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# AFR 110-14 ACCIDENT INVESTIGATION REPORT

FEDERAL REGULATORY COMMISSION

Docket No. \_\_\_\_\_ Official Exh. No. 162  
In the matter of PFS  
SFC \_\_\_\_\_ IDENTIFIED ☒  
Applicant ☒ RECEIVED ☒  
Int. No. \_\_\_\_\_ REJECTED \_\_\_\_\_  
Quota \_\_\_\_\_ WITHDRAWN \_\_\_\_\_  
DATE 7/1/02 Witness \_\_\_\_\_  
Clerk [Signature]

F-16C 86-0325  
9 NOVEMBER 1993

140TH FIGHTER WING  
BUCKLEY ANGB, COLORADO

PFS Exh. 162

57705

## 2. SUMMARY OF FACTS

A. HISTORY OF FLIGHT: On 9 November 1993 Cobra 1, a flight of two 140FW F-16s was scheduled to fly a local AGM-65 Maverick training mission from Buckley Air National Guard Base, CO on a round-robin flight plan. Routing was via Instrument Route (IR) 416. The flight leader was [REDACTED]. Cobra 2, the mishap aircraft, was piloted by [REDACTED]. Both pilots were assigned to the 120th Fighter Squadron, 140th Fighter Wing, Colorado Air National Guard. [REDACTED] was in active duty for training status following return from F-16 RTU. According to pilot testimony, mission preparation, briefing and preflight were normal. The flight departed Buckley Air National Guard Base (BANGB) at 1400 MST and navigated to the entry point of IR-416. Approximately 21 minutes after takeoff while recovering from a second Maverick simulated employment pass, Cobra 2 experienced an engine explosion, a degradation in engine thrust accompanied by high engine temperatures and decreasing RPM (TAB V-190). After unsuccessful engine restart attempts, [REDACTED] ejected from the aircraft. The mishap aircraft impacted in open prairie 15.5 nautical miles northwest of the Laramie Regional Airport, Wyoming. [REDACTED] landed on snow covered prairie sustaining a compound fracture of the left leg. Rescue and recovery of [REDACTED] was coordinated by Cobra 1 through area Air Traffic Control agencies. Medical evacuation (MEDEVAC) personnel from F. E. Warren AFB, WY were dispatched via rescue helicopter and arrived at the crash site approximately one hour and 10 minutes after pilot ejection (TAB V-197). The MEDEVAC team airlifted [REDACTED] to Fitzsimons Army Medical Center, Denver, CO. Cobra 1 remained on station over the downed pilot until MEDEVAC was completed then returned to Buckley Air National Guard Base (TAB V-263).

B. MISSION: The mission was planned as a Maverick One (1) training ride in accordance with a local AGM-65 orientation and training program (TAB G-7). This was [REDACTED] first Maverick mission. The mission scenario included a low level navigation profile on IR-416 to the Cougar Military Operation Area (MOA). Recovery from the Cougar MOA was scheduled via stereo flight plan with recovery at Buckley ANGB. The mission was approved in accordance with ANGR 55-010 (TAB K-3).

C. BRIEFING AND PREFLIGHT: The mishap pilot indicated that [REDACTED] was well rested and mentally and physically prepared for the flight (TAB V-199). [REDACTED]

completed mission planning prior to brief time and along with [REDACTED] went to the squadron weight training facility for exercise and conditioning workout (TAB V-200). The briefing began on schedule for a planned takeoff time of 1400 hours MST. According to both flight member's testimony (TAB V-190, 259), all aspects of the mission were briefed in accordance with the 140FW Briefing Guide with emphasis given to the tactical employment of the AGM-65 Maverick mission. Training rules were briefed as standard. Emergency and abnormal procedures briefing items included by coincidence, an extensive discussion of an inflight emergency that resulted in pilot ejection with further discussion on search and rescue and wingman CAP procedures. Mission briefing ended on schedule and the pilots stepped to the aircraft. Aircraft preflight, after start ground procedures and take-off were accomplished without incident.

