NATIONAL TRANSPORTATION SAFETY BOARD
OFFICE OF AVIATION SAFETY
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December 15, 2003

ADDENDUM NUMBER 4 TO THE SYSTEMS GROUP CHAIRMAN'S FACTUAL REPORT OF INVESTIGATION - A300-600 GROUND TEST

DCA02MA001

A. ACCIDENT

Operator: American Airlines
Aircraft: A300-600R
Location: Belle Harbor, New York
Date: November 12, 2001
Time: 09:16 EDT

B. SYSTEMS GROUP

Chairman	Steven Magladry National Transportation Safety Board Washington, DC
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C. SUMMARY

On November 12, 2001, American Airlines flight 587, an Airbus Industrie A300-600R, N14053, crashed at Belle Harbor, New York, shortly after takeoff from John F. Kennedy International Airport (JFK), Jamaica, New York. The aircraft was equipped with General Electric CF6-80C2A5 engines. The airplane had taken off from runway 31 left and had turned southbound when it crashed. The aircraft was operated under the provisions of Title 14 of the U.S. Code of Federal Regulations Part 121 as a regularly scheduled international passenger flight from JFK to Santo Domingo, Dominican Republic. The 2 pilots, 7 flight attendants, and 246 passengers plus 5 lap children on board were killed.

A review of the Flight Data Recorder information for the accident flight showed large motion of the yaw controls. Representatives of the Systems Group convened at Airbus Industrie, in Toulouse, France between 9 and 12 September 2002 to test the characteristics of the yaw control system of the A300-600 airplane. The airplane tested was manufacturer's serial number 0701. The following report describes the test set-up, the test plan, and provides the results.

D. DETAILS OF THE INVESTIGATION

1.0 TEST INSTALLATION

Data acquisition and recording systems were installed on MSN 0701 by Airbus Industrie and NAWCAD, Patuxent River, Maryland. Appendix A (Report TAP 01-05-533) is a NAWCAD report which provides the parameter list, calibrations, and test equipment installation used for the tests. An overview of the test set-up, the sensor locations, a schematic of the signal generator installation, and a table of test configurations is provided in Appendix B.

2.0 TEST PLAN

The test plan is provided in Appendix C. Appendix C also describes the test set-up, but does not include information about the pedal force sensor installed by NAWCAD.

3.0 REVIEW OF TEST AIRCRAFT RUDDER CONTROL SYSTEM

The systems group reviewed the condition of the rudder control system prior to the start of tests. The following inspections were performed:

> The rig pins were installed in the pedal quadrant, the aft rudder quadrant and the bellcrank of the lower servo control, and the rudder was observed to align with the index mark (neutral).

A desynchronization check of the rudder system was performed. This check confirmed that all three rudder servos were adjusted within tolerance.

The linear measurement of maximum rudder deflection was recorded for full left and right deflection from the index mark.

Left deflection – 105.7 cm (Airbus Flight Test Instrumentation (FTI), rudder: -30.09 degrees)
Right deflection –107.1 cm (Airbus FTI rudder: 30.51 degrees)

Full left and right rudder were applied at the pedals, and the adjustable stops on the aft rudder quadrant were inspected. The variable stop lever contacted the output lever cam prior to contacting the adjustable stop. The adjustable stop was no more than 0.5 mm from contacting its stop.

4.0 REVIEW OF HYDRAULIC POWER SUPPLY

The ground tests were performed with three hydraulic ground units, providing pressure and flow to each of the three aircraft systems. This was used in lieu of the airplane hydraulic pumps, so the tests could be performed without operating the engines. The capacity of the ground units and estimated maximum consumption of the aircraft green hydraulic system is provided in Appendix D.

Tests were performed to check the sufficiency of the pressure and flow of the ground hydraulic carts. Each of the three carts, the hydraulics pressure readings on the ECAM in the flight deck, and the test recording system displays were monitored by personnel during these tests. The flight controls were manipulated through a full range of motion in all three axis, simultaneously, at approximately 20-30 degrees per second rate of change.

The first test was conducted at 240 knots, simulated Vc.

