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NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

**MASSEY-FERGUSON, INC.,
GATES LEARJET 25D, N137GL
DETROIT, MICHIGAN
JANUARY 19, 1979**

NTSB-AAR-80-4

UNITED STATES GOVERNMENT

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16. Abstract

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During the descent, the aircraft flew in light to moderate, occasionally severe icing conditions. Shortly before the Learjet was to land, a McDonnell-Douglas DC-9 was cleared for takeoff. Witnesses saw the Learjet cross the threshold in a normal landing attitude and seconds later roll violently. The airplane was in a steep right bank when the wing tip tank struck the runway 2,640 ft from the threshold and the airplane burst into flames. The two pilots and four passengers were killed.

The National Transportation Safety Board determines that the probable cause of the accident was the pilot's loss of control. The loss of control may have been caused by wake turbulence of a departing aircraft, by a premature stall caused by an accumulation of wing ice, by a delayed application of engine thrust during an attempted go-around, or by any combination of these factors.

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SYNOPSIS

On January 19, 1979, at 1934 eastern standard time, a Learjet Model 25D (N137GL) crashed while landing on runway 9 at Detroit Metropolitan Wayne County Airport, Detroit, Michigan. The airplane was returning executives of Massey-Ferguson, Inc., to South Bend, Indiana, Detroit, Michigan, and Toronto, Canada, following a meeting at the company's headquarters in Des Moines, Iowa.

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1. FACTUAL INFORMATION

1.1 History of the Flight

On January 19, 1979, a Gates Learjet modified model 25D aircraft (N137GL) was being operated privately under 14 CFR 91 between Des Moines, Iowa, and Toronto, Canada, with stops at South Bend, Indiana, and Detroit, Michigan. The aircraft was leased and operated by Massey-Ferguson, Inc., Des Moines, Iowa, to provide corporate transportation. At the time of the accident, five company employees were returning from an executive meeting to their respective domiciles. About 1535 c.s.t., 1/ the pilot of the Learjet was briefed by Federal Aviation Administration (FAA) personnel at the Des Moines Flight Service Station (DSMFSS) on the current and forecast weather along his proposed route of flight. He was also informed of a significant meteorological information advisory (SIGMET) which pertained to the presence of frequent moderate to severe mixed or clear icing in clouds and precipitation in his intended flight area. He was further provided with pilot reports (PIREPS) which described the height of cloud tops and icing conditions at Fort Wayne, Indiana, and Chicago, Illinois. The pilot then filed three instrument flight rule (IFR) plans, one for each segment of his route of flight.

The Learjet departed Des Moines about 1657 with five passengers and a crew of two. The flight to the South Bend airport was routine. At South Bend, the aircraft remained on the ground about 15 minutes while a passenger deplaned. At 1803, the aircraft departed for Detroit Metropolitan Wayne County Airport, Detroit, Michigan. The Learjet climbed and maintained cruise flight at 19,000 ft until cleared at 1811:14 to descend to 12,000 ft by the Cleveland Air Route Traffic Control Center. At 1815:13, the pilot acknowledged the en route controller's request to slow the aircraft to 225 kns (indicated air speed) and to continue the descent to 8,000 ft. About 1 minute later, the controller requested the flight to reduce speed further to 220 kns. At 1819, the flight was cleared to contact Detroit approach control; 2 minutes later, while being radar vectored by the Detroit approach controller for a VOR instrument approach to runway 9, the Learjet was cleared to descend and to maintain 4,000 ft. Three minutes later, the flight acknowledged a request to reduce airspeed to 180 kns and, at 1825:51, the approach controller informed the pilot that his aircraft was 10 mi west of the Willow Run VOR, the final approach fix. From that position, the Learjet was cleared for the instrument approach and instructed to maintain 2,500 ft until reaching the VOR station. At 1826:38, while the aircraft was slowing to the requested 160 kns, the flight reported descending through 4,000 ft for 2,500 ft.

At 1830:23, the Learjet reported to the Detroit tower local controller that the flight was inbound over the VOR station. The flight was then informed that it was following North Central Flight 704, a McDonnell-Douglas DC-9, which was 3 miles from runway 9. The Learjet responded that the landing traffic was in sight. At 1832:30, the local controller told the Learjet that another aircraft, Delta Airlines Flight 713, would be cleared for takeoff before the Learjet could land. The controller remarked that the taxiway was slippery where the departing aircraft was entering the runway, but that the separation between the aircraft would be adequate. Upon request, the Learjet flightcrew was told that the departing traffic was a Douglas DC-9 and the local controller remarked the aircraft would "... be airborne before you cross the threshold." The Learjet pilot also was told that the wind velocity was 110° at 12 kns and that runway braking was good. At 1834:08, the Learjet acknowledged the local controller's transmission.

1/Unless noted otherwise, all times herein are eastern standard time, based on the 24-hour clock.

About 1834:40, the Learjet crashed on runway 9. Several witnesses watched the aircraft on its approach to runway 9. A tower controller stated that he first saw the accident aircraft when it was 4 to 5 mi from the runway. He recalled that when the aircraft was about 2 mi from the runway, its groundspeed, as depicted on tower radar, was 100 to 120 kns. He observed the aircraft at a height of 75 to 100 ft as it crossed the runway threshold in a normal, but slightly nose-high, approach descent attitude. The controller had expected the Learjet to land abeam of the VASI lights. Seconds later, his attention was drawn to a brilliant flash and he saw the landing aircraft sliding in flames along the runway. He estimated that the ground fire started just west of the VASI lights and that the burning aircraft continued to slide to a point about 2,600 ft from the threshold.

Another tower controller stated that he saw the aircraft nearing the threshold. The aircraft appeared stabilized at normal heights and it entered a normal flare. Almost immediately, he was aware of a ball of fire on the runway, and he initiated the crash notification.

A police officer, who was seated in the terminal building, recalled that he first saw the Learjet shortly after it crossed the runway threshold at a height of 75 to 100 ft. The aircraft's flightpath appeared to be normal until it suddenly and rapidly began four roll oscillations. The rolling maneuvers began as the left wing dropped and ended with a barrel-type roll to the right. As the aircraft rolled to the right, the officer lost sight of it behind a terminal building. He believed the roll angles may have been as high as 60°. An explosion and fire followed immediately.

A fireman at the airport fire station, which is located near the approach end of runway 9, stated that he saw the accident aircraft pass over the first part of the runway in normal flight. The aircraft was several feet off the ground when it passed from his view. When the aircraft was just out of sight, he heard a sudden increase in engine thrust, followed closely by an explosion.

North Central Flight 704, which had landed in front of the accident aircraft, was taxiing westbound on the runway 9 parallel taxiway as the Learjet approached the runway threshold. The pilots of the North Central flight had an unobstructed view of the Learjet's flightpath. The first officer observed the erratic movement of the aircraft's landing lights as the aircraft made three vertical rolls from side to side. The pilots believed that the last two rolls may have exceeded 90° of bank. During the rolling maneuvers, the aircraft appeared to have been descending on a normal glidepath. The captain believed that the aircraft was accelerating when the first rolling motion began. No unusual pitch attitudes were noticed. At the end of the third roll, the aircraft appeared to hit the ground with the right wing and nose. A fireball erupted instantly.

The accident occurred during hours of darkness. The location was 42°13'00" N and 83"21'30" W at an elevation of 639 ft m.s.l.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Others
Fatal	2	4	0
Serious	0	0	0
Minor/None	0	0	0

1.3 Damage to Aircraft

The aircraft was destroyed by impact forces and postcrash fire.

1.4 Other Damage

The runway surface was damaged slightly.

1.5 Personnel Information

The flightcrew were certificated and qualified for the flight. The pilot obtained his Learjet type-rating on December 7, 1977, and the copilot obtained his Learjet type rating on April 23, 1974. Each pilot held a current first-class medical certificate with no limitations. (See appendix B.)

