National Transportation Safety Board
Aviation Incident Final Report

Location:	CHARLOTTE, NC	**Incident Number:**	ATL94IA088
Date & Time:	05/01/1994, 1309 EDT	**Registration:**	N890US
Aircraft:	FOKKER F28 MK 0100	**Aircraft Damage:**	Minor
Defining Event:		**Injuries:**	94 None
Flight Conducted Under:	Part 121: Air Carrier - Scheduled		

Analysis

THE FLIGHTCREW REPORTED THAT WHILE EXTENDING THE LANDING GEAR, THE NOSE GEAR DID NOT INDICATE DOWN AND LOCKED. AFTER FURTHER ATTEMPTS TO LOWER THE NOSE GEAR WERE UNSUCCESSFUL, THE AIRCRAFT WAS LANDED WITH THE NOSE GEAR NOT DOWN AND LOCKED. INSPECTION REVEALED THAT THE NOSEWHEEL STEERING SYSTEM WAS INCORRECTLY RIGGED; THE NOSE GEAR WOULD NOT PROPERLY CENTER ITSELF, AND THE NOSEWHEEL STEERING CABLE TENSIONS WERE BELOW REQUIRED LIMITS. THIS RESULTED IN A SITUATION WHERE THE NOSE GEAR WOULD IMPINGE ON THE SIDE WALL OF THE GEAR WELL, PREVENTING EXTENSION. THE AIRCRAFT MANUFACTURER REPORTED THAT IT REQUIRED A COMBINATION OF NOSE GEAR MISRIGGING, WITH REDUCED CABLE TENSIONS, TO DUPLICATE THIS SCENARIO. ABOUT TWO WEEKS PRIOR TO THE INCIDENT, THE NOSEWHEEL STEERING CONTROL VALVE WAS REPLACED, WHICH WOULD HAVE REQUIRED A CHECK OF THE NOSE GEAR RIGGING.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this incident to be: THE IMPROPER RIGGING OF THE NOSE WHEEL STEERING SYSTEM BY COMPANY MAINTENANCE PERSONNEL.

Findings

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

Findings
1. (C) LANDING GEAR,STEERING SYSTEM - INCORRECT
2. (C) MAINTENANCE - IMPROPER - COMPANY MAINTENANCE PERSONNEL
3. LANDING GEAR,NOSE GEAR - JAMMED

Factual Information

HISTORY OF FLIGHT

On May 1, 1994, AT 1309 eastern daylight time, a Fokker F28 MK 100, N890US, landed without the nose landing gear extended at the Douglas International Airport, in Charlotte, North Carolina. Flight 323 was operated under the provisions of 14 CFR Part 121 by USAir, Inc., as a scheduled, domestic, passenger flight. The airline transport pilot and first officer, three flight attendants, and 89 passengers were not injured. There was minor damage to the airplane. Visual meteorological conditions existed at the time, and an instrument flight rules flight plan was filed for the flight to Charlotte. The flight originated in Detroit, Michigan at 1119.

The flight crew reported the following: This was the third day of the three-day trip sequence, and the first day in this particular aircraft (N890US). On the day of the incident, the only flights flown by them were a flight to Detroit, and the flight to Charlotte (the incident flight). They reported no minimum equipment list entries regarding the landing gear system. There was an entry from the previous flight crew which stated that the nose wheel steering would occasionally bind while in operation. The nose wheel steering performed normally during the flight to Detroit, and the flight crew was not aware of any maintenance being performed on the aircraft in Detroit. The ground, takeoff, and enroute portions of the incident flight were normal. Approaching Charlotte, the flight was cleared for a visual approach to runway 18R. At 2,000 to 1,700 feet above ground level (agl), the landing gear handle was lowered. At approximately 1,300 feet agl, the main gear "snapped" into position. The nose gear indicated an "in transit" condition. They performed a missed approach, climbed to a higher altitude, and set the autopilot on. They attempted to recycle the gear, and again observed the "in transit" light on the nose gear, with the nose gear indicating that it was not down and locked. The first officer read the checklist, as the captain flew the airplane. The alternate landing gear extension checklist was performed, and the nose gear still did not indicate down and locked. The partial gear checklist was read, and Air Traffic Control personnel informed them that the nose gear appeared to be up. The aircraft was landed on runway 18R, and an emergency evacuation was accomplished. The captain reported that the antiskid switch was on when the aircraft was landed.