D. FLIGHT ACTIVITY: Cobra 1 flight made a single ship afterburner take-off departing on schedule at 1400 MST. The flight clearance was via a local stereo route (TAB K-2) to entry point A of IR-416. In accordance with the Maverick training scenario, Cobra 2 was to select targets of opportunity along the IR-416 centerline for practice employment of the Maverick. The low level progressed without incident along the route structure to a point 15 - 20 miles northwest of Laramie Regional Airport. No abnormal engine indications or warnings were noted by [REDACTED] during this phase of flight. Engine monitoring systems and flight data recorder readouts indicated Fan Turbine Inlet Temperature (FTIT) excursions above the engine operating limit of 935 degrees centigrade immediately after lift-off and again at FDR time 0:17:04 (TAB O-27). The aircraft warning systems do not provide aural or engine warning light indicators until 1000 degrees centigrade is exceeded for two seconds (TAB O-54). These conditions were not recorded. [REDACTED] testified that no FTIT analog gauge abnormalities were observed by [REDACTED] during takeoff or enroute to the low level structure. Coming off the target on the second simulated attack, Cobra 2 noted a loud engine thump (TAB V-190). The intensity was described as fairly violent. This was followed by three less violent engine thumps (TAB V-190). The aircraft aural warning system activated with "warning, warning, warning" (TAB V-190). Cobra 2 called a knock-it-off and began a gradual climb. [REDACTED] reported to [REDACTED] flight lead that [REDACTED] had an engine problem and the FTIT was pegged at 1,000 degrees (TAB V-190, 260). Engine instrument indications showed RPM rolling back and FTIT dropping to 800 degrees. Airspeed was estimated at 330 KIAS or "a little less" (TAB V-191). [REDACTED] initiated the Critical Action Procedures (CAPS) for an AIRSTART and began a gradual climb. Engine response to the AIRSTART procedure was reflected in an increase in engine RPM to a maximum of 70% (TAB V-192). External stores were jettisoned over open terrain at the direction of Cobra 1. With engine RPM stabilized at a maximum of 70%, a second AIRSTART procedure was attempted with similar engine response (TAB V-192). [REDACTED] communicated [REDACTED] altitude to [REDACTED] flight lead passing 8,900 feet mean sea level (MSL) during [REDACTED] second AIRSTART attempt. [REDACTED] indicated at that point that ejection was imminent. Terrain elevation in the impact area is approximately 7,600 MSL. Airspeed was estimated at 240 KIAS and decreasing (TAB V-193). Based upon Seat Data Recorder (SDR) and FDR data, ejection occurred at 194 knots calibrated airspeed, 8210 feet mean sea level (610' above ground level) wings level, 4 degree descent (TAB O-14, 47 thru 51). The mishap aircraft impacted in open, unpopulated terrain at 1425 MST.

FLIGHT DATA RECORDER AND SEAT DATA RECORDER  
CORRELATIONS OVER TIME (TAB O-14, 47 thru 51)  
(Ground Elevation - 7600 Feet Mean Sea Level)

<u>TIME</u>	<u>ALTITUDE</u> <u>(MSL)</u>	<u>AIRSPEED</u> <u>(KCAS)</u>	<u>AOA</u>	<u>FTIT</u> <u>(DEGREES C)</u>
0:17:05	8,061 (FTIT Exceedance)	286	5.68	946
0:18:20	8,630	327	4.91	560
0:18:40	9,860 (Engine Compressor Stall)	377	3.01	965
0:19:12	10,432	387	2.39	1015
0:19:50	13,840 (EPU Activation)	227	5.91	810
0:20:16	12,171	243	8.02	780
0:21:20	9,973	209	8.49	688
0:22:24	8,204 (EJECTION)	194	10.13	695
0:22:36	IMPACT	194	7.0	695

Cobra 1 observed the ejection from a chase position above Cobra 2 and watched the aircraft impact. [REDACTED] saw a good chute and began the search and rescue effort (TAB V-262). Cobra 1 established contact with Cheyenne approach control and requested support in organizing the search and rescue effort through F.E. Warren AFB, WY. Cheyenne approach control passed the word of the mishap to Buckley ANGB. [REDACTED] jettisoned [REDACTED] empty fuel tanks over open terrain and remained over the crash site and [REDACTED] until the rescue helicopter approached. Cobra 1 initiated an air-to-air intercept on the helicopter (TAB V-263) and guided it to the crash site. After [REDACTED] was aboard the rescue helicopter and enroute to Fitzsimons Army Medical Center, Cobra 1 returned to Buckley ANGB (TAB V-263). Elapsed time from ejection to rescue team arrival was approximately one hour and ten minutes (TAB V-197).

