----- SYSTEMS GROUP CHAIRMAN'S FACTUAL REPORT -------

A. ACCIDENT:

Location:	Rome, Georgia
Date:	March 14, 2016
Time:	About 1508 local (EDT)
Aircraft:	Raytheon Aircraft Company 400A
Registration:	N465FL

B. SYSTEMS GROUP:

Chairman:	Michael Bauer National Transportation Safety Board Washington, D.C.
Member:	Homayoun Jandaghi Federal Aviation Administration Washington, D.C.
Member:	Doug Lightcap Flight Options Cleveland, OH.
Member:	Tony Kurpely Nextant Aerospace Cleveland, OH.
Member:	Brian Ramsey Crane Aerospace and Electronics Burbank, CA.

C. SUMMARY

On March 14, 2016, at 1508 eastern daylight time, a Raytheon Aircraft Company (RAC) 400A, N465FL, was substantially damaged during a runway excursion while landing at Richard B. Russell Regional Airport (RMG), Rome, Georgia. The pilot was uninjured and the co-pilot received minor injuries. The airplane was registered to Flight Options, LLC and was being operated in accordance with Title 14 Code of Federal Regulations Part 91 as a positioning flight that originated at Jackson County Airport-Reynolds Field (JXN), Jackson, Michigan. The flight was operating under an instrument flight plan and visual meteorological conditions were reported at the airport at the time of the accident.

The systems group was formed on July 19th 2016, during the examination of the anti-skid brake components.

D. DETAILS OF THE INVESTIGATION:

D.1 Braking System Description

The main landing gear wheels are equipped with disc brakes installed on the main landing gear axles. Wheel braking action, with the exception of the emergency brake system, is initiated by the master cylinders. Displacement of each master cylinder piston transfers hydraulic pressure to the power brake anti-skid control valve via the mixing valves. The mixing valves provide a means of interconnecting the four master cylinders in parallel to permit actuation of the brakes from either the pilot's or copilot's rudder pedals. Hydraulic fluid is provided to the master cylinders from a pressurized hydraulic reservoir installed on the forward side of the forward pressure bulkhead. The power brake anti-skid control valve is used to release and apply hydraulic pressure to the main gear brake assemblies. The control valve's three modes of operation include "manual", "power" and "anti-skid".