PERSONNEL INFORMATION

Information on the captain is included in this report at the section titled "First Pilot Information." Information on the first officer is included in Supplement E, attached to this report.

AIRCRAFT INFORMATION

The nose wheel steering (NWS) system on this aircraft consists of the following main components (shown in figures 1, 2, and 3, attached to this report):

- The steering handwheel (tiller), which is connected to the rudder interface unit (IFU) through cables. - The rudder pedals, which are connected to the rudder IFU through a lever on the rudder torque tube and a push-pull rod. - The rudder IFU, which controls the NWS control unit through cables. - The NWS control unit, which operates the steering control valve when there is a difference between the selected and actual steering angles. - A nose wheel steering shut off valve which, when closed by the energized solenoid, prevents hydraulic

pressure and flow to the steering control valve, and thus prevents the nose gear turning tube from turning. - The steering control valve, which controls the steering motor, which in turn operates the nose landing gear (NLG) turning tube with the sliding member and nose wheels. - A position feedback cable, which controls the steering control valve via the nose wheel steering control unit, such that the steering motor stops operating when the nose wheels are in the selected position. - A centering mechanism, to center the NLG when the landing gear lever has been selected to the up position.

An input in the NWS system can be given by the tiller (up to 76 degrees either side). The steering input is supplied via the IFU to the NWS control unit. The tiller can override rudder pedal steering commands.

On the NWS control unit are the pulleys for the input cables (from the rudder IFU) and the position feedback cables (from the NLG turning tube). The pulley system controls the steering control valve through an idler bar. When there is a steering input, the idler bar starts to turn. When the idler bar moves, it gives an input to the steering control valve, which allows hydraulic pressure to the NLG steering motor. When the NLG starts to turn, the position feedback cables move pulleys A and B (which are connected to each other). As a result, the idler bar turns back to the neutral position. The steering control valve is back in the neutral position when the nose wheels are in the selected position.

The centering mechanism centers the NLG after a gear up selection, through the use of a centering cam and cam rollers (see figure 3). When the NLG moves during steering, the feedback input moves the cam. From the moment the landing gear lever is selected to the up position (pressure in the up lines), the centering actuator is pressurized, and extends, pushing the cam against the cam follower, through rollers. When the nose wheels are not in the centered position, the cam and follower are not aligned, and the cam contacts the rollers as the centering actuator is extended. This gives an input to the steering control valve. Because the NWS system is still pressurized, the NLG moves to the centered position during retraction. Hydraulic pressure in the up lines maintains the NLG in the retracted and centered position during flight. From the moment the landing gear lever is selected to the down position, (1) an electrical circuit energizes the nose wheel steering shut off valve solenoid, and thus depressurizes the NWS system, and (2) the hydraulic up lines and thus the centering actuator are depressurized, and the centering actuator is retracted by spring force. This causes the cam to disengage from the cam follower, and deactivates the centering mechanism. Via ground flight switches and a time delay relay, the nose wheel steering shut off valve solenoid remains energized, and thus the nose wheel steering system remains depressurized, until five seconds after touchdown.

The aircraft maintenance records revealed that on April 14, 1994, a leaking nosewheel steering control valve was found. The steering control valve was replaced on April 20, 1994, during scheduled maintenance. According to the Fokker 100 Aircraft Maintenance manual (Procedure 32-52-02, Steering Control Valve Removal/Installation), an operational test of the steering control valve (after replacement) includes two checks if the nose wheels return to the center position: the first after the hydraulic system is pressurized, and the second after the steering handwheel and thus the NLG has been turned left and right.

An inspection of the aircraft maintenance records revealed that an incorrect procedure number was entered after the steering control valve was replaced. Procedure number 32-52-01 (Steering Shut-off Valve Removal and Installation) was entered instead of procedure number

32-52-02. The mechanic who performed the work reported that although procedure number 32-52-01 was entered in the records, he used procedure number 32-52-02, the correct procedure. It was noted that procedure number 32-52-01 calls for a visual inspection of the nose wheel operation to the center position, and does not require the use of the rigging indicator tool, as does procedure number 32-52-02.

Two flights prior to the incident flight, the flight crew entered into the aircraft maintenance logbook that the nosewheel steering would occasionally bind, when turning. The corrective maintenance action was to lubricate the nose landing gear. During the post-incident investigation, it could not be determined which parts of the nose landing gear had been lubricated.

METEOROLOGICAL INFORMATION

Weather information for Charlotte, North Carolina (CLT) is included in this report at the section titled "Weather Information."