E. IMPACT: The mishap aircraft impacted the ground in a wings level, shallow glide on an easterly heading. The only witnesses to the impact were the mishap pilot from [REDACTED] parachute and Cobra 1 as [REDACTED] passed over the crash site. The F-16 impacted 15.5 nautical miles northwest of Laramie Regional Airport, Wyoming at longitude N41 30'09", W105 53'12" (TAB A-1, O-1). The crash site is privately owned open prairie grass land. Approximately six acres of grass land were burned by the impact explosion (TAB P-1). Disintegration of the F-16 contaminated the ground with corker fiber, a composite material comprising much of the F-16 airframe (TAB P-1). Wreckage parts and debris were identified and inventoried by the 90th CES Disaster Control Group recovery team (TAB P-1).

Recovery of some debris was hampered by snowfall that occurred following the mishap. Site clean-up will be completed in the March - April, 1994 time period when snow cover dissipates. Clean-up will be accomplished by 140FW personnel. Negotiations between the civilian land owner and the F. E. Warren AFB Judge Advocate's Office are pending.

F. EJECTION SEAT: Based upon SDR, FDR data, and pilot testimony, ejection from the aircraft was within the performance envelope of the egress system under the following conditions: Altitude - 610 feet above ground level; Airspeed - 194 knots calibrated airspeed; shallow descent; wings level (TAB O-14). [REDACTED] stated that [REDACTED] achieved good ejection position prior to initiating the ejection sequence.

G. PERSONAL AND SURVIVAL EQUIPMENT: Inspections on all personal and survival equipment were current. The post ejection riser "four line pull" was not utilized by [REDACTED]. While reaching to insure deployment of the survival kit, [REDACTED] felt a ground rush and impacted the ground (TAB V-194). [REDACTED] released [REDACTED] canopy and retrieved [REDACTED] survival equipment and raft from the snow. Using a survival knife and lanyard, [REDACTED] fashioned a leg splint and used the inflated raft to protect [REDACTED] from cold and the snow covered ground (TAB V-195). The URT 33 C/M radio beacon located in the survival kit failed to activate with a radio signal on Guard Frequency (243.0 MH). The unit was found with a broken antenna cap and bent antenna (TAB C-1, S-7).

H. RESCUE: Following the aircraft impact Cobra 1 attempted contact with Denver Air Route Traffic Control Center, the controlling agency for flight operations on IR-416 (TAB V-262). Due to [REDACTED] low altitude, contact could not be established with Denver Center or any other air traffic control (ATC) agency until a climb to 20,000 feet was accomplished (TAB V-262). The first ATC response to [REDACTED] calls on guard frequency came from Cheyenne Approach Control (TAB V-262). [REDACTED] requested coordination for a search and rescue effort through Cheyenne Approach who contacted F.E. Warren AFB for rescue support. Approach Control then contacted Buckley ANGB with word that Cobra 2 was down (TAB V-262). A 37th RQF MEDEVAC helicopter from F.E. Warren AFB was launched and proceeded to the crash site. Enroute to the site, [REDACTED] established radio contact with the rescue helicopter, completed a radar intercept on the aircraft and vectored the crew to [REDACTED] (TAB V-263). [REDACTED] was incapacitated on impact with the ground during the parachute landing fall (PLF). From the time of landing until the arrival of the MEDEVAC team, [REDACTED] concentrated [REDACTED] efforts on retrieving [REDACTED] survival equipment, keeping warm and slowing the flow of blood from an open wound in the left leg (TAB V-195). Upon arrival, the MEDEVAC team found a triple compound fracture of the tibia of [REDACTED] left leg. The leg was placed in an air splint and [REDACTED] was airlifted to Fitzsimons Army Medical Center, Denver, CO at 1645 MST (TAB O-4). [REDACTED] arrived at Fitzsimons AMC at approximately 1725 MST, three hours following the ejection.

