



The Unknown Known:

USAF B-2 Type A Mishap

Leadership ViTS Meeting

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The Mishap:

- At 10:30AM local time on February 25, 2008, the B-2 “Spirit of Kansas” lifted off from Andersen Air Force Base on the island Guam. Seventeen seconds later, the aircraft crashed on the airfield as both crewmembers ejected.
 - One of the two pilots was injured but is expected to fully recover
 - Aircraft was a total loss at \$1.4 billion



On the day of the incident, the system that feeds all air data to the four on-board computers that operate the Flight Control System (FCS) was incorrectly calibrated such that the FCS pitched the B-2 up into an unrecoverable attitude immediately after takeoff.

- USAF legal investigation opinion: “Vital local knowledge had not been incorporated into maintenance procedures,” and the mishap was preventable.

Note: the safety investigation was not released to the public. This presentation cites the USAF Accident Investigation Board Statement of Opinion and Summary of Facts (6/25/2008).



Timeline

2006: USAF maintenance crews identify moisture in the B-2 Air Data System (ADS) as a daily nuisance in Guam's humid environment. Contractor engineers recommend a technique in addition to the published system recalibration procedure: use an internal instrument heater (called pitot heat; designed for in-flight use only) to dry the sensors prior to ADS recalibration. While effective, **this technique is not communicated to supervisors.** Some but not all B-2 technicians learn this technique.

2/25/2008

09:30AM local time: Mishap crew gets "AIRDATA CAL" ADS error message during preflight system checks. Maintenance personnel follow published recalibration procedure, but do not use the pitot heat technique. Three of twenty-four air data sensors require and accept calibration. The error message disappears because the system is now calibrated for its current condition (three moist and 21 dry sensors).

10:29AM: The crew taxis the mishap aircraft for takeoff and turns on pitot heat per their checklist, drying the moist sensors. The ADS is now delivering incorrect data, but the FCS is in flight mode, not maintenance mode, and no error message appears. Distorted air data causes an altimeter error of 136 feet above the airfield elevation, but **the mishap crew never sees this error** because there is no field elevation placard on the runway.

10:30AM: On the takeoff roll, the mishap aircraft's yellow AIR DATA caution light illuminates. The mishap crew analyzes instrument indications and sees airspeed is over 100 knots, the go-no-go "decision speed" for the B-2. The light goes out after several seconds; the crew elects to continue takeoff. Unknown to the crew, **actual airspeed is 12 knots less than airspeed indicated** in the cockpit.

10:30:49AM: Immediately after liftoff, the mishap B-2's FCS calculates a negative angle of attack based on skewed data and **itches the aircraft nose up 30°**. The resulting low energy condition (high angle of attack, high gross weight, low airspeed, low altitude, hot air temperature) proves unrecoverable by the crew, who both eject when the left wingtip touches the ground.



Proximate Cause

Moisture in the Port Transducer Units (PTUs) caused significant bias to be programmed into the ADS during calibration. Based on this skewed data, the flight computers calculated an inaccurate airspeed and negative angle of attack, which contributed to the early rotation, 30° pitch up, and subsequent stall and crash.

Root Cause/Underlying Issues

The pitot heat technique to remove moisture from the PTUs was not formally documented for several reasons:

- The “AIRDATA CAL” message was typically discovered during the time-critical preflight by the flight crew. Such unscheduled maintenance was not documented in the same detail as scheduled work. Thus, the issue was never documented or formally shared.
- There was a wide lack of understanding of the complex ADS/FCS interface:
 - Air data calibrations were considered a “benign” recalibration of the altimeter that would have isolated impact on one instrument; actually, the ADS was crucial to flight control, and distorted data could result in complete loss of air data shortly after takeoff.
 - Had the crew or management understood the significance of the ADS calibration, they might well have formally raised the issue.
- Most supervisors were not aware of the increased ADS calibration requirements during Guam deployments. They were focused on issues that grounded jets; air data calibrations were not known to have prevented a takeoff.

“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 systems that raised concerns...” –B-2 Accident Investigation Board



NASA Applicability

A “minor” maintenance issue may represent a serious hazard in the flight environment—the “unknown known”

- Document changes and workarounds developed in the field. Always ensure the issue is captured when a workaround seems necessary to a process; share the information with cognizant supervisors and personnel using a closed loop reporting system such as PRACA or IRIS.
- Supervisors must maintain conditions for open, effective communications.
- Make it a priority to capture and transfer knowledge from personnel who work on complex systems and hardware.
- Develop a comprehensive understanding of relevant systems and hardware.

Minimize the “unknown known”

- Sustainable systems—even when complex—should not require profound system knowledge in the field.
- Design equipment tests and calibration procedures to simulate field use conditions. Procedures should enable optimal system operation in all anticipated environments.
- When an operational margin of safety is subject to external points of reference, verify system control effects using external points of reference.

