



Log 2455

# National Transportation Safety Board

Washington, D.C. 20594  
Safety Recommendation

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Date: May 9, 1994  
In reply refer to: A-94-101

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American Institute of Aeronautics and Astronautics  
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The National Transportation Safety Board recently investigated two accidents that occurred during experimental test flights being conducted by the manufacturers. The first accident involved a modified Lockheed C-130 airplane known as the High Technology Test Bed (HTTB). The HTTB was used by Lockheed primarily to evaluate and demonstrate advanced technology concepts. The airplane had a highly modified flight control system that featured fly-by-wire, power-by-wire technology. The accident occurred when the HTTB became airborne during an intended ground minimum control speed ( $V_{mcg}$ ) test. The second accident involved a Canadair Regional Jet 600 that stalled and lost control during a low speed test maneuver at an altitude of 12,000 feet. The airplane did not recover from the loss of control despite being

equipped with an anti-spin parachute. The Safety Board believes that issues raised during these investigations would be of considerable interest to the flight test community.

On February 3, 1993, at 1330 eastern standard time, the Lockheed HTTB crashed shortly after takeoff from runway 11 at Dobbins Air Force Base in Marietta, Georgia. The accident occurred while the test crew was performing a  $V_{mcg}$  evaluation that required them to accelerate from a stop and intentionally shut down the No. 1 engine as the indicated air speed reached 83 knots. Handling qualities were to be evaluated as the crew attempted to restore the airplane's track on the runway centerline while continuing to accelerate with the remaining three engines producing power. Once the airplane was brought back to the centerline, the crew was to stop the airplane. Although the planned test did not involve flight, the airplane became airborne and crashed just north of the airport. All seven people on board were fatally injured, and the airplane was destroyed.

The evidence indicates that when the HTTB's No. 1 engine was shut down, a large right rudder pedal input was made as the crew attempted to restore the track of the airplane on the runway centerline. Several seconds later, control of the rudder was lost, and the airplane veered off to the left of the runway. The pilot then elected to take off, and the airplane crashed shortly after becoming airborne.

The airplane was configured with a rudder Integrated Actuator Package (IAP), which was designed by an avionics manufacturer. The IAP is an electrically powered, electrically commanded servoactuation system with a self-contained hydraulic reservoir and pump. This system incorporates both fly-by-wire and power-by-wire technology.

One software feature of the rudder IAP computers was designed to protect the airplane from experiencing an uncommanded rudder hardover, which may cause loss of control. This protection was achieved by comparing the commanded rudder position from the rudder pedals to the actual rudder position. The logic was such that if a difference greater than the threshold value of approximately  $10^\circ$  was detected continually for 2.5 seconds, the IAP computers would disengage the rudder by removing all hydraulic pressure and illuminating warning lights to alert the flightcrew. This logic caused disengagements on two prior tests dating back to a year prior to the accident. Those disengagements were troubleshooted by engineers from the IAP manufacturer and the flight controls staff at Lockheed but no design flaws in the logic were found.

After the engine was shut down during the accident test, a large rudder pedal input was made and directional control was initially maintained. However, as the airplane accelerated, increasing airloads reduced the actual rudder deflection angle. The difference between commanded and actual rudder deflection eventually exceeded  $10^\circ$  and activated the IAP rudder hardover protection logic. Moments later, control of the rudder was lost, and the airplane lost directional control.

Lockheed and the manufacturer of the IAP did not account for known aerodynamically imposed rudder deflection limitations when implementing the IAP rudder hardover protection

logic. Additionally, Lockheed Stability and Control engineers, who would likely have discovered this IAP design logic oversight, were not made aware of the logic.

The Safety Board determined that the probable cause of the Lockheed HTTB accident was the disengagement of the rudder flight control system because of inadequate design criteria by the manufacturer of the IAP, which allowed a total loss of rudder control capability; and insufficient systems safety review by the airplane manufacturer of the consequences of the known design feature to all flight regimes.