1.6 Aircraft Information

The Gates Learjet Model 25D, registration N137GL, was issued a standard airworthiness certificate on February 9, 1978, at Wichita, Kansas. On February 10, 1978, it was flown to the company's facilities at Tucson, Arizona, where "Century III" performance improvement modifications were made. These modifications were designed to improve the slow-speed performance of the airplane and to permit flight operation on shorter runways.

A review of the maintenance records and aircraft logbook disclosed no uncorrected aircraft discrepancies. However, a postaccident interview with the company chief of maintenance revealed that the copilot's barometric altimeter was sticking at 40,000 ft and the pilot's airspeed indicator knob for setting the speed reference was jammed.

The maximum certificated takeoff and landing gross weights of the Learjet 25D were 15,000 lbs and 13,300 lbs, respectively. The 15,000-lb c.g. envelope was 17 to 30 percent mean aerodynamic chord (MAC). At an operating weight of 11,750 lbs, the c.g. range was 11 to 30 percent MAC.

The aircraft departure weight at Des Moines was estimated to have been 15,042 lbs and the c.g. was about 20.9 percent MAC. Fuel distribution on landing at Detroit was estimated to be 1,659 lbs in the wing tanks and 500 lbs in the fuselage tank. There was no fuel in the wingtip tanks. The landing weight was about 11,750 lbs, with 19.8 percent MAC.

1.7 Meteorological Information

SIGMET ALPHA 5, Chicago, issued at 1440 c.s.t., January 19, and valid from 1440 c.s.t. to 1840 c.s.t. on January 19, was as follows:

"Flight precautions over southern Minnesota, northern Wisconsin, and east central Illinois, southern Lake Michigan, southwestern lower Minnesota, northern and central Indiana, northern Kentucky, for frequent moderate occasional severe mixed or clear icing in clouds and precipitation. Conditions moving slowly northeastward. Continue advisory beyond 1840."

Forecast weather

South Bend 1722 c.s.t.: Ceiling — 600 ft overcast; visibility — 2 mi, fog; wind 140° at 15 kns; occasional ceiling — zero ft obscured; visibility —zero -- light drizzle, fog.

Detroit 1722: Ceiling — 2,500 ft broken, 3,000 ft overcast; wind 110° at 15 kns; occasional ceiling — 1,000 ft overcast; visibility -- 2 mi — light snow; chance of ceiling — 400 ft overcast; visibility — 1 mi light freezing drizzle, fog.

Detroit 1950: Measured ceiling — 2,100 ft overcast; visibility — 10 mi; temperature -- 20° F; dewpoint — 15° F; wind 090° at 8 kns; altimeter -- 29.94 inHg.

The surface weather observations and forecast weather for the route of flight were, in part, as follows:

Surface weather

South Bend 1656 c.s.t.: Measured ceiling 600 ft overcast; visibility -- 1 1/2 mi — light freezing drizzle, fog; temperature — 25° F; dewpoint 23° F; wind 140° at 12 kns; altimeter — 29.82 inHg.

Detroit 1848: Measured ceiling — 2,300 ft overcast; visibility — 12 mi; temperature — 19° F; dewpoint — 13° F; wind 100° at 15 kns; altimeter -- 29.94 inHg.

Detroit 1950: Record Special — Measured ceiling 1,700 ft overcast; visibility — 10 mi; temperature — 21° F; dewpoint--15° F; wind 090° at 8 kns; altimeter — 29.94 inHg.

Pilot Reports

1519: Over Fort Wayne; flight level 9,000 ft; Piper Seneca; sky overcast tops 6,500 ft, 7,500 ft thin overcast above with top at 8,000 ft; cirrus above; temperature 32° F at 4,000 ft, 34° F at 5,000 ft; 34° F at 6,000 ft; 32° F at 7,000 ft; light mixed icing until 7,000 ft.

1539: Over Chicago; flight level — unknown; Boeing 727; sky overcast [illegible],000 ft; severe rime, surface to 5,500 ft during climb eastbound.

Upper Air Soundings

At 1900, a radiosonde observation was taken at Flint, Michigan. This observation of the upper air would have been representative of the air in the vicinity of Detroit at the time of the accident. The sounding disclosed that cloud tops were about 10,000 ft m.s.l. and cloud bases were about 2,400 ft m.s.l. Freezing temperatures were evident below 8,000 ft. A temperature inversion existed between 2,030 ft and 8,000 ft. At higher altitudes, the temperatures continued to decline below freezing. It was estimated that the liquid water content of the air from the surface to about 2,400 ft m.s.l. was .01 grams per cubic meter of air. From 2,400 ft m.s.l. to about 8,000 ft m.s.l., about 0.7 grams of water per cubic meter of air was present.

1.8 Aids to Navigation

Runway 9 is provided with a VOR instrument approach procedure. The inbound crossing altitude at the Willow Run VOR, the final approach fix, was 2,500 ft m.s.l. and the distance on the 103° magnetic heading from the final fix to the missed approach point was 7.3 nmi. The landing minimum for a straight-in approach was 1,040 ft m.s.l. and 1 mi visibility. Elevation of the touchdown zone was 639 ft m.s.l.

On January 22, the FAA conducted a flight inspection of the VOR approach to runway 9; inspection disclosed satisfactory operation of the navigational equipment.

1.9 Communications

There were no known communication difficulties.

1.10 Aerodrome Information

The Detroit Metropolitan Wayne County Airport is located 17 mi west-southwest of the city of Detroit. The airport, which is surrounded by level terrain, is equipped with four runways. Three runways, designated 3/21, parallel each other; two are 10,000 ft long and the third is 8,500 ft long. Runway 3L/21R is equipped with an instrument landing system (ILS). Runway 9/27 is 200 ft wide and 8,700 ft long. This runway is equipped with high-intensity runway lights (HIRL), runway end identifier lights (REIL), and two Visual Approach Slope indicators (VASI) light systems, which are available for landings in either direction. At the time of the accident, all runway lighting systems were operating normally.

A notice to airmen (NOTAM) issued at 1430 on the day of the accident stated that the first 4,500 ft of runway 9 was covered with 1/2 inch of compacted snow and ice. The remainder of the runway was uncovered, and aircraft braking reported to be excellent. The airport operations log disclosed that the runway condition remained unchanged at the time of the accident. The NOTAM was available to the pilots before departure from Des Moines.

1.11 Flight Recorders

The airplane was not equipped with a flight data recorder or a cockpit voice recorder, nor was either required by regulation.

1.12 Wreckage and Impact Information

The first sign of ground impact marks was located on the runway 2,640 ft from the threshold and 30 ft to the left of the runway centerline. The impact site was characterized by diagonal gouges in the runway, broken pieces of glass, and a fan-shaped soot pattern oriented at a 20° angle to the right of the runway magnetic heading. Pieces of the right wing navigation light were found imbedded in the gouges; several wing vortex generators were found in the immediate area.

Except for the fuselage and a portion of the left tip tank, wreckage debris was confined on a 455-ft area of the runway. The wings separated as a single unit from the fuselage by tearing out the keel beam. The right flap, right tip tank, and forward portions of the left tip tank separated from the wings. The leading edges of the wings were crushed. The right aileron was crushed from the outboard edge to the balance tab push rod attachment fittings. The left aileron was intact but jammed in the up position.

Investigation disclosed that the main landing gear was fully extended and locked, the wing flaps were positioned at 40°, and the spoilers were retracted and locked.

Scratch marks were found on the underside of the left wingtip tank, which remained attached to the wing. Elliptical marks were located on the aft tank body and fin. The fin was bent upward.

Geometric calculations of the tip tank scratch marks revealed that the tank struck the ground while the airplane was airborne in a 19° left roll, and a 3° noseup and 7° right yaw attitude. No impact marks on the ground could be associated with the left tip tank.

