# Aviation Investigation Final Report

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| **Location:** | McMinnville, Oregon | **Accident Number:** | WPR13FA227 |
| **Date & Time:** | May 13, 2013, 12:45 Local | **Registration:** | N22MS |
| **Aircraft:** | GATES LEARJET CORP. 35A | **Aircraft Damage:** | Substantial |
| **Defining Event:** | Landing area overshoot | **Injuries:** | 3 None |
| **Flight Conducted Under:** | Part 91: General aviation - Positioning | | |

## Analysis

The crew of the twinjet reported that the positioning flight after maintenance was uneventful. However, during the landing roll at their home base, the thrust reversers, steering, and braking systems did not respond. As the airplane approached the end of the runway, the pilot activated the emergency braking system; however, the airplane overran the end of the runway, coming to rest in a ditch. None of the three occupants were injured, but the airplane sustained substantial damage to both wings and the fuselage.

Two squat switches provided redundancy within the airplane's electrical system and were configured to prevent inadvertent activation of the thrust reversers and nosewheel steering during flight and to prevent the airplane from landing with the brakes already applied. Because postaccident examination revealed that the squat switch assemblies on the left and right landing gear struts were partially detached from their mounting pads such that both switches were deactivated, all of these systems were inoperative as the airplane landed.

The switch assemblies were undamaged, and did not show evidence of being detached for a long period of time. The brakes and steering were working during taxi before departure, but this was most likely because either one or both of the switches were making partial contact at that time. Therefore, it was most likely that the squat switch assemblies were manipulated on purpose during maintenance in an effort to set the airplane's systems to "air mode." Examination of the maintenance records did not reveal any recent procedures that required setting the airplane to air mode, and all mechanics involved in the maintenance denied disabling the switches. Mechanics did, however, miss two opportunities to identify the anomaly, both during the return-to-service check and the predelivery aircraft and equipment status check. The anomaly was also missed by the airplane operator's mechanic and flight crew who performed the preflight inspection.

The airplane's emergency braking system was independent of the squat switches and appeared to operate normally during a postaccident test. Prior to testing, it was noted that the emergency brake gauge indicated a full charge; therefore, although evidence suggests that the emergency brake handle was used,

it was not activated with enough force by the pilot. The pilot later conceded this fact and further stated that he should have used the emergency braking system earlier during the landing roll.

The airplane was equipped with a cockpit voice recorder (CVR), which captured the entire accident sequence. Analysis revealed that the airplane took just over 60 seconds to reach the runway end following touchdown, and, during that time, two attempts were made by the pilot to activate the thrust reversers. The pilot stated that as the airplane approached the runway end, the copilot made a third attempt to activate the thrust reversers, which increased the engine thrust, and thereby caused the airplane to accelerate. Audio captured on the CVR corroborated this statement.

## Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this accident to be:

Failure of maintenance personnel to reattach the landing gear squat switches following maintenance, which rendered the airplane's steering, braking, and thrust reverser systems inoperative during landing. Contributing to the accident were the failure of both the maintenance facility mechanics and the airplane operator's mechanic and flight crew to identify the error during postmaintenance checks, a failure of the airplane's pilot to apply the emergency brakes in a timely manner, and the copilot's decision to attempt to engage the thrust reversers as the airplane approached the runway end despite multiple indications that they were inoperative and producing partial forward, rather than reverse, thrust.

### Findings

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| **Personnel issues** | (general) - Maintenance personnel |
| **Personnel issues** | Forgotten action/omission - Maintenance personnel |
| **Personnel issues** | Forgotten action/omission - Flight crew |
| **Personnel issues** | Identification/recognition - Pilot |
| **Personnel issues** | Delayed action - Pilot |
| **Personnel issues** | Incorrect action performance - Copilot |

# Factual Information

## History of Flight

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| **Prior to flight** | Aircraft maintenance event |
| **Landing-landing roll** | Landing area overshoot (Defining event) |
| **Landing-landing roll** | Collision with terr/obj (non-CFIT) |

