RAS 5385 72-22-ISFSI – Applicant Exhibit 173 – Rec'd 7/1/02

AFI-51503
USAF AIRCRAFT ACCIDENT INVESTIGATION BOARD

20 SEP 94
HILL AFB, UT

F-16CG AIRCRAFT	388 FW
S/N 88-0488	421 FS

INVESTIGATION OFFICER
ROBERT L. ARMOUR JR, LT COL, USAF

HQ
12TH AIR FORCE

COPY NUMBER 1 OF __

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DEPARTMENT OF THE AIR FORCE
HEADQUARTERS TWELFTH AIR FORCE (ACC)
DAVIS-MONTHAN AIR FORCE BASE, ARIZONA

14 DEC 1994

MEMORANDUM FOR HQ 12 AF/JA

FROM: 12 AF/CC
5340 E. Gafford Way, Ste 130
Davis-Monthan AFB, AZ 85707-4250

SUBJECT: Aircraft Accident Investigation: F-16CG, SN88-0488, 20 Sep 94, 388 FW, Hill AFB, UT

Subject aircraft accident investigation is approved.

THOMAS R. GRIFFITH
Lieutenant General, USAF
Commander

58043

AIRCRAFT ACCIDENT INVESTIGATION

FORMAL REPORT OF INVESTIGATION

Hill AFB, UT 20 Sept 1994
F-16CG S/N 88-0488
02 December 1994

1. AUTHORITY AND PURPOSE:

The Commander, Twelfth Air Force, Air Combat Command (ACC), appointed Lieutenant Colonel Robert L. Armour Jr., Air Force Advisor, 138 Fighter Group, Tulsa IAP, OK, on 13 October 1994 under Air Force Instruction 51-503 to investigate and determine the facts and circumstances surrounding the aircraft accident involving F-16CG aircraft S/N 88-0488, which occurred 20 September 1994 near Hill AFB, UT. Captain Steven B. Barnett, 355 LSS/LST, Davis-Monthan AFB, AZ, was appointed on 13 October 1994 as a maintenance technical advisor. Captain Kevin L. Cutler, Chief Civil Law Branch, Ogden Air Logistics Center, Hill AFB, UT was appointed on 13 October 1994 as a legal advisor. (TAB Y-1 to Y-3)

The purpose of the investigation was to obtain and preserve all available evidence for claims, litigation, disciplinary and administrative actions and for all other purposes deemed appropriate by competent authority

2. SUMMARY OF FACTS:

a. History of Flight:

(1) Summary of the Flight. Two F-16CG aircraft, call signs Cold 41, the Accident Aircraft, and Cold 42 launched at approximately, 1030 hours Mountain Daylight Time (MDT) 20 September 1994 on a training mission to the Utah Test and Training Range(UTTR), approximately 75 nautical miles (NM) west of Hill AFB, UT (TAB G-5, AA-1-1, &AA-1-3). The flight was directed to execute a simulated attack on a designated ground target. On the first pass Cold 42, piloted by Captain Bjorn Granviken, was unable to identify the target. During the reattack, the pilot of Cold 42 lost sight of Cold 41 and immediately informed Cold 41(TAB AA-4-2). Captain Michael D. Goldfein, the pilot of Cold 41, informed Cold 42 that he was at 17,500 Mean Sea Level (MSL) and directed Cold 42 to go to 16,000 MSL to ensure altitude deconfliction (TAB AA-4-2). Shortly after directing the altitude separation, at approximately 1049 MDT, the pilot felt and heard a large bang in his aircraft (TAB V-1-2). The bang was produced by an engine stall which was the result of a progressive failure of the number four roller bearing assembly (TAB J-3, J-4, J-7 through J-12 & O-137). The engine continued to stall and although it was operating within it's normal operating limits it was not producing the revolutions per minute (RPM) and subsequently the thrust that was called for by the throttle setting (TAB O-38 & V-1-2). The thrust was insufficient to maintain level flight at the given alttude and aircraft configuration (TAB V-1-2). Captain Goldfein initially thought he had experienced a mid-air collision with Cold 42 and tried to ensure the two aircraft were separated while initiating a recovery to Hill AFB, UT (TAB V-1-2). As the bangs continued, Captain Goldfein considered a possible engine problem and initiated an airstart while climbing to approximately 18,200' Mean Sea Level (MSL) (TAB O-46 & V-1-1). The engine restarted immediately, all engine instruments were indicating in the normal operating range and the bangs continued, which led Captain Goldfein to refocus on the possibility of a structural problem (Tabs O-36, O-38, O-46, O-47 & V-1). Captain Goldfein realized he had an engine problem versus a structural damage problem when he noted he could not maintain 300 knots in level flight (TAB V-1-1). He jettisoned his external fuel tanks, placed the engine control switch in the secondary (SEC) mode and established a constant speed, descent towards Hill AFB (TABs O-29 ,O-33 & O-34). Attempts to obtain more thrust by selecting afterburner and accomplishing a second airstart were unsuccessful (TABs-O-38 & V-1). When Captain Goldfein determined he was unable to recover the aircraft at Hill AFB, he climbed to approximately 3,300' above ground

level (AGL) and initiated a successful ejection at approximately 11:01 hours MDT (TABs O-31, O-33 & V-1). The aircraft impacted the ground at approximately 1103 hours MDT and was destroyed (TAB A-1, O-72 & O-86) The uninjured pilot was picked up by a UH-1 Huey helicopter, callsign Sport 57. from the 545 Test Group at approximately 11:06 hours MDT and transported to the Hill AFB hospital (TAB V-12-1 & V-12-2) The aircraft crashed on private properties 283° true bearing, 8 NM from Hill AFB, Utah (TAB A). Actual damage to private property included ground contamination by fuel, an impact crater in a marshy "wetlands" area, destruction of several fence sections, and the disruption of the laser leveling of the harvested cornfield were the bulk of the aircraft landed. (TABs P-1 & AA-11-1). The external fuel tanks landed at 4122.29° North latitude, 11312.44° West longitude on privately owned high desert land with no apparent damage (TAB AA-11-1).

(2) All accident sequence times are approximate based on Cold 41's recorded takeoff time of 10:30.00 added to the event data recorded by the crash survival flight data recorder (CSFDR) and the seat data recorder (SDR). Aircraft impact data is based on the CSFDR data termination, which is able to record data until approximately 1/2 second prior to impact (TAB O-22).