I. CRASH RESPONSE: The accident occurred at 1425 MST (TAB A-1). The 90th Civil Engineering Squadron, F. E. Warren AFB Disaster Control Group received notification of the F-16 mishap and was dispatched to the crash site with a team complement. A para-rescue team aboard a 37th RQF MEDEVAC helicopter departed F.

E. Warren AFB and arrived at the crash site at approximately 1530 MST (TAB V-197, 263). Medical evacuation of [REDACTED] from the crash site was completed at 1645 MST as the MEDEVAC helicopter departed for Fitzsimons Army Medical Center with the patient on board. The 140FW Flying Safety Officer was notified of the mishap at approximately 1445 MST and directed the impoundment of operations and maintenance records (TAB O-4). The 140FW Disaster Control Group (DCG) was recalled and briefed. The Flying Safety Officer was directed by the 140FW Commander to proceed to the crash site with the Fire Chief, Military Security Police and a Public Affairs Officer (TAB O-4). The 140FW DCG contingent arrived at the crash site at approximately 1645 MST via Colorado Army National Guard helicopter. The 140FW Flying Safety Officer was met at the scene by the DCG on-scene Commander from F. E. Warren AFB and the local County Sheriff (TAB O). A briefing took place on the potential hazards of Hydrazine and 20MM practice ammunition loaded on the mishap aircraft. The DCG team was directed to obtain fuel and hydraulic samples and take still photographs of various aircraft and engine components identified by the 140FW Flying Safety Officer. Military Police secured the area and classified equipment from the aircraft (TAB O-4). Wreckage recovery from the crash site took place between 10 November 1993 and 18 November 1993. Snow cover hampered recovery of wreckage and debris. On 18 November 1993, the Vice Commander, 12AF authorized release of the Security Police team at the crash site (TAB O-5). Further site cleanup was deferred to the March - April 1994 time frame, when snow cover will have dissipated. The remaining cleanup effort will be accomplished by 140FW personnel (TAB O-5).

J. MAINTENANCE DOCUMENTATION: No related discrepancies were noted in a review of the aircraft AFTO Form 781 or maintenance logs (TAB D-2, H-1 thru 20). No Time Compliance Technical Orders (TCTOs) were overdue. TCTO 2J-F110-597, Modification of HPT Nozzle Assembly and Rework of HPT Nozzle Outer Support, and its supplements was pending but not complied with in the mishap engine. This TCTO was published to introduce HPT nozzles with improved wear resistance and increased airflow to the HPT shroud assembly by increasing the diameter of 46 metering holes in the HPT nozzle outer support (TAB O-52). T.O. compliance was at unit level discretion until 60 days prior to recision date 30 June 1995. The mishap engine was equipped with a shroud assembly referred to as a GO-1 shroud. Shroud assemblies modified by TCTO-597 are identified as GO-2 shrouds. A history of failures of the GO-1 shroud assembly had been established in the GE F110 community (TAB U-57, 58, 254, 255). The unit's Ground Station Software (GSS) equipment used for analysis of Engine Monitoring System (EMS) data, was originally loaded with a software program that did not record certain engine performance parameters if the operating location was above 5000 feet elevation. In June 1993 a new software version was published to correct this anomaly and distributed by request to affected units (TAB V-183). The 140FW Engine Manager received the software upgrade in August, 1993. Analysis of the GSS software version following the mishap indicated the original version was installed in the GSS system (TAB V-64) limiting accurate EMS data collection. This limitation affected analysis of temperature spikes and correlations in T4B temperature trends versus fan speed changes (TAB S-4, 5, U-248, 249) that were indicative of engine performance degradation.

K. MAINTENANCE PERSONNEL AND SUPERVISION: Preflight servicing and launch procedures of the mishap aircraft were normal. Individuals performing preflight and launch activities were qualified and properly supervised (TAB V-217).