On May 13, 2013, about 1245 Pacific daylight time, a Gates Learjet 35A, N22MS, overran the runway during landing at McMinnville Municipal Airport, McMinnville, Oregon. The airplane was registered to Evergreen Equity, Inc., and operated by Evergreen International Aviation, Inc., under the provisions of 14 Code of Federal Regulations Part 91, as a post-maintenance positioning flight. The airline transport pilot, commercial rated copilot, and company mechanic/passenger were not injured. The airplane sustained substantial damage during the accident sequence. The cross-country flight departed Grand Junction Regional Airport, Grand Junction, Colorado, about 1145 mountain daylight time, with a planned destination of McMinnville. Visual meteorological conditions prevailed at McMinnville, and an instrument flight rules flight plan had been filed.

The NTSB investigator traveled in support of this investigation, and performed an examination of the airframe subsequent to recovery.

The pilot reported that prior to departure he had been briefed by the mechanic who was to fly with them, that all preflight inspections had been completed. The pilot and the copilot then performed a pre-start checklist, which he described as extensive because the airplane had just come out of maintenance. All systems were normal, including the brakes and nose wheel steering.

The pilot reported that the flight and landing approach were uneventful, and as the airplane touched down about 500 feet beyond the approach end of runway 22 he deployed the spoilers, and then pulled the thrust levers to the idle/deploy detent position. The DEPLOY lights did not illuminate, so he recycled the thrust levers back into the detent, but again the reversers did not deploy. With about 2,000 feet remaining on the marked runway and at a speed of about 25 knots, he applied pressure to the foot pedal brakes, but did not feel a response, even though the brake pressure gauge indicated normal pressure. The copilot also attempted, but reported that the pedals felt loose, and the airplane did not slow down.

The pilot stated that as the airplane approached the runway end, the copilot pulled the thrust levers past the deploy detent; the engine speed increased and the airplane began to accelerate. He warned the copilot, concerned that this action was increasing forward thrust, and he moved the levers back to the Idle/Deploy detent. The pilot then engaged the STEER LOCK switch, and attempted to steer the airplane left with the nose wheel, but the airplane did not respond. Just prior to reaching the end of the stopway, he activated the emergency braking lever; however, the airplane rolled off the stopway, through a set of instrument landing system antennas, and down an embankment.

The pilot stated that this was his first experience using the emergency brake system in a Lear 35, and

that he did not feel the need to use them during the later stages of the ground roll because it appeared the airplane was coming to a stop by itself. He was concerned that activating them earlier or more aggressively would cause the brakes to lock, leaving minimum control with the inoperative steering.

## Pilot Information

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| **Certificate:** | Airline transport; Commercial; Flight instructor | **Age:** | 70 |
| **Airplane Rating(s):** | Single-engine land; Multi-engine land | **Seat Occupied:** | Left |
| **Other Aircraft Rating(s):** | None | **Restraint Used:** | 4-point |
| **Instrument Rating(s):** | Airplane | **Second Pilot Present:** | Yes |
| **Instructor Rating(s):** | Airplane multi-engine; Airplane single-engine; Instrument airplane | **Toxicology Performed:** | No |
| **Medical Certification:** | Class 1 With waivers/limitations | **Last FAA Medical Exam:** | September 12, 2012 |
| **Occupational Pilot:** | Yes | **Last Flight Review or Equivalent:** | August 3, 2012 |
| **Flight Time:** | 17563 hours (Total, all aircraft), 996.9 hours (Total, this make and model), 11535 hours (Pilot In Command, all aircraft), 17.2 hours (Last 90 days, all aircraft), 2.2 hours (Last 30 days, all aircraft), 2.2 hours (Last 24 hours, all aircraft) | | |

