Landing gear separation on landing, Douglas DC-9-31, September 9, 1999

Micro-summary: **The hard landing of this McDonnell Douglas DC-9-31 resulted in the separation of the left main landing gear.**

Event Date: **1999-09-09 at 1138 CDT**

Investigative Body: **National Transportation Safety Board (NTSB), USA**

Investigative Body's Web Site: **http://www.ntsb.gov/**

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1. Accident reports can be and sometimes are revised. Be sure to consult the investigative agency for the latest version before basing anything significant on content (e.g., thesis, research, etc).

2. Readers are advised that each report is a glimpse of events at specific points in time. While broad themes permeate the causal events leading up to crashes, and we can learn from those, the specific regulatory and technological environments can and do change. ***Your company's flight operations manual is the final authority as to the safe operation of your aircraft!***

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National Transportation Safety Board

FACTUAL REPORT AVIATION

NTSB ID: MIA99IA249	Aircraft Registration Number: N993Z
Occurrence Date: 09/09/1999	Most Critical Injury: Minor
Occurrence Type: Incident	Investigated By: NTSB

Location/Time

Nearest City/Place	State	Zip Code	Local Time	Time Zone	
NASHVILLE	TN	37217	1138	CDT	

Airport Proximity: On Airport	Distance From Landing Facility:	Direction From Airport:

Aircraft Information Summary

Aircraft Manufacturer	Model/Series	Type of Aircraft
Douglas	DC-9-31	Airplane

Sightseeing Flight: No Air Medical Transport Flight: No

Narrative

Brief narrative statement of facts, conditions and circumstances pertinent to the accident/incident:

HISTORY OF FLIGHT

On September 9, 1999, at about 1138 central daylight time, a Douglas DC-9-31, N993Z, TWA Flight 600, registered to First Security Bank, North American Trustee, operated as a 14 CFR Part 121 domestic passenger flight, experienced a separation of the left main landing gear during touchdown and landing rollout at Nashville International Airport, Nashville, Tennessee. Visual meteorological conditions prevailed and an IFR flight plan was filed. The airplane sustained minor damage. The airline transport rated pilot-in-command (PIC), first officer (FO), 3 flight attendants and 38 passengers reported no injuries. Three passengers were transported and released from a local area hospital with minor injuries. The flight originated from St. Louis, Missouri, 54 minutes before the incident.

The FO stated he was flying the airplane and was vectored to the downwind and cleared for a visual approach to runway 02 left. He turned final and his sink rate was between 600 to 800 feet. They were in the landing configuration, normal profile, flaps 40, VREF 116, and there was not much of a crosswind correction used for the wind angle, nor did they encounter any wind shear on the approach or receive any advisories. The airplane touched down hard on the right main landing gear, which surprised him and the PIC. The PIC immediately got on the flight controls with him as the airplane bounced. He asked the PIC if they were going to land or make a go-around. He received no response and continued with the landing. On the second impact he felt a vibration, and it became evident that they had a directional control problem. He initially thought they had a landing gear strut or tire failure. The left wing started to settle and made contact with the ground. The PIC informed the tower to roll the equipment, and pulled the left start fuel lever to the off position. He pulled the right start fuel lever to the off position, and the airplane came to a stop. The crash rescue fire (CRF) vehicles arrived, and the PIC communicated with them and the tower. They completed the evacuation checklist, and briefed the flight attendants and passengers. After some communication with the CRF personnel an evacuation was made down the evacuation emergency slide at the L-1 door.

The PIC stated right before touchdown, he knew the FO was not going to make a good landing. He stated he did not add any power during the event, and he could not recall if the spoilers deployed on the first touchdown. The airplane touched down hard, but he did not expect a hard landing of that magnitude. He stated in a subsequent statement, "Everything was stabilized on final approximately 4 miles out. Aircraft was a little fast on final. The F/O throttled back to compensate and at about 500' I called bug+12 sink 800. On short final the speed decayed a bit more and some sink developed. The F/O added power and I urged him to add more." He immediately got on the flight controls and remained on the controls until the airplane came to a stop. On the second touchdown, he felt a wobble on the left side. The airplane started a left roll, and he experienced directional control problems. He used right brake to keep the airplane on centerline. As soon as the airplane stopped, he started coordinating with CRF and tower personnel. The CRF arrived without

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delay. They ran the evacuation checklist, and he briefed the flight attendants and passengers. A short time later after coordination with the CRF personnel, he commanded an evacuation out the L-1 door.