To prevent similar flight test accidents, the Safety Board believes that all manufacturers involved in the design of flight control systems should give due consideration to aerodynamically imposed control surface deflection limitations and should make flight control system logic details available to Stability and Control engineers, System Safety engineers, and other staff who might find flaws in the logic.

On July 26, 1993, at 1355 central daylight time, a Canadair Regional Jet 600 departed controlled flight while maneuvering and crashed near Byers, Kansas. The two pilots and test engineer aboard were fatally injured; the airplane was destroyed. The airplane was operated by its manufacturer on a test flight to evaluate flying qualities in a new 8° takeoff flap setting and to demonstrate compliance with 14 CFR 25.177. The loss of control occurred during a low speed steady-heading sideslip test maneuver at 12,000 feet.

The airplane was equipped with an anti-spin parachute system that, according to Canadair, was designed to assist in recovery from a deep stall or spin. The system features a tail-mounted parachute that can be deployed by the flightcrew, then jettisoned once control of the airplane is regained. A control panel mounted above the main instrument panel in the center of the cockpit is used to operate the system.

The parachute is attached to the airplane through a hydraulically powered jaws mechanism. The jaws mechanism is designed to disconnect the parachute from the airplane when an unintentional deployment would be hazardous or following intentional deployment and successful recovery. During normal flight the jaws are open, allowing the parachute to fall free if inadvertently deployed. When the jaws are closed, they grasp a shackle fitting on the end of the parachute, thereby attaching it to the airplane. Canadair test procedures call for the jaws to be open during takeoff, then closed at the flightcrew's discretion prior to any test maneuver that may result in a deep stall or spin.

The control panel has four switches that perform the following functions: (1) apply electrical power to the anti-spin parachute system, (2) arm the deployment pyrotechnic charges, (3) lock the jaws mechanism, and (4) fire the deployment pyrotechnic charges to deploy the parachute. System design allows the parachute to be deployed regardless of the position of the jaws mechanism.

Conversation recorded by the cockpit voice recorder indicated that the flightcrew verified that the jaws were functioning properly and were in the open position for takeoff. After takeoff, there was no mention of closing the jaws in preparation for the maneuver. Interviews with other company flight test personnel indicated it is likely that the flightcrew believed the test maneuver did not have the potential to result in a deep stall or spin.

The test plan called for the steady-heading sideslip maneuver to be terminated at 15° of sideslip or at activation of the stall warning stick shaker. However, the captain continued past the stick shaker and reached 21° of sideslip when the departure occurred.

The captain requested that the copilot deploy the parachute as the airplane descended through 8,000 feet. There was no conversation about closing the jaws prior to deployment. Shortly after deployment, the captain asked the copilot if the parachute was out and the copilot responded affirmatively. Data from the flight data recorder indicated that there was no change in the airplane's acceleration when the parachute was deployed. Control was not regained and the airplane descended to the ground.

A witness reported seeing the parachute fall free of the airplane as it was deployed. The parachute was found 3 miles from the accident site. There was no evidence of damage to the parachute, risers, shroud lines, or shackle. The shroud lines retained many of the packing folds, indicating that they had not been tensioned.

The jaws mechanism showed no evidence of preimpact failure, but since the hydraulic fluid had drained out, its preimpact position could not be determined. The control panel was destroyed in the postaccident fire, and the position of the switch that closes the jaws mechanism could not be determined.

Based on the evidence, the Safety Board believes that the flightcrew performed the test maneuver with the jaws open and that the copilot deployed the parachute without first closing the jaws. This allowed the parachute to fall free of the airplane without assisting in recovery from the uncontrolled maneuver.

During the investigation, the Board learned that other aircraft manufacturers use design features that prevent anti-spin parachutes from deploying if the jaws are open. Two such design features are as follows: (1) a T-shaped handle, which must be rotated 90° (to lock the jaws) before the handle can be pulled out to deploy the parachute, and (2) the provision of electrical power to the parachute deployment switch only when a position sensor indicates that the jaws are closed.