## Co-pilot Information

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| **Certificate:** | Commercial | **Age:** | 46 |
| **Airplane Rating(s):** | Single-engine land; Multi-engine land | **Seat Occupied:** | Right |
| **Other Aircraft Rating(s):** | None | **Restraint Used:** | 4-point |
| **Instrument Rating(s):** | Airplane | **Second Pilot Present:** | Yes |
| **Instructor Rating(s):** | None | **Toxicology Performed:** | No |
| **Medical Certification:** | Class 1 Without waivers/limitations | **Last FAA Medical Exam:** | January 7, 2013 |
| **Occupational Pilot:** | No | **Last Flight Review or Equivalent:** | July 12, 2011 |
| **Flight Time:** | 2553 hours (Total, all aircraft), 94 hours (Total, this make and model), 188 hours (Pilot In Command, all aircraft), 17 hours (Last 90 days, all aircraft), 4 hours (Last 30 days, all aircraft) | | |

The pilot held an airline transport pilot certificate with ratings for airplane multiengine land including commercial privileges for airplane single-engine land. He held type ratings for the B-727, B-747, DC-8, G-IV, and LR-JET, as well as a flight instructor certificate for airplane single- and multiengine land, and instrument airplane. He reported a total flight time in all aircraft of 17,563.2 hours, with 996.9 in the accident make and model. He had flown the accident make and model 17.2 hours in the previous 90 days, and 2.2 hours in the last 30 days. He held a first-class medical certificate, with limitations that he wears corrective lenses.

The copilot held an airline transport pilot certificate with ratings for airplane multiengine land including

private privileges for airplane single-engine land. He held type ratings for the DHC-8 (second in command privileges). He reported a total flight time in all aircraft of 2,553 hours, with 94 in the accident make and model. He had flown the accident make and model 17 hours in the previous 90 days, and 4 hours in the last 30 days. He held a first-class medical certificate, with no waivers or limitations.

## Aircraft and Owner/Operator Information

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| **Aircraft Make:** | GATES LEARJET CORP. | **Registration:** | N22MS |
| **Model/Series:** | 35A | **Aircraft Category:** | Airplane |
| **Year of Manufacture:** | 1978 | **Amateur Built:** | |
| **Airworthiness Certificate:** | Transport | **Serial Number:** | 209 |
| **Landing Gear Type:** | Retractable - Tricycle | **Seats:** | 10 |
| **Date/Type of Last Inspection:** | May 13, 2013 Continuous airworthiness | **Certified Max Gross Wt.:** | 18300 lbs |
| **Time Since Last Inspection:** | 2.2 Hrs | **Engines:** | 2 Turbo fan |
| **Airframe Total Time:** | 15047.1 Hrs as of last inspection | **Engine Manufacturer:** | GARRETT |
| **ELT:** | C126 installed, not activated | **Engine Model/Series:** | TFE 731 SER |
| **Registered Owner:** | EVERGREEN EQUITY INC | **Rated Power:** | 3500 Lbs thrust |
| **Operator:** | Evergreen International Aviation Inc. | **Operating Certificate(s) Held:** | On-demand air taxi (135) |
| **Operator Does Business As:** | | **Operator Designator Code:** | EIAA |

## Meteorological Information and Flight Plan

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| **Conditions at Accident Site:** | Visual (VMC) | **Condition of Light:** | Day |
| **Observation Facility, Elevation:** | MMV,163 ft msl | **Distance from Accident Site:** | 0 Nautical Miles |
| **Observation Time:** | 11:53 Local | **Direction from Accident Site:** | |
| **Lowest Cloud Condition:** | Scattered / 2600 ft AGL | **Visibility** | 10 miles |
| **Lowest Ceiling:** | Broken / 3100 ft AGL | **Visibility (RVR):** | |
| **Wind Speed/Gusts:** | 7 knots / None | **Turbulence Type Forecast/Actual:** | / |
| **Wind Direction:** | 220° | **Turbulence Severity Forecast/Actual:** | / |
| **Altimeter Setting:** | 30.07 inches Hg | **Temperature/Dew Point:** | 17°C / 12°C |
| **Precipitation and Obscuration:** | No Obscuration; No Precipitation | | |
| **Departure Point:** | Grand Junction, CO (GJT ) | **Type of Flight Plan Filed:** | IFR |
| **Destination:** | McMinnville, OR (MMV ) | **Type of Clearance:** | IFR |
| **Departure Time:** | 11:45 Local | **Type of Airspace:** | Class E |

An automated surface weather observation was issued at McMinnville airport at 1153. It indicated wind from 220 degrees at 7 knots, visibility 10 miles, with scattered clouds at 2,600 feet, broken at 3,100, and an overcast ceiling at 5,500 feet, temperature 17 degrees C, dew point 12 degrees C, with an altimeter setting at 30.08 inches of mercury.

