 CFR Parts 300-799) and has been categorized as ECCN: 9E991.

Please feel free to contact us if you have any questions.

Best regards,

[redacted] for

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Chief Engineer
Air Safety Investigation

Enclosure: FDR Analysis for SWA N753SW NLG Collapse

Boeing Performance Analysis – Southwest (SWA) 737-700 N753SW
Nose Landing Gear Collapse on Landing, LaGuardia, New York, 22 July 2013

Summary:
Southwest Airlines (SWA) reported that a 737-700 with winglets (YA051/N753SW) experienced a nose gear collapse upon touchdown on July 22, 2013 at La Guardia Airport (LGA), New York. It was reported that 3 passengers were injured during the evacuation. The airplane sustained substantial damage during the landing and rollout; the nose gear strut penetrated the Electronic Equipment (EE) Bay, the fuselage was scraped and wrinkled, and the right engine nacelle was damaged. The event is being investigated by the National Transportation Safety Board (NTSB) with assistance from Boeing. The Flight Data Recorder (FDR) data were provided to Boeing for analysis.

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The FDR data show the airplane configured for a flaps 40 approach with the autopilot and autothrottle engaged, and on glideslope and localizer at 500 feet Radio Altitude (RA). The autopilot and autothrottle were disengaged at approximately 410 feet RA. As the approach continued, the airplane began deviating above the glide path due to increased thrust and a slight increase in pitch attitude while maintaining the selected speed of VREF40+6. At the runway threshold, the airplane was at 60 feet RA and on a 2.1-degree glide path. The throttles were reduced to forward idle at 46 feet RA, and at 32 feet RA the cockpit voice recorder indicated that a transfer of control was made from the First Officer to the Captain. After the transfer, but prior to touchdown, the control column relaxed to neutral deflection, the throttles were advanced.

Due to the early reduction in thrust to forward idle, the absence of control column input prior to touchdown, and the nose-down pitch tendency in ground effects, the airplane pitch attitude decreased to a nose-down attitude of -3.1 degrees and touched down on the nose gear prior to the main gear touching down.

Event Report:

SWA reported that a 737-700 with winglets (YA051/N753SW) experienced a nose gear collapse on landing at La Guardia Airport (LGA), New York, on July 22, 2013.

The airplane sustained substantial damage during the landing and rollout; the nose gear strut penetrated the Electronic Equipment (EE) Bay, the fuselage was scraped and wrinkled, and the right engine nacelle was damaged. The event is being investigated by the National Transportation Safety Board (NTSB) with assistance from Boeing. The Flight Data Recorder (FDR) data were provided to Boeing for analysis to assist in determining the cause of the nose gear collapse.

FDR Data Analysis

Time history plots of the pertinent longitudinal and lateral-directional parameters are attached as Figures 1 through 4. A ground track of the final approach through touchdown is attached as Figures 5 and 6, and Figure 7 is a time history plot of the recorded column force data.

The FDR data show the airplane descending through 700 feet Radio Altitude (RA) with the autopilot and autothrottle engaged, the flaps set to 30 degrees, and the speedbrake handle in the armed detent (Figure 1). During the approach, the flight directors were ON, and the autoflight modes were engaged in Glideslope (G/S) and Localizer (LOC) at 2000 feet RA (not plotted), indicating that the flight director bars for pitch and roll were visible on the Primary Flight Display (PFD) and were providing guidance based on glideslope and localizer deviation information (Figures 1 and 2). A 10-knot right crosswind was present at the start of final approach but diminished as the airplane descended, and the wind changed from a tail wind to a headwind, with the headwind reaching approximately 5 knots at touchdown (Figure 2)

500 Feet to 175 Feet RA (Orange Shaded Area in Figures 1 and 2)

From 500 feet to 175 feet RA, the glideslope deviation and localizer deviation remained within 0.35 dots and 0.2 dots of zero deviation, respectively (Figures 1 and 2). The flaps transitioned to 40 degrees around 500 feet RA by time 7738 seconds, and the autothrottle and autopilot were disengaged at approximately 410 feet RA (Figure 1). The descent rate was an average of about 750 feet/minute (calculated vertical speed = -750 feet/minute). Small thrust adjustments were commanded to maintain airspeed and glide path. The pitch attitude was, on average, approximately 2 degrees and varied between 4 degrees and 0 degrees. Based on the airplane weight and flap setting, the reference speed was VREF40 (128 knots) and the Mode Control Panel (MCP) Selected Speed was 134 knots (VREF40+6). The selected speed was maintained to within 4 knots during the final approach until just before touchdown.