Failure of internal engine components focused the investigation on historical data applicable to the engine installed in Aircraft 86-0325. In the course of the investigation, the 140th Consolidated Maintenance Squadron (CAMS) Engine Shop personnel training and supervision were analyzed. The 140FW converted from the Vought A-7D aircraft equipped with the Allison TF-41 engine to the Lockheed F-16C, General Electric (GE) F110 engine in late 1991 through early 1992. The conversion required retraining of engine shop maintenance personnel on the GE F110 engine. A substantial part of the training was done by Air Force Field Training Teams (FTT) over a three month period (TAB V-10, 65). Follow-on training of personnel in technical data interpretation was completed through on-the-job training (OJT) with assistance from a Contract Engineering Technical Services (CETS) technician provided by the engine manufacturer. This person provided technical expertise to maintenance personnel in their training progression, however, no formal syllabus training or training documentation was involved (TAB V-69). The CETS technician reported to the Chief of Maintenance on a routine basis. According to testimony of [REDACTED] the CETS technician always reported normal and favorable performance of engine shop personnel (TAB V-10). Engine mechanics testified that no formal borescope training was completed in FTT lesson plans (TAB V-65, 81). Conversion training documentation for each individual was recorded on Air Force Form 623. [REDACTED] testified that by the completion of conversion training all technician personnel within the engine shop were qualified for all engine work on the GE F110 with one exception (TAB V-83). According to testimony of the [REDACTED] one engine mechanic was not fully trained in engine borescoping procedures and techniques (TAB V-52, 70). This member was not allowed to do borescope inspections of the high pressure turbine shroud assembly (TAB V-43, 52, 83). All other shop maintenance personnel were considered fully qualified to perform all aspects of engine inspections and repair (TAB V-83). The engine mechanic restricted from HPT borescoping work was assigned to an incoming shop inspection of the mishap engine on 26 February 1993 (TAB V-52). This inspection required evaluation of the High Pressure Turbine and shroud assembly. The [REDACTED] testified that [REDACTED] was not aware of borescoping requirements on the HPT when [REDACTED] assigned the mechanic to the inspection.

No formal training in monitoring or analyzing engine trend analysis data was provided to engine shop personnel during conversion to the F-16C (TAB V-100, 253). Data extracted from the aircraft Engine Monitoring Systems (EMS) were downloaded daily through a data transfer unit and placed into a software data base for evaluation (TAB V-17, 139). Post-accident technical evaluation by GE consultants of the mishap engine data stored in the unit's Ground Station Software (GSS), showed trends in engine performance that suggested problematic conditions within the engine prior to the mishap flight (TAB S-4, 5, V-248). Portions of this evaluation and analysis were completed under laboratory conditions not available at the field unit level. These trend points were not identified by the engine shop personnel or the engine manager. According to testimony by the [REDACTED] and other maintenance personnel, a general lack of guidance and training on data analysis and interpretation of EMS data (TAB V-18, 100) existed in the F-16 community at the time of the mishap. Air Combat Command and the National Guard Bureau provided no guidance for engine trending and diagnostics programs.