## Airport Information

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| **Airport:** | McMinnville MMV | **Runway Surface Type:** | Asphalt |
| **Airport Elevation:** | 163 ft msl | **Runway Surface Condition:** | Dry |
| **Runway Used:** | 22 | **IFR Approach:** | ILS;Visual |
| **Runway Length/Width:** | 5420 ft / 150 ft | **VFR Approach/Landing:** | Straight-in |

McMinnville airport was located at an elevation of 163 feet. Runway 22 was 5,420 feet long by 150 feet wide, and paved with asphalt. An additional 1,025 feet asphalt blast pad/stopway extended beyond the departure threshold.

## Wreckage and Impact Information

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| **Crew Injuries:** | 2 None | **Aircraft Damage:** | Substantial |
| **Passenger Injuries:** | 1 None | **Aircraft Fire:** | None |
| **Ground Injuries:** | N/A | **Aircraft Explosion:** | None |
| **Total Injuries:** | 3 None | **Latitude, Longitude:** | 45.190277,-123.15139 |

The airplane came to rest within a bramble patch down an embankment just beyond the instrument landing system antennas at the departure end of runway 22. The fuselage remained intact, and sustained damage to the nose landing gear, which had folded aft. The belly skin just aft of the nose landing gear door was punctured, with corresponding damage to the belly stringers. Both wings exhibited multiple indentations to their leading edges, crushing them back to the forward spar. Examination of a series of rivets around the cabin area revealed dislocation consistent with deformation of the airplanes primary structure.

Although tire marks were present in the soft mud beyond the runway, no corresponding skid marks were noted along the runway surface.

## Flight recorders

The airplane was equipped with a Universal CVR-30 cockpit voice recorder. The unit did not sustain any damage, and was sent to the NTSB Vehicle Recorder Division's Audio Laboratory for audio extraction and content summary. The unit had recorded the last 30 minutes of the flight on two separate channels, which included the intercom system and the cockpit area microphone (CAM).

The recording essentially supported the pilot and copilot statements, and began with the airplane at flight level 280, with the pilot flying as pilot-in-command. Over the next 27 minutes, the crew communicated with air traffic control, initiated an uneventful descent, and completed checklists in a challenge/response fashion. The pilot asked for flaps 8, and the copilot acknowledged, as air traffic control personnel advised them to switch to the McMinnville advisory frequency. The flight progressed with the landing checks, and the landing gear was heard to extend. The landing checks were completed during the descent. A short time later there were three audible clicks recorded by the CAM, followed by a sound of "bump-bump," similar to touchdown.

Four seconds later, the pilot reported that the thrust reversers had not come out. The copilot asked if the control was all the way back, and a click was heard followed by a decrease in engine noise. The engine noise then increased, and the pilot stated, "no. they're sure not workin". A click and snap sound was then heard, and the pilot stated, "I can hear 'em though". The copilot stated that he had taken off his headphones to try and listen for the reversers. The engine noise again decreased, and the pilot stated he would try the thrust reverser's again. Thirty seconds had now passed since touchdown, and the engine sound again began to increase. The pilot then stated that they were not working, and the copilot

exclaimed, "you got it?" to which the pilot replied in the affirmative, and the copilot said, "slow'er down". Over the next 10 seconds, they continued to exchange words regarding slowing down and exiting the runway. The pilot then stated, "oh, emergency" and the sound of three snaps were heard followed by an increase in engine noise. A few seconds later, the pilot stated, "emergency brake...okay" and the engine noise began to decrease. Over the next 8 seconds the crew expressed concern that they could not stop before the end of the runway, and then a thump sound was heard similar to impact. For the next 33 seconds until the end of the recording, sounds similar to an engine shutdown and crew-egress were recorded.