The fuselage, with empennage attached, came to rest on its left side. The nose gear was extended. The aft portion of the fuselage was partially separated between fuselage frames near the baggage compartment. The aft pressure bulkhead was dislodged at the bottom of the fuselage. The empennage was twisted upright, and both outboard portions of the horizontal stabilizer were damaged by impact forces.

The right side of the fuselage exhibited the brunt of impact forces and postcrash fire consumed the major portion of the passenger cabin. The lower half of the fuselage was destroyed by fire. The fuselage fuel tank was ruptured and the tank and the surrounding fuselage structure were destroyed by fire. The dorsal fin and the vertical stabilizer were lightly sooted.

The right engine was broken loose from the fuselage at the pylon attachment. The compressor inlet case was crushed, the inlet guide vanes were damaged, and the rotor blades exhibited extensive rotational damage as well as leading and trailing edge damage. Some of the blades were broken at the root platforms, and others were broken at the airfoil sections.

The left engine remained attached to the pylon and was intact. The thrust reverser buckets of both engines were stowed. The cockpit control columns were intact and rotated counterclockwise to the stops. One wheel could be rotated and the control system forward of the burned fuselage area functioned properly. The fuselage cables were separated at the wing keel beam sector. The aileron sector was damaged and pulled forward and outboard to the left. The wing cable pulleys attached to the underwing keel beam were damaged. The aileron trim tab actuator was intact.

The pilot's rudder pedals were intact with the left pedal full forward. Although this position corresponded to the position of the copilot's rudder pedals, the copilot's rudder pedals were jammed because of impact damage to the right side of the fuselage. The carpeting and scuff plates under the rudder pedals were securely fastened. There was no evidence of the crew's shoes having become jammed by these furnishings. Control cable continuity was established in the rudder control system. The rudder trim tab actuator was intact.

Both engine power levers were in the full forward thrust position. The reverser arming switches were in the ARM position.

The electrical trim actuator for the horizontal stabilizer had been damaged by impact. Measurement of the actuator disclosed that the stabilizer was in a -4.9° to -5.4° leading edge down, or noseup, trim position.

The electrical pitch and roll servos were found intact. The primary and secondary yaw servos were also intact. The yaw damper switch was OFF, the primary yaw damper was selected, and the secondary yaw damper indicator showed a neutral position.

All anti-ice panel switches were operable. The selector positions were:

Windshield/radome alcohol - OFF
Windshield heat - OFF/MAN
Stabilizer and Wing heat - OFF
Nacelle heat (LH and RH) - OFF
Pitot heat LH - ON
Pitot heat RH - OFF

1.13 Medical and Pathological Information

Postmortem examinations showed that both crewmembers died as a result of similar multiple traumatic injuries. Both sustained a tearing of the ascending thoracic aorta. Both incurred severe head lacerations and burns to the head and neck. Toxicological specimens from the crewmembers disclosed negative alcohol and drug findings. Tests for carbon monoxide showed an 8 percent saturation in blood containing 21.0 percent gm hemoglobin for the pilot and 2 percent in blood containing 19.4 percent gm hemoglobin for the copilot. These findings indicate that smoke was not a causal factor.

The passengers sustained varied injuries but all died as a result of multiple impact trauma and thermal effects. The passengers showed negative carbon monoxide findings.

1.14 Fire

Four vehicles and seven firefighters responded to the crash notification alarm. Equipment arrived at the accident site within 2 minutes of the alarm. On arrival, three prominent fires were occurring. Initial firefighting efforts were directed to extinguishing the fire within the fuselage. The fire was extinguished after 440 gallons of 6 percent light water were applied.

1.15 Survival Aspects

Initially, firemen did not know the type of airplane involved. They believed it was either a military or civil cargo airplane and they did not know if passengers were aboard. Rescue personnel responded first by extracting the flightcrew. Access was gained to the cockpit through the copilot's windshield by the use of fire axes and a circular carbide bladed power saw. About 1 hour later, all occupants had been removed from the wreckage.

The interior of the forward passenger cabin was heavily sooted. The carpeting, upholstery and interior furnishings of the rear cabin had extensive fire damage. The cabin windows were melted. The fuselage fuel tank, which was estimated to contain 500 lbs of fuel, had ruptured upon impact and fuel spilled into the cabin through the separated aft pressure bulkhead.

The crew seats, which were furnished with seatbelts and inertial reel shoulder harnesses, remained in place. The seatbelts and shoulder harnesses of both crewmembers were fastened. The passengers occupied the four rear cabin seats; the back seat was a double occupancy divan. Only one passenger seatbelt was confirmed to be fastened; however, this single seat had separated from the floor structure. The accident was not survivable.

1.16 Tests and Research

1.16.1 Aircraft Performance

As a result of similarities in the preimpact flightpaths of other Learjet Model 25 aircraft, the Safety Board conducted a study of selected low-speed handling characteristics of the Learjet. The study disclosed that sufficient data are not available to evaluate the dynamic stability and flight handling characteristics of the Century III Learjet in the low-speed regimes of flight and that there were insufficient data available to assess the long-term accuracy of the stall warning system to insure compliance with Lear Special Condition CAR 3.120 or with FAA Order 8110.6. The study also disclosed that there are not sufficient data to permit a meaningful assessment of the adequacy of the anti-ice systems. Therefore, the Safety Board conducted flight tests to investigate the performance aspects of stall characteristics, stall warning system operation, low-speed handling qualities in landing, go-around and, to some extent, takeoff, and the effect of ice on these stall and low-speed handling qualities.

The accident aircraft was modified with the Gates Learjet Century III performance kit, which incorporates an increase in the radius of the leading edge forward of the 6 percent chord station. This change to the leading edge delays the stall of the wing by several knots. Also, a strake 2/ was added at the juncture of the wingtip and the tiptank to improve the effectiveness of the aileron.

Because of the stall characteristics of the early Learjet models and all Century III Learjet models, FAA certification requires that a stickshaker and a stickpusher activate before the actual stall to prevent further loss of airspeed and uncontrollable rolling of the wings. The Century III modification added an electronic computer circuit to the stall warning system that uses the rate of change of the angle-of-attack sensor vane to automatically raise the stall warning stickshaker/pusher speeds to compensate for accelerated entry to the stall. This circuit, called the alpha dot system, permitted the stickpusher activation speed to be set within 1 knot of the stall speed and wing rolloff of the aircraft in unaccelerated flight. Theoretically, the computer raises the stickshaker/pusher speeds at about the same rate that the stall speed increases under accelerated stall conditions.

The Century III stall warning system is adjusted during production so that the stickpusher activates at the stall speed listed on the Airplane Flight Manual (AFM) stall speed chart for the gross weight at which the stickpusher acceptance test is conducted. If the stickpusher activates at the scheduled speed or can be adjusted to activate at the scheduled speed without wing rolloff and the stickshaker activates at 1.07 V_s, the system is accepted.

The characteristics and speeds of a 1-"g" stall were investigated in landing configuration using 1 kn/sec and 3 kn/sec entry rates with idle power and 85 percent engine rpm. In addition, stall characteristics and speeds were checked in clean, 8° and 40° flap settings with landing gear extended. Scheduled stall stickpusher speeds were achieved within 1/2 kn in all configurations; except at 8° flaps, rolloff occurred simultaneously with stickpusher actuation, activating 3 to 4 kns higher than scheduled speeds.

2/ A large cambered fairing.

Small sideslips had no apparent effect on stickshaker/pusher actuation in the landing configuration. The effect of turbulence on stabilization during the approach descent flightpath could not be evaluated since only light turbulence existed during the flight tests.