(3) Media Coverage. The accident generated local news interest and was covered by the local television networks and newspapers. News releases were provided to the public by the 388th Fighter Wing Public Affairs office, Hill AFB UT. Pictures of the crash site were published in the local paper (TAB AA-3).

(4) Significant Facts Preceding the Accident Mission. The malfunction attributes programmed into the F-16 simulator for simulating engine compressor stalls produces an audible bang or series of bangs accompanied by fan turbine inlet temperature (FTIT) and percentage of revolutions per minute (RPM) guage fluctuations (TAB AA-12).

b. **Mission**: The mission was the second of four planned flights for the accident pilot and his wingman as part of a 388 FW operational readiness exercise (ORE). The flight was planned as a Killer Scout Support training mission (TAB K-4 & V-1). The Killer Scout role is that of an armed attack fighter in an air interdiction environment tasked to validated tasked targets, mark targets, and to direct dedicated ground attack fighters against lucrative targets. An F-16, call sign Nail 31, was the Killer Scout for the mission and Cold 41 flight was tasked to support Nail 31 attacking targets as directed by Nail 31 (TAB N-9). The mission was to the Utah Test and Training Range (UTTR), approximately 75 nautical miles (NM) west of Hill AFB, UT (TAB G-5, AA-1-1, &AA-1-3). Mission objectives were to provide support for the designated Killer Scout by putting bombs on target. The mission overview called for single ship takeoffs with 20 seconds spacing, rejoin to a route formation, proceeding directly to the area, executing attacks on designated targets, and returning to Hill AFB for a tactical straight in recovery (TAB V-1-1)

c. **Briefing and Preflight**: Captain Goldfein had adequate crewrest for flying on 20 September 1994 and was prepared for the mission (TAB V-1-1). The mission briefing was conducted in two parts. Major Les Long, 421 FS/DO conducted a mass briefing to cover required general briefing items from MCR 55-116 along with the ORE special instructions (TAB V-11). A mission specific briefing was conducted by Captain Goldfein utilizing the combat briefing guide in the 388 FW inflight guide. The mass briefing and the mission specific briefings covered all required briefing items and no problems or misunderstandings arose during the briefings (TAB V-1-1, V-2-1 & V-11).

d. **Flight Activity**:

(1) Cold 41 flight was filed on a IL-04 stereo flight plan This is an instrument flight rules (IFR) flight plan that requests an IFR clearance routing to take the flight from Hill AFB to Restricted Area 6404 and the adjoining Lucin Military Operating Area (MOA), delay in the special use airspace to perform their Killer Scout Support Mission, and then obtain an IFR clearance for recovery to Hill AFB (TAB AA-1-1) The flight took off at 10.30 hours MDT as briefed, proceeded to the Lucin MOA and contacted Nail 31, the Killer Scout, for target tasking (TAB V-1-1).

(2) Nail 31 directed Cold 41 flight to attack a ground target in the MOA. During the first pass on the target, Cold 42 was unable to positively identify the target and did not simulate dropping his ordnance (TABs N-9, N-10 & V-2-1). The flight then executed a reattack on the same target. During the reattack, Cold 42 lost sight of Cold 41 and informed Cold 41 that he had lost sight by transmitting "blind". Cold 41 immediately informed Cold 42 that he was at 17,500' MSL and directed him to maintain 16,000' MSL (TAB AA-4-1).

(3) Approximately 13 seconds after Cold 42's "blind" call, at 10:49 hours MDT, Captain Goldfein felt and heard a large bang in his aircraft (TAB V-1-1 & AA-4-1). The bangs were produced by engine stalls, which were the result of a progressive failure of the number four roller bearing assembly (TAB J-3, J-4, J-7 through J-12). At the time of the first engine stall, as recorded by the SDR, the aircraft was in approximately 40 degrees of left bank turning through south-southeast at approximately 16,900' MSL in a 3 degree climb at 410 Knots Calibrated Airspeed (KCAS) (TABs O-33, O-44 & O-50). Captain Goldfein initially thought he had experienced a mid-air collision with Cold 42 and tried to ensure the two aircraft were separated by continuing his turn and climbing at the same time initiating a recovery to Hill AFB, UT (TAB V-1-2).

(4) Captain Goldfein described the bangs as rhythmic, about 5 seconds apart, loud and physical (TAB V-1-2) The stalling engine did not produce sufficient thrust for the maintenance of level flight (TAB V-1-2). The engine FTIT, RPM, and nozzle position remained within normal operating limits through out the entire accident sequence and consequently, no malfunction lights illuminated (TABs O-35, O-36, O-38 & V-1-2). Engine RPM, and subsequently the thrust produced, was less than called for by the throttle position (O-36 & O-38). The maximum sustained engine RPM obtained after the initial engine stall was approximately 90% RPM versus 104% RPM for the same throttle settting prior to the engine stalls (TAB O-38). After a third bang, Captain Goldfein began to suspect an engine problem and at approximately 10 50.03 hours MDT (39 seconds after the initial stall), Captain Goldfein initiated an airstart by cycling the throttle to off then immediately back to a mid-range position (TABs O-38,V-1-2 & AA-4-1). The engine immediately retarted but the bangs (resulting from the engine stalls) continued. Capt Goldfein misinterpreted the successful airstart and the within limits engine instrument readings as an indication that he was not experiencing an engine problem and refocused on some type of structural damage problem (TABs O-35, O-36, O-38 & V-1-2).