175 Feet RA to Touchdown (Yellow Shaded Area in Figures 3 and 4)

From 175 feet RA to touchdown, the airplane began to deviate above the glideslope beam due to the manual increase in thrust at time 7767.5 seconds which was maintained for approximately 11 seconds (Figure 3). The descent rate fluctuated between 800 feet/minute and 400 feet/minute and was maintained at approximately 500 feet/minute for 6 seconds. The bank angle oscillated to a maximum of around 5 degrees to the left and right with opposing control wheel input that reached a maximum of approximately 30 degrees to the right and left (Figure 4). At 60 feet RA, time 7784 seconds, nose-up column was commanded to 2 degrees; the column was relaxed, then nose-up column was commanded again and maintained at 1.5 degrees (Figure 3). This resulted in a pitch attitude increase from 0 to 2.3 degrees, and the descent rate decreased from 800 feet/minute to 400 feet/minute. Concurrent with the column pull that began at time 7781 seconds, the throttles were reduced from 49 degrees to forward idle (33 degrees). The commanded column deflection relaxed to neutral deflection at 27 feet RA (time 7786 seconds) and remained in the neutral position until the airplane came to a stop. Approximately 1 second after the column position relaxed to neutral, the throttles were advanced. The absence of nose-up column deflection and the reduced thrust setting to forward idle, along with the nose-down pitch tendency due to ground effects, caused the pitch attitude of the airplane to decrease to a nose-down attitude just prior to touchdown.

Touchdown

Touchdown occurred at time 7788.6 seconds, at a pitch attitude of -3.1 degrees (nose-down), pitch rate of -2.8 degrees/second, descent rate of 960 feet/minute (16 feet/second), and normal load factor of 3.2 g's (Figure 3). Due to the nose- down pitch attitude of -3.1 degrees, the nose gear contacted the runway first. Immediately after touchdown, both left and right main gear air/ground parameters transitioned to GROUND. The nose gear air/ground discrete remained in the AIR state, inferring that the nose gear air/ground switch may have been damaged during the landing. The right throttle transitioned to forward idle (the left throttle remained advanced at 66 degrees TRA [forward thrust]), and the flaps transitioned from flaps 40 to flaps 30. The speedbrakes were deployed approximately 8 seconds after touchdown, and the airplane came to rest to the left of the runway centerline, 18 seconds after touchdown, in a right bank of 1 degree, a heading of 49 degrees, and nose-down pitch attitude of -6.3 degrees (Figures 3 and 4)

A ground track was generated to show the airplane's path during the approach to touchdown (Figure 5). Runway 04 at LGA has a length of 7001 feet and a width of 150 feet. Longitudinal and lateral distances were calculated using a combination of inertial data (ground speed, drift angle, heading), glideslope/localizer deviation, and airport information (runway dimensions, localizer antenna location, etc). The distances were then referenced to the runway based on the coordinates of the airplane's touchdown location, which were provided by the NTSB.

Figure 5 shows the final approach from 250 feet geometric altitude to touchdown. Both the glideslope deviation and the Precision Approach Path Indicator (PAPI) were available during the approach to provide vertical guidance. The glideslope antenna is located approximately 1120 feet beyond the runway threshold and the PAPI is located approximately 1425 feet beyond the runway threshold. The geometric altitude is the calculated height of the airplane above sea level. Ground level is referenced to the elevation above sea level of the Runway 04 threshold which is 18 feet. The data shown on the first axis in Figure 5 are the geometric altitude at the Center of Gravity (CG) with the 3-degree glideslope beam profile and the profiles of the 1-dot high and 2-dots high glideslope deviations shown for reference. The data shown on the second axis are the geometric altitude at the pilot's eye with the visual cues from the PAPI; on path (2 white/2 red lights), slightly high (3 white/1 red light), and high (4 white /0 red lights).

