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AIRCRAFT ACCIDENT INVESTIGATION

AUTHORITY AND PURPOSE

AUTHORITY

Under the provisions of Air Force Instruction (AFI) 51-503, the Air Force Materiel Command (AFMC) Commander, General George T. Babbitt, appointed Colonel Ronald L. McKim to conduct an aircraft investigation of the F-16B (S/N 82-1037) accident that occurred at Eglin AFB, Florida, on 22 August 1997. The accident resulted in no injury to either pilot, but totally destroyed the aircraft. No private property damage was caused. The investigation was conducted from 23 September to 10 Oct 97. Technical advisors were Captain David A. G. Kendrick (Legal Advisor), Captain Manuel Griego (Maintenance Advisor), and Captain Evan Thomas (Pilot Member) (Tab Y).

PURPOSE

An aircraft accident investigation is convened under AFI 51-503. The investigation is intended primarily to gather and preserve evidence for claims, litigation, disciplinary and administrative needs. In addition to setting forth factual information concerning the accident, the investigating officer (IO) is also required to state his opinion concerning the cause or causes of the accident (if there is clear and convincing evidence to support that opinion), or to describe those factors, if any, that in the opinion of the IO substantially contributed to the accident. This investigation is separate and apart from the safety investigation conducted under AFI 91-204. The report is available for public dissemination under the Freedom of Information Act (5 U.S.C. 552) and AFI 37-131.

SUMMARY OF FACTS

1. History of Flight

The mishap aircraft (MA), call sign SHARK 2, was an F-16B flying as chase aircraft for an F-15E, call sign SHARK 1, test platform. The original rear cockpit crew member of the MA was changed out prior to the flight after mission delays extended the mission timing beyond his duty day (V-3, V-10). Maj Paul A. Krause, mishap pilot 1 (MP1), is an Air Force Development Test Center (AFDTC) instructor pilot (IP). Capt Stephen E. Gurney, mishap pilot 2 (MP2), occupied the rear cockpit and is also an AFDTC IP. Briefing and preflight were uneventful, and takeoff occurred at 1359L on 22 Aug 97. The flight within Warning Area 151 (W-151) was uneventful for the first 2 hours and 48 minutes (O-6). The MA's engine failed while the flight was on the final leg of the mission. Two engine restart attempts were unsuccessful (V-5, V-12). MP1 and MP2 both ejected safely with no injuries (X-2, X-3). MA impacted the water 13 miles south of Eglin AFB and was destroyed. MP1 and MP2 were rescued by a local tour boat (V-47, V-49). The Eglin AFB (AFMC) Public Affairs Office handled inquiries with only moderate interest shown by local television stations and newspapers (AB-2-10).

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NUCLEAR REGULATORY COMMISSION

Docket No. _____ Official Exh. No. 194

In the matter of PFS

Staff _____ IDENTIFIED ✓

Applicant ✓ RECEIVED ✓

Intervenor _____ REJECTED _____

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Contractor _____ DATE 7/1/02

Other _____ Witness _____

Reporter GH

2. Mission

The objective of the mission was to conduct a captive compatibility flight and collect structural integrity data for F-15E carriage of the Advanced Unitary Penetrator store (K-5, K-6). SHARK 2 was to provide safety chase for SHARK 1 while performing high speed runs at differing altitudes. SHARK 2 was to fly area chase and periodically do a visual check of SHARK 1 (K-5, K-6, V-3).