(5) Captain Goldfein continued to focus on the possibility of some type of structural damage immediately following the airstart attempt and at approximately 10:50:38 hours MDT (1 min. 14 seconds after the initial stall) Captain Goldfein informed Cold 42, " I don't know what I have but something is open, like a door" (TAB AA-4-3). Continuing to suspect a structural problem, at approximately 10 50 53 hours MDT (1 min 29 seconds after the initial stall) Captain Goldfein asks Cold 42 "You didn't hit me did you?" Cold 42 replies "negative, I don't think so" (TAB AA-4-4). Cold 42 obtained a radar contact on Cold 41 at this time and was approximately 10 miles in trail (to the west) of Cold 41 trying to rejoin. At 10 51:36 hours MDT Captain Goldfein initiated a 20 second unsuccessful attempt to light the afterburner (TAB O-38) During the afterburner attempt the aircraft climb apexed at 18,200' MSL and 290 KCAS (TAB O-46) Captain Goldfein continued to analyze the problem and at some point during or after the afterburner attempt confirmed he was experiencing an engine problem versus a structural damage problem when the afterburner did not light and he realized he could not maintain 300 knots in level flight (TAB V-1-2) Captain Goldfein established a constant speed (5-6 degrees AOA) descent towards Hill AFB. During this same period Captain Goldfein instructed the flight to switch both UHF and VHF channels to the UHF airspace exit frequency and the VHF 388 FW supervisor of flying (SOF) frequency Cold 42 missed the channel change call and there is a short period of time when Cold 41 and Cold 42 lost interflight communications (TABs N-7 & V-1-2). At 10.52:46 hours MDT, he jettisoned the external fuel tanks and then placed the engine control switch in the secondary (SEC) mode (10 52 54 hours MDT) (TAB O-29, O-33 & O-34) Shortly after Captain Golfein jettisoned his external fuel tanks, Cold 42 completed his rejoin to a chase position from which he could accomplish a visual inspection of Cold 41's aircraft (TABs N-2, V-1-2 & V-2-1).

(6) The secondary mode (SEC) is a back up engine fuel control mode which allows the engine to operate independent of the afterburner fan temperature control (AFTC) which normally controls both the engine and the afterburner. Placing the engine in the secondary mode had no appreciable effect on the engine RPM (O-29, O-30 &O-38). At 10:54:53 hours MDT Captain Goldfein cycled the SEC switch to PRI for one second and then back to SEC for the remainder of the flight, again no appreciable effect was seen in the engine RPM (TABs

O-30, O-38, & V-1-2) Captain Goldfein found a throttle setting that stopped the engine stalling with the throttle below 87% RPM but the engine was not producing enough thrust to stop the aircraft's descent (TAB V-1-3) CFSDR data indicates that Capt Goldfein tried several throttle settings but the engine RPM remained relatively constant regardless of throttle setting as long as the throttle was above 50° engine power lever angle (EPLA) (TAB O-38) If the throttle setting was moved to less than 50° EPLA the engine RPM dropped accordingly (TAB O-38) Capt Goldfein set the throttle at 87% (55° EPLA) for approximately 2 minutes and 15 seconds. During this period the stalls stopped and the CFSDR reflects engine RPM at approximately 87% RPM (55 ° EPLA) (TABs O-38 & V-1-3) Captain Goldfein moved the throttle to military power (full throttle) for approximately 20 seconds attempting to gain more thrust and accepting the engine stalls (TAB V-1-3) CFSDR data reflects the engine RPM remained at approximately 84-86% with the throttle at military and after the throttle was returned to approximately 87% (55° EPLA) (TAB O-38). Following approximately two minutes with throttle at 87%, Captain Goldfein unsuccessfully attempted a second afterburner light at 10:57:55 hours MDT, again with no appreciable effect on the engine RPM (TAB O-38). After conferring with the SOF, who was referring to the F-16 checklist procedures for engine stalls, Captain Goldfein accomplished a second airstart at 10.59:52 hours MDT, at an altitude of approximately 10,400' MSL (TABs N-3 & O-63). On the second airstart attempt the throttle was in the cut-off position approximately three to four seconds which allowed the RPM to drop below 55% which caused the main and standby generators to fall off the line and the emergency power unit (EPU) to fire (TABs O-31, O-36, O-38 & O-63). In conjunction with the second airstart attempt Captain Goldfein selected jet fuel starter (JFS) start two position in accordance with the flight manual airstart procedures at 11:00.25 hours MDT (TAB O-21). The greater drop in RPM and FTIT resulting from the throttle remaining in off a longer period of time, coupled with the continued destruction of the number four bearing assembly, resulted in a slower start than the first airstart and less usable thrust than before the airstart (TABs N-4, O-38, & V-1-3)

(7) Following the second airstart attempt the engine would not provide more than 83% RPM and shortly after the airstart attempt Captain Goldfein informed the SOF that the engine was quitting (TABs N-4 & O-38). At this point Captain Goldfein determined the aircraft was not recoverable and initiated a zoom (rapid climb) prior to ejecting from the aircraft (TAB V-1-3) CSFDR data reflects that the engine did not quit but that prior to the ejection the throttle was cycled to the off position a third time and the engine completed a third airstart sequence (TAB O-38). Captain Goldfein successfully ejected at 11:01:25 hours MDT at approximately 7500' MSL (3300' AGL) (TABs O-31, O-33 & V-1-3). The aircraft flew approximately 7 more miles until impacting the ground with the engine operating (TABs O-28 & AA-6-1) The aircraft impacted the ground at 11:03 hours MDT and was destroyed (TAB A-1, O-21 & O-22)

(8). Killer Scout missions are communications intensive, as fighters check in with the Killer Scout and as the Killer Scout passes target information to fighters, as was the case during the accident mission Additionally, the range control agency, call sign Clover, added communications traffic coordinating fighter hand-offs into the airspace. During the period when Captain Goldfein was reacting to the initial engine stalls and analyzing his problem Gouge flight, another F-16 flight, was checking on the frequency for his Killer Scout mission (TABs AA-4-2 & AA-4-3) As recorded on Cold 42's video tape recorder (VTR) tape there were 31 radio transmissions in a 1 minute 41 second period from the time Captain Goldfien made his first "Knock It Off" call, until Cold 42 turned off his VTR tape (TABs AA-4-3, AA-4-4). Twelve of the 31 transmissions were mission related transmissions made by flights and ground control agencies unaware that Cold 41 was experiencing a problem. (TABs AA-4-3, AA-4-4) Following the initial engine stall Captain Goldfein transmitted "KNOCK IT OFF" a term used to stop all peacetime training activities for safety of flight reasons, at least 5 times with at least one of the transmissions being on the airspace discrete UHF frequency (TABs N-10, AA-4-2 &AA-4-3) Cold 42 immediately responded to the first "Knock It Off" transmitted on VHF (TAB AA-4-3). Nail 31, Gouge 31 and Clover were all on the same UHF frequency as Cold 41 flight but did not respond to the "Knock It Off" call as it was partially stepped on and inaudible (TAB N-10 & N-11) During the period when Captain Goldfein was analyzing the problem (i e. between the initial stall and jettisoning of external fuel tanks) he made 15 radio transmissions with only two periods between calls lasting longer than 10 seconds (TABs O-28 & 0-29). The transmissions were made to "Knock It Off," ensure separation from his wingman, effect a rejoin to determine if he had structural damage, have the flight change frequencies to the VHF supervisor of flying (SOF) frequency and Clover exit control frequency and to reestablish radio communications with Cold 42 who missed the frequency

change call (TABs V-1-2, AA-4-2, & AA-4-3). Once the flight was checked in on the SOF VHF frequency at approximately 16:52:46 hours MDT, communications problems were not a factor through the rest of the mishap sequence (TABs N-2 & V-1-2).