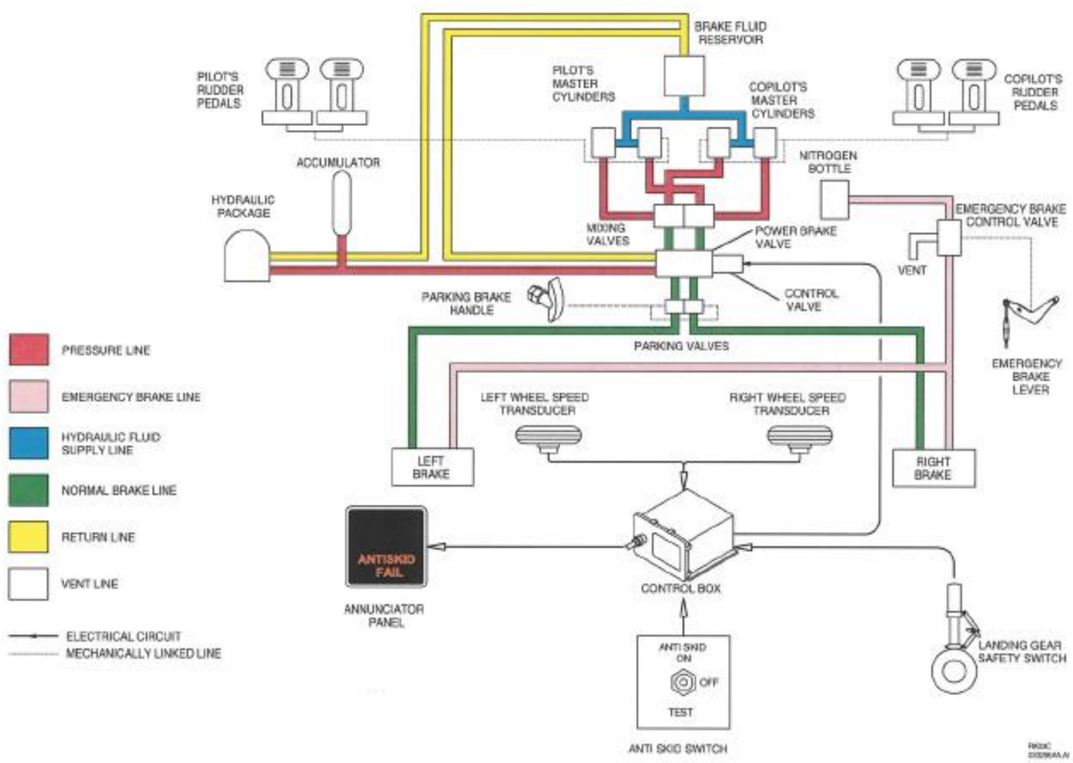

Figure 1 - RAC 400 Brake System Schematic (from Beechjet 400A Pilots Operating Manual revision date 9/28/2006)

D.1.1 Manual Mode

When 1,500 psi (105 kg/cm·) hydraulic pressure is not available to the power brake anti-skid control valve, hydraulic pressure from the master cylinders will hold the shuttle valves in the control valve open, thereby allowing hydraulic fluid pressure from the master cylinders to actuate the brake assemblies. The power brake anti-skid control valve acts only as plumbing and the anti-skid system is nonfunctional in the "manual" mode.

D.1.2 Power Brake Mode

When 1,500 psi (105 kg/cm·) of hydraulic pressure is available to the power brake anti-skid control valve, the internal shuttle valves are moved to the closed position and the control valve functions in the "power" mode. With the shuttle valves in the closed position, master cylinder hydraulic pressure is no longer applied to the brake assemblies, but to the metering valves inside the control valve. The metering valves apply the hydraulic system pressure to the brake assemblies at a 2:1 ratio, as compared to hydraulic pressure from the master cylinders. An accumulator installed just aft of the left hand (LH) main landing gear wheel well provides a fluid reserve to stabilize hydraulic pressure during pressure fluctuations of the hydraulic system. The accumulator is also equipped with an accumulator charging valve and pressure gauge. The "power" brake system will operate with or without anti-skid control.

D.1.3 Anti-Skid Power Brake Mode

An anti-skid control system is installed on the airplane to electronically monitor and control the "power" brake system, thereby providing maximum braking efficiency on all runway surfaces through the prevention of wheel skidding. The anti-skid control system consists of the "power" brake system components, an anti-skid control box and both the LH and RH wheel speed transducers. The system also utilizes a hydraulic servo control valve that is installed on the power brake anti-skid control valve, located in a compartment near the left main landing gear. The power brake anti-skid control box is located in the aft compartment and the wheel speed transducers are mounted inside the axles of their respective main landing gear wheel assemblies.

D.1.4 Anti-Skid System Operation

The anti-skid system is powered through the switch placarded ANTI-SKID, ON-OFF-TEST on the center pedestal. When the ANTI-SKID switch is in the OFF position, the brake system functions in either the "manual" or "power" mode, as determined by the availability of 1,500 psi (105 kg/cm·) of hydraulic pressure to the power brake anti-skid control valve. When the ANTI-SKID switch is placed in the ON position, 28 VDC from the LH load bus is applied to the anti-skid control box. The momentary TEST position initiates a functional test of the anti-skid system.

Signals from each wheel speed transducer are input to the anti-skid control box where control calculations are performed. Should a transducer signal indicate a skid condition, the anti-skid control box provides a signal to the hydraulic servo control valve and reduces brake pressure on each side of the brake system simultaneously. The left and right brake pressures are reduced proportionally to maintain any differential braking inputs that the crew may be using.