1.16.2 Anti-ice Systems

Considerable FAA and manufacturer effort was expended during the original development of the heated leading edge on the Learjet wings. As in most recent certifications, the majority of the date available is analytical. On all of the airplanes certified, a specific minimum power setting is required to get effective wing anti-ice. Even with this minimum power setting, the outermost portions of the Learjet 25 wings are susceptible to ice accumulation in the extreme corners of the icing envelope set forth in 14 CFR 25. For this reason, Gates Learjet and the FAA have flown test aircraft with large abnormal ice shapes or natural icing that simulated inadvertent icing of the heated portion of the wings. During the investigation, Gates Learjet provided information from a Century III Learjet Model 35 operator who experienced a very hard landing. A postflight inspection revealed a very small amount of ice accumulation on the wing's leading edges. The pilot had not used wing anti-ice during his descent.

Ice shapes constructed to simulate the ice observed by the Gates Learjet customer were flown on February 26 and 27, 1979, on Learjet 25B-076, N711CA. The shapes were applied symmetrically to both wings and extended about 9 ft inboard from the tip tanks, were 1/8- to 1/4-inch thick at the stagnation point, and tapered to zero thickness about 1 inch from each side of the stagnation point. With these shapes installed, aerodynamic rolloff always started before stickshaker/pusher actuation. In a landing configuration at representative gross weights and c.g. positions, the rolloff began 10 to 12 knots above the target stickpusher speed at 1 kn per second to 3 kns per second entry rates and at idle to 85 percent power. At heavy weights, the rolloff was difficult to control. At light weights, rolloff was easily controllable and the stickpusher activated. With an 8° flap setting, similar characteristics were noted; however, rolloff began as high as 15 to 17 knots above the target stickpusher speed, near the normal V_R and V_2 speeds for the clean-wing airplane.

Two additional flights were conducted simulating asymmetric leading edge ice (or protuberances), first using a 9-ft rod with a 3/16-inch diameter and then using a 9-ft rod with a 1/16-inch diameter taped to the left leading edge. Rolloff started at almost exactly the same speeds for these devices as it did for the symmetrical shapes. However, a left uncontrollable rolling tendency was experienced with the asymmetric installations. In a final flight, a 9-ft rod with a 1/16-inch diameter was taped symmetrically to both wings at the stagnation point. The stall speeds and rolloff characteristics were nearly identical to those experienced on the earlier flight in which the simulated ice shapes were installed. These tests appear to indicate that a very small amount of ice or foreign matter on the wing leading edge (other than immediately in front of the ailerons) can possibly negate the entire stall warning system (stickshaker/pusher). Flares from high sink rates in the landing configuration produced abrupt left wing drops during the flare.

In normal, wings-level landing approaches with no simulated wing ice, no abnormalities were observed in the low-speed handling characteristics from Vref to pusher actuation. Simulated go-arounds were executed and the airplane was easily controllable in both roll and pitch axes. In an effort to reenact the accident, attempts were made to induce a stall in simulated go-around situations. Attempted go-arounds were started from a 600-ft-per-minute rate of descent, 20° left bank, and 1/2 to 1 ball width left sideslip. Go-arounds were simulated at altitudes of 5,000 to 9,000 ft by simultaneously applying takeoff power, applying aft elevator control to prevent contact with the simulated "ground-plane", and applying full opposite aileron control in an attempt to level the airplane. On go-around attempts at speeds within the stickshaker range, the downgoing wing was observed to stall and induce roll angles nearing vertical. On some occasions, the stickpusher would actuate; however, on other occasions the stickpusher would not actuate. Just before the wing dropped, the airplane missed-approach response was excellent, but after the first indication of a wing stall, a climb was not possible without a loss of 100 ft of altitude while the air flow was reattaching to the wing surface.

After the wing began to drop, the lateral control was not effective. The roll could be reversed with aileron and rudder but so slowly that 500 ft of altitude was lost for the first reversal. There was no tendency for the airplane to reverse roll rate abruptly after the stall. During rapid rolls at speeds just above the wing-drop speed, the downgoing wing stalled and dropped rapidly, but only with a large altitude loss and with no tendency to reverse.

The roll control characteristics of the airplane is good during deceleration to the stall; however, roll damping was low and control wheel centering caused by force feedback was low. The roll control sensitivity was low because of the possible large (110°) control wheel movement. A release of roll control force will not stop the roll rate. According to the study, these characteristics were different from most lower performance aircraft and probably were part of the conditions which cause pilot over-controlling observed in training.

The stabilizing of dihedral effect was positive but there was very little undamped "Dutch roll." Directional stability was low, but rudder effectiveness was good and yawing was easily damped with rudder alone. There was no tendency to induce a roll oscillation.

Low-speed handling characteristics in the go-around configuration were also conducted with the test aircraft configured with a 1/4-inch ice simulation. As in the stall tests, the simulated ice shape was applied to both wings from station 72 outboard to the wingtip tanks. Flares from high sink rates in the landing configuration produced abrupt left wing drops during the flare. The remainder of the low-speed characteristics above wing rolloff were unchanged from the performance of the aircraft without ice.

1.16.3 Wing Anti-Ice Protection

The flight profile of the accident aircraft as it flew from Des Moines to Detroit was reconstructed from ATC radar and communications data. All communication transcripts between the flightcrew of the Learjet and ATC personnel were transcribed. Flight tests then were conducted to determine the most probable power settings used in the descent to the Detroit airport. Two flight techniques for the initial descent matched the time sequences extracted from radar data. The first case, without wing spoilers and near idle power, produced the descent rates and leveloff timing of the Learjet. The second case, with spoilers extended and 80 percent N1 engine speed, produced the same profile. In both cases, after level off and before final descent, there was a period of 6 minutes at power below 80 percent N1 which provided less than optimum anti-ice protection.

A wing structure temperature indicator in the cockpit provides the pilot with anti-ice protection information. When the indicated temperature is above 35° F, the wing structure is warm enough to prevent ice accretion. With indicated temperatures below 35° F, the wing heat system should be used. If the wing heat system is on, the temperature indicates wing heat system failure or low engine rpm. Below 15,000 ft, using normal descent procedures at minimum 80 percent rpm, enough heat should result to remove all wing leading edge ice.

1.17 Additional Information

1.17.1 Stall Characteristic Requirements

The original type certificate of the basic Learjet was issued under CAR Part 3. CAR Section 3.10, Eligibility for Type Certification, stated in part that "an airplane shall be eligible for certification under the provisions of this part if it complies with the airworthiness provisions hereinafter established or if the Administrator finds that the provisions not complied with are compensated for by factors which provide an equivalent level of safety, provided that the Administrator finds no feature or characteristic of the airplane which renders it unsafe for the category in which it is certificated." Lear Special Condition CAR 3.120, 3/ Stalling Symmetrical Thrust, stated that clear and distinctive stall warning shall be apparent to the pilot with sufficient margin to prevent inadvertent stalling of the airplane both in straight and turning flight. It shall be acceptable for the warning to be furnished either through the inherent aerodynamic qualities of the airplane or by a device which will give clearly distinguishable indications under all expected conditions of flight.

A stall warning indication beginning at a speed 7 percent above the stalling speed (1.07 Vs) is normally considered sufficient margin. Other margins may be acceptable depending upon the degree of clarity and duration of the warning evidenced during the approach to the stall. The airplane was considered to be stalled when, at an angle of attack measurably greater than that at maximum lift, the inherent flight characteristics give a clear indication to the pilot that the airplane was stalled. According to FAA performance standards, a nosedown pitch or a roll which cannot be readily arrested are typical indicators of stall. Other indications, such as marked loss of control effectiveness, abrupt changes in control force or motion, characteristic buffeting, or a distinctive vibration of the pilot's controls, may also serve as stall indicators.

3/ The applicable special conditions on stalls of CAR 3.120 are the same as CAR 4b.160 and 4b.162 which applied to subsequent Learjet models.