e. Airmanship:

(1) The three basic rules for handling an emergency are as follows (TAB AA-8-1):

1. Maintain Aircraft Control
2. Analyze the Situation and Take Proper Action
3. Land as the Situation Dictates.

Captain Goldfein's initial reaction was to turn toward Hill AFB while maintaining aircraft control, and analyzing the situation. Captain Goldfein maintained consistent aircraft control throughout the accident sequence. He flew close to a five-six degree AOA recovery speed until he made the decision to eject (TAB O-33). It took Captain Goldfein 3 minutes 22 seconds from the time of the initial stall until he jettisoned the external fuel tanks and committed himself to an attempted recovery at Hill AFB (TABs O-29, O-137 & V-1-2). Significant factors relevant to the length of time it took to analyze the situation include:

(a) Initial predisposition to suspect a mid-air collision based on the recent "blind" call by Cold 42 (TAB V-1-1)
(b) The loud and physical nature of the stalls (TAB V-1-1)
(c) Engine instrument indications in the normal operating range with no fluctuations (TABs O-38 & V-1-1)
(d) Priority placed on effecting a rejoin with his wingman to verify the suspected structural damage (TABs V-1-2 & AA-4-3)
(e) Heavy communication traffic on the radio, both inter-flight and among the flights/agencies unaware of a serious inflight emergency in progress (TABs N-10, N-11, AA-4-2 &AA-4-3)
(f) Directing the flight to different frequencies to obtain SOF support and the momentary loss of interflight communications with his wingman (TAB V-1-2)

(2) Until a point approximately 5 NM after the external tanks were jettisoned, the aircraft was closer to Wendover Airfield UT than to Hill AFB UT (TAB AA-6-2). After confirming he had an engine problem Captain Goldfein considered Wendover airfield as a recovery base, but at that time he thought he was as close to Hill AFB as to Wendover and elected to continue to Hill AFB since he was already heading in that direction (TAB V-1-2). The SOF was contacted at approximately the same time as Captain Goldfein was jettisoning the external tanks and he asked if Michaels AAF was closer. Captain Goldfein answered that Hill was closer. (TAB N-1) The total flight path distance of the accident aircraft reflects that the aircraft could have flown to Wendover airfield from the point of the initial stall until approximately the point were the external tanks were jettisoned (TAB AA-6-2). Significant factors relevant to a decision to go to Wendover include:

(a) Aircraft Configuration - 8820 lbs of fuel and non-jettisonable stores (TAB AA-13)
(b) Runway length / field elevation - 9,100' in length @ 4240' elevation (TAB AA 6-2)
(c) No arresting gear (TAB AA-6-2)
(d) Unknown amount of thrust being generated by the engine operating in SEC at idle
(e) Altitude on arrival at Wendover
(f) Pilot proficiency

(3) Captain Goldfein's actions in dealing with the engine malfunction did not sequentially follow the flight manual procedures for a non-afterburner engine stall recovery. The engine stall procedures for non-afterburner engine stalls are as follows (TAB AA-8-1):

(a) Throttle - Idle

(b) Engine Control Switch - SEC
(c) Initiate Airstart.

Capt Goldfein initiated an airstart in the primary (PRI) engine control mode, 39 seconds after the first stall indication (engine bang), without a pause in idle. Additionally, he did not put the engine control switch in SEC until 3 minutes 30 seconds after the first stall indication (TABs O-28, O-29 & O-38). The airstart was acomplished correctly according to the procedural steps of the flight manual (T.O. 1F-16CG-1), however, it was contrary to a note in the flight manual provided under the background text for airstart procedures which states the following:

NOTE

> If the throttle is retarded to OFF to clear a stall, it should be maintained in OFF for a few seconds to allow the stall to clear (TAB -AA-8-2).

The pilot left the throttle in OFF for less than two seconds on the first airstart (TAB O-45). This note is not contained in the F-16 pilot checklist, nor is it addressed under the subject of Engine Stalls in the flight manual. Although he failed to leave the throttle in OFF for a few seconds as noted for clearing a stall, he did perform a successful airstart (TAB O-38). Capt Goldfein did not accomplish step two of the airstart procedure. Stores Jettison (if required) during the first airstart actions, as he continued to analyze the situation (TAB 0-28, & O-29). Immediately after the airstart sequence Captain Goldfein was still focused on a possible structural failure/damage with an operating, albeit, compressor stalling engine (TABs O-38, V-1-2 & AA-4-3). When he confirmed that he was experiencing an engine malfunction and thrust deficient situation, he jettisoned the stores and attempted engine operation in SEC (TABs O-29 & V-1-2). Following the initial airstart CFSDR data reflects that Captain Goldfein's actions had no appreciable affect on increasing the amount of RPM/thrust the engine was able to produce (TAB O-38).

f. **Impact:** F-16CG aircraft S/N 88-0488 crashed and was destroyed at 11:03 MDT (TAB A-1). The aircraft impacted a marshy area, bounced in the air traveling approximately 850' before crashing in a harvested field (TABs R-1, S-2 & S-3). The crash site was in Davis County Utah, 1 NM from Hooper UT and 283 degrees true bearing and 8 NM from Hill AFB, UT (TAB A-1). The marshy wetlands area where the aircraft initially impacted is owned by the Stone family and the harvested field where the bulk of the aircraft landed is owned by the partnership of HL Parker Farms (TAB P-1). The external fuel tanks that were jettisoned landed on high desert land owned by Basin Land and Livestock Company at 4122.29° north latitude, 11312 44° west longitude. There was no apparent damage to this property (TAB AA-11-1). Final CSFDR data reflecting approximate aircraft flight parameters on initial impact are as follows (TABs O-72 & O-86):