WRECKAGE AND IMPACT INFORMATION

The aircraft came to rest on runway 18R, with its nose on the runway, and the nose gear inside the wheel well. An examination of the runway revealed four parallel black skid marks, each about 115 feet in length, leading to the main gear tires. The main gear tires exhibited flat spots, consistent with skidding. The antiskid switch was found in the "on" position during the documentation of the cockpit.

An inspection of the runway surface revealed a 12 inch long, quarter inch drive ratchet extension in the middle of the runway, about 100 feet north of the main tire skid marks. No witness marks were found on the extension, other than light scraping signatures, consistent with runway surface scraping. An examination of the NLG wheel well did not reveal positive evidence of the tool having been wedged in the well. The origin of the extension was not determined.

During the investigation, a kink was found in the lower feedback cable of the nose wheel steering system. The function of the cable is described in the "Aircraft Information" section of this narrative. The origin of the kink was not positively determined.

The aircraft lower, forward fuselage, (NLG) wheel well, and NLG doors were damaged from scraping contact with the runway surface. Portions of the NLG doors and door hold-open rods were found inside the wheel well. The left NLG door casting (at the end of the hold-open rod) exhibited runway scraping at two different angles. One angle was consistent with the door full open position, and the other was indicative of a partially opened position.

The nose of the aircraft was lifted from the runway surface with air bags. As the nose was raised from the runway, the NLG emerged freely from the wheel well, and extended to the down and locked position. The aircraft was then towed to the USAir heavy maintenance hangar for subsequent examination.

TESTS AND RESEARCH

During the evening of May 1, 1994, the aircraft was put on jacks so that an examination of the landing gear system could be performed. With the aircraft on jacks, and with all three landing gear down and locked, the nose landing gear was manually turned to the left. When a landing gear up selection was made, the NLG centered, and retracted normally. A landing gear down

selection was made, and the landing gear extended and locked normally.

With the landing gear down, the nose gear was then manually turned to the right. The landing gear lever was then selected to the up position, and the nose gear retracted, but did not fully center. This put the nose gear in the wheel well, in a cocked position. A mechanic was able to push the nose gear into a position that would allow the nose gear to hang up on the wheel well wall structure, and not extend out of the nose wheel well after landing gear down selection. It was also observed that steering of the nose wheel was possible with the nose gear in the retracted position.

A preliminary survey of the landing gear system revealed that the NWS cable tensions appeared to be low. The cable tensions were measured. The input cable tensions were 12 pounds each. The tensions of the upper and lower feedback cables were 10 and 9 pounds, respectively. The correct value of the cable tensions should have been 27 to 31 pounds.

Several actions were performed on the aircraft after the NWS cable tensions were read. A test was performed to determine if the nose gear would center if the gear was selected to the up position. The NLG was jacked, and the downlock pin was installed. When the nose gear was moved to the left (gear down, full left rudder pedal input), the nose landing gear turned to the left, 4 degrees. When the gear handle was raised, the nose gear centered. The same action was again performed, this time to the right. When full right rudder pedal was input, the nose gear turned 14 degrees to the right. When the gear handle was raised, the gear went to a 6 degrees right-of-center position. The nose gear should have centered at the neutral (zero degree) position.

Another test was performed to determine if the nose gear remained centered with the gear in the up position. The gear system is designed so that after selecting the landing gear lever to the up position, hydraulic pressure becomes and remains available for extension of the centering actuator (via the up lines). Hydraulic pressure also remains available for the NWS system (to center the NLG). This implies that the use of the rudder pedals will result in nose gear deflections if the pressurized centering actuator is overpowered. Subtask 32-51-00-830-065-A00 of the Fokker 100 AMM gives a 1.5 degree limit with full left or right rudder. On the incident aircraft, activation of the NWS with the rudder pedals (nose gear in the retracted position, low cable tensions) showed that the nose gear could be turned considerably. Further manipulation of the controls showed that considerable rudder pedal input during a landing gear down selection with low cable tensions for the NWS system and the already off-center NLG could result in a situation where the nose gear would impinge on the side of the gear well, preventing extension.

The steering centering actuator and steering control valve were replaced, it that order, to determine if those components affected the performance of the nose gear or nose wheel steering. The replacement of these components did not correct the off center nose gear position.