On June 19, 1984, the FAA Central Region requested a review of its finding that Learjet Model 23 did not meet special condition CAR 3.120 in that the inherent flight characteristics did not give a clear indication to the pilot that the airplane was stalled before entering a flight condition from which normal recovery could not be accomplished. The manufacturer objected to this finding; however, it proposed a stickshaker/pusher installation that would activate at a point that would bring the aircraft into compliance with the stall warning requirement that a device give distinguishable indications under all expected flight conditions. Department of Transportation, FAA Order 8110.6, Review Case No. 38, required that on the Learjet Model 23, dual, independent stickshaker and stickpusher stall warning systems must be provided. Later models, including the Learjet Model 25D, were provided with similar warning systems.

Under current FAA stall characteristic requirements, it must be possible to produce and correct roll and yaw by unreversed use of the aileron and rudder controls, up to the time the aircraft is stalled. No abnormal noseup pitching may occur. It must be possible to promptly prevent stalling and to recover from a stall by normal use of the controls. For level wing stalls, the roll between the stall and the completion of the recovery may not exceed 20°. For turning stalls, the action of the airplane after the stall may not be so violent or extreme as to make it difficult, with normal piloting skill, to effect a prompt recovery and to regain control of the aircraft.

1.17.2 Flight Controls

Since the autopilot servos were connected to the primary flight controls, a functional check of the servos and autopilot computer was conducted. The tests showed that the autopilot computer and the servos were capable of normal operation. The pitch servo clutch slipped at 175 inch-pounds whereas slippage should have occurred at 250 $\pm$ 25 inch-pounds. The change in slippage was not significant to the accident.

1.17.3 Ice Protection and Windshield Defogger

The wing anti-ice pressure regulator was removed for examination. The cone was in the closed position, and there was no evidence of damage. The electric solenoid operated normally.

The timer from the horizontal stabilizer deicer boot was removed and examined. There was no evidence of damage. The timer was checked electrically and it operated properly.

The horizontal stabilizer deicer boots exhibited some impact damage. The wiring was checked, and some of the wires were shorted together. There were no shorts to the aircraft structure.

The windshield defogger valve was removed and examined. There was no evidence of damage. The valve was open about 15° and the control knob was pulled to the full-on position. Operational tests of the defogger valve and actuator revealed normal operation. The pressure regulator solenoid for the windshield defogger was operated normally.

1.17.4 Pitot and Static Systems

Examinations of the pitot and static system lines did not reveal evidence of preimpact discrepancies. The pitot probes, static ports, and connecting lines had been damaged severely by impact. The pitot heaters were found to be operable.

The pilots' airspeed indicator was bench-checked and found to operate within the specified tolerances. The airspeed reference bug was set at 101 kns. The alternate static source selector switch was wired in the normal position. The copilot's airspeed indicator needle was fixed at 100 kns and the reference bug was set at 112 kns.

The pilot's altimeter was reading 640 ft m.s.l. and the barometric setting was 29.93 inHg. The indicator in the copilot's altimeter was broken; barometric setting was 29.92 inHg.

1.17.5 Stall Warning System

The stall warning computer, accelerometer switch, left and right stall vane transducers (minus flag), and left and right angle-of-attack indicators were functionally tested. The stall vane flags were broken by crash impact forces and could not be tested for anti-ice heater continuity. Otherwise, all other components functioned within prescribed specifications.

The wiring to the left and right wing flap switches was intact. The left switch functioned normally. Operation of the right switch actuated all internal switches normally. The stall warning lamps in the cockpit indicator were found to be operational. The left and right control column stickshaker motors were found to be operational.

1.17.6 Powerplants

The engines were disassembled and examined. Examination confirmed high rotational speed damage to the right engine. The left engine compressor section had been damaged slightly by a foreign object, and the 8th stage blade tips were rubbed and bent opposite the direction of normal rotation. The turbines of both engines were intact. Neither turbine assembly showed evidence of overheating.

The two bleed valve actuators, the anti-ice valve, the main fuel control, and the fuel pump of the left engine were functionally tested and were found to function satisfactorily. Also, the ignitor box, plugs, and leads functioned satisfactorily. Impact damage precluded testing similar components of the right engine except for the ignitor system which functioned normally.

Debris was found in the front frame anti-ice manifold downstream of the exit side of the left engine anti-ice valve. Fine metallic particles were found inside the double wall of the right engine bullet nose. These particles were carried by the compressor bleed air system through the anti-ice system and into the bullet nose. The engine anti-ice valves are held electrically in the closed position until opened by the nacelle heat switches. When electrical power is lost to the system, the anti-ice valves open automatically.

The alignment of an impact mark on one of the variable inlet guide vanes of the left engine indicated that the strut was in the full open position at impact. If the vanes were partially closed at impact, the strut would not have been damaged by debris. The right engine inlet guide vanes were also in the full open position. This position indicates 94 percent or greater engine rotor speed.

1.17.7 Wake Vortex Study

The assumed flight track data of the Learjet were submitted to the Transportation Systems Center (TSC), Cambridge, Massachusetts, where it was used to determine the position relationships of the Learjet to the wake vortices generated by the DC-9. Because of the wing velocity and time separation, the TSC ruled out wake vortices after liftoff as a causal factor in the accident. However, the report noted that wake vortices are generated whenever an aircraft wing is creating lift and that wake vortices are generated between initial rotation and liftoff. Accordingly, if vortex turbulence caused the violent rolling of the Learjet, the vortex could only have been created by the DC-9 after rotation but before liftoff. Although the strength, persistence, and flow patterns of wake vortices created during ground rotation are not fully known, their characteristics are being included in a current TSC data collection program.

The TSC study found that if the Learjet had continued to land rather than to begin a go-around, the aircraft would have remained below the altitude of the vortices and should have been able to complete a safe landing. However, the study also found that if the Learjet pilot initiated the attempted go-around because the landing approach was considered to be high, or for other reasons not related to a vortex encounter, the go-around flightpath may have entered into an area of significant turbulence.

1.17.8 Pilot Techniques

During postaccident interviews, company pilots who had flown extensively with the pilot of the accident aircraft stated that the pilot would have turned on the anti-ice systems before entering known icing conditions and that he probably would have turned the systems off as he descended below the overcast. They also stated that the Learjet company pilots used a rule of thumb to determine approach reference speeds. The rule was based on 95 kns, as the basic reference speed for all aircraft operating weights; 5 kns per 1,000 lbs of fuel and 1 kn per passenger was added to compute the actual reference speed.

1.18 New Investigative Techniques

None

2. ANALYSIS

The pilots were properly certificated and currently qualified to operate the aircraft. Postmortem examination of the crewmembers disclosed no evidence of incapacitation or physical impairment before impact.

The aircraft was properly certificated and it had been maintained in accordance with approved procedures. The investigation disclosed no evidence of preexisting failure or malfunctions of the aircraft systems or structure before impact. Both engines were determined to be capable of normal operation. At the time of impact, the engines were developing 94 percent or greater rotor speed. There were two uncorrected maintenance discrepancies which were not recorded in the aircraft logs. The copilot's barometric altimeter was reportedly sticking at 40,000 ft and the movable indicator for setting speed reference on the pilot's airspeed instrument was jammed at the 100-kn position. Wreckage examination disclosed that the speed indicator was jammed at the 101-kn position.

The Safety Board is under a considerable handicap in its accident investigation when in-flight recording devices are not available. Information from flight data recorders and cockpit voice recorders provide invaluable assistance to identify the causal factors of an accident. In this accident, the Safety Board was forced to depend primarily upon witness observations, the sole source available, to establish the critical flightpath of the landing aircraft. In most investigations, witness statements are supportive of recorded fact. Witness statements lack essential time relationships of height and motion essential for definitive analysis.