Heading	99.8° True Heading
Pitch	4 2° nose down
Roll	4.2° right roll
Airspeed	192 KCAS
Angle of Attack (AOA)	10.547 °
Engine RPM	N1 83 5%, N2 58%
Nozzle	3°open
Fuel Flow	3008 PPH

g **Egress System:** The mishap pilot initiated a successful ejection at approximately 7500' MSL /3300' AGL in a wings level climb at approximately 175 Knots Calibrated Airspeed (KCAS), well within the performance envelope of the egress system (TABs O-31, O-33 O-41 & O-69). Captain Goldfein accomplished a four line modification following parachute opening and accomplished an uneventful parachute landing in approximately one to two feet of water in the Great Salt Lake (TAB V-1-3). No defects in the egress system were noted.

h Personal and Survival Equipment: All personal and survival equipment inspections were current (TAB T-38 through T-43) The personal and survival equipment functioned as designed with no defects noted (TAB V-1-3)

i. Rescue: The aircraft crashed at 11:03 hours MDT (TAB A-1). Hill AFB tower personnel initiated the rescue response through the base primary crash net at approximately 10.56 hours MDT (TAB AA-7-7) As the emergency was in progress, Sport 57 a UH-1 helicopter was returning to Hill AFB from a training mission (TAB V-12-1). When Captain Goldfein informed the SOF that he would have to eject Hill AFB tower personnel asked Salt Lake approach control to request rescue assistance from Sport 57. Salt Lake approach control informed Sport 57 of the need for rescue response. Sport 57 contacted Hill AFB tower and received a vector towards the incoming emergency aircraft shortly after the pilot ejected (TAB V-3-2 & V-12-1). The crew of Sport 57 visually acquired the aircraft after the pilot ejected and prior to impact (TAB V-12-1). The crew of Sport 57 watched the aircraft impact and proceeded beyond the crash site and visually acquired the downed pilot approximately one mile off the lake shore in the Great Salt Lake on the HIF 270/09 (TABs V-12-1 & AA-1-7). The rescue helicopter flew over the downed pilot, received a "thumbs-up" signal and set up a hover at approximately 25 feet for hoisting the pilot into the helicopter (V-12-1). The uninjured pilot was brought into the helicopter via a forest penetrator assisted by the crew of Sport 57 from within the helicopter at approximatley 11:07 hours MDT (TABs V-12-1 & AA-1-7) The helicopter transported Capt Goldfein to the Hill AFB hospital arriving at approximatley 11:15 hours MDT (TAB V-12).

j. Crash Response: There were no delays between the time the accident was discovered, the rescue call, and rescue teams arrival at the site. The following agencies and units responded to the scene:

(1) 388th Security Police Squadron was notified of the inflight emergency at approximately 10:56 hours MDT (TAB AA-7-3). The Disaster Control Group (DCG) was activated at approximately 11.05 hours MDT. Two SPs were dispatched to the crash site at 11:09 hours MDT, and arrived at 11:27 hours MDT (TAB AA-7-2).

(2) The Weber County Fire Department was notified of the crash at 11:01 hours MDT, and dispatched two engines to the scene, which arrived at 11:08 hours MDT. The two engines attempted to extinguish a portion of the fire without success The two Weber County units departed the scene at 12:16 hours MDT after Hill AFB fire units arrived and extinguished the fires (TAB AA-7-14 & 15).

(3) The Weber County Sheriff's Department was notified at 11:02 hours MDT, and dispatched 3 units to the scene, arriving at 11:10 MDT hours. The three officers established site security, and performed traffic control (TAB AA-7-13).

(4) The Roy City Fire and Rescue Department dispatched one rescue unit to the scene at 11:01 hours MDT . The unit arrived at the scene at 11:08 hours MDT, and remained until 12:15 hours MDT. The unit did not treat any injuries while at the site (TAB AA-7-18)

(5) The Hill AFB Fire Department was notified of the In-Flight emergency at 10.56 hours MDT, and dispatched Chief-2, Rescue-18, and Crash-4, 5, and 6 vehicles to the flightline. At 11:02 hours MDT, the units were advised that the aircraft had crashed off base At 11:02 hours MDT, Chief-2, Rescue-18, and Crash-4 vehicles responded to the off-base crash site, arriving at 11:17 hours MDT. Crash-4 unit initiated extinguishment of the fires at 11:21 hours MDT, utilizing light water (Aqueous Film Forming Foam) agent. The aircraft fire was extinguished at 11:34 hours MDT, while all other fires in the field were extinguished by 11:40 hours MDT (TABs AA-7-2 through AA-7-8).

(6) The disaster control group (DCG) formed at 11:50 hours MDT, and arrived at the crash site at 12:21 hours MDT (TAB AA-7-2)

(7) Explosive Ordnance Disposal (EOD) was called to the scene by Chief-2 at 11:34 hours MDTarrived on scene at 11:50 MDT (TAB AA-7-9). The EOD marked and secured the 20 MM training ordnance at the crash site (TAB AA-7-6).

k. Maintenance Documentation:

(1) **AFTO Forms 781.** No discrepancies were noted in the Aircraft AFTO Form 781 Series for aircraft 0488 that relate to this accident (AFTO Forms 781, TAB H).

(2) **TCTO Status:**

(a) TCTOs not completed at time of accident (Automated Records Check (ARC), TAB U-1):

TCTO #	STATUS	RECISION DATE
11L1-2-30-505	NO KIT	25MAR96
14S1-11-505	NO PARTS	24FEB95
1F-16-1790	ABEYANCE	31JAN96
1F-16-1865	NO PARTS	23MAR96
1F-16-1881	ABEYANCE	30NOV94
1F-16-1889	ABEYANCE	30NOV95
1F-16-1894	NO KIT	31AUG97
1F-16-1912	NO KIT	30JUN95
1F-16-1918	NO PARTS	01AUG95
1F-16-1931	NO PARTS	29FEB96
1F-16-1936	NO PARTS	31MAY95
1F-16-1992	READY	10AUG95
2J-F110-665	READY	9JUN95
2J-F110-668	NO KIT	05NOV95
2J-F110-674	READY	17MAY95
2J-F110-678	NO KIT	31JAN96
31S5-4-3546-520	NO PARTS	07JUN95
L388404	READY	04APR95

(b) **Completed TCTOs.** Review of completed TCTOs revealed no actions which relate to this mishap (TAB U-2)

(c) **TCTO Discrepancies.** There are no TCTO discrepancies that relate to this mishap.

