STATEMENT OF OPINION
B-2A, T/N 89-0127 ACCIDENT
23 FEBRUARY 2008

Under 10 U.S.C. 2254(d), any opinion of the accident investigators as to the cause of, or the factors contributing to, the accident set forth in the accident investigation report may not be considered as evidence in any civil or criminal proceeding arising from the accident, nor may such information be considered an admission of liability of the United States or by any person referred to in those conclusions or statements.

1. OPINION SUMMARY

I find by clear and convincing evidence that distorted data introduced into the Mishap Aircraft (MA) flight control computers caused an uncommanded, 30 degree nose-high pitch-up on takeoff, resulting in a stall and subsequent crash. Moisture in the port transducer units (PTU) during an air data calibration caused a larger than necessary "bias" or correction to the air data system. Using this moisture distorted data, the MA flight computers calculated inaccurate airspeed and a negative angle of attack (AOA) which contributed to an early rotation, an abrupt 30 degrees nose-high pitch-up, and loss of all air data on takeoff. Deteriorating airspeed and resulting stall culminated in a yaw and roll to the left. The lack of altitude and airspeed, combined with degraded flight controls response, denied Mishap Pilot 1 (MP1) the ability to recover the MA. As the left wing made contact with the ground the Mishap Crew (MC) successfully ejected. The MA impacted the ground and was destroyed by fire.

The following items are considered substantially contributing factors to the mishap:

a. Moisture in the PTUs
b. Inaccurate airspeed and negative AOA calculation
c. Low altitude and airspeed
d. Ineffective communication of critical information regarding a suggested technique of turning on pitot heat in order to remove moisture from the PTUs prior to performing an air data calibration.

2. DISCUSSION OF OPINION

a. Moisture in the Port Transducer Units

With no physical evidence of engine performance discrepancies, flight control failure or crew error, the board turned its attention to abnormalities in the air data system. During pre-flight, the MC identified a requirement for an air data calibration and called for maintenance. A flight controls specialist responded to the MA and performed the air data calibration per the technical order. Following the air data calibration, altimeter readings were within standards and the flight control abbreviated built-in-test (ABIT) passed satisfactorily. However, analysis of the MA PTUs and tests done on the air data system following the mishap indicate that moisture was almost certainly present in the PTUs prior to engine start. Performing the air data calibration with moisture in the PTUs drove "latent errors" into the system which then transmitted as

distorted data to the flight control computers. Moisture in the PTUs is considered a substantially contributing factor to this mishap.

b. Decision to Takeoff

When cleared for takeoff, the MC turned on pitot heat and performed a static takeoff, holding brakes and running engines to maximum continuous thrust before releasing the brakes and beginning the takeoff roll. All engines performed normally throughout the takeoff. Turning on pitot heat at this point in the mission began removing the moisture in the PTUs. However, this removal of moisture after the air data calibration had been accomplished, reintroduced a disparity between PTU sensors. This discrepancy was inconsequential until the MA reached 70-80 knots indicated airspeed (KIAS) and the flight control computers were able to sense a discrepancy between PTU sensor readings. Approximately 19 seconds after brake release, while still on takeoff roll, a master caution light illuminated accompanied by a Flight Controls Systems (FCS) caution on the status display. Seconds later, the MC observed air data faults displayed on the flight controls systems page. The flight control faults were resolved within 6 seconds and the FCS caution rescinded.