Blue System

Start flow: 6.5 litre per minute
Peak flow: 50.4 litre per minute

Start pressure: 200 bar
Low pressure: 190 bar

Green System

Start flow: 27.4 litres per minute
Peak flow: 60.0 litre per minute

Start pressure: 206 bar
Low pressure: 195 bar

Yellow System
Start flow: 8.5 litre per minute
Peak flow: 42.7 litre per minute

Start pressure: 206 bar
Low pressure: 206 bar

The second test was conducted at 0.0 knots, simulated Vc for more surface deflection.
Blue System
Start flow: 6.5 litre per minute
Peak flow: 39.8 litre per minute

Start pressure: 200 bar
Low pressure: 195 bar

Green System
Start flow: 27.4 litre per minute
Peak flow: 70.0 litre per minute

Start pressure: 206 bar
Low pressure: 200 bar

Yellow System
Start flow: 8.5 litre per minute
Peak flow: 46.5 litre per minute

Start pressure: 206 bar
Low pressure: 195 bar

Due to these tests, the hydraulic ground carts were considered sufficient for the systems group testing being performed.

5.0 REVIEW OF AIRCRAFT CONFIGURATION

The systems group reviewed the configuration of MSN 0701, as compared with the accident airplane (MSN 0420), and determined there are no significant differences in rudder control system and related electronic flight control systems. In addition, all mandatory service bulletins related to the rudder control system had been completed on MSN 0701 and MSN 0420.

Note: For these tests, the nose wheel steering spring rod was disconnected.

6.0 RUDDER PEDAL FORCE MEASUREMENT

Loads on the rudder pedals were determined using two methods; force gauges on the pedals, and a strain gage-instrumented control rod (Appendix B). Airbus provided a formula for conversion of the control rod force measurement to pedal force (Appendix B). Calibration tests were then performed to compare the two measurement methods. After the conversion formula was applied to the control rod forces, a difference was still noted in the measured forces. Additional tests were performed on the airplane with a calibrated lab load tool applied approximately perpendicular at the center of the right pedal load transducer in order to resolve the discrepancy. It was later determined that the conversion formula assumed that the load was applied perpendicular to the pedal linkage, however, the pedal sensor recorded the force applied perpendicular to the pedal face. It was shown that angle of application of the pedal load affected the resultant load at the control rod. Though an effort was made during the tests to apply a load perpendicular to the pedal face, there was no way to control this, so there may be some discrepancies when the recorded data is reviewed. The following summarizes these pedal force calibration tests:

Applied Load	Measured Control Rod Load	Measured Pedal Load	Calculated Airbus Force on Pedal from rod force
22.26 lbs	26.52 lbs	22.64 lbs	17.5 lbs
44.96 lbs	64.95 lbs	45.42 lbs	42.87 lbs

Full pedal displacements were performed to the Rudder Travel Limiter stop and the force was increased until the pedal load sensor displayed 228 lbs. The corresponding control rod force displayed 460 lbs. Airbus calculated this measurement to be 278 lbs of force at the rudder pedal. During the test when the pedal force, measured by the load transducer, remained constant (near 228 lbs), a small increase in the control rod force was observed before reaching the maximum.

Additional tests were performed by three different operators, applying a constant 40 daN (88 lbs) force as measured by the control rod (1.0 volt = 40.0 daN) to determine the effect of the various foot position/angle on the measured force. By substantially changing the angle and position of the force applied by his foot on the pedal, differences in forces measured at the pedal were observed, while the measured force on the control rod was constant. The test results were as follows:

Foot position	Force (lbf) supplied by ball of foot			Force (lbf) supplied near toes of foot	Force (lbf) supplied by heal of the foot
Force position	Right	Left	Center	Center	Center
Seat in normal position	46	50	60, 54, 64	45	54, 57
Seat in back position			46		
Seat in forward position			60		

The team agreed to record both force measurement parameters and that the 225 pound pedal limit, as determined by the pedal load sensor, would provide an adequate margin of safety below the limit load for the rudder control system.

The team agreed to perform a second set of rudder pedal force and rudder position comparison tests between the two data systems.

Right Hand Pedal; Vc = 300 knots

	Measure 1	Measure 2	Measure 3	Measure 4	Measure 5
Force on Control Rod NAWCAD	64.88 daN	75.38 daN	87.67 daN	94.87 daN	99.57 daN
Force on Control Rod Airbus	65.00 daN	75.40 daN	88.30 daN	94.60 daN	99.60 daN

Left Hand Pedal; Vc = 300 knots

	Measure 1	Measure 2	Measure 3	Measure 4	Measure 5
Force on Control Rod NAWCAD	66.08 daN	72.48 daN	77.38 daN	88.37 daN	96.77 daN
Force on Control Rod Airbus	66.50 daN	72.60 daN	77.30 daN	88.70 daN	97.40 daN

Vc = 0.0 knots; Maximum right rudder deflection (degrees)