The Safety Board determined that the probable cause of the Byers, Kansas accident was the captain's failure to adhere to the agreed-upon flight test plan for ending the maneuver at the onset of prestall stick shaker, and the flightcrew's failure to assure that all required switches were properly positioned for anti-spin parachute deployment. A factor that contributed to the accident

was the inadequate design of the anti-spin parachute system, which allowed deployment of the chute with the hydraulic lock switch in the unlock position.

In an attempt to prevent future flight test accidents, the Safety Board believes that all anti-spin parachute systems should incorporate a design feature that prevents the parachute from deploying if the jaws are open.

The Safety Board believes that widespread dissemination of the information learned from these two accidents should be made throughout the flight test community. Therefore, the National Transportation Safety Board recommends that the Society of Flight Test Engineers, the Society of Experimental Test Pilots, the American Institute of Aeronautics and Astronautics - Flight Test Committee, and the System Safety Society:

- (1) Inform members of the circumstances of these accidents, (2) urge all companies involved in the design of flight control systems to give due consideration to aerodynamically imposed control surface limitations and to make flight control system logic details available to Stability and Control engineers, System Safety engineers, and other staff who might find flaws in the logic, and (3) urge all companies involved in the flight test of airplanes with anti-spin parachute systems to incorporate a design feature that would prevent the parachute from deploying if the jaws securing the parachute to the airplane are open. (Class II, Priority Action) (A-94-101)

The National Transportation Safety Board is an independent Federal agency with the statutory responsibility "to promote transportation safety by conducting independent accident investigations and by formulating safety improvement recommendations" (Public Law 93-633). The Safety Board is vitally interested in any action taken as a result of its safety recommendations. Therefore, it would appreciate a response from you regarding action taken or contemplated with respect to the recommendation in this letter. Please refer to Safety Recommendation A-94-101 in your response.

Chairman VOGT, Vice Chairman HALL, and Members LAUBER and HAMMERSCHMIDT concurred in this recommendation.



By: Carl W. Vogt  
Chairman

Brief of Accident

File No. - 0071 7/26/93 BYERS, KS A/C Reg. No. CFCRJ Time (Lcl) - 1352 CDT

---Basic Information---

Type Operating Certificate-NONE (GENERAL AVIATION)

Type of Operation -FLIGHT TEST  
Flight Conducted Under -14 CFR 91  
Accident Occurred During -MANEUVERING

---Aircraft Information---

Make/Model - CANADAIER CL-600-2B19  
Landing Gear - TRICYCLE-RETRACTABLE  
Max Gross Wt - 53000  
No. of Seats - 5

Aircraft Damage  
DESTROYED  
Fire

Crew Pass  
Fatal 3  
Serious 0  
Minor 0  
None 0

Eng Make/Model - GE CF-34-3A1  
Number Engines - 2  
Engine Type - TURBOFAN  
Rated Power - 8730 LBS THRUST  
ELT Installed/Activated - YES/NO  
Stall Warning System - YES

---Environment/Operations Information---

Weather Data  
Wx Briefing - COMMERCIAL WX SERVICE  
Method - IN PERSON  
Completeness - FULL  
Basic Weather - VMC  
Wind Dir/Speed - 160/015 KTS  
Visibility - 10.0 SM  
Lowest Sky/Clouds - UNK/NR  
Lowest Ceiling - NONE  
Obstructions to Vision- NONE  
Precipitation - NONE  
Condition of Light - DAYLIGHT

Airport Proximity  
OFF AIRPORT/STRIP

Airport Data

Runway Ident - N/A  
Runway Lth/Wid - N/A  
Runway Surface - N/A  
Runway Status - N/A

---Personnel Information---

Pilot-In-Command  
Certificate(s)/Rating(s)  
COMMERCIAL, FOREIGN  
SE LAND, ME LAND