All flight attendants stated the airplane experienced a hard landing. All personnel completed an emergency evacuation out the L-1 door in an orderly fashion. No problems were encountered with the emergency equipment.

Witnesses who observed the incident stated the airplane touched down in the touchdown zone. The airplane touched down hard, ballooned or bounced into the air between 50 to 100 feet, and the left main landing gear separated from the airplane. The airplane continued down the runway and came to a stop.

Review of recorded transmissions between TWA 600, Nashville Approach Arrival East (ARE), and Nashville Tower Local Control (LC1), revealed TWA 600 informed ARE at 1625:06 (1138:06), "nashville twa six hundred out of uh twelve four for uh one zero thousand with hotel." TWA 600 was cleared to land at 1635:02. At 1638:06, Northwest Airlines flight 1746 informed the tower that TWA had just lost its gear.

The FO of Northwest 1746 wrote in a statement to the NTSB, "While taxing out to runway 02L for takeoff I witnessed the "hard Landing" of a TWA DC-9-30. I observed the aircraft as it approached about 1 mile from the runway until it touched down. The approach looked very stable until the very short final, IM guessing it was at somewhere between 100 to 75 feet agl., (IM not certain of the specific altitude) when the sink rate of the aircraft really began to increase. You could tell from just watching this sink rate that it was going to hit hard. It appeared that whoever was flying the aircraft was trying to arrest this high sink rate with "pitch" only and not power. I never saw the exhaust of smoke that one sometimes sees when power is being applied to a jet engine!...Needless to say we observed an extremely hard touchdown of the main gears. The aircraft subsequently went airborne again from the initial touchdown. When it did I observed the "flutter" of the attached gear door of the left main landing gear. The gear itself (the left main gear) then separated from the aircraft when the airplane was at the apex of the bounce! Seeing that we both saw the gear separate from the aircraft the captain I was flying with picked up the mike on tower frequency and told them that "TWA just lost his left main gear."

PERSONNEL INFORMATION

The PIC was hired by TWA on April 22, 1988, and was qualified as a captain in the DC-9 on March 6, 1999. He holds an airline transport pilot certificate with ratings and limitations for airplane multiengine land, airplane single engine land, glider aero tow, flight instructor, airplane single engine, and instrument airplane issued on January 26, 1999. In addition, he holds a flight engineer certificate with rating for turbojet powered issued on October 14, 1988. He was issued a first class medical certificate on July 7, 1999. All pertinent aviation regulations, 14 CFR Part 121, airman competency and proficiency checks, had been recorded as conducted for the PIC.

The FO was hired by TWA on February 18, 1999, and was qualified as a DC-9 FO on May 4, 1999. He holds an airline transport pilot certificate with ratings and limitations for airplane multiengine land, airplane single engine land, flight instructor airplane single engine land, and instrument airplane issued on March 22, 1999. In addition, he holds an aircraft dispatcher certificate, mechanic certificate with rating for airframe, and an advanced ground instructor certificate issued on March 22, 1999. He was issued a first class medical certificate on January 22, 1999. All pertinent aviation regulations, 14 CFR Part 121, airman competency and proficiency checks had been recorded as conducted for the FO.

The L-1 flight attendant was hired by TWA on May 3, 1977, and was qualified as a flight attendant on June 1, 1977. The R-1 flight attendant was hired by TWA on February 2, 1978, and was

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qualified as a flight attendant on March 29, 1978. The C-1 flight attendant was hired by TWA on February 26, 1978, and qualified as a flight attendant on March 29, 1978. All pertinent aviation regulations, 14 CFR Part 121, airman competency and proficiency checks had been recorded as conducted for all three flight attendants.