3. Briefing and Preflight

The MA's original crew, Maj Krause (MP1) and Maj Archambault, arrived at the squadron and attended a mission briefing with SHARK 1. The test engineer briefed specifics of the test points. SHARK 1's pilot, Capt James L. Wertz, briefed the mission profile to be flown, chase procedures, and takeoff and area emergencies (V-3, V-10, V-37). Each crew covered procedures internal to their respective aircraft (V-10). Prior to arrival at their aircraft, SHARK 1 was notified of a problem with the test weapon (V-37). The crew members then reassembled at the test squadron to reassess their plan. The concern was that Maj Archambault would be out of crew rest prior to mission completion (V-37). The squadron operations officer then asked Capt Gurney (MP2), the Supervisor of Flying (SOF), to substitute for Maj Archambault, because he had adequate crew rest and was familiar with this mission (V-10). Maj Krause and Capt Wertz both conducted a mission review with Capt Gurney as a result of the crew member change (V-3, V-40). The crew members returned to their aircraft. MP1 reviewed the aircraft forms, however the exceptional release was not signed off per Technical Order 00-20-5(V-4, U-21-22). Preflight, engine start, and taxi were uneventful for both aircraft (V-4, V-24, V-41).

4. Flight

The flight takeoff was uneventful with SHARK 2 taking position as the chase aircraft. The mission profile was flown within the confines of W-151 south of Eglin AFB. The mission profile consisted of high speed test points for the F-15E test aircraft, at varied altitudes from 35,000 ft. mean sea level (MSL) to 500 ft. above ground level (AGL) (K-5, K-6). SHARK 2 maintained the chase role throughout the profile, and both aircraft received periodic air refuelings from Turbo 91 (KC-135) operating in an air refueling orbit within W-151 (V-4, V-11). The mission went as planned and was uneventful until approximately 2 hours and 50 minutes into the flight. On the final northbound test run at approximately 1,000 ft. AGL and 25 miles south of Eglin AFB, SHARK 2 selected mid-range afterburner and began closing on SHARK 1 to rejoin (V-4, V-12). Approximately 15 seconds later, the pilots on SHARK 2 heard and felt a loud bang from the engine (V-4, V-12). MP1 snapped the throttle to military power and started an immediate climb, believing he had an afterburner malfunction. The engine continued to bang at military power, and MP1 reduced the throttle to idle, where the engine continued to bang. Recognizing a serious engine malfunction, a "knock-it-off" radio call was made and the engine instruments checked (V-5, V-12). MP1 observed the ENGINE warning light was on, and both pilots saw the fan turbine inlet temperature (FTIT) was above 1000°C and rising (V-5, V-12). MP1 moved the throttle to off, and began restart procedures (V-5, V-12). Unknown to the pilots, a 4th stage compressor blade had fractured, damaging multiple compressor stages and leading to a titanium fire in the 7th stage. The first airstart was initiated in unified fuel control (UFC) mode to preserve RPM, shortly before MP1 pushed over from the climb and gradually slowed to glide speed. The MA was outside of glide range, committing the crew to an airstart (J-12). Both pilots observed the airstart

stagnating, RPM below 60% and FTIT rising above 800°C (V-5, V-13), and MP1 shut the throttle off. MP1 stated that he now selected the Back-up Control (BUC) mode. Both pilots observed the FTIT temperature decrease to between 700°C and 750°C, where it appeared to stabilize (V-6, V-13). Additional radio calls were made to SHARK 1, telling him that the engine had failed (V-2, V-13). MP1 stated that he moved the throttle to idle and carried out the procedures for a BUC airstart, while directing MP2 to monitor altitude (V-6, V-14), MP2 noted the FTIT between 900°C and 950°C and called altitude approaching 2000 ft. AGL (V-14). MP1 stated that FTIT rose to 1000°C as he reached the BUC idle position (V-6). MP2 called out 1800 ft., and the crew initiated ejection (V-6, V-14). The bail out occurred at approximately 1200 ft. MSL (J-13).

5. Impact

The MA crashed at low speed in a right wing low, nose high attitude and sank in approximately 65 feet of salt water (J-11). The right horizontal tail and the nose section, including both cockpits, separated from the aircraft at impact (J-11). The engine broke free from its mountings, but remained in the fuselage which settled upright on the bottom (J-11). Most wreckage was located within 50 yards of the fuselage section, further substantiating a low speed impact (J-11). The major pieces of wreckage were raised on 29 August and placed on a barge for transport to Eglin AFB (J-11). The fuselage section was placed on dunnage in a hangar to facilitate engine removal (J-11). This was accomplished on 30 August and a borescope inspection revealed that a catastrophic inflight engine failure occurred (J-11).