Age - 48  
Biennial Flight Review  
Current - YES  
Months Since - 14  
Aircraft Type - CL-600

Medical Certificate - VALID MEDICAL-WAIVERS/LIMIT  
Flight Time (Hours)  
Total - 3836  
Make/Model- 875  
Instrument- 785  
Last 24 Hrs - 0  
Last 30 Days- 24  
Last 90 Days- 91

Instrument Rating(s) - AIRPLANE

---Narrative---

THE CREW WAS PERFORMING A LATERAL & DIRECTIONAL STABILITY TEST. CHANGES FROM EARLIER TESTS COMBINED NEW LEADING EDGE FAIRING, NEW FLAP SETTING, LOWER REFERENCE AIRSPEED, AND TRIAL SETTINGS FOR THE STALL PROTECTION SYSTEM (SHAKER & PUSHER). ENGINEERS HAD BRIEFED THE CREW DATA WOULD BE SUFFICIENT IF THE STEADY HEADING SIDESLIP (SHSS) MANEUVER ENDED AT A 15 DEG SIDESLIP, OR AT ONSET OF STALL WARNING; CREW AGREED TO END AT STALL WARNING. DURING THE TEST THE CAPT CONTINUED PAST STALL WARNING TO 21 DEG SIDESLIP AT FULL RUDDER. THE AIRPLANE ROLLED RAPIDLY THROUGH 360 DEG & ENTERED A DEEP STALL. THE COPILOT ATTEMPTED TO DEPLOY THE ANTI-SPIN CHUTE. HOWEVER, ALL THE CHUTE SYSTEM COCKPIT SWITCHES WERE NOT PROPERLY PRESET; INSTEAD OF ASSISTING RECOVERY, THE CHUTE PARTED FROM THE AIRPLANE. FULL CONTROL WAS NOT REGAINED BEFORE IMPACT. THE CHUTE SYSTEM DESIGN ALLOWED DEPLOYMENT OF THE CHUTE EVEN WHEN THE HYD LOCK SWITCH WAS IN THE UNLOCKED POSITION & THE HOOKS CLASPING THE CHUTE SHACKLE TO THE AIRFRAME WERE OPEN. SYSTEM TESTED OK BEFORE FLIGHT.

Brief of Accident (Continued)

File No. - 0071

7/26/93

BIERS,KS

A/C Reg. No. CFCRJ

Time (Lcl) - 1352 CDT

Occurrence #1 LOSS OF CONTROL - IN FLIGHT  
Phase of Operation MANEUVERING

Finding(s)

1. PROCEDURES/DIRECTIVES - NOT FOLLOWED - PILOT IN COMMAND
2. STALL/SPIN - INADVERTENT - PILOT IN COMMAND

Occurrence #2 IN FLIGHT COLLISION WITH TERRAIN/WATER  
Phase of Operation DESCENT - UNCONTROLLED

Finding(s)

3. SAFETY SYSTEM(OTHER) - INADEQUATE
4. AIRCRAFT/EQUIPMENT, INADEQUATE DESIGN - MANUFACTURER
5. SAFETY SYSTEM(OTHER) - UNLOCKED
6. MISCELLANEOUS EQUIPMENT - IMPROPER USE OF - PILOT IN COMMAND
7. MISCELLANEOUS EQUIPMENT - IMPROPER USE OF - COPILOT/SECOND PILOT
8. SAFETY SYSTEM(OTHER) - SEPARATION