(3) **Scheduled Aircraft Inspections.** All scheduled aircraft inspections were documented as satisfactorily completed on time. No scheduled inspection discrepancies relate to this accident (TAB U-1).

(4) **Status of Oil Analysis Records.** Pre-accident oil samples were taken. No significant adverse trend in oil samples were apparent for the mishap engine (TAB O-2). The JOAP lab (388 MS/MAFN) was in conditionally certified status at the time of the accident, but has consistently scored above 95 on Interlaboratory Correlation Tests since Jun 94 (TAB U-3).

(5) **Status of Time Change Requirements.** All time changes were completed on time. No discrepancies were noted (ARC, TAB U-1)

(6) **Unscheduled Maintenance.** The following is a list of unscheduled maintenance performed on AC 0488 since its last scheduled inspection (routine unscheduled maintenance, such as tire changes, omitted)(excerpts from jacket file in TAB U-4).

DATE	MAINTENANCE PERFORMED
06JUL94	REPAIR MOUNTING STUD FOR WIRE HARNESS UNDER PNL 2206
06JUL94	REMOVE AND REPLACE FCC BATTERIES
07JUL94	REMOVE AND REPLACE CANOPY POWER RELAY
12JUL94	REMOVE AND REPLACE DFLCC
25JUL94	REMOVE AND REPLACE LANDING GEAR POSITION LIGHT C/B
28JUL94	REMOVE AND REPLACE HUD EU
01AUG94	REMOVE AND REPLACE HUD EU
18AUG94	REMOVE AND REPLACE IFF RT

(a) All unscheduled maintenance was performed by 421 FS personnel. None of the maintenance performed had a relationship to the accident.

(b) Unscheduled engine maintenance: The accident engine was installed during the aircraft's last scheduled phase inspection (phase 2; 27 - 30 Jun 94). The last time the engine was in the Jet Engine Intermediate Maintenance shop was from 6 - 16 Jun 94, having been removed from AC A0424 for high oil consumption. At this time, the Low Pressure Turbine (LPT) was removed in order to accomplish TCTO 676; numerous seals and gaskets were replaced; and some compressor blades were blended (i.e small nicks filed down within specified technical order limits) (TAB U-6-44). Engine workpackage documentation indicates that the #4 bearing outer race was removed from the High Pressure Turbine aft shaft, properly inspected and found serviceable (bearing inspection log, TAB U-5), and re-installed. The TCTO performed on the LPT did not require the removal of the inner race and bearing assembly, so it was not inspected. A post maintenance test cell run revealed a grinding noise coming from the engine (TAB U-46). This noise was isolated to the engine hydraulic pump that actuates the exhaust nozzles. Removal and replacement of the hydraulic pump eliminated the noise and post engine run JOAP tests and chip detector inspections checked good (TABs U-6-2, U-6-9, U-6-14 & U-6-47). All required In Process Inspections (IPI) were properly documented in the engine workpackage, with IPIs documented on the #4 bearing oil seal; seating of the #4 bearing outer race; and #4 bearing outer race retaining nut installation. Additionally, the engine workpackage meets or exceeds the minimum documentation requirements of ACCI 21-166 (engine maintenance workpackage), (TAB U-6-30, U-6-45 & U-6-46). The accident engine operated trouble free for 175.5 flying hours, up to the accident sortie, after its installation in AC 88-0488 (TAB J-2).

(7) **Maintenance Procedures and Practices.** No evidence was discovered to indicate that technical order (T.O.) procedures were not complied with on the accident engine. Engine workpackage documentation, and post impact measurements in the #4 bearing area, support an assertion of correct bearing installation (TABs U-6 & AA-9). However, the forward edge of the outer race chamfer area contains several dents caused by contact with the rollers during low pressure turbine (LPT) assembly (TAB J-4 & J-8). These dents have been seen on other engines and no evidence was found to prove that this roller and outer race assembly contact started the failure sequence of the bearing assembly (TAB J-4 & J-8).

l. **Maintenance Personnel and Supervision:**

(1) Aircraft 88-0488 received a BPO/Preflight inspection on 20 Sep 94, 0100 hrs, and a throughflight inspection on 20 Sep 94, 0845 hrs (AFTO Form 781H, TAB H). All personnel were qualified to perform the tasks accomplished, according to AF Form 623, AF Form 797, and special certification roster. All interviewed 421 FS maintenance personnel conveyed a professional and dedicated attitude to the work performed All Propulsion Flight personnel who performed maintenance on the engine were interviewed and likewise found qualified to perform the work accomplished, with a high degree of professionalism and job knowledge. Supervision in the Propulsion Flight was both knowledgeable and involved in flight operations.

(2) No evidence was found to indicate maintenance procedures or practices were a factor in this accident.

m. **Engine, Fuel, Hydraulic, and Oil Inspection Analysis:**

(1) Post accident fuel, and hydraulic test reports were reviewed and found to be normal (TAB O-6).

(2) Review of Joint Oil Analysis Program (JOAP), Engine Monitoring System (EMS) data, and engine historical records reveal no pre-impact adverse trends in either engine performance, or metal wear (TAB O-2 through O-5, J-2 & J-3). Engine monitoring system (EMS) data was not available for the accident sortie due to impact damage to the EMS Computer (TAB J-2). The Joint Oil Analysis Program is designed to detect progressive bearing wear through routine analysis of the engine oil to detect particles of metal in the oil system which are indicative of a failing bearing. The JOAP did not identify a progressive bearing failure in this engine (TAB J-3).

(3) The engine chip detector is designed to allow the crew chief to visually detect excess or unusual metal particles within the oil system through the use of a magnet in the oil system that is inspected following each flight. The main chip detector was not found in the crash site, however, analysis of samples taken from the oil system, post crash, indicate that while materials are present they would not be sufficient in size to reject an engine (TAB J-4).

n. <u>Airframe and Aircraft Systems</u>:

(1) Engine teardown reports from the Oklahoma City Air Logistics Center Materials Engineering Laboratory, and F110-GE-100 Engine System Program Office indicate a failure of the accident engine's #4 bearing roller cage assembly from a combination of high, and low cycle fatigue (TABs J-3, J-4 & J-8). The high cycle fatique (HCF), resulting from a high volume of stress cycles over a relatively short period of time, preceded the low cycle fatique in the failure sequence (TABs J-3, J-4 & J-8). The low cylce fatique (LCF), resulting from fewer but much larger stress cycles than the HCF, joined the HCF cracks and progessed through the side of the bearing cage assembly. This resulted in a castastrophic failure of the number four bearing which in turn led to compressor stalls and loss of sufficient thrust to maintain level flight (TABs J-2, J-3, J-4, J-8, J-12 & O-38). Evidence was not found to determine the source of the high cycle fatigue. The following describes damage of the number four bearing assembly which occurred prior to aircraft impact and teardown analysis:

(a) High cycle fatigue cracks are evident in the corners of all cage roller pockets indicative of a long term failure prior to the catastrophic failure (TAB J-8).

