AFI 51-503
AIRCRAFT ACCIDENT INVESTIGATION REPORT

1. AUTHORITY AND PURPOSE

a. Authority: On the evening of 24 August 1998, F-16CG aircraft 88-0519 impacted the water and was destroyed during a routine training sortie The pilot successfully ejected and was quickly rescued by a Korean fishing vessel. He was uninjured. Paragraph 1.1 of Air Force Instruction (AFI) 51-503, *Aircraft, Missile, Nuclear, and Space Accident Investigations,* requires the major command (MAJCOM) commander or his designee to convene an accident investigation board (AIB) to investigate every such "Class A" mishap (reportable damage of $1 million or more, or a fatality or permanent total disability). The mishap aircraft was assigned to the 36th Fighter Squadron, 51st Fighter Wing, Osan AB, Republic of Korea (ROK) (Tab A) [1] In turn, the 51st Fighter Wing is a component unit of the Pacific Air Forces (PACAF) major command.

By a memorandum dated 15 September 1998, General Patrick K. Gamble , PACAF Commander, convened an aircraft accident investigation board (AIB) to investigate the mishap (Tab Y) Col Thomas J. Fiscus, PACAF Staff Judge Advocate (SJA), acting as the MAJCOM commander's designee amended the original appointment memorandum on (Tab Y) The investigation was conducted at Osan Air Base, ROK, from 28 Sep 98 through 15 Oct 98. As finally constituted, the AIB consisted of the following members

BOARD MEMBERS	POSITION
Colonel Michael P. Erdle	President
Capt Richard T. Wigle	Pilot Advisor
Capt Michelle P. Tilford	Legal Advisor
Capt Lawrence J. Schuh	Maintenance Advisor
TSgt Glenn D. Klomp	Assistant Maintenance Advisor
SSgt John C. Quilleon	Administrator
SSGt Realiza D Guilles	Administrator

b. Type and Purpose. This investigation was conducted to find and preserve evidence relating to the loss of F-16CG aircraft 88-0519 about 3 nautical miles southeast of Kangnung, South Korea, on 24 August 1998, for possible later use in claims, litigation, disciplinary actions, adverse administrative proceedings, and for all other purposes except mishap prevention. The purpose of the investigation was to ascertain the relevant facts and circumstances of the accident and, if possible, to determine its cause or causes. In addition to setting forth factual information concerning the accident, the board president is also required to state his opinion concerning 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 board president, substantially contributed to the accident. This investigation is separate and apart from the safety investigation conducted under AFI 91-

[1] Many of the facts stated in this report are repeated more than once in the attached documentary evidence. Where multiple citations would not further the reader's understanding, this report cites only the primary source document

NUCLEAR REGULATORY COMMISSION

Official Exh. No. 205

Docket No. ______

In the matter of PFS

Staff ✓

Applicant ______

Intervenor ______

Cont'g Off'r ______

Contractor ______

Other ______

Reporter Cell

IDENTIFIED ✓

RECEIVED ✓

REJECTED ______

DATE 7/1/02

Witness ______

204 The report is available for public dissemination under the Freedom of Information Act (5 U S C 552) and AFI 37-131

2. SUMMARY OF FACTS:

a. History of Flight Activity.

The purpose of the mission was to train the lead pilot in techniques and procedures required to lead a flight of two F-16 aircraft in a variety of tactics The mission was planned as a routine local training sortie at Osan Air Base, Korea, on 24 August, 1998, consisting of two flights of two F-16 aircraft each, RAPTOR 1 (Capt Murphy, the mishap pilot) and 2, and GUIDO 1 and 2. RAPTOR flight intended to practice Close Air Support on this mission (described in paragraph 3.b.) The mission briefing was accomplished approximately 2 hours before the flight in a thorough and professional manner (Tab V-2 21). Ground operations were slightly abnormal in that the mishap pilot went to a spare aircraft after aborting his original aircraft for an oil leak, but this had no impact on the flight plans and they took off on time (Tab V-1 6) After an uneventful takeoff, the flights spent approximately 45 minutes searching for clear airspace where weather would not have an impact on their training At 1745 RAPTOR and GUIDO flights entered Military Operating Area (MOA) 6 and split the airspace for each flight to practice close air support attacks, with RAPTOR taking the southern half. At 1800 the flights began conducting intercept training, with RAPTOR flight simulating adversary tactics for GUIDO flight. At 1808, during the first intercept, RAPTOR 1 experienced an engine malfunction and terminated the intercept training (Tab N) After receiving assistance from both Airedale and GUIDO 1 in determining that Kangnung was the closest divert base, RAPTOR 1 established a descent to maximize his chances to reach Kangnung and continued efforts to restart his failed engine. He delayed jettisoning his external fuel tanks, which were then empty, due to his proximity to populated areas. RAPTOR 1 continued toward Kangnung with GUIDO 1 providing assistance as GUIDO 1 continued to close the distance to RAPTOR 1 from his position several miles away. As it became apparent RAPTOR 1 did not have enough altitude to reach Kangnung, he turned his aircraft toward the ocean and successfully ejected once the aircraft was clear of any populated areas (Tab N, R, V-1.12, V-2 24) The aircraft impacted the water less than one mile off shore and was destroyed. The crash did not cause either property damage or substantive injury. (Tab P, R, X)

b. Mission.

1. Fighter Mission. Fighter aircraft perform a variety of missions These include: Counter-air operations, to attain or maintain air superiority by destroying or neutralizing enemy air forces, Counter-land operations, to support ground operations by destroying or neutralizing enemy surface forces; Counter-sea operations, the equivalent of Counter-land operations in the maritime environment; Strategic Attack, or strikes at the enemy's centers of gravity to achieve specific objectives; Offensive Counter-information, to disable enemy information systems; and Combat Search and Rescue. Counter-air operations are further divided into Offensive Counter-air, or strikes against enemy air forces and air defense, and Defensive Counter-air, or defending friendly forces against enemy air strikes Counter-land operations include Interdiction, or

disruption of an enemy's ability to transport forces and supplies, and Close Air Support, or attacks upon enemy forces in close proximity to friendly forces. (Tab EE-7)