-----Probable Cause-----

The National Transportation Safety Board determines that the Probable Cause(s) of this accident was:  
THE CAPTAIN'S FAILURE TO ADHERE TO THE AGREED UPON FLIGHT TEST PLAN FOR ENDING THE TEST MANEUVER AT THE ONSET OF  
PRESTALL STICK SHAKER, AND THE FLIGHTCREW'S FAILURE TO ASSURE THAT ALL REQUIRED SWITCHES WERE PROPERLY POSITIONED FOR  
ANTI-SPIN CHUTE DEPLOYMENT. A FACTOR WHICH CONTRIBUTED TO THE ACCIDENT WAS THE INADEQUATE DESIGN OF THE ANTI-SPIN CHUTE  
SYSTEM WHICH ALLOWED DEPLOYMENT OF THE CHUTE WITH THE HYDRAULIC LOCK SWITCH IN THE UNLOCKED POSITION. (WHEN IN THE  
UNLOCKED POSITION, THE HOOKS CLASPING THE CHUTE SHACKLE TO THE AIRFRAME ARE OPEN.)

Brief of Accident

File No. - 0736      2/03/93      MARIETTA, GA      A/C Reg. No. N130X      Time (Lcl) - 1327 EST

-----Basic Information-----  
Type Operating Certificate-NONE (GENERAL AVIATION)      Aircraft Damage DESTROYED      Injuries Fatal 7      Serious 0      Minor 0      None 0

Type of Operation -FLIGHT TEST      Fire ON GROUND      Crew 0      Pass 0  
Flight Conducted Under -14 CFR 91  
Accident Occurred During -TAKEOFF

-----Aircraft Information-----  
Make/Model - LOCKHEED L382E-44K-20      Eng Make/Model - ALLISON 501-M71K      ELT Installed/Activated - NO -N/A  
Landing Gear - TRICYCLE-RETRACTABLE      Number Engines - 4      Stall Warning System - YES  
Max Gross Wt - 155000      Engine Type - TURBOPROP  
No. of Seats - 7      Rated Power - 5250 HP

-----Environment/Operations Information-----  
Weather Data      Itinerary      Airport Proximity      Airport Data  
Wx Briefing - MILITARY      Last Departure Point      ON AIRPORT      DOBBINS AFB  
Method - ACFT RADIO      SAME AS ACC/INC      Runway Ident - 11  
Completeness - WEATHER NOT PERTINENT      Destination      LOCAL      Runway Lth/Wid - 10000/ 300  
Basic Weather - VMC      Type of Clearance - VFR      Runway Surface - CONCRETE  
Wind Dir/Speed- 130/003 KTS      Type Apch/Lndg - NONE      Runway Status - DRY  
Visibility - 7.0 SM      ATC/Airspace  
Lowest Sky/Clouds - 25000 FT SCATTERED      Type of Flight Plan - COMPANY (VFR)  
Lowest Ceiling - NONE      Type of Clearance - VFR  
Obstructions to Vision- NONE      Type Apch/Lndg - NONE  
Precipitation - NONE  
Condition of Light - DAYLIGHT

-----Personnel Information-----  
Pilot-In-Command      Age - 42      Medical Certificate - VALID MEDICAL-NO WAIVERS/LIMIT  
Certificate(s)/Rating(s)      Biennial Flight Review      Flight Time (Hours)      Total      Last 24 Hrs - UNK/NR  
ATP,CFI,FLT ENG      Current - YES      - 7658      Make/Model- 1260      Last 30 Days- 16  
SE LAND,ME LAND      Months Since - 4      Instrument- 1124      Multi-Eng - 7498      Rotorcraft - UNK/NR  
Aircraft Type - CE-550