Flight recorders are not required by regulation for general aviation aircraft in 14 CFR 91 operations. The lack of this information has hampered some Safety Board investigations. 4/ On April 13, 1978, during its investigation of an accident in McLean, Virginia, 5/ the Safety Board made three recommendations (A-78-27 through -29) to the FAA regarding the mandatory use of recorders in these aircraft. The Safety Board reiterated the recommendations on December 21, 1978, in its report of an accident in Richland, Washington; on September 20, 1979, in its report of an accident in Sanford, North Carolina; and on December 13, 1979, in its report of an accident in Anchorage, Alaska. 6/ The FAA has not completed regulatory action that would implement these recommendations. The Safety

4/ "Aircraft Accident Report--Jet Avia, Ltd., Learjet LR24B, N12MK, Palm Springs, California, January 6, 1977" (NTSB-AAR-77-8); "Aircraft Accident Report--Johnson and Johnson, Inc., Grumman Gulfstream II, N500J, Hot Springs, Virginia, September 26, 1976" (NTSB-AAR-78-4).

5/ "Aircraft Accident Report--Southern Company Services, Inc., Beech-Hawker 125-600A, N40PC, McLean, Virginia, April 28, 1977" (NTSB-AAR-78-11).

6/ "Aircraft Accident Report--Columbia Pacific Airlines, Beech 99, N199EA, Richland, Washington, February 10, 1978" (NTSB-AAR-78-15); "Aircraft Accident Report--Champion Home Builders Company, Gates Learjet 25B, N99HG, Sanford, North Carolina, September 8, 1977" (NTSB-AAR-79-15); "Aircraft Accident Report--Inlet Marine, Inc., Gates Learjet 25C, N77RS, Anchorage, Alaska, December 4, 1978" (NTSB-AAR-79-18).

Board, for the fourth time, reiterates these recommendations and urges the FAA to expedite the regulations that would require the use of flight recorders in certain general aviation aircraft.

With limited information in hand, the Safety Board considered the possibility that the accident aircraft encountered the vortex or other wake turbulence from the departing Delta DC-9 and also considered the possibility that leading edge wing ice had accumulated during the descent and had affected the flight dynamics of the landing aircraft. The Safety Board further considered the possibility that a delayed application of engine thrust during an attempted go-round at a low speed may have induced large roll angles.

Wake Turbulence

At 1932:30, the Detroit local controller told the Learjet that the DC-9 would be departing on runway 9 before the Learjet landed. The DC-9's FDR speed data disclosed that the pilot of this aircraft had applied full engine thrust during a rolling takeoff at 1933:43. Twenty-six seconds later when 2,200 ft down the runway, the DC-9 was rotated for takeoff. About 1934:14, the aircraft lifted off at a point 3,410 ft down the runway. Ten seconds later, about 1934:24, the landing Learjet had crossed the runway threshold while descending on a normal 3° glide slope. According to an air traffic controller, the pilot's intended touchdown point appeared to be 1,200 to 1,500 ft down the runway. The witness saw the accident aircraft cross that area at an altitude of 10 to 15 ft. Other witnesses stated that the pilot apparently initiated a go-around a few seconds later.

At the time of the accident, the component of the 12-kn wind would have moved wake vortex turbulence generated by the DC-9 at about 18 ft per second. The Learjet was observed to have entered the rolling maneuver 4.5 seconds before the impact 2,640 ft past the threshold. At an average groundspeed from the threshold of 100 kns (169 ft per second), the destabilized flight maneuver probably started about 1,800 ft past the threshold. The Learjet would have reached the 1,800-ft runway position about 15 to 16 seconds after the DC-9 started rotation. The turbulence generated from the DC-9 rotation could have drifted in the wind to a point about 2,000 ft from the runway threshold. Since the precise times at which the Learjet may have been at specific locations can be placed only within about 5 seconds, it is conceivable that the Learjet could have encountered wake turbulence when it was first seen to roll abruptly.

The assumed flight track data of the Learjet was submitted to the Transportation Systems Center (TSC), Cambridge, Massachusetts, where it was used to determine the position relationships of the Learjet to the wake vortices generated by the DC-9. Because of the wind velocity and time separation, the TSC ruled out wake vortices after liftoff as a causal factor in the accident. However, the report noted that wake vortices are generated whenever an aircraft wing is creating lift and therefore wake vortices are generated between initial rotation and liftoff. Accordingly, if vortex turbulence caused the violent rolling of the Learjet, the vortex could only have been created by the DC-9 after rotation but before liftoff. Although the strength, persistence, and flow patterns of wake vortices created during ground rotation are not fully known, their characteristics are being included in a current TSC data collection program.

Without essential documentation, which would have been provided by an FDR, the Safety Board could not reconstruct the dynamics of the Learjet flightpath nor establish the possibility that dissipating wake vortex turbulence of the DC-9 rotation caused the destabilization and rolling maneuvers of the Learjet.

To eliminate the hazards of wake vortex turbulence, air traffic controllers are required by air traffic control handbook 7110.65A to separate arriving or departing traffic, or combinations of similar traffic, by aircraft category. In this accident, both aircraft were Category III aircraft and in this classification, separation should provide that the arriving aircraft does not cross the landing threshold until the departing aircraft has crossed the runway end or a minimum distance of 6,000 ft exists between the aircraft. When the Learjet crossed the landing threshold of runway 9, the DC-9 had not crossed the other end of the same runway; however, the distance separating the aircraft was greater than the minimum required distance.

Effects of Ice on Flight Dynamics

National Weather Service ground observations and upper air soundings recorded conditions associated with icing in the flight environment. About the time of the accident, several air carrier pilots reported that their aircraft had accumulated moderate to severe airframe icing at the lower altitudes in the Detroit area. Although the cloud base was 2,300 ft above ground level and visibility was 10 mi, light icing was also reported below the overcast. Flight tests, conducted by the Safety Board, evaluated the relationships between engine power output during the descent profile and during the airspeed reduction changes of the Learjet. The tests found that the engines would have been operated for several periods at power outputs less than 80 percent N1 engine speed. These low settings would have been below optimum icing protection heat levels and wing icing may have occurred. Pilots who had flown extensively with the pilot of the accident aircraft believed that he would have turned on the anti-ice systems before entering any known icing condition and that he would have more than likely turned it off as he descended below the overcast. Examination of the wreckage disclosed that all anti-ice protection switches, except the pilot's pitot heater switch, were turned off. Examination of the wreckage disclosed that all anti-ice protection switches, except the pilot's pitot heater switch, were turned off. When the engine nacelle anti-ice switches are turned off, the engine anti-ice valves are held closed electrically. Dirt and debris which were found within the engine disclosed that the anti-ice valves were open during the crash and revealed that the engine anti-ice system was not electrically powered at that time. The power loss was attributed to impact forces.

Therefore, the Safety Board concludes that before the attempted landing, the accident aircraft was exposed to a possible accumulation of moderate to severe wing ice while descending in the clouds and light wing icing below the overcast. Accordingly, the Learjet may have had ice adhering to the aircraft, particularly the wings, during the landing.

The Safety Board's performance study indicated that an accumulation of relatively small amounts of ice on the leading edge of the Learjet wing could have increased stall onset by 10 to 12 kns. According to the aircraft flight manual at the estimated weight and landing configuration of the Learjet, the stall speed would have been 88 kns. The approach reference speed would have been about 114 kns. However, if the pilots had used the company rule of thumb of 95 kns, based on the basic airplane operating weight, and added 5 kns per 1,000 lbs of fuel and 1 kn per passenger, the Vref speed for the approach would have been 109 kns. The copilot's airspeed reference bug was set at 112 kns and during the impact sequence, his airspeed indicator needle jammed at 100 kns. The captain's airspeed indicator needle was found at the zero reading and his reference "bug" was set at 101 kns. If the pilot had inadvertently monitored the malfunctioning bug for speed guidance, the error would have placed the aircraft 13 kns slower than the Aircraft Flight Manual speed and only 7 kns above the 94-kn stickshaker actuation speed of the stall warning system. Without the effects of ice, the speed margin errors would have been adequate for the pilot to successfully complete the landing.