2 F-16 Aircraft. The F-16 is a multi-role fighter aircraft, built by the Lockheed Martin company in several versions. The Air Force has more F-16's in its inventory than any other fighter aircraft. The F-16C entered production in the mid-1980's and incorporated improved avionics and engines compared to the original F-16A The F-16CG is a specific version of the F-16C modified to carry and employ the Low Altitude Navigation and Targeting Infra-Red for Night (LANTIRN) system. Most F-16CG's were built with General Electric GE-100 engines and are known as "Block 40" aircraft. All F-16CG aircraft have a single seat for the sole crew member, the pilot. The mishap aircraft, tail number 88-0519, was an F-16CG Block 40 aircraft. It was assigned on 28 Jul 93 to the 36th Fighter Squadron, 51st Operations Group, 51st Fighter Wing, Osan AB, ROK (Tab D)

3 36th Fighter Squadron. The 36th Fighter Squadron (36 FS), nicknamed the "Flying Fiends", flies F-16CG aircraft in defense of the Republic of Korea. Missions of the 36th FS include Offensive and Defensive Counter-air, Interdiction, and Close Air Support. (Tab EE-7)

c. Briefing and Preflight.

1. Mission Planning and Briefing

a. Forecast Weather. Surface weather conditions at Osan AB forecast for the flying period from scheduled takeoff to scheduled landing included the following: winds 280 degrees at 14 knots, visibility 7 miles, cloud layers of 3,000 feet scattered, broken 7,000 feet broken, 25,000 feet broken, ambient temperature 75° Fahrenheit, and altimeter setting 29.68 inches of mercury. Average wind from the surface to 5000 feet were forecast from 270 degrees at 20 knots The sea temperature on the east coast was briefed as 73° Fahrenheit, with a 2-4 foot waves and a westerly current The briefed sunset was 1914, well after the planned landing time (Tab K-2).

b. Mission Planning. The mishap pilot and the other members of RAPTOR flight (RAPTOR), RAPTOR 1 and RAPTOR 2, and GUIDO flight (GUIDO), GUIDO 1 and GUIDO 2, planned the mission at Osan AB on 24 Aug 98. Crew rest for the mishap pilot (RAPTOR 1) was within regulation (Tab V-1.3). The mishap pilot (RAPTOR 1) flew a flight lead upgrade profile for the Close Air Support mission (FLUG-4) (Tab EE-7). The major mission planning tasks were performed by the mishap pilot. These tasks included designating mission objectives, planning sequence of events, coordinating the specific administration of the Close Air Support, and preparing the mission briefing (Tab V-1.5) The other members of the flight obtained the weather and Notices to Airman (NOTAM) (Tab AA). In addition, the other flight members made maps of the operating area and navigation steer points, obtained takeoff and landing data, and other minor planning tasks (Tab V-1 4).

c. Mission Briefing. The briefing began at 1445L Present for the entire brief were both members of RAPTOR and GUIDO flight (Tab V-1.5) Supervision present at the brief consisted of the 51st Fighter Wing Vice Commander (GUIDO 2), the 51st Operations Support Squadron Commander, Lt Col H. D. "Jake" Polumbo (GUIDO 1), the 51st Fighter Wing Chief of F-16 Standardization and Evaluation (RAPTOR 2), and the 36th Fighter Squadron C Flight Commander (the mishap pilot, RAPTOR 1) (Tab T-1). The mishap pilot (RAPTOR 1) conducted the brief in accordance with the 36th Fighter Squadron Flight Lead Close Air Support upgrade training syllabus (Tab V-1.5, EE-7). The brief covered all required items including an expanded discussion on the Close Air Support contracts and roles, emergency airfields for the operating area, Air to Air and Air to Ground Training Rules, and an alternate mission The briefing was normal for this type of mission and thorough (Tab V-2.21).

2. Ground Operations The members of RAPTOR and GUIDO flight were transported from their operations building to their aircraft at 1600L and started engines at 1620L. The mishap pilot aborted his original aircraft, number 89-2052, for an engine nozzle pump filter leak (Tab T-1). The spare aircraft was 88-0519. A thorough preflight was performed on 88-0519 with special attention given to the fluid levels, cockpit setup, and the aircraft forms. The mishap pilot testified that he was not under a time constraint and had adequate time for the preflight on the spare aircraft. At 1640L RAPTOR 2 and GUIDO flight taxied to the end of the runway for final checks and waited for RAPTOR 1 who taxied to rejoin the flight at 1648L (Tab V-1.6, V-2.24).

d. Flight Activity:

1. Flight Lead Close Air Support Syllabus Sorties

a Mission Requirements. The mission requirements were directed by the Slight Lead Close Air Support training syllabus. The events to be accomplished included: conduct a complete and thorough mission briefing befitting a flight lead; execute effective inflight control of the two-ship flight conducting Close Air Support operations; conduct a thorough and effective debriefing; demonstrate an understanding and execution of correct flying area procedures; effectively coordinate with all controlling agencies and successfully put bombs on target; and receive proper clearance prior to expending ordnance (Tab EE-7).

b. Planned Maneuvers. The briefed mission tasks followed the Flight Lead Close Air Support upgrade syllabus guidance RAPTOR and GUIDO were briefed to function as two coordinated two ships in a visual formation. The briefed takeoff was RAPTOR 1 and 2 followed 20 seconds later by GUIDO 1 and 2. Following the takeoff, the flights were to fly a departure to the North East to an orbit point south of the working area. After successfully contacting the proper controlling agency-the ground based Forward Air Controller (FAC), call sign "ICEBOX"-RAPTOR and GUIDO would enter the working area. "ICEBOX" would pass a target location and description to RAPTOR and GUIDO, who would than find and positively identify the target. Upon target identification "ICEBOX" would provide clearance for RAPTOR and GUIDO to employ ordinance (simulated) and destroy the target (Tab V-1.7, V-2 21).

c Aircraft Configuration. All members of RAPTOR and GUIDO were configured identically. Each had an AN/ALQ-184 electronic counter measure pod mounted on the fuselage centerline station, LANTIRN navigation and targeting pods on the intake stations, one 370-gallon external wing tank on each wing, a triple-ejection rack (TER) on each wing, missile launchers on each of the four outboard wing stations, an AIM-9M captive training missile on the left wingtip launcher, an Acceleration Monitoring Device (AMD) on the right wingtip launcher (Tab T-7,8).