The anti-skid control box contains both a touch-down-protection and valve-dump-detection circuit. The valve-dump-detection circuit monitors the anti-skid control valve command signals. If a valve-dump release command is received for an extended period of time (3.4 +/- 0.5 seconds), the valve-dump-detection circuit signals the anti-skid control box to illuminate the amber ANTISKID FAIL annunciator. The touch-down-protection circuit prevents the application of brake pressure by the crew until the wheels are on the ground or if a wheel spins up to 37 knots. The positions of two ground safety relays are monitored by the anti-skid control box to operate the touch-down protection circuit.
A loss of electrical power to either the anti-skid control valve or control box will disable anti-skid control. The system will continue operation in the "power" mode, without anti-skid control, providing 1,500 psi (105 kg/cm·) of hydraulic pressure is still available. If 1,500 psi (105 kg/cm·) of hydraulic pressure is not available, the brake system reverts to the "manual" mode. The anti-skid system will not operate unless the brake system is in the "power" mode.

D.2 Anti-Skid System Detailed Examination

The anti-skid control box, power brake relay valve and wheel speed transducers were shipped to the manufacturer, Crane Aerospace and Electronics in Burbank, California and subjected to additional testing. The testing was performed by Crane Aerospace personnel and witnessed by the systems group chairman, the FAA, Nextant Aerospace, Flight Options and Crane Aerospace. Table 1 contains a list of the component part and serial numbers tested at Crane Aerospace.

Table 1. Brake components tested at Crane Aerospace Hydro-Aire

Part Number	Description	Serial Number
42-901	Anti-Skid Control Box	780
38-771	Power Brake Relay Valve	754
140-3110	Wheel Speed Transducer (LH Wheel)	1694
140-3110	Wheel Speed Transducer (RH Wheel)	1949

D.2.1.1.1 Anti-Skid Control Box Testing

The unit was removed from its shipping container and visually inspected. The unit appeared to have no visible signs of damage, see Figure 2.

Figure 2 - Anti-skid control box from N465FL after unpacking at Crane Aerospace and Electronics

The unit was placed on a test bench and tested according to functional test procedure TP-42-901, Rev A, 1, released 08/26/2003. The unit passed all tests performed and the data sheets were retained by the NTSB.

D.2.1.1.2 Power Brake Relay Valve Testing

The unit was removed from its shipping container and visually inspected. The valve was generally clean and very little hydraulic fluid remained with the unit, see Figure 3. Prior to performing the functional test procedure the filter assembly on the Left Brake Port had to be removed and replaced. During the packaging of the unit, a portion of the plastic cap covering the port became lodged in the port, Figure 4. The part was removed but debris was still present in the port, therefore the group agreed to remove and replace the filter and its associated O-ring.

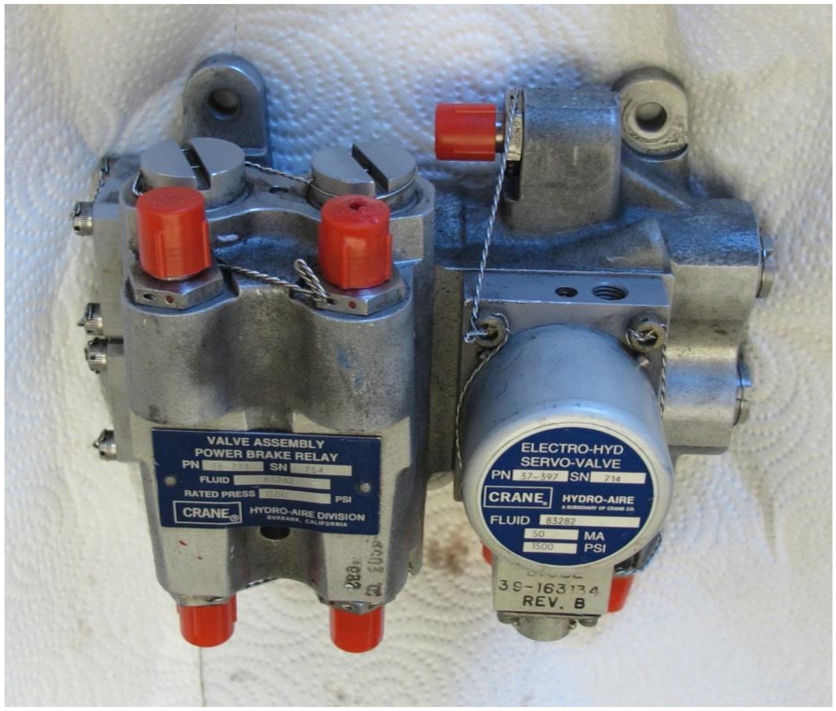

Figure 3 - Power brake relay valve from N465FL after unpacking at Crane Aerospace and Electronics