AIRCRAFT INFORMATION

The airplane is a Douglas model DC-9-31, serial No. 47082, registration No. N993Z, manufactured in 1967. The airplane is registered to First Security Bank NA Owner Trustee, Salt Lake City, Utah, and is operated by Trans World Airlines, Bridgeton, Missouri. The airplane is equipped with two Pratt & Whitney JT8D-9A 14, 500 pounds of thrust engines. Available maintenance records indicates the last continuous airworthiness inspection was conducted on December 7, 1998. The airplane has flown 1,874 hours since the last inspection and has accumulated 77,374 total airframe hours. The left main landing gear was removed, overhauled, and installed on N993Z on August 28, 1992. The current cycles were 34, 177, and the current time was 16,453 hours. There were 6,547 hour remaining on the landing gear until overhaul. (For additional information see NTSB Airworthiness Group Chairman's Factual Report of Investigation an attachment to this report.)

METEOROLOGICAL INFORMATION

The nearest weather reporting facility at the time of the accident was Nashville International Airport, Nashville, Tennessee. The 1140 surface weather observation was: 9,000 broken, visibility 10 miles, temperature 82 degrees Fahrenheit, dew point temperature 52 degrees Fahrenheit, wind from 030 degrees at 10 knots, and altimeter 29.96 inHg. Visual meteorological conditions prevailed at the time of the incident. Review of recorded communications of the Nashville Air Traffic Control Tower Arrival Automated Terminal Information Service (ATIS) revealed the 1638:18 ATIS information was: "nashville international airport arrival information hotel one five five three zulu wind three six zero at niner gusts one six visibility one zero few clouds at one five thousand two five thousand scattered temperature two seven dewpoint one one altimeter two niner niner six all aircraft shall read back all runway hold short instructions including aircraft identifications simultaneous visual approaches runway two left runway two center runway two right in use notices to airman bird activity in vicinity of airport advise on initial contact you have information hotel." Review of Terminal Doppler Weather Radar (TDWR) for the time period 16:15:01 to 16:50:10 reveals no indication of wind shear. (For additional information see TDWR information and ATIS recorded transcripts an attachment to this report.)

FLIGHT RECORDERS

N993Z was equipped with a Fairchild model A100 cockpit voice recorder. The recorder was forwarded to the NTSB laboratory for analysis. The recording consisted of four channels of good quality audio information. The recording began at 1109:06, while TWA 600 approached Nashville, Tennessee. At 1124:25, TWA 600 was frequency changed from Memphis Air Route Traffic Control Center to Nashville approach control while descending. The crew prepared for the approach into Nashville International airport and continued their descent. Nashville approach control vectored to Nashville International airport and cleared TWA Flight 600 for the visual approach to runway 2L. At 1135:02, TWA Flight 600 was cleared to land. The crew performed their arrival checklists and confirmed the landing check complete at 1137:05. At 1138:00, a sound similar to the first landing impact was recorded on the CVR. At 1138:04, the captain elected to continue the landing and a sound similar to a second touchdown was recorded at 1138:10. The captain notified the tower to send crash rescue fire (CRF) equipment, radioed Nashville tower and TWA ramp control regarding the evacuation of passengers. The recording ended at 1141:15. (For additional information see NTSB Group Chairman Cockpit Voice Recorder Factual Report an attachment to this report.)

N993Z was equipped with a Fairchild model F800 digital flight data recorder (FDR). The recorder was forwarded to the NTSB laboratory for analysis. A successful FDR readout was performed.

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The FDR subframe reference numbers are recorded in seconds. The total time covered in the FDR readout is between 900 to 1040 seconds. According to the FDR data the following information was obtained: (Additional information concerning the parameters of the hard landing (989 to 1003 seconds) is included in NTSB Flight Data Recorder Factual Report, an attachment to this report.)

* At 992.2 seconds, the aircraft was wings level with a positive pitch attitude of 2.4 degrees, a positive 10.8 degrees control column position, an airspeed of 114 knots and a pressure altitude of 646 feet and a calculated descent rate of approximately 907 feet per minute.

* At approximately 993.1 seconds when the vertical acceleration started to rise, the descent rate was calculated to be approximately 763.8 feet per minute.

* At 993.3 seconds, the vertical acceleration spiked at 2.08 g's indicating initial touchdown. At this time, the FDR recorded a 2.1 degree left roll attitude, an 8.1 degree pitch attitude, a 5.4 degree control column position and an airspeed of 107 knots.