	Measure 1	Measure 2	Measure 3
FTI transducer	30.34	30.48	30.34
Aircraft transducer (NAWCAD)	29.90	30.03	30.02
Aircraft transducer (Airbus)	30.42	30.59	30.59

Vc = 0.0 knots; Maximum left rudder deflection (degrees)

	Measure 1	Measure 2	Measure 3
FTI transducer	29.96	30.02	30.03
Aircraft transducer (NAWCAD)	30.47	30.53	30.53
Aircraft transducer (Airbus)	29.90	29.99	29.99

The neutral point of the rudder control system was checked once more with the following results. Rigging pins were installed in the pedal mechanism below the flight deck and the servo control location on the vertical fin.
NAWCAD aircraft transducer = 0.6 degrees
Airbus aircraft transducer = 0.04 degrees
FTI transducer = 0.015 degrees

7.0 TEST RESULTS AND NOTES

The test results are provided in Appendix E through Appendix I. Refer to the Test plan (Appendix C) matrix “Comments/GMT” field for the test number. The complete parameter list in Appendix A, page III-4, provides the parameter name, description and range. The test results in Appendix E through Appendix I represent a portion of the total data recorded and presents only those parameters which were considered significant. Here are the plotted parameters and their description.

ABRPF - Airbus Rudder Pedal Force (LBS). This is the load on the control linkage down-stream of the pedal. This was measured by a strain gauge on a pushrod below the cockpit.

CAS – Computed Airspeed (Knots). This was simulated by a function generator. It was introduced in to the various airplane systems which require CAS for computation.

FUNGEN – Function Generator (VDC). This was used to introduce signals directly into a particular actuator.

RDRPOSANLG - Rudder Position (Degrees). This is the angle of the rudder surface relative to the neutral rigged position. Measured by a sensor attached to a rudder hinge near the base of the rudder.

RDRTRVLFLC1 - Rudder Travel Limiter Fault, Feel and Limitations Computer (FLC) 1 (Discrete). This records the fault status of FLC1.

RDRTRVLFLC2 - Rudder Travel Limiter Fault, Feel and Limitations Computer (FLC) 1 (Discrete). This records the fault status of FLC1.

RPFRH - Right Rudder Pedal Force (LBS). This is the force applied at captain's right rudder pedal. This was measured by a sensor installed on the pedal.

RPFLH - Left Rudder Pedal Force (LBS). This is the force applied at captain's left rudder pedal. This was measured by a sensor installed on the pedal.

RPP - Rudder Pedal Position (Degrees). This is the angle of the pedal relative to the neutral rigged position. This was measured by a sensor attached to a bellcrank on the pedal linkage.

VARSTPACTPOS - Variable Stop Actuator Position (mm). This is the position of the variable stop actuator relative to the neutral rig position. This is measured by a linear transducer at the actuator.

YAAC - Autopilot Yaw Actuator Command (milliamps). This is the current going to the Yaw autopilot actuator.

YAWPOSFACOUT - Yaw Damper Position as determined by the Flight Augmentation Computer (Degrees).

YAWRATE - Yaw Rate (Degrees/Second). This signal was introduced to simulate yaw rate to system components.

YAWSERFCCOUT - Yaw Autopilot Actuator Position as Determine by Flight Control Computer 2 (Degrees).

YDAC - Yaw Damper Actuator Command (milliamps). This is the current going to the Yaw Damper Actuator.

Additional notes concerning test IV-0-3.003:

The aim of the emergency AC electrical test was to observe the action of the VSA during AC electrical power loss. To avoid disconnecting the external power from the aircraft, Airbus suggested a procedure to force the aircraft to use only battery in the emergency mode and use the emergency electrical bus:
3PP DC essential bus supplied by the battery
4XP AC emergency bus supplied by the static inverter
To force the 3PP DC bus to be supplied by the battery, the contact 2PC was opened by pushing the pushbutton 10PC labeled Reset Fault TRU ESS. (See ASM 24-35-00, Schematic 1) In this configuration, it can be confirmed that the battery supplied the 3PP DC bus on the ECAM display page (consumption around 30 A).
To force the 4XP AC bus to be supplied by the static inverter, the contact 6XE and the static inverter 4XE have to be energized. This action can be accomplished by opening the circuit breaker 2XH, which opens the relay 6XH. (See ASM 24-52-00) This relay indicates a loss of the AC essential bus and supplies the contact 6XE and the static inverter automatically. (See ASM 24-24-00) This action can be checked by observing the flight deck warning light labeled AC ESS BUS OFF and AC EMER ON INV on the panel 424VU illuminated and a battery consumption increase up to approximately 50 amperes on the ECAM display page.

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