**L. ENGINE, FUEL, HYDRAULIC, AND OIL INSPECTION ANALYSIS:** Laboratory analysis of fuel and hydraulic samples showed samples to be within limits (TAB D-30 thru 34). Engine spectronic oil analysis (SOAP) samples showed no abnormal indications (TAB D-1). Engine inspection history for the previous 10 months for engine series #500114 included three separate borescope inspections. One was completed during an Incoming Shop Inspection (also referred to as an Acceptance Inspection) 26 February 1993. The incoming inspection is a precursor to a follow-on 150 hour phase inspection. The 150 hour inspection was completed 23 March 1993 (TAB H-1, 18, 20). A 75 hour Borescope and Ultra Sonic Inspection was completed 15 June 1993 (TAB H-1, 18, 20). The 75 hour inspection did not require inspection of the HPT or shroud assembly. Engine time at the Incoming Inspection was 1393.5; time at the 150 hour Phase Inspection was also 1393.5 and engine time at the 75 hour Borescope 15 June 1993 was 1464.3 (TAB O-56, 57). The engine mechanic assigned to the incoming shop inspection was not fully qualified in borescope inspections. The engine shop supervisor had restricted this worker from borescoping inspections of the HPT-1 turbine wheel and shroud assembly (TAB V-70). A complete engine phase inspection was subsequently completed 23 March 1993 (TAB H-18). AFTO Form 781 and Core Automated Maintenance System (CAMS) documentation shows all phase work card and item numbers for the engine phase inspection complied with (TAB H-18). Tracking of the engine inspection work was documented on a 140FW local form MAE-11 (TAB O-58). This document was not filed in the engine historical records. The engine manager and engine shop supervisor testified that the form had apparently been lost in the distribution and filing process (TAB V-52, 168). Further research into phase inspection documentation included the aircraft phase dock records which included the engine work history for this phase inspection. 140FW Phase Inspection Work Card Control Log dated 16 March 1993 (TAB U-1 thru 6) cross referenced the missing form MAE-11. The log showed all engine phase work cards and item numbers complied with. Work cards 3-089 and 3-089-1, HPT-1 and shroud assembly were completed by employee number 00040 (TAB U-4). Employee 00040 was identified as TSG Billy E. Gallimore. TSG Gallimore testified that he completed the work identified by the phase card and documented on the Phase Inspection Work Card Control Log (TAB V-209, 210, 211). This borescope inspection took place 119 hours prior to the mishap and was the last inspection required of the HPT-1 and shroud assembly prior to the mishap. No discrepancies in this engine region were identified or documented on AFTO Form 781, CAMS, or phase control log records (TAB D, H, U). Engine serial #509114 was installed in aircraft 86-0325 on 26 March 1993 (TAB H-13). Engine time at phase completion and installation was 1393.5 (TAB O-57). A 75 hour borescope and ultrasonic inspection was accomplished 15 June 1993 (TAB O-57). This time compliance inspection did not require a borescope of the high pressure turbine or shroud assembly section of the engine. Engine time at the 75 hour borescope inspection was 1464.3 (TAB O-57). Engine time at mishap was 1512.5.

**M. AIRFRAME AND AIRCRAFT SYSTEMS:** Airframe and systems analysis was performed through review of data downloaded from the aircraft seat data recorder (SDR) and the flight data recorder (FDR). The recordings establish a baseline time at lift off 0:00:00 and continue to the time of ejection at 0:22:24 for the SDR and 0:22:36 for the FDR (time of impact). Recordings at time 0:01:04 through 0:19:12 indicated a routine flight with no flight control systems anomalies or failures (TAB O-13 thru 16). At 0:19:51 voltage is interrupted to flight control systems that indicate a main generator power loss. At 0:19:52 flight control

computer logic indicates electrical power was being supplied by the emergency power unit (EPU) (TAB O-13). Flight data recorder data shows EPU activation at 0:19:52. Flight control integrated servo actuator (ISA) and electronic components assembly (ECA) faults cleared within one second of main generator interruption indicating normal flight control function through impact at 0:22:36. No abnormal indications of aircraft flight controls or instrumentation were identified (TAB O-13). Technical analysis of the engine wreckage was completed by [REDACTED] for OC-ALC/LPARA, Tinker AFB, OK (TAB J-7). Investigation focused on the High Pressure Turbine (HPT) area and the surrounding shroud assembly. Five segments of the shroud assembly (TAB J-4, 13, V-246) and portions of adjacent segments were missing or badly eroded (TAB J-4, V-246). The remaining HPT shroud segments showed little thermal distress though signs of scraping and rubbing were visible (TAB V-246). Examination of the High Pressure turbine blades showed all squealer tips worn nearly flush with the tip caps. Most of the tip surfaces showed smearing and rub marks running in the direction opposite rotation. Thirty percent of the blades were missing portions of tip cap (TAB J-4, V-246). Downstream from the HPT the Low Pressure Turbine (LPT) region showed extensive mechanical and temperature related damage and severe foreign object damage (TAB J-4 thru 6, V-246). Aft of the area where shroud segments were missing, there was deep burning and erosion in the leading edges of the Low Pressure Turbine Nozzle (LPT). There was no evidence to indicate fatigue component failure from the point of the HPT shroud upstream to the front of the engine (TAB V-247). All main engine bearings, journals and sump cavities appeared to be in good condition; no operational distress or significant post impact damage was apparent (TAB J-7).