* Between 994 and 1005 seconds, the pitch attitude values indicated 3 oscillations from 9.8 degrees to 3.08 degrees, up to 6.4 degrees down to 2.4 degrees and then down to -1.1 degrees. It remained below -0.8 degrees for the rest of the recorded FDR data (1080 seconds.) During this time the roll attitude went from 0 degrees to 8.17 degrees to 3.96 degrees then to 10.9 degrees.

* At approximately 1005 seconds, the longitudinal acceleration decreased from -0.09 g's to -0.16 g's and remained below -0.1 g's for the next 31 seconds before increasing to approximately 0 g's. During this time the computed airspeed steadily decreased from 107 to 11 knots. These conditions are consistent with the aircraft slowing down to a stop at 1037 seconds.

* While the aircraft was slowing down (between 1005 and 1036 seconds), the roll attitude increased from 10.9 degrees to approximately 14 degrees left wing down where it remained at 14 degrees for the rest of the recorded FDR data (1080 seconds.)

WRECKAGE AND IMPACT INFORMATION

N993Z was located on runway 02L, 5,207.6 feet from the landing threshold, 4,930.3 feet from the initial touchdown point, and 12.5 feet left of runway centerline on a heading of 025-degrees magnetic. The left main landing gear assembly had separated from the airplane, and was located about 2,425 feet from the initial touchdown point on the A2 taxiway.

Examination of tire marks on the runway revealed the right main landing gear touched down first followed by the left main landing gear. There was evidence of tire marks (inboard and outboard tires) immediately after the initial touchdown indicating the left main landing gear was castering to the right and left.

The first evidence of fluid on the runway was noticed 45 feet 10 inches from the initial point of touchdown in the vicinity of the left outboard main landing gear tire mark. There was no other left main landing gear tire marks present on the runway. The left main landing gear inboard tire continued to caster down the runway until the airplane became airborne (bounced). The second touchdown point was not located on the runway.

The components that separated from the left main landing gear were found 46 feet 3 inches from the landing threshold, scattered on both sides of the centerline, and extended down the runway for the next 2,700 feet.

Examination of the airframe, revealed a rubber tire transfer mark was present on the left side of the fuselage in the vicinity of the No. 1 engine assembly. There was no evidence of a precrash mechanical failure or malfunction of the engine assembly and accessories, and flight

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control assembly. All components necessary for flight were present. Continuity of the flight control system was confirmed for pitch, roll, and yaw.

Examination of the left main landing gear wheel well revealed a portion of the outer cylinder was still hanging in the wheel well. The outer cylinder forward trunnion section exhibited evidence of a preexisting crack at the inboard side where the forward trunnion gusset intersects with the outer cylinder barrel. The outer cylinder aft trunnion barrel section had evidence of a matching preexisting crack inboard from the bottom side of the aft trunnion bore apex. The left main landing gear inner and outer cylinder and shimmy damper were forwarded to the NTSB Materials Laboratory for further analysis.

Review of aircraft records revealed the left main landing gear was removed from N986Z. The landing gear was overhauled and installed on N993Z on August 28, 1992. An engineering order was issued to clean dents from the main landing gear piston and returns it to service with a minimum outer diameter of 5.222 inches. The current cycles on N993Z were 81,376 and the current time was 77,373 hours. The left main landing gear cycles were 34,177 and the current time was 16,453 hours. There were 6,547 hours remaining until overhaul. The last C check was performed in December 1998. Inspection task cards were reviewed for the inspection of anti-skid and main landing gear structure and support. All struts were serviced.

The past 60 days of logbook write-ups, routine and non-routine work orders and discrepancies were reviewed. The left and right shimmy dampers were replaced per TWA Modification Order 72J73AA on August 30, 1999. The main landing gear was inspected per the DC-9 Layover Service Inspection on August 27, 1999. The main landing gear struts were serviced during the Time Control Service Check on June 24, 1999. There was a trend of discrepancies stemming from March 1999 to July 1999 of the number 2 brake seizing and series of flat spotted tires. (For additional information see NTSB Airworthiness Group Chairperson's Factual Report of Investigation an addendum to this report.)