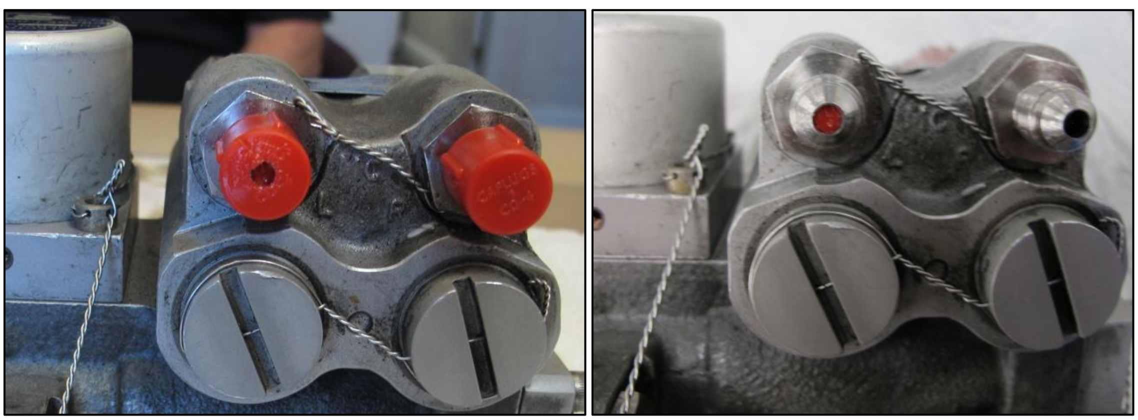

Figure 4 – Side by Side pictures of plastic cap installed (left) and after removed (right) showing debris in port

The unit was placed on a test bench and tested according to functional test procedure TP-38-771, Rev B, 1, released 10/09/1991. Plots generated by the Power Brake Valve Test (Left and Right) and Servo Modulation test (Left and Right) produced results outside of the result limits for a new production valve. The left tests were repeated after the first set of tests. The second set of tests showed improved valve response when compared to the first test. Discussions with the group and the manufacturer's representative stated that the plots were consistent with a functioning in service valve and would not have any effect on braking operation. Fluid samples were taken from both the left and right brake ports and the pressure port during testing from the hydraulic test rig. The fluid samples were within acceptable limits for particulates. The unit passed all other tests performed and the data sheets were retained by the NTSB.

D.2.1.1.3 Wheel Speed Transducer Testing

Each unit was removed from its shipping container and visually inspected. Each unit appeared to have no damage, see Figure 5.

Figure 5 - Wheel speed transducers from N465FL

Each unit was placed on a test bench and tested individually according to functional test procedure TP-40-92141, Rev C, 1, released 02/24/1995. Prior to the start of testing, in consultation with the group and the manufacturer, the dielectric and insulation resistance tests were not performed

The LH wheel speed transducer passed all tests performed and the data sheets were retained by the NTSB.

The RH wheel speed transducer passed the functional test except for the voltage variation at 100 Hz. During the low speed (100 Hz) test, the frequency trace of the transducer output was inconsistent and variable. The transducer was then tested at 1200 Hz (highest speed) and the waveform stabilized. The waveform remained stable throughout the remaining test points (200 Hz – 1200 Hz), except for the 100 Hz test point. The 100 Hz test is below the speed in which the antiskid system is operational in the aircraft.

During manual rotation of the RH transducer, a small area of non-smooth rotation could be felt when compared to the LH transducer. The transducer was disassembled and the seal at the rotor was found lifted slightly. The technician noted that new production transducers have an updated seal design. It was also noted that the bearing on the rotor shaft, when rotated by hand, exhibited a slight binding feel during rotation. No additional tests were performed on the disassembled transducer components.

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