6. Egress System

The rear seat pilot initiated the ejection with the Ejection Mode Select Valve in the Aft mode (J-17). Both seats operated properly in Mode 1 as determined through investigations performed by San Antonio Air Logistics Center (ALC) and Kelley ALC (J-25-34).

7. Personal and Survival Equipment

Personal and survival equipment inspections were up to date (H-20). The survival radio for MP2 transmitted okay but did not receive transmissions from others (V-15, I-2). The Life Preserver Units (LPU) and Universal Water Activated Release Systems (UWARS) all automatically activated in the water for MP1 and MP2 (V-7, V-15). The one-man life rafts inflated properly and were used by both pilots (V-7, V-15). The 46 OSS/OSCL submitted a product quality deficiency report on the survival radio (I-2, V-15).

8. Rescue

SHARK 1 observed the bailout and remained in an overhead orbit to insure both pilots had good chutes (V-36). A local charter boat, TOP GUN, was operating to the north of the aircraft impact area and observed the aircraft impact and the crew members' parachutes (V-7, V-16). The charter boat captain, Mr. John Cox, immediately responded to the area and was further guided to the pilots by SHARK 1 (V-7, V-16, V-46, V-49). The local charter boat picked up both pilots and their survival gear (V-7). The local charter boat then transferred the pilots to a Coast Guard

boat which transported them to the Coast Guard station (V-16). Both pilots were transported to Eglin AFB hospital by AF ambulances (V-7, V-16).

9. Crash Response

There was no crash response other than local notifications of command post and others. The SOF called the Coast Guard who then responded by boat to pick up the pilots from the charter boat (V-33).

10. Maintenance Documentation

The MA's active forms were reviewed and there was no indication of any pending mechanical, electrical, or jet engine failure (H-8-24). A review of 180 days of Core Automated Maintenance System history divulged no negative trends or open discrepancies in maintenance actions, scheduled inspections, and time change items contributing to this accident. Inspection of the MA's F-100-PW-200 mishap engine's (ME, s/n 703065) maintenance documents did not disclose any abnormalities. All required time compliance technical orders (TCTO) on both the airframe and engine were accomplished and properly documented (H-3-4). No TCTO discrepancies were noted which may have related to the accident. No maintenance procedure, practice, or performance was found to be related to the accident. The Joint Oil Analysis Program at the home base was mature and operated within command standards. Pre-accident oil analysis were taken and no discrepancies were noted (J-23). A combined Basic Post-Flight and Pre-flight inspection was accomplished on 21 Aug 97, at 1700 hours (H-8). A Thru-Flight inspection was completed after the MA's first flight of the day, 22 Aug 97, at 0930 hours with no defects noted (H-8).

11. Maintenance Personnel and Supervision

The crew chiefs' AF Forms 623 (On The Job Training Records) and AF Forms 797 (Job Qualification Standard Continuation/Command JQS) and the squadron's Special Certification Roster (SCR) were reviewed. The individuals assigned to work the MA were properly trained and held the skill level required to perform assigned duties. The 39th FTS Maintenance Supervision provided adequate oversight and was effectively organized in the manner specified in AFMCI 21-119 (Test/Evaluation Aircraft Maintenance Management Policy). No maintenance practice or procedures were deemed a factor in the accident.

12. Engine, Fuel, Hydraulic, and Oil Inspection Analysis

Fluid samples taken from the fuel truck, in-flight refueling aircraft and the test aircraft, oil servicing cart, and hydraulic servicing cart used to service the MA passed testing for purity, composition, and quality (U-2-11). The last 7 oil samples showed no signs of negative trending (an increase in wear metals) or indicating a potential for engine failure (D-2). Post impact oil samples were taken and high contents of metal were found (D-2).