2. In-Flight Conditions

a Weather. The observed weather closely resembled the forecast weather conditions At 1800L, the Osan observer recorded the surface conditions as few at 3,000 feet, broken at 5,000 feet, and broken at 10,000 feet with unlimited visibility. The winds were 270 degrees at 8 knots At Camp Page, which is co-located with the briefed working area, the observer recorded surface conditions as broken at 5,500 feet and overcast at 7,000. In the accident area, the Kangnung observer recorded surface conditions as scattered at 4,000 feet with unlimited visibility Surface winds were 230 degrees at 10 knots (Tab W-2)

b. Communication. The F-16 has two on board radios, one using Very High Frequencies (VHF) and the other using Ultra High Frequencies (UHF). All members of RAPTOR and GUIDO used local channel 11 (125.225 MHz) as a common inter-flight VHF frequency with a back up of channel 12 (124.425 MHz), which GUIDO flight used during the intercept portion of the mission. (Much of this unclassified communications data was obtained from the heads-up display (HUD) video tape, which is a classified item and therefore cannot be attached to this report.) All members of RAPTOR and GUIDO monitored common UHF frequencies for the entire day. The monitored UHF frequencies were 316.8 MHz for engine start-which is monitored by the 36th Fighter Squadron Operations, 253.7 MHz for Osan Ground , 308.8 MHz for Osan Tower, 234.2 MHz for Osan Departure Control, 352.2 MHz for Airedale, and 270.1 MHz for the area Forward Air Controller "Icebox". All flight members and Airedale also monitored the UHF emergency frequency (Guard) of 243.0 MHz These frequencies are all included in the 51 FW Viper Pilot Aid

c NAVAIDS and Facilities. All navigational aids relevant to the mission were operating normally on 24 Aug 98. The Notices to Airman (NOTAMS) for 24 Aug 98 revealed no pertinent facilities limitations or outages that affected the mission (Tab AA).

d. Planned Route

1) Airspace. RAPTOR and GUIDO were scheduled for the exclusive use of Military Operating Area (MOA) 6 High and Low, and Pilsung Range from 1700L to 1800L on 24 Aug 98 On the morning of the mishap, the mishap pilot, following established procedures, coordinated through the Senior Operations Duty Officer (SODO) to schedule an entry into the controlled airspace P518 (Tab V-1.2, V-2.21). The lateral limits of the airspace are depicted on RAPTOR and GUIDO flight's area map, attached as Tab R-1. MOA 6 Low airspace includes all altitudes from 3,000 feet to 9,000 feet, MOA 6 High includes 10,000 feet to 40,000 feet, and Pilsung Range includes surface to 25,000 feet.

2) Maneuvering Limitations. The maneuvering limitations for RAPTOR and GUIDO flight were based upon configuration limits for their aircraft, limits selected by the flight leader, and administrative limits imposed by governing instruction. The aircraft configuration limits from the flight manual included a maximum symmetric acceleration of 7 G's, increasing to 7.33 G's once the external fuel tanks were empty. Asymmetric (rolling) limits were 4.5 G's, rising to 5.5 G's once all of the fuel in the external tanks have been deleted. Maximum allowable airspeed was 550 knots or Mach .95, whichever was lower. Air to Air and Air to Ground training rules from AFI 11-214, were briefed by the flight leader. In addition, once any flight member reached "bingo" fuel of 4,000 pounds remaining, the mission would cease and the flight would return to Osan AB (Tab V-1 8).

3 Flight Activity Prior to Mishap

a. Departure. RAPTOR and GUIDO flights performed single ship takeoffs with 20 second spacing between aircraft. The deviation from the briefed takeoff was due to the bird hazard indicator being raised to bird moderate. A single ship takeoff with 20 seconds between aircraft is in accordance with regulation for a bird moderate condition. The remainder of the departure to the northeast took place as briefed (Tab V-1.7).

b Close Air Support Mission. RAPTOR and GUIDO entered the controlled airspace P518 at 1720L and communication was established with the Ground Based Forward Air Control (FAC), "Icebox". "Icebox" gave RAPTOR and GUIDO a FAC to fighter target brief at 1723L RAPTOR 1 than completed the fighter to fighter target brief with his flight members and initiated the attack run. As a result of the target area weather conditions, positive target identification was never established and the attack was aborted. In an effort to complete the upgrade mission RAPTOR and GUIDO exited P518 at 1732L and proceeded to MOA 6, Pilsung searching for airspace clear of weather. RAPTOR and GUIDO entered MOA 6, Pilsung at 1745L, found some useable airspace and accomplished Close Air Support training until 1800L (Tab V-1.7).

4 Air to Air Intercept.

a. Intercept Set-up. The egress heading from the last Close Air Support attack placed GUIDO in the northern part of MOA 6 and RAPTOR in the south. After completing gas checks, RAPTOR 1 determined that all flight members had enough fuel for one of the briefed Air to Air intercepts RAPTOR 1 and 2 in the south simulated adversary airframes and adversary tactics. GUIDO 1 and 2 in the north flew the US Air Force tactics. Separation between RAPTOR and GUIDO flights was 19 nautical miles (NM) at the start of the intercept (Tab N-1, V-1.7).

b Intercept Sequence. GUIDO 1 and 2 proceeded 165 degrees, at 22,000 feet, and 370 knots in a close formation from the north. In the south, RAPTOR 1 tracked north at 16,000 feet and 350 knots with RAPTOR 2 eight nautical miles in trail flying the same parameters. RAPTOR 2 targeted GUIDO 1 with his RADAR. GUIDO 1 and 2 performed a defensive maneuver, tracking 240 degrees, when RAPTOR 1 was 10 NM off GUIDO's nose.

RAPTOR 1 continued to track north. RAPTOR 2 tracked northwest attacking GUIDO. At 1808 04L, RAPTOR 1 called "GUIDO, Knock it Off, Knock it Off, Knock it Off" to stop the engagement. At the "Knock it Off" call RAPTOR 1 was 5 NM east of GUIDO and 8 NM north of RAPTOR 2 (Tab N-1, R-1, V-1.8).