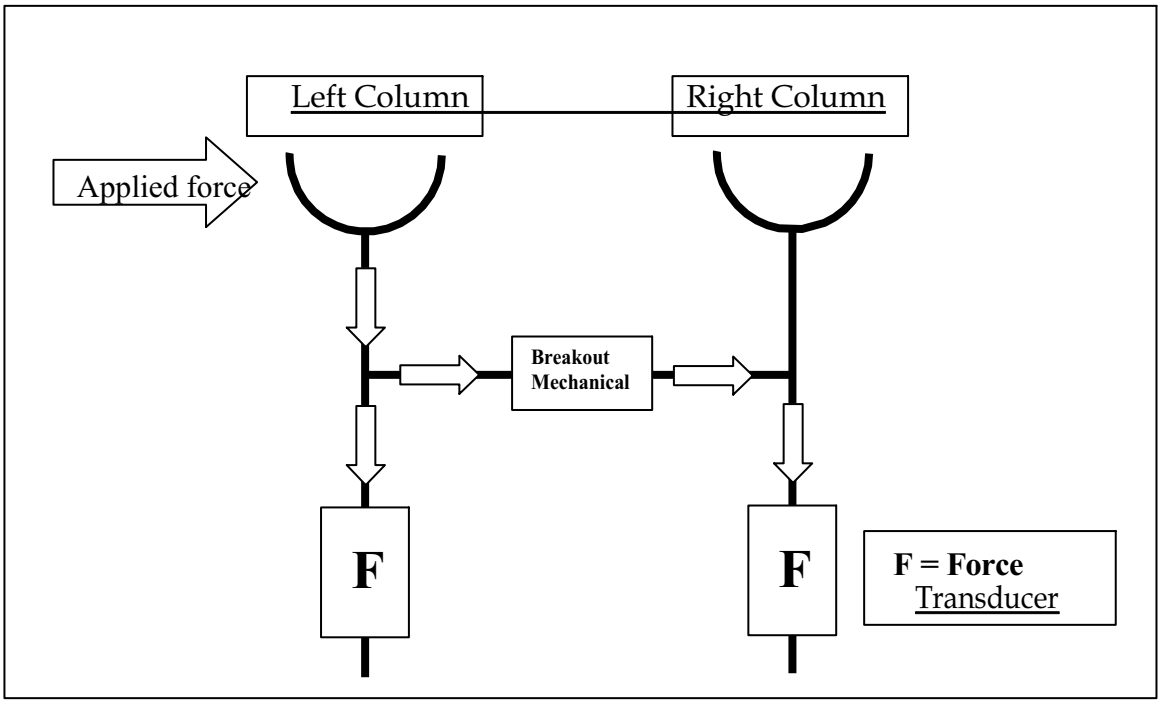
Based on the glideslope intercept guidance, at 250 feet geometric altitude (3800 feet prior to the runway threshold), the airplane was slightly below the glideslope beam (Figure 5). As the descent continued, the airplane passed through the beam at 145 feet geometric altitude (1650 feet prior to the runway threshold) and began to deviate above the beam. The airplane continued to deviate above the beam and passed through the 1-dot high profile at approximately 125 feet geometric altitude (1050 feet prior to the runway threshold), and passed through the 2-dot high profile at 115 feet geometric altitude (650 feet prior to the runway threshold). Based on the PAPI intercept guidance, at 250 feet geometric altitude (3700 feet prior to the runway threshold), the pilot's eye was below the approach path. As the descent continued, the pilot's eye passed through the approach path at 130 feet geometric altitude (1000 feet prior to the runway threshold) and began to deviate above the nominal approach path. The airplane continued to deviate above the approach path, and the crew would have received the slightly high (3 white/1 red) visual PAPI cue at 120 feet geometric altitude (650 feet prior to the runway threshold) and would have received the high (4 white/0 red) visual PAPI cue at 105 feet geometric altitude (200 feet prior to the runway threshold). At the runway threshold, both the glideslope deviation and PAPI visual guidance indicated that the airplane was high. The airplane was following a 2.1-degree glide path from approximately 1400 feet prior to the runway threshold to touchdown and was high on the approach. Touchdown occurred at 1425 feet beyond the runway threshold on the runway centerline