(b) Low cycle fatigue cracks are evident in the cage roller pockets that have through cracks (TAB J-4 & J-8)

(c) The rollers are worn to approximately 50 percent of their normal diameter and are frozen by bearing debris packed into the cage assembly. Rollers are also skewed (worn out-of-round) and show no evidence of fatigue (TAB J-3)

(d) Some of the inner race oil holes are plugged with debris The race contains 4 shoulder oil holes. Two sets of two with each set being 180° apart. The race also contains 4 race pocket holes. One set is totally plugged with debris and all eight oil holes contained extruded metal from the skidding rollers.(J-3 & J-7)

(e) The outer race contains one region of spalling. The spall is approximately 1.25 inch long and 0 500 inch wide and irregular in shape. The width of the spall is wider than the width of the roller length (TAB J-4).

(2) Analysis of the engine oil delivery system indicates that it was operating within normal parameters at the time of impact. However, the #4 bearing suffered a lubricant failure (the rings, rollers and cage were discolored from blue/brown to black) (TAB J-12). Additionally, post crash examination of the #4 bearing and surrounding area revealed the bearing and the surrounding area were not oil wetted (TAB J-3) This lack of lubrication was compounded as the failure sequence of the bearing progressed (TAB J-12). However, no evidence was found to determine at what point in the sequence lubrication to the bearing became inadequate.

(3) The #4 bearing experienced a material failure. However, sufficient evidence was not discovered to identify the initial cause of the failure sequence due to the bearing damage caused by continued engine operation after the initial bearing failure (J-11 & J-12). This failure was progressive in nature as indicated by the high cycle fatigue cracks preceding the low cycle fatigue referenced in n(1)(a) above. The time required for the high cycle fatigue to develop cannot be accurately estimated, however, expert opinion indicates that more than the accident sortie's duration would be required (Sandra Griffin, Materials Engineering Lab, Oklahoma City Air Logistics Center). This fatigue damage led to a loss of lubrication to the bearing, accelerated bearing wear, and ultimately to complete bearing failure (TAB J-12).. Failure data on the #4 bearing assembly from the Propulsion Management Divison, Oklahoma City Air Logistics Center, suggests a possibility of an infant mortality situation related to installation/assembly (TAB AA-10-2). The average time of failure of seven previously confirmed #4 bearing failures is 207 hours compared to a B1 calculated life of 2800 hours (B1 life is when a 0.1% failure rate of the bearing is expected to occur). Statistical analysis of fleet experience reveals the current observed life of the #4 bearing is 3100 hours until a 0.1% failure rate occurs. Consequently, the #4 bearing failure in this accident, which failed 175.5 hours after installation (755.6 hours total operating time), failed below the average time from installation to failure of the seven previous failures. Additionally, this accident engine was like four of the confirmed failures in that the imminent bearing failure was not detected by chip detector indications, (TABs J-2 & AA-10-2).

(4) The failed bearing was installed in the accident engine at the Oklahoma City Air Logistics Center in June 1992, and had accumulated 755.6 operating hours at the time of the accident and 175.5 hours since the last installation (TAB J-2).

(6) Hydraulic, electrical, mechanical, and avionics systems operated as designed throughout the accident. No teardown or operational analysis of these components was accomplished

o. **Operations Personnel and Supervision:** The flight was authorized as an operational readiness exercise (ORE) mission directed by the exercise Air Tasking Order and documented on a local flight clearance form 35 (TAB K-3). The mission briefing was conducted in two parts with Major Les Long conducting a mass briefing to cover required general briefing items from MCR 55-116 along with the ORE special instructions (TAB V-11) A mission specific briefing was conducted by Captain Goldfein utilizing the combat briefing guide in the 388 FW inflight guide. The mass briefing and the mission specific briefings covered all required briefing items and no problems or misunderstandings arose during the briefing (TAB S-V-1, V-2 & V-12)

p. **Crew Qualifications:**

(1). Examination of aircrew flight records revealed that Captain Goldfein was qualified and current in the F-16CG. He is a flight commander, instructor pilot, mission commander, four-ship flight lead and functional check flight pilot (TAB T-21).

(2). Captain Goldfein had 2443 5 hrs total flying time prior to the accident sortie (TAB G-3) He has been flying the F-16C since October 1989 accumulating 1065 2 hours prior to the date of the accident (TAB T-2). Review of his training records revealed no discrepancies or weaknesses in training or progression (TAB T). Captain Goldfein received an "Exceptionally Qualified" rating on his last emergency procedures evaluation. Captain Goldfein's 30/60/90 day flying experience prior to the accident sortie follows:

	30	60	90
Flying hrs	11.9	28.9	54.6
Sorties	8	18	30

Note. The 30/60/90 flying hour/sortie totals were computed by adding .7 hrs and 1 sortie to the data provided in TAB G-2. This accounts for the sortie flown earlier in the morning on 20 Sept. 94 These totals do not count the mishap sortie, which was .5 hrs in duration.

q. Medical: Captain Goldfein was medically qualified at the time of the mishap (TAB T-13) Post accident medical examination revealed no injuries other than slight erythema (redness) of the medial and superior thighs from the parachute straps (TAB X-1). The toxicologoy tests were negative (TAB AA-2-1).

r. Navaids and facilities: All NAVAIDS and facilities relevant to this mission were operating and functional during the mission (TAB AA-1-7).

s. Weather: The forecast weather at Hill AFB was for 13,000' scattered, 20,000' broken, greater than 7 miles visibility. The weather observation at Hill AFB at 1155 MDT was 8,000' scattered, 13,000 scattered, estimated 18,000' broken cloud layers, visibility greater than 7 miles. The range forecast for the north range was 6,000' scattered, 15,000,' scattered 20,000' broken with greater than 7 miles visibility. The weather was not a factor (TAB W & V-1-3).

t. Governing Directives and Publications:

(1). The following publications were applicable to this mission:

AFR 60-1	Flight Management	4 Feb 90
AFR 60-16	General Flight Rules	27 Jan 92
MCR 51-50 Vol. VIII	F-16 Pilot Training	14 Feb 93
MCR 55-116	F-16 Pilot Operations Procedures	7 May 93
T.O.1F-16CG-1	F-16CG Flight Manual	24 Jan 94

(2). There were no known or suspected deviations from the directives or publications by the pilot.