However, if the wing leading edges had accumulated ice in a form similar to the flight test airplane and if the stall speed increased to 99 kns, the Learjet would have flared before landing at a speed slightly above the ice-induced stall speed. Under these conditions, upon flare rotation and as the wing loading and wing angle of attack were increased to lessen the descent rate, the wing may have stalled. When the wing stalls, wing rolloff is nearly instantaneous and is not preceded by wing rock. This stall characteristic is inconsistent with the wing rocking observed before the impact of the accident aircraft.

Witnesses described rapidly increasing engine thrust noise either before or during the rolling maneuver. One witness believed that the aircraft was accelerating as the rolling began. Postaccident engine teardown disclosed that both engines were developing 94 percent or greater thrust at impact. These findings indicate that, at some point in the attempted landing, the pilot decided to go-around. His decision to abandon the landing may have been due to his concern as he met dissipating wake turbulence or the decision may have been made after the left tip tank struck the runway during the first lateral upset.

During the Safety Board's performance study, go-around maneuvers from 20° bank angles were simulated at altitude by simultaneously applying takeoff power, applying aft elevator control to prevent contact with a simulated groundplane, and applying full opposite aileron to level the airplane. On go-around attempts at speeds above stickshaker activation (approximately 1.07 Vs or greater), no problems were encountered. However, during similar go-around attempts at speeds within the shaker range, the downgoing wing was observed to stall and resulted in nearly vertical bank angles. In this accident, 1.07 Vs was about 94 kn and it is unlikely that the Learjet slowed to that speed before the first roll. However, if leading edge ice accumulation had increased the stall entry speed by 10 to 12 kn or greater, the equivalent 1.07 Vs air flow pattern over the wings may have been about 106 kn. It is possible the Learjet may have slowed to this airspeed and the go-around attempt in this comparative speed range caused the aircraft to begin the rolling maneuver, which resulted in a loss of altitude and ground impact. Such an occurrence would be consistent with the findings of the performance study.

However, the Safety Board could not determine the airspeed or acceleration of the Learjet as the go-around attempt was begun, and, therefore, cannot draw a conclusion in this regard.

The Safety Board found during flight performance studies at altitude that after wing rolloff following the stall, lateral control was not effective. The roll could be reversed with aileron and rudder, but at such a rate that 500 ft of altitude was lost during the reversal. After the stall, there was no tendency for the aircraft to abruptly reverse roll direction. The roll control power of the aircraft was good until stall entry; however, roll damping was low and control wheel centering due to force feedback was low. The low roll control sensitivity was due to the large 110° wheel throw and a release of roll input did not stop the roll rate. These handling characteristics are different from lower performance aircraft and could account for response actions in which some pilots might tend to overcontrol if they used sudden, large and untimely control wheel displacements. In this accident, low roll control sensitivity and the possibility of a sudden pilot reaction might have sustained the rolling maneuvers following the initial wing drop.

The influence of ground effect on the Learjet Century III's lateral control during the rolling maneuvers is not known and the Safety Board was not able to explore the potential influence of ground effect at large bank angles because of the obvious risks involved in flight testing under these conditions. However, as ground effect increases wing lift, induced drag decreases and the total effect on the wing may increase roll control authority near stall airspeed. The influence of ground effect on a stalled wing rolling downward, however, would probably be neutralized as the descending wing entered deeper into the stall. Therefore, if a rapid roll occurred at low altitude and near the stall speed, recovery to level flight would be unlikely.

Without FDR information, the Safety Board could not determine whether the aircraft entered the stall speed range at any time. The Safety Board concluded that for roll reversals to have occurred, neither wing could have been stalled before the final roll to the right. The large roll angles reported by witnesses were probably illusionary since the accident aircraft would not have remained airborne during the large banked attitudes because of the associated loss of lift.

The scratch marks on the left wingtip tank indicate that the aircraft was in a 19° left roll, a 9° noseup and a 7° right yaw attitude when the tip tank struck the runway. The small yaw angle indicates that the tip tank probably hit the runway during the first roll. Also, the relatively high pitch attitude at that time indicates that the aircraft may have "dropped out" and that the pilot may have initiated an abrupt pitch change to stop the increasing descent rate and to prevent a hard landing. According to the flight test data, stalls accelerated by landing flares can be achieved with a rapid pitch increase and result in abrupt left wing drops. A simultaneous increase of engine thrust may have accelerated the aircraft above the stall entry speed and reinstituted roll control. The changes in airfoil characteristics and airspeed while near the stall airspeed might have made the aircraft susceptible to roll oscillations. The combination of ground effect and the increased thrust may have been sufficient to keep the aircraft above the stall speed and above the runway during the roll reversals until the bank angle and roll rate increased to the extent that the descending wing stalled at an altitude too low for recovery.

3. CONCLUSIONS

3.1 Findings

1. The pilots were currently certificated and qualified for the flight.

2. There was no evidence of physical impairment or incapacitation of the pilots.

3. The airplane was certificated and maintained according to approved procedures.

4. There was no evidence of a preexisting structural failure or systems malfunction.

5. Witnesses watched the Learjet cross the runway threshold in a normal landing attitude. Seconds later, the aircraft began a series of rapid, steep roll oscillations which ended in a crash.

6. The aircraft had flown in moderate to severe icing conditions during the descent. The flight may have encountered light icing conditions below the overcast.

7. The pilot is believed to have used the anti-ice systems until clear of the clouds.

8. The wing surfaces may have accumulated a significant trace of ice after the anti-ice system was turned off.

9. A trace of ice on the leading edge of the wings may have caused a premature stall.

10. Wake turbulence of a departing aircraft may have initiated the rolling maneuvers of the Learjet.

11. During a performance study, no abnormalities were found in the low-speed handling characteristics at speeds above the stickshaker speed.

12. Coupled with abrupt pitch and roll control inputs during a go-around attempt at speeds within the stickshaker range, a delay in adding thrust can result in a rapid, rolloff stall.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was the pilot's loss of control. The loss of control may have been caused by wake turbulence of a departing aircraft, by a premature stall caused by an accumulation of wing ice, by a delayed application of engine thrust during an attempted go-around, or by any combination of these factors.

4. SAFETY RECOMMENDATIONS

As a result of this accident and several others involving general aviation aircraft, the National Transportation Safety Board reiterates the following recommendations made to the Federal Aviation Administration on April 13, 1978:

> Develop, in cooperation with industry, flight recorder standards (FDR/CVR) for complex aircraft which are predicated upon intended aircraft usage. (Class II, Priority Action) (A-78-27)
>
> Draft specifications and fund research and development for a low-cost FDR, CVR, and composite recorder which can be used on complex general aviation aircraft. Establish guidelines for these recorders, such as maximum cost, compatible with the cost of the airplane on which they will be installed and with the use for which the airplane is intended. (Class II, Priority Action) (A-78-28)
>
> In the interim, amend 14 CFR to require that no operation (except for maintenance ferry flights) may be conducted with turbine-powered aircraft certificated to carry six passengers or more, which require two pilots by their certificate, without an operable CVR capable of retaining at least 10 minutes of intracockpit conversation when power is interrupted. Such requirements can be met with available equipment to facilitate rapid implementation of this requirement. (Class II, Priority Action) (A-78-29)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ ELWOOD T. DRIVER
Vice Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ G.H. PATRICK BURSLEY
Member

JAMES B. KING, Chairman, filed the following concurring and dissenting statement:

I fully support the report. But without a CVR/FDR to establish the aircraft's performance and operational sequence, the probable cause without further caveat overstates the degree of certainty concerning the three factors. I would write the probable cause as follows:

> The National Transportation Safety Board determines that the probable cause of the accident was the pilot's loss of aircraft control <u>for unknown reasons</u>. The loss of control may have been caused by wake turbulence of a departing aircraft, by a premature stall caused by an accumulation of wing ice, by a delayed application of engine thrust during an attempted go-around, or by any combination of these factors.