Finally, the steering input and feedback cables were properly tensioned, and rigged according to the Fokker 100 Aircraft Maintenance Manual task 32-51-00-830-815-A, and the steering control valve involved in the incident, which had been replaced during the post-incident investigation, was reinstalled. The correct rigging of the NWS cables corrected the nose gear off center position within limits, and the correct cable tensions considerably reduced the nose gear deflections when using the rudder pedals with the nose gear retracted.

Following the on-site investigation of this incident, Fokker Aircraft initiated testing to determine the effects of reduced cable tensions on nose wheel operation. They determined that low cable tensions alone would not result in a condition where the nose landing gear would hang up in the wheel well. Their test data indicates that a combination of a misrigged nose wheel, and low cable tensions, result in the proper deflection required to hang up the nose wheel (plus or minus 4.25 degrees).

Pilot Information

Certificate:	Airline Transport; Flight Instructor; Commercial; Flight Engineer	**Age:**	41, Female
Airplane Rating(s):	Multi-engine Land; Single-engine Land	**Seat Occupied:**	Left
Other Aircraft Rating(s):	None	**Restraint Used:**	Seatbelt, Shoulder harness
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):	Airplane Single-engine	**Toxicology Performed:**	No
Medical Certification:	Class 1 Valid Medical--w/ waivers/lim.	**Last FAA Medical Exam:**	11/09/1993
Occupational Pilot:		**Last Flight Review or Equivalent:**	
Flight Time:	9000 hours (Total, all aircraft), 1000 hours (Total, this make and model)		

Aircraft and Owner/Operator Information

Aircraft Make:	FOKKER	**Registration:**	N890US
Model/Series:	F28 MK 0100 F28 MK 010	**Aircraft Category:**	Airplane
Year of Manufacture:		**Amateur Built:**	No
Airworthiness Certificate:	Transport	**Serial Number:**	11365
Landing Gear Type:	Retractable - Tricycle	**Seats:**	100
Date/Type of Last Inspection:	04/29/1994, AAIP	**Certified Max Gross Wt.:**	95000 lbs
Time Since Last Inspection:	10 Hours	**Engines:**	2 Turbo Fan
Airframe Total Time:	5845 Hours	**Engine Manufacturer:**	Rolls-Royce
ELT:	Not installed	**Engine Model/Series:**	TAY MK650-15
Registered Owner:	USAIR, INC.	**Rated Power:**	15100 lbs
Operator:	USAIR, INC.	**Operating Certificate(s) Held:**	Flag carrier (121)
Operator Does Business As:		**Operator Designator Code:**	USAA

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual Conditions	**Condition of Light:**	Day
Observation Facility, Elevation:	CLT, 749 ft msl	**Distance from Accident Site:**	0 Nautical Miles
Observation Time:	1250 EDT	**Direction from Accident Site:**	0°
Lowest Cloud Condition:	Scattered / 6500 ft agl	**Visibility**	25 Miles
Lowest Ceiling:	None / 0 ft agl	**Visibility (RVR):**	0 ft
Wind Speed/Gusts:	12 knots /	**Turbulence Type Forecast/Actual:**	/
Wind Direction:	240°	**Turbulence Severity Forecast/Actual:**	/
Altimeter Setting:	29 inches Hg	**Temperature/Dew Point:**	28°C / 13°C
Precipitation and Obscuration:			
Departure Point:	DETROIT, MI (DTW)	**Type of Flight Plan Filed:**	IFR
Destination:	, NC (CLT)	**Type of Clearance:**	IFR
Departure Time:	1119 EDT	**Type of Airspace:**	Class E

Airport Information

Airport:	DOUGLAS INTERNATIONAL (CLT)	**Runway Surface Type:**	Concrete
Airport Elevation:	749 ft	**Runway Surface Condition:**	Dry
Runway Used:	18R	**IFR Approach:**	Visual
Runway Length/Width:	10000 ft / 150 ft	**VFR Approach/Landing:**	None

Wreckage and Impact Information

Crew Injuries:	5 None	**Aircraft Damage:**	Minor
Passenger Injuries:	89 None	**Aircraft Fire:**	None
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	94 None	**Latitude, Longitude:**	

Administrative Information

Investigator In Charge (IIC):	RALPH E HICKS,	**Report Date:**	04/27/1995
Additional Participating Persons:	DONALD E GARDNER; CHARLOTTE, NC PETER W VAN WARMERDAM; CORAPOLIS, PA FRANK HILLDRUP; WASHINGTON, DC RONALD P ROBSON; CHARLOTTE, NC		
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/.		

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