13. Airframe and Aircraft Systems

The MP did not report any abnormality in the hydraulic, electrical, mechanical, or avionics systems during pre-flight and take-off (V-4, V-11).

The last major maintenance completed on the ME occurred in the 46th Maintenance Squadron, Propulsion shop, and passed the Test Cell run on 3 Dec 96 (U-12-13). The major maintenance included replacing the #5 bearing area oil pressure tubes, and removing and replacing an anti-ice valve S/N 2840. Inlet borescope ports 2 and 6 were inspected, and the #5 area was found serviceable. The ME was reinstalled on 17 Dec 96. The most recent maintenance performed on the ME was a phase inspection accomplished on 16 July 97 consisting of 50, 100, and 200 hour borescope inspection criteria (U-14). The fourth stage compressor area is specifically checked during the 100 hour borescope inspection. No defects were noted (U-14).

An engineering analysis revealed that the ME sustained relatively little damage in the crash impact (J-2). With the exception of the exhaust nozzle, which had separated forward of the nozzle static structure, the ME was intact (J-2). The inlet module fan was in excellent condition and was not dissembled (J-2).

The core module was intact but had several burned areas on the forward compressor case (J-2). The High Pressure Compressor (HPC) was partially disassembled to investigate the source of the burn damage to the forward compressor case (J-3). Damage to the Rear Compressor Variable Vanes (RCVV) was noted primarily heavy on the trailing edges of the Inlet Guide Vanes (IGV), fourth stage vanes and fifth stage vanes. The HPC disks were intact and appeared to be undamaged (J-3). Stages four through seven are a titanium alloy and stages eight through thirteen are a nickel-based alloy (J-3). Analysis of the fourth stage blades displayed excessive damage to both the leading and trailing edges (J-3). One blade was fractured approximately one fourth inch above the blade platform (J-3). Its airfoil was liberated and was not recovered (J-3). The fracture surface exhibited fatigue characteristics from the leading edge to approximately two-thirds of the chord length (J-3). The remainder exhibited overstress features (J-3-4). Four other blades were visually cracked in the same area (J-3). Counted clockwise from the rear looking forward, with the fractured blade being number one, the four cracked blades were numbers 5, 17, 25, and 30 (J-4). Compressor stages 5 through 13 all exhibited some level of burning, and leading or trailing edge damage but none of the blades were discovered missing (J-3).

HPC Stator Case significant findings were found in the seventh stage. The case was heavily damaged (J-5). The entire forward portion of the case, including the blade tip area, was burned away (J-5). One section of the forward snap diameter, consisting of approximately one-half of the circumference of the case was recovered (J-5). The outboard tips of the vanes were burned to a depth of approximately one-third chord on the leading edge and one-fourth chord on the trailing edge (J-5). Portions of the outer shroud of the case were liberated from 12:00 to 2:00 and at 4:00 (J-5). Several pieces of the shroud were recovered inside the forward compressor case (J-5).

Evaluation of the outer compressor case showed heavy damage. It was burned through from 1:00 to 2:00 in the plane of the seventh stage blades (J-6). Two other burn areas were near 3:00, on each side of the elbow fitting for the number four bearing air supply particle separator (J-6). Other heat damaged areas on the case were also in the seventh stage blade plane; burn through did not occur, however these areas had been subjected to very high temperatures (J-6).

Analysis of the controls and accessories was also conducted. Of significance, the Back-up-Control (BUC, s/n GL2196) was intact and remained bolted in place on the UFC (J-7) . There

was no apparent external damage other than some minor scrapes consistent with the crash impact (J-7). The BUC solenoid was removed and x-ray inspected at the 46TW Non Destructive Inspection Lab (J-7). The solenoid is magnetically latched and tends to retain its position when power is lost (J-7). The position of the internal components of the solenoid indicated that the BUC was in OFF mode at impact (J-7).

Expert analysis of the mishap engine, PWOE703065, determined that liberation of the fourth stage blade damaged the ME to the extent that restart attempts would not have been successful (AA-3).