Robert L. Armour Jr.

Robert L. Armour Jr, Lieutenant Colonel, USAF
AFI 51-503 Investigating Officer

3. **STATEMENT OF OPINION:**

a Under 10 U.S. Code 2254(d) any opinion of the accident investigators as to the cause of or factors contributing to, the accident set forth in the accident investigation report may not be considered as evidence in any civil or criminal proceedings 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.

b. Investigation of the 20 Sept 1994 aircraft accident on involving F-16CG S/N 88-0488 has resulted in the following opinions:

(1). (CAUSE) A failure of the engine's number four bearing resulted in engine compressor stalls and loss of sufficient thrust to maintain level flight. Clear and convincing evidence was not found to determine the initial event, action or flaw that initiated the bearing failure sequence. This lack of evidence was due to bearing damage incurred as the engine continued to operate with the bearing in a progressive failure sequence mode. The unknown event, action or flaw, initiated a high cycle fatigue condition in the number four bearing cage assembly through either damage to the components in the bearing assembly or disruption of adequate lubrication to the bearing This high cycle fatigue condition led to abnormal bearing wear, low cycle fatigue in the bearing cage assembly, clogging of the bearing lubrication ports and eventually, total bearing failure. Possible sources of the unknown event, action or flaw that initiated the high cycle fatigue:

(a). A manufacturing flaw in the bearing outer race, bearing cage assembly or the bearing rollers
(b). Damage to the bearing cage assembly during installation or while out of the engine
(c). Damage to the bearing rollers during installation or while out of the engine
(d). Damage to the #4 bearing outer race during installation or while out of the engine
(e). Foriegn object contamination of the bearing during installation or while out of the engine

(2). Capt Michael Goldfein was confronted with a serious in-flight emergency that was not easily diagnosed due to the circumstances surrounding the initial stages of the accident sequence. Capt Goldfein's handling of the emergency reflect sound adherence to the three basic rules which apply to all emergencies, maintaining aircraft control, analyzing the situation and taking proper action and finally landing as the situation dictates. He made a decision to initiate a climb and turn towards Hill AFB while he analyzed the situation. A quick diagnosis of the situation was not accomplished for the following reasons:

(a). The predisposition to suspect a mid-air collision with his wingman based on the blind call made approximately 13 seconds prior to the first bang of the engine

(b). The apparent lack of any abnormal engine indications or warning lights immediately after the engine stalls started and after the completing an engine airstart. Additionally, the lack of any abnormal FTIT or RPM fluctuations, which are always present in the compressor stall malfunction attributes of the F-16 simulator, may have been a factor in recognizing the bangs as an engine stall

(c). The communications intense environment which made it difficult to isolate the problem, effect a rejoin, get his flight on the same frequencies, declare an emergency, and ask for asssistance while flying the aircraft

(d). The distracting physical nature of the engine stalls, extremely loud and violent

The immediate success of the first airstart reinforced his focus on a possible mid-air collision or structural damage problem and masked the need to immediately jettison the external stores. Focusing on a structural damage situation Capt Goldfein placed emphasis on rejoining with his wingman to permit visual evaluation of the suspected damage. As he continued to analyze the situation, the failed attempt at lighting the afterburner drew his attention back to the possibility of an engine malfunction. The engine malfunction was confirmed when he discovered he had insufficient thrust to maintain level flight. The time required to correctly analyze the situation was approximately 3 1/2 minutes. During this time Captain Goldfein was closer to Wendover airfield than to Hill AFB.

(3). The aircraft could have recovered at Wendover airfield had Captain Goldfein made a quicker diagnosis of his problem or if he had made his initial heading towards Wendover airfield versus Hill AFB. Attempting to recover at Wendover airfield would have provided Captain Goldfein an opportunity to safely recover the aircraft. However, an attempted recovery at Wendover airfield would not assure the safe recovery of the aircraft. Executing an emergency landing at a strange airfield in a partial power situation, with a heavy weight configuration, at high field elevation on a 9,000 ' runway length with no arresting gear would have been extremely challenging. It is therefore impossible to accurately predict the outcome of an attempted recovery at Wendover. Capt Goldfein did not attempt to recover at Wendover airfield because by the time he confirmed that he was dealing with an engine malfunction he perceived he was as close to Hill AFB as to Wendover and was already heading towards Hill AFB. Deciding to continue towards Hill AFB allowed Capt Goldfein to continue trying to resolve the problem without making a greater than 90° turn to recover at Wendover airfield.

(4) The progressive failure of the number four bearing resulted in a thrust limited situation which deteriorated over time. CFSDR data reflects that none of the pilot actions in this aircraft accident sequence increased available engine RPM. It is not possible to exact determine the effect of a different set or sequence of pilot actions. The situation, as it presented itself to Captain Goldfein, did not require the immediate execution of any critical action procedure (CAP). Captain Goldfein elected to accomplish an airstart, which is a critical action procedure, to correct any possible engine problem. The airstart was successful and correctly performed in accordance with the flight manual procedural steps but in conflict with the note in the discussion text, which states the throttle should be left in off to clear a stall. However, had he left the throttle in off for several seconds, it is unlikely it would have improved the situation. The external tanks were not jettisoned during the initial airstart due to the success of the airstart, which masked the engine problem. All other actions by Capt Goldfein were consistent with good judgment and flight manual guidance. Captain Goldfein made a timely decision to eject when he determined the aircraft could not be recovered.

Robert L. Armour.

Robert L. Armour Jr, Lieutenant Colonel, USAF
AFI 51-503 Investigating Officer

CERTIFICATION

I certify that the documents contained in this report are the originals or true copies of the originals.

Robert L. Armour Jr.

ROBERT L. ARMOUR JR., Lt Col, USAF
Investigating Officer