N. OPERATIONS PERSONNEL AND SUPERVISION: The mission was conducted under the authority of the 140FW and the 120FS. Flight clearance was authorized by the 140 Operations Group Commander (TAB K-3). The briefing was conducted by the flight lead, [REDACTED]. Mission objectives for the flight were specified and were considered consistent with scenario guidance for Maverick training outlined in 120 Fighter Squadron Maverick Training (TAB G-7 thru 10). No supervisory personnel attended the briefing. Currency and qualification for both members of the flight were checked by the supervisor of flying.

O. CREW QUALIFICATIONS: [REDACTED] was a Mission Ready (MR) pilot, qualified and current to perform the scheduled mission. A review of training records revealed no deficiencies or discrepancies. [REDACTED] attended F-16C Combat Crew Training at McDill AFB, FL from August, 1992 through February, 1993 (TAB U-189). Mission qualification (MQT) and unit top-off training at the 120FS began in March, 1993. Mission Qualification Training was completed on 9 September 1993 with the accomplishment of the Air Combat Command 60-2 Tactical Qualification flight evaluation (TAB G-6). The [REDACTED] evaluated [REDACTED] training performance as satisfactory with normal progression throughout [REDACTED] 120FS MQT and continuation training (TAB V-239). [REDACTED] last flight prior to the mishap was two days prior on 7 November 1993 (TAB G-5). Experience of the mishap pilot as of 9 November 1993 is summarized below:

<u>TOTAL HOURS</u>	<u>TOTAL F-16C/D</u>	(TAB G-3)
382.5	165.1	

P. MEDICAL: [REDACTED] was medically qualified for the flight at the time of the mishap. Post accident toxicology analysis was conducted by the Armed Forces Institute of Pathology, Washington D.C. All results were negative (TAB O-2, 3). [REDACTED] suffered a compound fracture of [REDACTED] left tibia on post ejection impact with the ground. In addition to bone fracture, an open wound resulted from bone protrusion. During initial treatment, the wound was debrided and a titanium pin was installed in the bone. Following several weeks of healing, the wound became infected, resulting in several debridement procedures since (TAB X-1, 2). Attending physicians estimate recovery at six months. The primary care physician is [REDACTED], [REDACTED] medical evaluation of [REDACTED] as of 28 February 1994 is filed at TAB X.

Q. NAVAIDS AND FACILITIES: Review of published Notices to Airmen (NOTAMS) applicable to the area of flight operations showed no impact on the mission.

R. WEATHER: The forecast weather for the IR-416 low level training route and the Cougar Military Operating Area was clear, visibility greater than seven miles, surface winds 290 degrees at 15 knots, altimeter setting 30.20 (TAB W-1). The weather observation taken at Laramie Regional Airport at 1354 MST was reported as clear, visibility greater than sixty miles, temperature 44 degrees F, wind 190 degrees at 13 knots, altimeter setting 30.25 (TAB W-2). Weather and surface winds were not considered a factor in the mishap, search and rescue or crash response.

#### S. DIRECTIVES AND PUBLICATIONS

##### 1. Directives and publications applicable to the mission were:

Regulation	Title
AFR 65-110	Status and Inventory Reporting
TACR 66-4	Impound of Aircraft and Aircraft Involved in Explosive Related Mishaps
ANGR 66-14	Maintenance Management, Air National Guard
ANGR 66-38	ANG Non-Destructive Inspection (NDI) Program
ANGR 66-39	Oil Analysis Program (OAP) [Modifies AFR 66-39]
140FW REG 66-1	Operations/Maintenance Scheduling
AFR 66-1	Deviation Procedures
MCI 11-208	Maintenance Management Policy
120 FS	Tactical Aircrew Training
AFR/ANGR 60-1/	Flying Training (Local upgrade, MQT, etc.)
ACC SUP 1	Flight Management
AFR 60-16/	General Flight Rules
ACC SUP 1	F-16 Procedures
MCI 114-16	Command, Control, and Flight Following
ANGR 55-010	Aircraft Flight Manual
F-16C-1	

2. The F-16C-1 Aircraft Flight Manual establishes 2,000 feet above ground level (AGL) as the minimum safe altitude for ejection under controlled flight conditions (TAB O-53). While attempting a second airstart the mishap pilot descended below 2,000 feet initiating the ejection sequence at 610 feet AGL (TAB O-14). The low altitude egress reduced the time required for completing post ejection egress procedures in preparation for the parachute landing fall. Ground contact occurred before the parachute riser "four line pull" was accomplished (TAB V-194).