Examination of the interior cabin revealed that row 4 D and F oxygen masks panel is deployed, but the masks were still attached to the panel. There was no damage or deficiencies noted with the emergency exits. Flight crew seats, flight attendant jump seats, and passenger seats including restraint systems, revealed no evidence of damage or malfunction.

The NTSB Materials Laboratory conducted examination of the left main landing gear inner and outer cylinders and the shimmy damper. The left main landing gear outer cylinder housing contained a fracture area near its upper end that separated the forward trunnion from the barrel and another fracture area that separated the lower end of the housing from the barrel. In addition, the barrel contained a gaping crack that extended from the trunnion arm fracture area to the lower fracture area. Initial visual examination showed that almost all of the fractures in the outer cylinder housing were typical of overstress that stemmed from a pre-existing fracture region in the trunnion arm fracture area. The fracture region was very darkly colored compared to the adjacent overstress fracture areas which appeared clean and contained minimal corrosion deposits or other discoloration. Substantial deposits of cadmium were found over about one half of the preexisting crack. No obvious cracks were noted in the shimmy damper housing. (For additional information see NTSB Materials Laboratory Factual Report No. 99-245 an addendum to this report.)

MEDICAL AND PATHOLOGICAL INFORMATION

Toxicology studies of specimens from the PIC, FO, and flight attendants were requested by the NTSB investigator-in-charge. Toxicology samples were only taken from the PIC and the FO. Toxicology of specimens from the PIC and FO were performed by E.M.S.I. Nashville, Tennessee. These studies were negative for alcohol, neutral, acidic, and basic drugs.

The TWA Manager, for Drug Abatement, elected not to test the flight attendants, using

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information that was available at the time that their performance did not contribute to the accident or incident. This decision was made without conferring with the NTSB investigator-in-charge or the Managing Director Flight Operations at TWA.

TWA AIRCRAFT ACCIDENT / INCIDENT PROCEDURES MANUAL, EMERGENCY RESPONSE SYSTEM, II. DRUG AND ALCOHOL TESTING INFORMATION states, "Determine need for drug and alcohol testing. If the accident meets the NTSB accident definition, federal regulations require that employees whose performance either contributed to the accident or cannot be discounted as a contributing factor to the accident must be tested, using the best available information at the time. This may include flight deck crew, flight attendants, mechanics, weight and balance agents, passenger screening guards or any other covered employee under FAA regulations. Testing must occur as soon as possible after the accident.

The TWA Managing Director Flight Operations put out an all hands message stating, "In the future, this determination should only be made by the senior accident Investigator or Emergency Coordinator at the EEC as stated in the Accident Manual page 3.16.37. This testing should be coordinated with the VP Flight Operations as stated on page 3.16.41.

ADDITIONAL INFORMATION

The airplane was released to Mr. Robert Young, Director TWA Flight Operations Safety, on September 11, 1999. The left main landing gear inner and outer cylinder, and shimmy damper with the separated forward trunnion arm of the outer cylinder were released to Mr. Robert Young, in three shipments on January 21, 2000, January 31, 2000, and March 31, 2000.

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Landing Facility/Approach Information

Airport Name	Airport ID:	Airport Elevation	Runway Used	Runway Length	Runway Width
NASHVILLE INTERNATIONAL	BNA	599 Ft. MSL	2L	7702	150

Runway Surface Type: Concrete

Runway Surface Condition: Dry

Type Instrument Approach: NONE

VFR Approach/Landing: Traffic Pattern

Aircraft Information

Aircraft Manufacturer	Model/Series	Serial Number
Douglas	DC-9-31	47082

Airworthiness Certificate(s): Transport

Landing Gear Type: Retractable - Tricycle

Homebuilt Aircraft?	Number of Seats:	Certified Max Gross Wt.	Number of Engines:
No	107	108000 LBS	2

Engine Type:	Engine Manufacturer:	Model/Series:	Rated Power:
Turbo Fan	P&W	JT8D-9A	14500 LBS

- Aircraft Inspection Information

Type of Last Inspection	Date of Last Inspection	Time Since Last Inspection	Airframe Total Time
Continuous Airworthiness	12/1998	1874 Hours	11838 Hours