5 Attempted Recovery. Following the "Knock it Off" call, RAPTOR 1 implemented the initial steps of handling an emergency -- maintain aircraft control and analyze the situation. GUIDO 1 initiated a fuel check, determined that he had the most fuel in the flight, and cleared GUIDO 2 and RAPTOR 2 to return to Osan while he provided assistance to RAPTOR 1. GUIDO 1 turned northeast and proceeded to attempt to rejoin with RAPTOR 1. Airedale Control provided RAPTOR 1 a directive vector north to Kangnung, the closest divert base. RAPTOR 1 started a climb and reached a maximum altitude of 17,000 feet, 25 NM south of the airfield at 1808·28L The mishap pilot placed the engine into a secondary (SEC) mode of operation at 1809.16L The mishap pilot delayed the decision to jettison the external tanks since his flight path took him over population. This decision delayed the jettison until 1810:50L, 15 NM south of Kangnung (Tab DD-2). The engine stagnated below sub-idle rotations per minute (RPM) and the mishap pilot initiated the critical action procedures (CAPS) for an engine airstart (Tab DD-1) at 1811:03L. The airstart was not successful and the aircraft never regained useful thrust. At 1812.10L, 10 NM south of Kangnung, RAPTOR 1 turned 30 degrees to the east to position himself for a left base turn to final into Kangnung. The mishap pilot turned out towards the ocean and prepared for ejection (Tab DD-3) passing 3,000 feet, 7 NM south of Kangnung, at 1812·00L. Ejection occurred at 1814:06L, 5 NM south of Kangnung at 1,100 feet above the water. (Tab N-1, R-1,2,3, V-1.8, V-2.22)

e. Impact: The aircraft crashed approximately a quarter mile off the coast in the water, 2 miles south, southeast of Kangnung AB (Tab B, R) There is no damage to personal property from the crash (Tab P) Two empty external fuel tanks were jettisoned over mountainous terrain approximately 3 minutes before the crash. The tanks are located on the side of a steep mountain in uninhabitable terrain and caused no property damage (Tab R). The tanks were not recovered due to their location, the anticipated cost of recovery exceeding the value of the items, and the fact that the empty tanks pose no environmental hazard. (Tab P)

f. Egress System: Capt Murphy accomplished a successful Mode I ejection from his aircraft at approximately 1100 feet above ground level and less than 200 knots Although he was well within the capability of the ACES II seat, or "in-the-envelope" as described in the technical order, he was also well below the minimum altitude of 2000 feet above ground level recommended to guarantee a safe ejection sequence under controlled conditions. The entire egress system and equipment functioned normally The pilot sustained no injuries and all his survival equipment was available to him (Tab J, V-1.16)

g. Personal and Survival Equipment:

1. Maintenance and life support records show all of the survival equipment inspections were properly performed and up-to-date (Tab BB-2-11). The following items were recovered following the aircraft mishap life raft, seat kit, survival kit, personal locator beacon, survival

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vest, Combat Edge vest, G-suit with contents, harness, life preserver units (LPU), helmet with visor, mask with CRU-94/P connection attached, flight suit, flight gloves, boots, undergarments, pilot's kneeboards, map, PRC-90 battery. Everything was recovered in good condition with the exception of the G-suit, the pockets of which were ripped (Tab BB-1).

2 All indications point to a MODE I type ejection sequence. The pilot inflated the LPU's prior to entering the water. The LPU's inflated and worked properly. The mask was removed from the helmet but left connected to the CRU-94/P. Upon entering the water, the left Universal Water Activated Release System (UWARS) parachute harness connector released immediately The mishap pilot reached for the right connection and is uncertain if he released it or the right UWARS functioned after a small delay All other life support equipment was used properly and indicated normal operation (Tab V-1.16, BB-1).

h. Rescue: The time of the ejection was 1814L (Tab J) The time of the aircraft crash (water impact) was also 1814L, estimated at less than 10 seconds after the pilot ejected (HUD tape). The downed pilot performed all applicable survival procedures, quickly entered his life raft and attempted radio contact with GUIDO 1 orbiting overhead However, the pilot was rescued by a Korean fishing boat within 5 minutes of landing in the water and was not able to establish radio contact with GUIDO 1. GUIDO 1 observed the fishing boat approaching the life raft and relayed the information to the controlling agency (Airedale). The fishing boat transported the pilot to the nearest pier where he was met by ROKAF officials and a flight surgeon from Kangnung AB. (Tab V-1.17, V-2.24)

i. Crash Response: All appropriate crash response procedures were accomplished given the circumstances of the mishap. GUIDO 1 observed a fishing boat rescue the mishap pilot before GUIDO 1 departed the area due to low fuel. 51 FW command structure coordinated with the ROKAF to confirm the pilot was safe and that he was in good condition. The extremely fast and fortuitous recovery of the pilot and the rapid coordination between USAF and ROKAF forces obviated the launch of USAF rescue forces. A detachment of the 33rd Rescue Squadron from Kadena AB, Okinawa, equipped with HH-60 helicopters, was prepared to conduct rescue operations if needed. The pilot was met at the pier by ROKAF officials and flight surgeons from Kangnung AB after his rescue by the Korean fishing boat. He was then transported from Kangnung to Osan by a ROKAF CN235 aircraft (Tab V-1-4).

j. Maintenance Documentation: The Air Force Technical Order (AFTO) Forms 781 covering aircraft maintenance activity on aircraft 88-0519 during the period May 98 to Aug 98 were reviewed. There were no open discrepancies which would have compromised safety of flight. No Time Compliance Technical Orders (TCTOs) were overdue Five TCTOs were awaiting completion, but none were grounding items or related to safety of flight. Aircraft forms (Tab U-1), egress inspection checklist (Tab U-6), Maintenance History Inquiry from 26 May 98 to 24 Aug 98 (Tab U-9), Document Review Inquiries (Tab U-8), engine time change forecast (Tab U-12), aircraft AFTO Form 95 (Tab U-10), and engine AFTO Form 95 (Tab U-13) review show that all scheduled aircraft inspections were completed on time. The aircraft oil analysis record for one year prior to the mishap showed zero abnormal trends for Joint Oil Analysis Program (JOAP) atomic emissions (Tab U-2) Time change requirements were reviewed via aircraft forms (Tab U-