The total time from the sound of the landing gear making contact with the runway, to the sound of the presumed impact, was 63 seconds.

## Tests and Research

A complete report of the airplane systems examination is contained within the public docket.

Squat Switches

The airplane, by design, was equipped with a redundant series of squat switches located on the left and right main landing gear strut torque arms. The switches were positioned to activate when the landing gear was extended, and the airplane was on the ground. The switches were connected within the electrical system, and configured to prevent inadvertent activation of core airplane systems during various modes of flight. The design was such that when the airplane was on the ground, the following occurred:

- A circuit was broken, which prevented the airplane from landing with the brakes applied.

- A circuit was completed, which energized the squat switch relay panel, in turn disabling the nose wheel steering system, and preventing deployment of the thrust reversers.

Post-accident examination of both the left and right landing gear struts revealed that each of their squat switch assemblies were partially detached from their upper scissor arm fork pads. On both sides, all three switch attachment screws were loose, with the switches rising between 1/8 and 1/4 inches from the pads. The switch roller bearing surfaces were not making positive contact with their respective scissor arm cams, thereby deactivating the switches. Under these circumstances, the airplane systems would interpret that the airplane was in air-mode, when it was in fact on the ground.

The switches were removed, and their mounting screws and pad surfaces were examined. All the bolt threads were sharp, with no flattening damage noted to the thread crests. The scissor pad and squat assembly mating surfaces were lightly coated in dirt, grime, and paint debris, and no fretting damage was present.

Thrust Reversers

The airplane was equipped with two Garrett (Honeywell) TFE731 series geared turbofan engines, and an Aeronca electro-pneumatic thrust reverser system. The Thrust Reversers supplement of the airplane's flight manual stated that during landing - once the airplane has touched the ground, the thrust reverser levers must be pulled back to the Reverse Idle/Deploy position, during which time the UNLOCK light will illuminate on the reverser panel. The light will remain illuminated while the reversers are translating, and once they reach the fully deployed position, the corresponding DEPLOY light will illuminate. At that point, the throttle solenoid will unlock allowing further retraction of the thrust lever and an increase in reverse engine thrust.

A correlation between the thrust lever positions and the engines power lever angle (PLA) was accomplished at various forward and reverse thrust lever positions. In all cases, the lever positions matched the manufacturer's nominal engine PLA values.

According to the Learjet 35A maintenance manual section, "THRUST REVERSER - MAINTENANCE PRACTICES", a throttle control interlock switch, solenoid, and pawl incorporated in the control quadrant assembly prevented application of reverser thrust above approximately 45 percent N1 rpm until both thrust reversers are fully deployed. According to representatives from Honeywell, a 45 percent N1 speed correlates to about 531 pounds of static thrust per engine.

Emergency Braking System

The airplane was equipped with an emergency air brake system consisting of an emergency brake control valve connected to a high-pressure air bottle. The bottle was connected to the hydraulic brake system via a series of shuttle valves. The control valve was mounted on the pedestal within the cockpit, and manually operated by the pilot. Lowering the valve handle admitted high-pressure air into the brake hydraulic lines, thereby applying pressure to the braking system. An emergency air pressure indicator needle was mounted within the cabin, indicating an operating range of between 1,800 and 3,000 PSI.

According to the emergency procedures section of the airplane's flight manual, the emergency handle must be pushed down approximately 2 inches before braking action begins. The manual recommends applying the brakes smoothly, and with small movements to prevent the tires from skidding.

Examination of the emergency brake system following recovery revealed that the pressure indicator needle was one needle-width below the fully charged pressure of 3,000 psi.