- Emergency Locator Transmitter (ELT) Information

ELT Installed?	ELT Operated?	ELT Aided in Locating Accident Site?
No		

Owner/Operator Information

Registered Aircraft Owner	Street Address	City	State	Zip Code
1ST SECURITY BANK NA TRUSTEE	79 SOUTH MAIN STREET	SALT LAKE CITY	UT	8411

Operator of Aircraft	Street Address	City	State	Zip Code
TRANS WORLD AIRLINES INC.	11495 NATURAL BRIDGE ROAD	BRIDGETON	MO	63044

Operator Does Business As:

Operator Designator Code: TWAA

- Type of U.S. Certificate(s) Held:

Air Carrier Operating Certificate(s): Flag Carrier/Domestic

Operating Certificate:

Operator Certificate:

Regulation Flight Conducted Under: Part 121: Air Carrier

Type of Flight Operation Conducted: Scheduled; Domestic; Passenger Only

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First Pilot Information

Name	City	State	Date of Birth	Age
On File	On File	On File	On File	39

Sex: M | Seat Occupied: Left | Principal Profession: Civilian Pilot | Certificate Number: On File

Certificate(s): Airline Transport; Flight Instructor; Commercial; Private

Airplane Rating(s): Multi-engine Land; Single-engine Land

Rotorcraft/Glider/LTA: Glider

Instrument Rating(s): Airplane

Instructor Rating(s): Airplane Single-engine; Instrument Airplane

Type Rating/Endorsement for Accident/Incident Aircraft? Yes | Current Biennial Flight Review?

Medical Cert.: Class 1 | Medical Cert. Status: Valid Medical--no waivers/lim. | Date of Last Medical Exam: 07/1999

- Flight Time Matrix	All A/C	This Make and Model	Airplane Single Engine	Airplane Mult-Engine	Night	Instrument Actual	Instrument Simulated	Rotorcraft	Glider	Lighter Than Air
Total Time	13332	5022								
Pilot In Command(PIC)	5319	319								
Instructor										
Last 90 Days	138	138								
Last 30 Days	73	73								
Last 24 Hours	8	8								

Seatbelt Used? Yes | Shoulder Harness Used? Yes | Toxicology Performed? Yes | Second Pilot? Yes

Flight Plan/Itinerary

Type of Flight Plan Filed: IFR

Departure Point	State	Airport Identifier	Departure Time	Time Zone
ST. LOUIS	MO	STL	1044	CDT

Destination	State	Airport Identifier
Same as Accident/Incident Location		BNA

Type of Clearance: None

Type of Airspace: Class B

Weather Information

Source of Briefing: Company

Method of Briefing:

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Weather Information

WOF ID	Observation Time	Time Zone	WOF Elevation	WOF Distance From Accident Site	Direction From Accident Site
BNA	1140	CDT	599 Ft. MSL	0 NM	0 Deg. Mag.

Sky/Lowest Cloud Condition: Unknown 0 Ft. AGL

Condition of Light: Day

Lowest Ceiling: Broken 9000 Ft. AGL

Visibility: 10 SM

Altimeter: 29.00 "Hg

Temperature: 28 °C

Dew Point: 11 °C

Wind Direction: 30

Density Altitude: 2246 Ft.

Wind Speed: 10

Gusts:

Weather Condtions at Accident Site: Visual Conditions

Visibility (RVR): 0 Ft.

Visibility (RVV) 0 SM

Intensity of Precipitation: Unknown

Restrictions to Visibility: None

Type of Precipitation: None

Accident Information

Aircraft Damage: Minor

Aircraft Fire: None

Aircraft Explosion None

Classification: U.S. Registered/U.S. Soil

- Injury Summary Matrix	Fatal	Serious	Minor	None	TOTAL
First Pilot				1	1
Second Pilot				1	1
Student Pilot					
Flight Instructor					
Check Pilot					
Flight Engineer					
Cabin Attendants				3	3
Other Crew					
Passengers			3	38	41
- TOTAL ABOARD -			3	43	46
Other Ground	0	0	0		0
- GRAND TOTAL -	0	0	3	43	46

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Occurrence Type: Incident

Administrative Information

Investigator-In-Charge (IIC)

CARROL A. SMITH

Additional Persons Participating in This Accident/Incident Investigation:

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