1), egress inspection checklist (Tab U-6), Consolidated Aircraft Maintenance System (CAMS) Document Review Inquiry (Tab U-8), engine time change forecast (Tab U-12), and engine AFTO Form 95 (Tab U-13). Zero discrepancies were noted and all actions were completed within specified timelines. The basic postflight, preflight, walk-around inspections and aircraft servicing were properly documented prior to the mishap flight. The egress system final inspection was last accomplished on 13 August 98 (Tab U-6). A review of the mishap aircraft history revealed normal procedures with zero trends in reference to mission capable rates (Tab U-7), abort rates, in-flight emergencies, chargeable deviations, code 3 breaks (which result in grounding the aircraft until repaired), and repeat and/or recurring discrepancies (Tab U-17,18).

k. Maintenance Personnel and Supervision: A review of the aircraft forms for the day of the mishap revealed that the preflight, walk around inspection, and all required servicing was accomplished (Tab U-1). An Information Note in the aircraft Form 781A for a crew chief tool kit (CTK) and foreign object (FO) check due upon pilot arrival at the aircraft was not cleared prior to flight. This note is a routine, additional step mandated by local procedures and intended as a means of emphasizing these inspections. According to witness testimony, supervision on the flight line was adequate to ensure safe maintenance operations (Tab V-5.32, V-6.42, V-7.49, V-8 51) A review of individual training records and the special certification roster revealed that all maintenance personnel were certified to perform all tasks they signed off in the aircraft forms. A review of the Quality Assurance History (Tab U-11) revealed no adverse trends in 36th FS maintenance performance.

l. Maintenance Practices or Procedures.

1. Technical Order 1F-16CG-2-70FI-00-11, *Power Plant Fault Isolation*, provides fault isolation procedures for Engine Magnetic Chip Detector Inspection and Cleaning (Tab U-15) Fault code 79-00-YD directs the maintainer to Table 10-64 for Engine Oil Analysis. Solid Contamination. This table provides explicit instructions for examining metal contamination on the engine chip detector. These instructions include using a 10X magnifying glass to examine debris. The instructions also direct the maintainer to brush the chip detector over clean paper with a short bristled brush (to remove metallic particles). The table directs the maintainer to figures 10-92 and 10-93 to identify the type of contamination on the chip detector and determine acceptable limits of contamination. Table 10-64 defines a normal indication on the engine chip detector as "free of debris." Thus, any debris on the engine chip detector would be an abnormal indication The remedy for an abnormal indication is to "Go to fault code 79-00-YK." Fault code 79-00-YK provides a troubleshooting guide for correcting contamination on the engine chip detector. According to this guide, the minimum required action for debris, flakes, or chunks within the limits described in Figure 10-93 is to record an entry in the "781K/AFTO 95." The minimum required action for debris, flakes, or chunks outside the limits described in Figure 10-93 is to perform an engine isolation run per Table 10-65. The engine isolation run consists of a 1 hour engine run with the engine being operated at different power settings After the isolation run, the magnetic chip detector, magnetic isolator plugs and engine oil filter are inspected for contamination. If the chip detector and oil filter element are clean, the engine may be returned to service but must be monitored. A JOAP sample is also taken and the engine is placed on JOAP surveillance for 10 flight hours If contamination continues, the engine is replaced.

2 During an Integrated Combat Turn (ICT) performed on 21 August 98, after the last flight before the mishap flight, metal particles were discovered on the engine magnetic chip detector This discrepancy was entered in the aircraft AFTO Form 781A (Tab U-1) on a red dash symbol and signed off by the engine specialist. Testimony has revealed that a significant amount of flakes, light debris, and fuzz was discovered on the engine chip detector (Tab V-5.35, V-7.51, V-9 62, 9 64, V-10.70). Testimony from several individuals who examined the chip detector described the particulate matter as covering as much as 75 percent of the tip area of the chip detector Testimony also indicates the chip detector contained both metal flakes and light debris. In accordance with the aforementioned TO, acceptable limits of light debris or fuzz is a maximum of 10 particles over 0 010 inch, or particles under 0.010 inch, up to 15 percent of the tip area (Tab U-15) Testimony clearly indicates that the amount of light debris and fuzz exceeded acceptable limits

3 The testimony given by the engine specialist who signed off the red dash discrepancy for "metal flakes on chip detector" indicated that he did not properly utilize the TO to inspect the debris on the chip detector (Tab V-6 42-6.45). The engine specialist did not use a 10X magnifying glass to inspect the debris on the chip detector. He did not brush the metal particles onto clean paper. He did not properly clean the chip detector, nor did he document his findings in the AFTO Form 781K or Engine AFTO Form 95 to allow the engine to be monitored. All these steps are required by TO 1F-16CG-2-70FI-00-11. (Tab U-15)

4. Additional Information. During aircraft recovery operations a tool was found with the wreckage (Tab FF-2). This tool, a pair of mechanical fingers, normally 18 inches long, was recovered with the aircraft wreckage. Investigation revealed that a 3 inch piece was severed from the end of the mechanical fingers. A review of lost tool logs and reports for the 36th Fighter Squadron, 25th Fighter Squadron, and 51st Maintenance Squadron for the period of Jan 97 to Aug 98 revealed that no mechanical fingers were identified as lost at Osan AB during that time period (Tab U-14) It should be noted that damage to the engine fan and compressor blades was caused upon impact with the water. No foreign object damage (FOD) was found within the engine that could be identified as being caused by the missing piece of the mechanical fingers.

m. Engine Fuel, Hydraulic, and Oil Inspection Analysis: The mishap aircraft engine oil analysis samples for the year prior to the mishap sortie were normal (Tab U-2) Oil samples retrieved from the engine after the mishap showed an increase in iron from 0 to 4 parts per million (Tab U-2) Fuel samples taken from the vehicles that last serviced the mishap aircraft were satisfactory for use (Tab U-5) The samples of oil and liquid oxygen taken from the oil servicing cart and liquid oxygen servicing cart respectively were within normal limits (Tab U-3,4). A hydraulic sample was not taken from the hydraulic servicing cart after the mishap.

n. Airframe and Aircraft Systems:

1. The engine magnetic chip detector, four lube and scavenge pump screens, and the #4 bearing were submitted to General Electric Laboratories in Cincinnati, Ohio for analysis Due to the extensive damage sustained by the #4 bearing during the mishap event, they were unable to

determine the root cause of bearing failure. Investigation disclosed that bearing failure was not caused by sustained interruption of the oil supply to the bearing, damage during assembly, or material abnormality. The bearing outer race roller path contained a deep wear groove extending for 9 inches of the circumference. The raceway shoulders of the inner race were both well rounded due to wear, and 4 of the 8 oil supply holes were blocked, or partially blocked, with debris. The roller cage assembly was distorted and material was deposited on the cage rail outer surfaces for an approximate 6 inch circumferential length All rollers were locked to the cage and greatly damaged. All rollers were flattened on the side towards the inner race and bore no resemblance to their original shape. The #4 bearing inner race, outer race, and roller bearings are manufactured from M50 steel The #4 bearing cage assembly is manufactured from 4340 alloy steel. At least 4 metallic chips, identified as M50 bearing steel, were found on the magnetic chip detector. The majority of the debris on the magnetic chip detector was iron-based, but not M50 bearing material. No M50 bearing steel chips were found in the four different lube screens Pieces of carbon seal material were found in the "C" sump screen (Tab U-21)

2 One of the hydraulic pumps broke apart upon impact and the other was not found. No hydraulic fluid remained in the system to provide a sample for analysis. The only electrical system component recovered was the electrical control panel Recorded data from the crash survivable memory unit indicated that both generators failed prior to impact (because of a lack of engine core speed) and that the emergency power unit (EPU) was running with normal turbine speed. All avionics components were destroyed upon impact. Data was not retrievable from the digital flight control computer, however, recorded data showed that the flight control system warning light was not illuminated and the aircraft was responding to stick inputs (Tab J-2)

3 The engine was retrieved and returned to Osan Air Base for investigation. Saltwater contamination and subsequent corrosion of components had occurred. A large amount of debris was found on the tip of the main engine master chip detector. The front frame, fan rotor, and fan stator received extensive damage from impact with the water. The magnesium housings of the Accessory Gearbox were severely corroded allowing heavy corrosion to internal gearshafts and bearings The compressor rotor had minor nicks on stage 1-4 blades while the honeycomb seals on the compressor stator were deeply grooved. The High Pressure Turbine (HPT) blade squealer tips had rubbed down to the tip caps from rubbing on the HPT shroud. Honeycomb airseal areas on the Low Pressure Turbine (LPT) nozzles were deeply grooved The LPT rotor and turbine frame were in good condition. The #4 bearing was very heavily damaged. Its outer race was deeply grooved for approximately 200 degrees around the inner circumference with a large amount of transferred material deposits. Rolling elements were severely flattened and greatly reduced in size. The cage was distorted with the silver plating blistered. The inner race was indigo in color with roller track shoulders rounded. Inner race oiling holes were plugged with transferred metal and the carbon seal was shattered. The damage discovered in the engine is consistent with a #4 roller bearing failure. (Tab J-1)

o. Operations Personnel and Supervision: The mission was authorized by Lt Col Jeffrey Lofgren, Director of Operations, 36th FS. Supervision present at the brief and during the flight consisted of the 51st Fighter Wing Vice Commander (GUIDO 2), the 51st Operations Support Squadron Commander (GUIDO 1), the 51st Fighter Wing Chief of F-16 Standardization and

Evaluation (RAPTOR 2), and the 36th Fighter Squadron C Flight Commander (the mishap pilot, RAPTOR 1). RAPTOR 2 was the Instructor Pilot (IP) of record (Tab T-1)

p. Pilot Qualifications:

1. The mishap pilot has 1200.8 hours of total time with 783 hours in the F-16 (Tab G-2). Osan is his second operational tour. He served three years at Shaw AFB prior to arriving at Osan (Tab T-6) The mishap pilot left Shaw certified as a flight lead Due to his prior experience level, the 36th FS put the mishap pilot through an abbreviated mission qualification training (MQT), which he has completed, and flight lead upgrade (FLUG) course, which he is currently in (Tab EE-2,3). His progress through the MQT portion was above average and his progress through the FLUG program is average His recent flight time is as follows: (Tab G-1)

	Hours	Sorties
30 days	7.3	7
60 days	21.8	20
90 days	32.0	29

2. The Air Force Operational Management Records System (AFORMS) currency data base (Tab EE-6) indicates that the mishap pilot was overdue for the following ground training categories: LS04 Aircrew Chemical Defense Ensemble (ACDE) Training, LS07 Egress Ejection Training, LS09 Hanging Harness Ejection Training, LS 12 Hanging Harness with Aircrew Chemical Defense Ensemble (ACDE). The PACAF OI 11-301, Aircrew Life Support System, requires the aircrew member to be current in these training areas before flying. Capt Murphy was both a squadron and wing level life support officer during his previous assignment at Shaw AFB. All air training categories required for the accomplishment of this mission were current (Tab EE-6).

TASK ID	TASK NAME	DATE LAST ACCOMPLISHED	DATE DUE	OVERDUE
LS04	ACDE TRNG	31 MAY 97	31 MAY 98	YES
LS07	EGRESS, EJCT TG	04 FEB 98	04 AUG 98	YES
LS09	HH, EJECT TRNG	04 FEB 98	04 AUG 98	YES
LS12	HH, W/ ACDE	15 JUN 97	30 JUN 98	YES

q. Medical: A thorough review of the mishap pilot's medical and dental records, including the post-mishap physical exam and toxicology test, was performed. The mishap pilot was medically qualified at the time of the mishap. Capt Murphy had a current AF Form 1042 valid until 31 July 1999 (Tab X). He reported no medical problems prior to the mishap. He affirms that he felt perfectly fit to fly the day of the mishap, and in fact conducted his routine morning run before coming to work. (Tab V-1.18) The post-mishap toxicology test was normal. Specifically, there was no evidence of prescription or non-prescription medications in the blood or urine. All post-mishap tests, to include a complete radiological examination for fractures and/or spinal compression, were normal, with no signs of injury or fracture. Capt Murphy said he suffered some mild soreness from the ejection, but no other injuries. He was subsequently medically cleared for flying duties on 1 Sep 98. (Tab X)

r. Navaids and Facilities: Navaids, facilities and Notices to Airmen (NOTAMs) were reviewed All navigational aids relevant to the mission were operating normally on 24 Aug 98. The NOTAMS for 24 Aug 98 revealed no pertinent facilities limitations or outages that affected the mission (Tab AA)

s. Weather: The observed weather closely resembled the forecast weather conditions. At 1800L, the Osan observer recorded the surface conditions as few at 3,000 feet, broken at 5,000 feet, and broken at 10,000 feet with unlimited visibility. The winds were 270 degrees at 8 knots At Camp Page, which is co-located with the briefed working area, the observer recorded surface conditions as broken at 5,500 feet and overcast at 7,000. In the accident area, the Kangnung observer recorded surface conditions as scattered at 4,000 feet with unlimited visibility. Surface winds were 230 degrees at 10 knots (Tab W-2)

t. Governing Directives and Publications:

1) AFI 11-2F-16 Volume 1, *F-16 Training*, 1 May 98
2) AFI 11-2F-16 Volume 3, *F-16 Pilot Operational Procedures*, 21 Apr 95, and 51 FW supplement
3) AFI 11-214, *Aircrew Weapons Director and Terminal Attack Controller Procedures for Air Operations*, 25 Feb 97, and PACAF supplement
4) AFI 21-101, *Maintenance management of Aircraft*, 7 Jul 97, and PACAF supplement
5) AFI 21-103, *Equipment Inventory, Status, and Utilization Reporting*, 20 Jul 98, and PACAF supplement
6) AFI 21-104, *Selective Management of Selected Gas Turbine Engines*, 1 Jul 98
7) AFI 21-112, *Aircraft Egress and Escape Systems*, 1 Nov 97, and PACAF supplement
8) AFI 21-124, *Air Force Oil Analysis Program*, 1 Feb 96
9) PACAF Instruction 11-301, *Air Crew Life Support (ALS) Program*, 10 Oct 95
10) PACAF Instruction 21-101, *Aircraft Maintenance Organization and Procedures*, 25 Dec 96
11) PACAF Instruction 21-108, *Aircraft Flying and Maintenance Scheduling Procedures*, 2 Feb 98
12) 51FW Instruction 21-122, *Oil Analysis Program*, 1 May 97
13) *51st Fighter Wing Viper Pilot Aid*, 15 Oct 97, Change 3, 17 Jul 98
14) T.O. 00-5-1, *Air Force Technical Order System*
15) T.O. 1-1B-40, *Weight and Balance Data*, 1 Jan 93, (Change 14, 1 Sep 97)
16) T O. 1-1B-50, *Basic T.O. For USAF Aircraft Weight and Balance*, 1 Mar 93 (Change 13, 14 Jun 97)
17) T.O. 1F-16CG-1-2, *Supplement Flight Manual*, 1 May 97
18) T O. 1F-16C/D Blocks 40 and 42, *Flight Manual*, 27 May 96 (Change 3, 2 March 98)
19) T.O. 1F-16CG-2-12JG-00-1, *Job Guide Servicing*, 15 Sep 88 (Change 34, 13 Jul 98)
20) T.O. 1F-16CG-2-70FI-00-11, *Power Plant Fault Isolation*, 30 May 92 (Change 24, 30 April 98)

21) T O 1F-16CG-5-1 *Basic Weight Checklist*, 16 Sep 96 (Change 1, 8 May 98)
22) T.O. 1F-16CG-5-2, *Loading Data*, 16 Sep 96 (Change 1, 1 Jul 97)
23) T.O. 1F-16CG-6WC-1-11, *Combined Preflight/Postflight, End of Runway, Through Flight, Launch and Recovery, Quick Turnaround, Basic Postflight and Walk-Around after First Flight of the Day inspection Work Cards*, 25 Jul 88 (Change 31, 27 Jul 98)
24) T.O. 1F-16CG-34-1-1, *Avionics and Non-Nuclear Delivery Manual*, 2 Dec 91, (Change 78 Aug 97)

15 OCT 98

MICHAEL P. ERDLE, Colonel, USAF
Accident Investigation Board President

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STATEMENT OF OPINION

F-16 ENGINE FAILURE
24 AUG 98

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 OF THE UNITED STATES OR BY ANY PERSON REFERRED TO IN THOSE CONCLUSIONS OR STATEMENTS.**

2. **OPINION SUMMARY** (See Discussion of Opinion section after the Opinion Summary section for detailed explanation):

a The cause of this mishap, supported by clear and convincing evidence, was the failure of the number four engine roller bearing (#4RB). The failed bearing disabled the engine and aircraft to the extent that it could no longer be flown. All reasonable and prudent steps were taken by the pilot to attempt to recover the aircraft to a safe landing prior to his ejection from the aircraft.

b A contributing factor in this accident was the failure of maintenance personnel, specifically engine specialist SSgt Mark J. Nestved, to correctly follow Technical Order (TO) 1F-16CG-2-70FI-00-11, *Power Plant Fault Isolation*, in investigating evidence of impending engine failure. Had the tech order been followed, the bearing failure would have been discovered on the ground and the mishap aircraft would not have been flown.

3. **DISCUSSION OF OPINION:**

a Through post-mishap analysis of the engine, it is clear that the number four engine roller bearing failure caused the engine to fail, necessitating the subsequent ejection of the pilot and leading to the crash of the aircraft (Tab U-20, 21). The cause of the bearing failure is unknown. Predicting a bearing failure is a difficult proposition since we have no data to support any definitive pattern of failure. The magnetic chip detector (MCD) is perhaps the most effective means for predicting a bearing failure characterized by the presence of metal particles in the engine oil. The MCD is basically a magnet that attracts pieces of metal, or "chips", from the engine oil The MCD is inspected by the crew chief after every flight. The presence of metal particles on the chip detector and, therefore, in the oil is a possible indication of an impending bearing failure. Metal particles in the oil could also be a normal occurrence in an engine that has just had major maintenance, such as an overhaul, and the metal particles would occur as a normal result of the engine break-in. However, metal particles in the oil of an older engine, or one that has not been recently overhauled (as was the case in the mishap aircraft), is not a normal condition and should be cause for concern. It is possible that an engine bearing could fail quickly without