The emergency power system consists of an emergency power unit (EPU), hydrazine tank, nitrogen tank, and associated plumbing and valving (J-14). Emergency power system did not function during the mishap sortie upon requirement. Automatic activation occurs if main generator power is lost or if both system hydraulic system pressure drop below 1000 psi (J-14). The EPU always starts up on hydrazine except on ground tests. Nitrogen gas is used to pressurize the hydrazine storage tank, serviced at or around 3000 psi, depending on ambient temperature. The nitrogen valve assembly incorporates a regulator valve, a check valve, a shut-off valve, and a vent valve. (J-15) During this mishap sequence, the EPU should have commanded to operate on three occasions (O-3). A poppet valve in the gas generator is held in position by a nylon shear pin (J-15). Confirmation that the EPU did not fire was verified by the shear pin which was still intact (J-15). Further, the burst disk on the hydrazine tank was not ruptured, indicating hydrazine had not left the tank (J-15). The intact burst disk eliminated the possibility of the system failure being associated with the turbine unit, hydrazine catalyst bed, and speed sensors (J-15). During normal operation, hydrazine is forced out of the storage tank by the pressurized nitrogen (J-15). Since EPU operation (other than ground tests) is always initiated by hydrazine, the nitrogen control valve should always receive a signal from the EPU speed controller to open when the EPU is commanded to run (J-15). The control valve reduces 3000 pounds of pressure in the nitrogen storage reservoir to 400 psi and regulates this pressure to the hydrazine tank (J-15). The nitrogen pushes against a piston at one end of the tank to force the hydrazine to break the burst disk and allow pressurized hydrazine to flow to the EPU gas generator (J-15). The intact burst disk indicated that pressurized nitrogen never entered the tank (J-15). This disk normally breaks with 100 psi in the hydrazine tank (J-15). Servicing of the nitrogen tank was completed prior to the first sortie of the day according to Technical Order 1F-16A-6WC-1-21 and was signed off in the aircraft forms 721A's (H-11). There is no requirement in the technical orders for a re-check of nitrogen pressure during Thru-Flight inspections, reference Technical Order 1F-16A-6WC-1-21, part 2. A quality deficiency report was completed for the nitrogen valve, P/N 581670-2-2 (J-21). Depot inspectors concluded that the valve was functional at the time of testing; without further tests of other electrical components, the EPU non-operational anomaly is unanswered (J-21). Last major maintenance of the EPU was conducted during the last aircraft phase, 16 July 97 (U-17). The EPU system check-out is a work card item during the aircraft phase. An operational check-out was performed and failed (U-17). A write-up referring this failure to follow-on maintenance was not properly documented in the aircraft's active forms or in the Core Automated Maintenance System (CAMS) (U-17, U-18, U-19). A corrective action for the bad system check was documented in the forms and in the 39FTS Electrical/Environmental section's log book(U-18, U-23). An additional operational check-out of the EPU system was completed and passed operational requirements (U-18). Although not a

factor in the MA's mishap sequence, these documentation errors were violations of Technical Order 00-20-5, para 3-12 (U-20).

14. Operations Personnel and Supervision

The mission was authorized by MP1, Major Krause, 39 FTS Assistant Operations Officer, in accordance with AFI 11-206 and AFI 11-401 (K-2). The flight briefing was conducted by the F-15E pilot, Captain Wertz, in accordance with AFI 11-206/46 TW Supplement 1 and the 46 TW Briefing Guide (V-2, V-40). The briefing was attended by the F-15E aircrew and the originally scheduled F-16B aircrew (MP1 and Major Archambault). When problems with the test aircraft caused a slip in takeoff time, MP2 took the place of Maj Archambault due to duty day limitations. Capt Wertz reviewed the mission with MP2 after he was added to the mission (V-40). A crew coordination briefing was conducted by MP1 and MP2 before starting the mission (V-3, V-10).