A select few passages from the Cockpit Voice Recorder (CVR) transcript were provided to Boeing to assist in determining the sequence of events that led to the nose gear collapse on touchdown. The CVR passages were given with a time reference which was translated to a distance to provide a reference to the runway threshold. Figure 6 shows the ground track analysis with an overlay of the provided CVR passages. The data show that the Captain's 100-foot RA callout occurred when the airplane was at 110 feet RA. At 100 feet RA, the CVR indicated that the Captain may have stated "*Get it down,*" and at 85 feet RA a definitive "*Get it down*" statement was made by the Captain. The Captain requested control at 38 feet RA (570 feet beyond the runway threshold), and the transfer of control occurred at 32 feet RA (710 feet beyond the runway threshold). The control column relaxed to the neutral position at 27 feet RA, and the throttles were advanced after the control transfer but before touchdown. The sound of an impact occurred at 1425 feet beyond the runway threshold and correlates with the touchdown location based on the FDR data and touchdown coordinates provided by the NTSB.

Determination of Pilot Flying

On 737NG aircraft, there are two control column force transducers (one on each side). Applied column force is transmitted along two linkages that connect the control columns to these two transducers, as shown in the simplified system diagram below.

Control Column Force Measurement System Diagram



Because of compliance in the system, the transducer that is closest to the applied force will reflect larger forces in the recorded data and, therefore, indicate which column is being used to make inputs to the elevator.

The FDR data were evaluated to determine the pilot flying during the approach and landing segments of the flight. Figure 7 shows the column force data from the left and right seat, Captain and First Officer's, respectively. When the autopilot is engaged, the column force parameter will record a value near zero; when the autopilot is disengaged, the column force parameter will record the force applied to the column. The column force recorded on the side of the pilot flying will have slightly higher forces due to compliance in the system. Before evaluating the data to determine Pilot Flying (PF), biases were removed from both force parameters. The biases in the parameters were determined from pre-flight values, just after the control sweeps but before the takeoff roll, when the column was in the neutral position. After removing the biases, the column force data show that after the autopilot was disengaged, the forces on the right side (the First Officer's side) were slightly higher in the pull and push directions. This indicates that the First Officer took control of the column after autopilot disengagement at approximately 360 feet RA (time 7753.5 seconds). The First Officer remained in control of the column throughout the final approach, until approximately time 7786.5 seconds, when the control column forces decrease to near zero at 25 feet RA. The last recorded commanded column force data point was 14.8 pounds at 30 feet RA (time 7785.6 seconds) before the data decreased towards neutral.

Summary

The FDR data show that the airplane was high and on a shallow glide path during final approach. The airplane crossed the runway threshold at an altitude of 60 feet RA and the throttles were positioned at forward idle at 46 feet RA. At approximately 27 feet above the runway, a transfer of controls from the First Office to the Captain reportedly occurred. After the transfer, the throttles were advanced, but the column deflection was relaxed to the neutral position.

The early reduction of thrust, lack of control column input, and nose-down pitch tendency in ground effects, resulted in the airplane pitching to a nose-down (negative) pitch attitude. This caused the nose gear to contact the runway prior to the main gear. The touchdown occurred at a high descent rate, at a pitch rate of -2.8 degrees/second and a nose-down pitch attitude of -3.1 degrees, with the nose gear coming in contact with the runway first, resulting in the nose gear collapse.