/s/ <u>JAMES B. KING</u>
Chairman

PATRICIA A. GOLDMAN, Member, filed the following concurring and dissenting statement:

I believe this investigation was comprehensive and well-performed. I support fully this accident report.

I do not concur with the probable cause as adopted by the majority since I do not believe there is sufficient information to support it.

Conclusions 9, 10, and 12 respectively state--

9. A trace of ice on the leading edge of the wings may have caused a premature stall.

10. Wake turbulence of a departing aircraft may have initiated the rolling maneuvers of the Learjet.

12. Coupled with abrupt pitch and roll control inputs during a go-around attempt at speeds within the stickshaker range, a delay in adding thrust can result in a rapid, rolloff stall.

These conclusions are valid. Nevertheless, each of these factors must be read in context of the following analyses contained in the report.

> "Without essential documentation, which would have been provided by an FDR, the Safety Board could not reconstruct the dynamics of the Learjet flightpath nor establish the possibility that dissipating wake vortex turbulence of the DC-9 rotation caused the destabilization and rolling maneuvers of the Learjet."

* * *

"However, if the wing leading edges had accumulated ice in a form similar to the flight test airplane and if the stall speed increased to 99 kns, the Learjet would have flared before landing at a speed slightly above the ice-induced stall speed. Under these conditions, upon flare rotation and as the wing loading and wing angle of attack were increased to lessen the descent rate, the wing may have stalled. When the wing stalls, wing rolloff is nearly instantaneous and is not preceded by wing rock. This stall characteristic is inconsistent with the wing rocking observed before the impact of the accident aircraft."

* * *

"However, the Safety Board could not determine the airspeed or acceleration of the Learjet as the go-around attempt was begun, and, therefore, cannot draw a conclusion in this regard."

* * *

"Without FDR information, the Safety Board could not determine whether the aircraft entered the stall speed range at any time."

* * *

Also, I am not convinced that these three scenarios are the only factors which could have caused the loss of control. For example, the report states, "In this accident, low roll control sensitivity and the possibility of a sudden pilot reaction might have sustained the rolling maneuvers following the initial wing drop."

Therefore, I believe the probable cause of this accident should be:

The National Transportation Safety Board determines that the probable cause of the accident was the pilot's loss of aircraft control for undetermined reasons.

/s/ PATRICIA A. GOLDMAN
Member

April 29, 1980

5. APPENDIXES

APPENDIX A

Investigation and Hearing

1. Investigation

The Safety Board was notified of the accident about 2050 e.s.t., on January 19, 1979, and an investigation team departed to the scene from Washington, D.C., the following day. Investigation groups were established for operations, structures, systems, powerplants, weather, and aircraft performance.

Parties to the investigation were the Federal Aviation Administration, Gates Learjet Corporation, and Massey-Ferguson, Inc.

2. Public Hearing

No public hearing or depositions were held.

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APPENDIX B

Crew Information

Allan J. Hogue

Pilot Hogue, 36, held Airline Transport Pilot certificate No. 156072 with airplane multiengine land, and type ratings in the Learjet, Hawker Siddley HS-125, and the Lockheed L1329. He held commercial privileges in single-engine land airplanes. His commercial pilot certificate was issued September 5, 1964, and he also held a flight instructor certificate which was issued March 10, 1967.

The bulk of his early experience was as a flight instructor in Cessna 150's and 172's. His total flight instructor experience, as of January 15, 1979, was 2,569 hrs. His total time was 7,171 hrs of which 6,763 hrs were as pilot-in-command. His multiengine time totaled 4,266 hrs, of which 2,541 hrs were in turbojet airplanes.

	Pilot	Copilot
L1329	366	11
HS-125	1,216	160
LR 25B	463	26
LR 25D	61	0
Total	2,106	197 hrs

He commenced his Learjet training November 14, 1977, through Flight Safety International, Wichita, Kansas. He had already acquired 10 hrs in the Learjet prior to Flight Safety's training. While at Flight Safety he received 46 hrs of ground instructions, 4.5 hrs in the simulator and 12 hrs in the Learjet 25B (MK II). There were a few comments in his training file concerning the lack of crew coordination.

The pilot obtained his type rating in the Learjet December 7, 1977.

On December 4, 1978, he attended a 3-day Learjet refresher course at Flight Safety, Inc., along with another Massey-Ferguson pilot. They received 16 hrs of classroom instruction and 5.5. hrs in the simulator. They were graded as proficient in most areas. In the areas of crew coordination, conduct of emergencies, and use of checklists, they were critiqued as needing additional training.

The pilot had flown 149 hrs in the last 90 days and 8 hrs in the last 30 days before the accident. According to his logbook, he did not fly after December 8 until January 3. He made two flights in N137GL, one on January 3 and one on January 17 which was with the copilot to transport company executives to Des Moines for the meeting that was completed on January 19. The third flight before the accident was on January 15, which was a training flight in a Cessna 177RG.

Craig R. Barrows

Copilot Barrows, 27, held Airline Transport Pilot certificate No. 1881724 with airplane multiengine land and a type rating in the Learjet. He held commercial privileges in single-engine land airplanes. He obtained his commercial pilot certificate on January 26, 1970. He also obtained a flight instructor certificate on November 1, 1971.

His logbooks were not available and flight time information was obtained from company records and other pilots with whom he had flown. A record of his employment history showed that from January 1970 to May 1972 he served as a flight instructor and a charter pilot.

He commenced his Learjet training about March 1974 from a rated flight instructor under the provisions of 14 CFR 61. He received 24 hrs of ground and 50 hrs of flight instruction in a Learjet 25, from March 31 to April 23, 1974, at which time he acquired his type rating.

From April to June 1974, copilot Barrows flew a total of 96 hrs as pilot-in-command in the Learjet 25 and 14 hrs as copilot. As of May 1974, he had recorded a total of 3,740 hrs of flight time.

Copilot Barrows flew with Massey-Ferguson, Inc., on a part-time basis. According to the company's flight log and trip report forms, he flew on 12 flights; twice as pilot-in-command prior to the accident flight. He made 10 flights with the pilot, of which 4 were made 2 days before the accident. He had flown a total of 16 hrs in the last 90 days.

APPENDIX C

Aircraft Information

FAA certification of the Learjet 25D was approved May 20, 1976, under 14 CFR Part 25, effective February 1, 1965, with the addition of Special Conditions.

The accident aircraft, a Gates Learjet Model 25D, United States registry N137GL, serial number 25-237, was manufactured February 9, 1978. It had flown a total of about 299 hrs at the time of the accident. It was leased by Massey-Ferguson, Inc., on October 5, 1978, from Management Jet International, Inc., Lincoln, Nebraska. Massey-Ferguson had operated the airplane for 86 hrs from October 10, 1978, to January 19, 1979.

The airplane was equipped with a Gates Learjet Century III performance improvement modification in accordance with the Engineering Change Record 1511, and General Electric CJ-610-8A engines modified with a D. Howard Raisbeck thrust reverser bit.

The airplane was maintained in accordance with the manufacturer's suggested maintenance inspection program. The airframe log disclosed that a 150 hrs inspection was performed on December 12, 1978, at a total time of 293.3 hrs. The records showed that Airworthiness Directives had been complied with through No. 78-16-03. Review of the records disclosed no uncorrected discrepancies. The major maintenance item noted related to a slight vibration in the right engine at about 65 percent N1 rpm. This discrepancy prompted removal and a manufacturer's inspection. A replacement engine was used until December 5, 1978, when the original engine was reinstalled at a total airframe time of 288.4 hrs.

The operating times and serial numbers for the engines were:

Position	Serial No.	Total Time
Left	211-031A	299.8
Right	211-023A	190.9

The aircraft had been fueled to capacity with JetA-50 fuel before departure at Des Moines. No fuel was added at South Bend.