15. Aircrew Qualifications

Both mishap pilots were current and qualified to perform the mission in accordance with AFMCM 10-202. MP1 is a highly experienced F-16 Flight Examiner and Instructor Pilot, with 1230.9 F-16 hours and 2105.3 total hours (G-9, G-14). MP2 also is a highly experienced F-16 Instructor Pilot, with 1462.6 F-16 hours and 1687.7 total hours (G-16, G-17).

30/60/90 Day Flying Summary for MP1 (G-2)	
30 Day	0.0 hours/ 0 sorties
60 day	9.6 hours/8 sorties
90 day	30.9 hours/ 23 sorties

30/60/90 Day Flying Summary for MP2 (G-5)	
30 Day	19.5 hours/ 11 sorties
60 Day	29.4 hours/ 19 sorties
90 Day	47.5 hours/ 33 sorties

MP1 was non-current in instrument approaches, following a three-week convalescence from surgery (V-3). MP2 was onboard the aircraft to permit MP1 to regain currency. Additionally, MP1 was on a 60-day waiver for water survival training, IAW AFMCI 11-301, AFDTC Sup 1(T-13).

16. Medical

The pilots, MP1 and MP2, were both medically and dentally qualified to fly and had current flight physicals (X-2, X-3). Neither suffered any injuries as a result of the mishap (X-2, X-3). Toxicological examinations found carbon monoxide within normal limits and no evidence of ethanol or drugs (X-2, X3).

The command directed toxicological screens for all maintenance personnel associated with this aircraft accident were negative for alcohol and drugs of abuse (X-4).

17. NAVAIDS and Facilities

The Glide Path for the Instrument Landing System to Runway 19 at Eglin AFB was inoperative on 22 Aug 97 and had no effect on this mission (AA-4). All other airdrome Communications and Navigation Aids (NAVAIDS) were operational (AA-4). No published Notice to Airman bulletins affected the mission (AA-4).

18. Weather

Weather was not a factor. Actual weather at Eglin AFB, Florida, at the time of the accident was wind from 020 at 11 knots (W-3). Visibility of 7 miles plus (W-3). Sky conditions of clouds FEW at 30,000 feet. The temperature was 29 degrees Celsius (W-3).

19. Directives and Publications

AFI 11-401	Flight Management
AFI 11-206	General Flight Rules
	46 TW Supplement-General Flight Rules
AFMCM 10-202	Aircrew Training
T.O. 1F-16A-1	F-16A/B Flight Manual

There were no deviations from directives that contributed to the accident. There was a conflict between MP1 testimony and the post-crash analysis findings. The post-crash analysis found the BUC solenoid in the OFF position and the BUC switch in the OFF position (Guard Closed) at time of impact (J-7, J-16, J-18, V-5). Although MP1 stated that he selected BUC during his engine restart process (V-5), it is possible that MP1 positioned the BUC switch to OFF instead of BUC without realizing his mistake. Regardless of the switch position, the engine damage precluded an engine start in any mode (AA-3).

RONALD L. MCKIM, Colonel, USAF
Accident Investigation Officer

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STATEMENT OF OPINION

1. Under 10 U.S.C. 2254(d), any opinion of the accident investigator as to the cause or causes 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 an aircraft accident, nor may such information be considered an admission of liability by the United States or by any person referred to in those conclusions or statements.

2. The cause of this mishap, supported by clear and convincing evidence, was the result of a catastrophic fourth stage high pressure compressor blade fracture (J-10). This blade fracture caused severe damage to the remaining blades in the fourth stage and also resulted in a titanium fire centered in the seventh stage of the high pressure compressor (J-10). The titanium fire severely damaged the seventh stage and burned holes through the engine compressor case (J-6). The crew attempted two engine restarts but were unsuccessful (V-5, V-14). Consistent with the engineer's report, I conclude that the engine would not have restarted due to the extensive engine damage caused by HPC blade fracture (AA-3). The MA did not have enough altitude to glide to a recovery location (J-11). The loss of engine power precluded a safe recovery of this aircraft.

RONALD L. MCKIM, Colonel, USAF
Accident Investigating Officer

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