National Transportation Safety Board
Aviation Incident Final Report

Location:	NASHVILLE, TN	**Incident Number:**	MIA99IA249
Date & Time:	09/09/1999, 1138 CDT	**Registration:**	N993Z
Aircraft:	Douglas DC-9-31	**Aircraft Damage:**	Minor
Defining Event:		**Injuries:**	3 Minor, 43 None
Flight Conducted Under:	Part 121: Air Carrier - Scheduled		

Analysis

The first officer failed to maintain the proper rate of descent (sink rate) resulting in a hard landing on touch down, and separation of the left main landing gear during landing rollout. The pilot-in-command stated he knew the first officer was not going to make a good landing. He did not take any corrective action other than informing the first officer initially to increase power. Examination of the left main landing gear assembly revealed a preexisting crack in the outer cylinder housing.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this incident to be:
A preexisting crack on the left main landing gear outer cylinder housing and the first officer's failure to maintain the proper rate of descent resulting in a hard landing on touchdown, and subsequent total failure and separation of the left main landing gear on landing rollout. Contributing to the accident was the pilot-in-commands improper supervision of the first officer during the approach phase of the landing.

Findings

Occurrence #1: HARD LANDING
Phase of Operation: LANDING - FLARE/TOUCHDOWN

Findings
1. LANDING GEAR - FAILURE,TOTAL
2. (C) PROPER DESCENT RATE - NOT MAINTAINED - OTHER CREWMEMBER
3. (C) LANDING GEAR - FRACTURED
4. (F) SUPERVISION - IMPROPER - PILOT IN COMMAND
5. LANDING GEAR - SEPARATION

Factual Information

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 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 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. 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 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 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.

Pilot Information

Certificate:	Airline Transport; Flight Instructor; Commercial; Private	**Age:**	39, Male
Airplane Rating(s):	Multi-engine Land; Single-engine Land	**Seat Occupied:**	Left
Other Aircraft Rating(s):	Glider	**Restraint Used:**	Seatbelt, Shoulder harness
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):	Airplane Single-engine; Instrument Airplane	**Toxicology Performed:**	Yes
Medical Certification:	Class 1 Valid Medical--no waivers/lim.	**Last Medical Exam:**	07/06/1999
Occupational Pilot:		**Last Flight Review or Equivalent:**	
Flight Time:	13332 hours (Total, all aircraft), 5022 hours (Total, this make and model), 5319 hours (Pilot In Command, all aircraft), 138 hours (Last 90 days, all aircraft), 73 hours (Last 30 days, all aircraft), 8 hours (Last 24 hours, all aircraft)		

Aircraft and Owner/Operator Information

Aircraft Manufacturer:	Douglas	**Registration:**	N993Z
Model/Series:	DC-9-31 DC-9-31	**Aircraft Category:**	Airplane
Year of Manufacture:		**Amateur Built:**	No
Airworthiness Certificate:	Transport	**Serial Number:**	47082
Landing Gear Type:	Retractable - Tricycle	**Seats:**	107
Date/Type of Last Inspection:	12/07/1998, Continuous Airworthiness	**Certified Max Gross Wt.:**	108000 lbs
Time Since Last Inspection:	1874 Hours	**Engines:**	2 Turbo Fan
Airframe Total Time:	11838 Hours	**Engine Manufacturer:**	P&W
ELT:	Not installed	**Engine Model/Series:**	JT8D-9A
Registered Owner:	1ST SECURITY BANK NA TRUSTEE	**Rated Power:**	14500 lbs
Operator:	TRANS WORLD AIRLINES INC.	**Air Carrier Operating Certificate:**	Flag carrier (121)
Operator Does Business As:		**Operator Designator Code:**	TWAA

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual Conditions	**Condition of Light:**	Day
Observation Facility, Elevation:	BNA, 599 ft msl	**Observation Time:**	1140 CDT
Distance from Accident Site:	0 Nautical Miles	**Direction from Accident Site:**	0°
Lowest Cloud Condition:	Unknown / 0 ft agl	**Temperature/Dew Point:**	28°C / 11°C
Lowest Ceiling:	Broken / 9000 ft agl	**Visibility**	10 Miles
Wind Speed/Gusts, Direction:	10 knots, 30°	**Visibility (RVR):**	0 ft
Altimeter Setting:	29 inches Hg	**Visibility (RVV):**	0 Miles
Precipitation and Obscuration:			
Departure Point:	ST. LOUIS, MO (STL)	**Type of Flight Plan Filed:**	IFR
Destination:	(BNA)	**Type of Clearance:**	None
Departure Time:	1044 CDT	**Type of Airspace:**	Class B

Airport Information

Airport:	NASHVILLE INTERNATIONAL (BNA)	**Runway Surface Type:**	Concrete
Airport Elevation:	599 ft	**Runway Surface Condition:**	Dry
Runway Used:	2L	**IFR Approach:**	None
Runway Length/Width:	7702 ft / 150 ft	**VFR Approach/Landing:**	Traffic Pattern

Wreckage and Impact Information

Crew Injuries:	5 None	**Aircraft Damage:**	Minor
Passenger Injuries:	3 Minor, 38 None	**Aircraft Fire:**	None
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	3 Minor, 43 None	**Latitude, Longitude:**	

Administrative Information

Investigator In Charge (IIC):	CARROL A SMITH	**Adopted Date:**	05/09/2001
Additional Participating Persons:	MILLARD C ROBERTS; NASHVILLE, TN ROBERT YOUNG; BRIDGETON, MO MICHAEL A CERENO; ST. CHARLES, MO		
Publish Date:			
Investigation Docket:	NTSB accident and incident dockets serve as permanent archival information for the NTSB's investigations. Dockets released prior to June 1, 2009 are publicly available from the NTSB's Record Management Division at pubinq@ntsb.gov, or at 800-877-6799. Dockets released after this date are available at http://dms.ntsb.gov/pubdms/.		

The National Transportation Safety Board (NTSB), established in 1967, is an independent federal agency mandated by Congress through the Independent Safety Board Act of 1974 to investigate transportation accidents, determine the probable causes of the accidents, issue safety recommendations, study transportation safety issues, and evaluate the safety effectiveness of government agencies involved in transportation. The NTSB makes public its actions and decisions through accident reports, safety studies, special investigation reports, safety recommendations, and statistical reviews.

The Independent Safety Board Act, as codified at 49 U.S.C. Section 1154(b), precludes the admission into evidence or use of any part of an NTSB report related to an incident or accident in a civil action for damages resulting from a matter mentioned in the report.