An emergency brake system test was subsequently performed by activating the emergency brake handle and simultaneously observing the movement of the brake caliper pistons, pads, and disks for both wheels. With the emergency lever depressed by 2 inches, the pads began to move and make contact with their associated disks. The lever was cycled to its full down position of 4.5 inches, five times. Resistance was felt in the lever, with corresponding movement of the pads and the sound of hissing air. Upon completion, the emergency air gauge had moved to about 2,500 psi. In a subsequent interview, the pilot stated that he felt minimal resistance in the brake lever handle, and that he probably could have pushed it further down. He stated that in retrospect, he should have applied the emergency brake earlier in the landing sequence.

Maintenance

The airplane had just undergone maintenance, which included a flight management system (FMS) upgrade along with both a pitot static/transponder and a reduced vertical separation minimum (RVSM) certification check.

The work was performed at the facilities of West Star Aviation, Grand Junction, Colorado; the accident flight was the first since the maintenance was performed, and was to be the positioning flight back to the operator's base.

The work order and maintenance logbook entries for the upgrade were examined, and the mechanics that performed the maintenance were interviewed. The mechanic responsible for the FMS upgrade stated that he had performed "hundreds" of such upgrades, and it was not necessary to configure the airplane for flight-mode at any time during the installation or subsequent testing; installation instructions for the FMS system supported this statement. The quality assurance manager stated that the standard company practice when performing an operation that required "defeating" a system, such as disabling a squat switch, required that technicians flag the system with an orange ribbon. Both he and the mechanics who worked on the airplane stated that the squat switch was not disabled during any maintenance operation.

The last item on the work order was entitled "Quality Assurance... Comply with Return to Service," and included a statement from the inspector that he had inspected the airplane as required by 14 CFR 91.409 (f)(3). This regulation states that the airplane must be inspected utilizing, "A current inspection program recommended by the manufacturer."

According to representatives from Bombardier/Learjet, the equivalent recommended inspection program would have been the Learjet Phase A5 Inspection. The landing gear section of this list detailed the inspection of the landing gear squat switches for condition.

The pre-delivery aircraft and equipment status list, provided by the maintenance facility did not specifically denote a squat switch check, but did list inspection items in its immediate vicinity. These items included checking the tires, struts, gear doors, and anti-skid transducers, as well as a check of the gear well area for leaks. The airplane flight manual exterior preflight inspection checklist (located on the airplane) listed similar items, including a check of the landing light located just above the squat switches; but again, no specific check of the squat switches were called for.

The quality assurance manager for the maintenance facility reported that a post-maintenance test flight would typically have been performed; however, in this case, representatives from Evergreen declined the test, and instead sent one of their mechanics to perform a check as part of the return flight. The Evergreen mechanic assigned to the flight stated that upon arrival at the maintenance facility he reviewed the work orders, and found a few minor discrepancies. These were resolved, and he performed a ramp check prior to departure. He stated that his primary involvement at Evergreen was with heavy maintenance, and that he had no prior experience maintaining a Learjet 35A. He further stated that the company mechanic who normally worked with the Learjet 35A was unavailable.

The airplane's logbooks revealed that the last maintenance procedure that required configuring the airplane for air-mode was the replacement of the right-side stall warning system switch. This operation was completed on November 29, 2012, 60 flight hours, and 27 landings prior. This maintenance was

performed at the Evergreen facility by the company's Learjet mechanic. He stated that during the operation he did not disable the squat switches.

Performance

The pilot reported the airplane weight at the time of the accident to be 12,000 pounds. Utilizing the Learjet 35 series Crew Checklist and Quick Reference Handbook, the landing distance for dry field conditions at the airport elevation, and a temperature of 16 degrees C, would have been about 2,600 feet.

## Administrative Information

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| **Investigator In Charge (IIC):** | Simpson, Eliott |
| **Additional Participating Persons:** | Dan Ridgeway; Federal Aviation Administration FSDO; Portland, OR<br>David Studtmann; Honeywell; Phoenix, AZ<br>Scott Simpson; Bombardier; Wichita, KS |
| **Original Publish Date:** | October 27, 2014 |
| **Last Revision Date:** | |
| **Investigation Class:** | Class |
| **Note:** | The NTSB traveled to the scene of this accident. |
| **Investigation Docket:** | https://data.ntsb.gov/Docket?ProjectID=86889 |