-----Narrative-----  
Instrument Rating(s) - AIRPLANE  
THE ACFT WAS DESIGNED & USED AS THE COMPANY'S ENGINEERING TEST BED. AN EVALUATION OF THE FLY-BY-WIRE RUDDER ACTUATOR & GROUND MINIMUM CONTROL SPEED (VMCG) WAS BEING CONDUCTED. DURING THE FINAL HI-SPEED GROUND TEST RUN, THE ACFT ABRUPTLY VEERED LEFT & BECAME AIRBORNE. IT ENTERED A LEFT TURN, CLIMBED TO ABOUT 250 FT, DEPARTED CONTROLLED FLT & IMPACTED THE GRND. INVESTIGATION REVEALED A DESIGN FEATURE IN THE RUDDER ACTUATOR THAT REMOVES HYD PRESSURE WITHIN THE ACTUATOR IF THE RUDDER POSITION COMMANDED BY THE PILOT EXCEEDED THE ACTUAL RUDDER ACTUATOR POSITION FOR A SPECIFIED TIME, AND THE RUDDER AERODYNAMICALLY TRAILS. THE ACTUATOR PREVIOUSLY DISENGAGED IN FLT. THE COMPANY DID NOT CONDUCT A SYSTEM SAFETY REVIEW OF THE RUDDER BYPASS FEATURE & ITS CONSEQUENCES TO ALL FLT REGIMES, NOR OF THE VMCG TEST. THE FLT TEST PLAN SPECIFIED THAT ENGINE POWER BE RETARDED IF THE RUDDER BECAME INEFFECTIVE. NEITHER FLT HAD RECEIVED TRAINING AS AN EXPERIMENTAL TEST FLT. THE COMPANY ALLOWED EXPERIMENTAL FLT TESTS AT A CONFINED, METROPOLITAN ARPT.



Brief of Accident (Continued)

File No. - 0736

2/03/93

MARIETTA, GA

A/C Reg. No. N130X

Time (Lcl) - 1327 EST

Occurrence #1 LOSS OF CONTROL - ON GROUND  
Phase of Operation OTHER

Finding(s)

1. FLT CONTROL SYST, RUDDER CONTROL - INADEQUATE
2. AIRCRAFT/EQUIPMENT, INADEQUATE DESIGN - MANUFACTURER  
INADEQUATE SUBSTANTIATION PROCESS, INSUFFICIENT REVIEW - COMPANY/OPERATOR MGMT
3. INADEQUATE TRAINING - COMPANY/OPERATOR MANAGEMENT
4. FLT CONTROL SYST, RUDDER - DISENGAGED
5. DIRECTIONAL CONTROL - NOT POSSIBLE - PILOT IN COMMAND
6. PROCEDURES/DIRECTIVES - NOT FOLLOWED - PILOT IN COMMAND
7. INADEQUATE TRAINING - COMPANY/OPERATOR MANAGEMENT

Occurrence #2 LOSS OF CONTROL - IN FLIGHT  
Phase of Operation TAKEOFF - INITIAL CLIMB

Finding(s)

8. LIFT-OFF - PERFORMED - PILOT IN COMMAND
9. AIRCRAFT CONTROL - NOT POSSIBLE - PILOT IN COMMAND
10. STALL/SPIN - INADVERTENT - PILOT IN COMMAND

Occurrence #3 IN FLIGHT COLLISION WITH TERRAIN/WATER  
Phase of Operation TAKEOFF - INITIAL CLIMB

-----Probable Cause-----

The National Transportation Safety Board determines that the Probable Cause(s) of this accident was:  
DISENGAGEMENT OF THE RUDDER FLY-BY-WIRE FLIGHT CONTROL SYSTEM RESULTING IN A TOTAL LOSS OF RUDDER CONTROL CAPABILITY WHILE CONDUCTING GROUND MINIMUM CONTROL SPEED TESTS. THE DISENGAGEMENT WAS A RESULT OF THE INADEQUATE DESIGN OF THE RUDDER'S INTEGRATED ACTUATOR PACKAGE BY ITS MANUFACTURER; THE OPERATOR'S INSUFFICIENT SYSTEM SAFETY REVIEW FAILED TO CONSIDER THE CONSEQUENCES OF THE INADEQUATE DESIGN TO ALL OPERATING REGIMES. A FACTOR WHICH CONTRIBUTED TO THE ACCIDENT WAS THE FLIGHT CREW'S LACK OF ENGINEERING FLIGHT TEST TRAINING.