MP1 asked Mishap Pilot 2 (MP2) for a takeoff/abort decision. At approximately 120 KIAS, MP2 called "continue takeoff" as all caution indications had cleared and the MA was above the briefed 100 KIAS "decision speed." Decision speed is the speed at which pilots decide to continue the takeoff or abort. MP1 continued with what he perceived as a normal takeoff and rotated the MA for takeoff at approximately 142 KIAS. The fact that the MA was above the 100 KIAS decision speed and the FCS caution rescinded led the MC to make a reasonable decision to continue the takeoff.

c. Inaccurate Airspeed Indications, Negative AOA Calculation and Loss of Air Data

Data analysis shows that distorted data introduced into the flight control computers resulted in miscalculations of AOA and airspeed. The AOA computed by the flight computers just prior to liftoff was an excessive negative value (a positive AOA value would be expected with the MA on the ground). At liftoff, with a computed negative AOA exceeding the lower AOA limiter, the MA flight computers sensed a dangerous, nose-low attitude and commanded larger than appropriate inputs to the flight controls, leading to an abrupt 1.6 times the force of gravity pitch-up to a 30 degrees nose-high attitude. Distorted air data inputs also caused the MA indicated airspeed to read higher than actual speed. As a result, the MA lifted off the runway approximately 7 seconds and 1,450 feet sooner than the lead aircraft. Data analysis shows MA true airspeed at liftoff was approximately 132-134 knots, 10-12 knots slower than the airspeed being indicated on cockpit instruments. Loss of air data after liftoff resulted in degraded flight controls response and stability of the MA. Data analysis also showed that MP1 applied normal and appropriate flight control inputs during the takeoff and attempted recovery. Inaccurate airspeed indications and a negative AOA input to the MA flight control system are substantially contributing factors to this mishap.

d. Low Altitude and Low Airspeed

The MA reached an altitude of approximately 80 feet above the runway and airspeed deteriorated to an estimated 125 knots. The slow speed culminated in a yaw and roll to the left as the MA

departed controlled flight. The MC made the decision to eject as the left wing of the MA came into contact with the ground. The MA impacted the ground immediately after ejection of the MC. Experienced pilots given the same situation in the flight simulator were unable to recover the aircraft. This simulation combined with analysis of interviews and recorded stick movements by MP1 led to the conclusion that the MC actions were deemed reasonable and appropriate. Low altitude and low airspeed following the uncommanded pitch-up are substantially contributing factors to this mishap.

e. Human Factors - Communicating Critical Information

The human factor of communicating critical information was a contributing factor to this mishap. Increased air data calibration requirements that occurred almost exclusively while deployed prompted a dialogue that could have resulted in a process to mitigate the primary cause of this mishap. Communications between flight line technicians and support engineers that occurred in 2006 regarding air data calibrations was appropriate and led to a suggested technique of turning on pitot heat prior to performing an air data calibration. However, this technique was never formalized in a technical order change or captured in "lessons learned" reports. Hence, only some pilots and some maintenance technicians knew of the suggestion to use pitot heat prior to air data calibrations. While many of the flight controls specialists continued to use this technique during the most recent deployment to Guam, MP1, MP2 and the flight controls specialist that responded to the call for an air data calibration on the MA on 23 February 2008 were unaware of this technique. Likewise, the board found few maintenance supervisors above the shop level who had heard of an increased requirement for air data calibrations while deployed and only one who knew of a suggested technique to alleviate the requirement.

Three factors contributed to ineffective communication of critical information. First, the increased requirement for air data calibrations was intermittent, only surfacing as an issue during deployments that lasted only a few months a year. Second, a requirement for an air data calibration never caused an aircraft to miss a takeoff. While maintenance supervisors were concentrating on issues that grounded jets, air data calibrations never made it to their "Top 10" items of concern. Third, maintenance and operations personnel interviewed had a functional understanding of the air data system, but lacked an appreciation for the potential to induce catastrophic errors into air data sensors. Most of the individuals interviewed by the board viewed the air data calibration as a mechanism to correct the aircraft altimeters and nothing more. The board had to consult aircraft design engineers who had not been associated with the B-2 program for over 10 years to find a level of understanding in the system that raised concerns over a need to calibrate PTUs on the aircraft.

Calibration process improvements were investigated and implemented with some success during deployments. As supervision remained unaware of the issue, the suggested technique to mitigate an increased requirement for air data calibrations remained undocumented and non-standard. Ineffective communication of critical information is a substantially contributing factor in this mishap.

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