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any indication or warning, i.e , without any sign of metal particles on the MCD from the previous flight However, evidence indicates a larger percentage of #4RB failures are detected through the presence of particles on the MCD than through any other means The limits on the size and number of particles of varying shapes (chunks, slivers, flakes, etc.) accumulated on the MCD and the appropriate actions associated with each are addressed in the technical order. In a 25 July 1996 background report, General Electric, the engine manufacturer, stated that the F110-100 engine had experienced 13 #4RB failures at that time, 5 resulting in engine shutdown (4 in flight, 1 on the test cell.) Of the F110-100 events that were detected prior to engine seizure, 6 were found by the use of the MCD, 1 was found during unrelated maintenance, and 1 was not recorded as to the method of detection (Tab U-19).

b Technical Order 1F-16CG-2-70FI-00-11, Power Plant Fault Isolation (70FI), delineates the proper procedures for inspecting the MCD and provides direction for action required given varying results of the MCD inspection. 70FI also provides direction for proper documentation to insure the MCD inspection results accompany the engine and establish a history of anomalies for that particular engine. 70FI is specific about the number and size of metal particles discovered on the MCD that are acceptable or within limits. When the crew chief removes the MCD from the aircraft, if he sees particles on the MCD he should bring the MCD to the attention of his supervisor. An engine specialist should then be asked to investigate the particles by referring to 70FI, which presents logic tree options depending on the particles present If the particles exceed the threshold specified by 70FI, a ground engine run is required to isolate the problem. If particles do not exceed the threshold, the MCD is cleaned and returned to the aircraft, and the aircraft forms are documented on the 781K and engine AFTO Form 95 to insure the engine is monitored for further developments. The aircraft is then released for routine procedures in preparation for flight.

c. Testimony indicates metal particles in excess of that allowable by 70FI were detected on the MCD after the last flight prior to the mishap flight. Following its flight on Friday, 21 August 1998, aircraft 88-0519 was scheduled to be used by maintenance and weapons personnel in practicing an integrated combat turn (ICT), a procedure to quickly prepare an aircraft for a subsequent combat mission, to include loading the aircraft with a variety of weapons. One of the required steps is to check the MCD for metal particles. The crew chief checking the MCD identified the presence of a significant amount of metal particles and made an entry in the aircraft maintenance Form 781A. The crew chief brought the MCD to the attention of the ICT chief, who in turn notified the flight line expediter. The expediter notified the engine specialists on the radio to report to the ICT to investigate the MCD. Up to this point, all steps taken by each individual were appropriate. The testimonies of SSgt Keller, SrA Yates, SSgt Blankenship, and SSgt Stamper all indicate that the amount of small particles present on the MCD far exceeded the 15 percent total coverage allowable in the technical order (Tab V-5.35, V-7.51, V-9.64, 9.67, V-10 70). Upon reaching the ICT area, the engine specialist, SSgt Nestved, inspected the MCD, erroneously determined that it was within technical order limits, and signed off the entry made by the crew chief in the AF Form 781A documenting his inspection. In his testimony, SSgt Nestved addressed the size of the "flakes" he saw on the MCD but not the amount of coverage of small particles, and made his determination based on only one of the criteria listed in the TO, the size of the flakes In addition, SSgt Nestved displayed an incomplete knowledge of the tech order during his interview, and his testimony and the aircraft forms both confirm that he did not accomplish several steps required in the tech order. Specifically, SSgt Nestved did not brush the particles onto white paper and use a magnifying glass to determine the size of the "flakes" on the MCD; he did not clean the MCD in accordance with the technical order instructions, and he did not document the existence of metal particles in the 781K and AFTO Form 95 for engine tracking and monitoring purposes.

d. I have concluded, based on witness testimonies and evidence of non-compliance with the TO, that had the engine specialist properly followed the TO, an isolation run would have been performed on this engine and the impending #4 roller bearing failure would have been discovered prior to flight. Witness testimonies weighed heavily on this conclusion, since the MCD evidence *after* an engine has seized only corroborates the fact that the engine seized, and is not indicative of the condition of the MCD *before* the engine seizure or the ability at that time to predict a failure. The sole engine specialist to inspect the MCD prior to the mishap was SSgt Nestved, who claims the particles were within limits. None of the witnesses who dispute that testimony are engine specialists The expert testimony should normally weigh more heavily than the non-expert. However, when the threshold for coverage is 15 percent, and several witnesses testify the coverage was over 50 percent, the "expert" status of the one individual loses credibility. SSgt Nestved's failure to accomplish several other steps in the technical order raises serious doubts as to his familiarity with the technical order, and supports the conclusion that he did not follow the required steps in the technical order. In addition, SSgt Nestved's testimony regarding his inspection of the MCD using only one of several criteria strongly suggests only a partial understanding of the TO.

e. The pilot's actions were commendable in attempting to recover the aircraft and prevent injury or damage to individuals or property. The pilot delayed jettisoning the empty fuel tanks, an action that would reduce the aerodynamic drag on the aircraft and allow a greater glide distance, because he was over a populated area. His actions to point the aircraft towards the water and delay his ejection until the aircraft was clear of any populated area insured no one would be injured, but in doing so he placed himself at risk of injury or death. Capt Murphy ejected at 1100 feet above the ground, 900 feet below the recommended minimum ejection altitude to guarantee the egress systems would have time to function properly.

4. ADDITIONAL RELEVANT INFORMATION.

A set of mechanical fingers was retrieved with the wreckage (Tab Z-1,2, FF-2). Mechanical fingers are a hand tool used to pick up small objects in hard-to-reach places, and should not be in an F-16 when it flies. Approximately three inches have been severed off the end of the mechanical fingers Since the engine was salvaged, it was possible to investigate the possibility of foreign object damage to the engine. We found no such evidence, and I therefore have concluded that this tool was not related to the mishap.

5. CONCLUSION.

a It is my opinion, supported by clear and convincing evidence, that the failure of the #4 engine roller bearing was the cause of this accident.

b A contributing factor in this mishap was the failure of the engine specialist to correctly follow the technical order which would have identified the deteriorating #4 roller bearing and prevented the mishap aircraft from flying.

15 OCT 98

MICHAEL P. ERDLE, Colonel, USAF
Accident Investigation Board President