#### T. OBSERVATIONS:

1. Critical software updates for the unit Ground Software System (GSS) had been received but were not installed at the time of the mishap. This software version update corrected an anomaly that inhibited data recording of engine performance parameters at operating locations above 5000 feet elevation. Software updates with a potential for impacting safety of flight should be incorporated into a control system and managed through a technical order distribution process to insure proper compliance and timely installation. This software upgrade was announced by message 281838Z JUN 93 from OC ALC, Tinker AFB OK//LPA// and sent to AIG 10854 under subject: F110-GE-100 Engine Monitoring System Ground Station Software (GSS) Modification (TAB H-21). The message included no sense of urgency in acquiring the modification and placed responsibility on unit engine managers to order the upgrade through a routine computer program configuration item request. OC ALC did not insure a controlled process existed for the ordering and installation of the software modification by affected units.

2. Engine borescope training for 140FW engine shop personnel had been completed through OJT following unit conversion to the F-16 and the GE F110 engine. All technician personnel were considered by the shop supervisor to be qualified for unrestricted borescope inspections with one exception. One mechanic was restricted from HPT-1 and shroud assembly borescoping inspections (TAB V-52). On 26 February 1993, this individual was assigned to an incoming shop inspection of the mishap engine, a procedure that included a borescope of the HPT-1 and shroud assembly. Supervisors allowed a mechanic not fully certified in borescoping procedures to complete an inspection without supervision. However, on 23 March 1993 during the follow-on phase inspection, a complete engine borescope was completed by qualified engine shop personnel. A 140FW Local Form MAE-11 worksheet documenting the work could not be produced by the engine manager or engine shop supervisor. However, all AFTO 781 and CAMS forms reflect completion and documentation of all engine phase work cards including engine borescoping of the HPT-1 and shroud assembly (TAB H-7; U-5; V-53). Additionally, the aircraft phase dock package for AC 86-0325 included 140FW Phase Inspection Work Card Control Log dated 16 March 1993 showing all engine phase work cards complied with. Notwithstanding the absence of the form MAE-11, extensive formal documentation along with testimony of the engine shop supervisor, shop foreman, and the three members of the phase inspection team (TAB V-52; U-5) indicate a complete engine phase inspection and borescope was completed. No deterioration in the shroud assembly or abnormal wear patterns in the HPT Turbine Wheel were identified during the phase inspection.

3. An engine mechanic not fully qualified in all phases of engine borescoping was allowed to perform an unsupervised incoming phase inspection on the mishap engine nine months prior to the accident (TAB V-52). This inspection required borescope analysis of the high pressure turbine wheel and the surrounding shroud assembly. A follow-on phase inspection by fully qualified technicians was completed and documented prior to operation of the engine. (TAB H-5, 7, U-5) While this investigation does not establish causal or contributing relationship between the mishap and the borescope inspection by a technician not fully qualified for the procedure, the event identified a lack of supervision by the engine shop supervisor in work assignments within the 140FW Engine Shop.

## STATEMENT OF OPINION

Under 10 U.S.C. 2245(d) any opinion of the accident investigators as to the cause of, or the factors contributing to, the accident set forth in the accident investigation report may not be considered as evidence in any civil or criminal proceeding arising from 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.

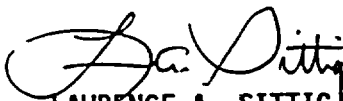
### 3. STATEMENT OF OPINION

Based upon the technical evidence found in the engine tear down and analysis, the cause of this mishap was catastrophic failure of the GE F110-100 engine due to deterioration of the shroud assembly surrounding the high pressure turbine wheel (TAB J-13, V-246). A history of component failure in this assembly had been identified and corrective action provided by the engine manufacturer and OC-ALC by Technical Order 2J-F110-597 (TAB O-52). Compliance date for this technical order is 30 June 1995. The technical order had not been complied with on the mishap engine. Engineering analysis performed by Caesar J. Sabatelli, propulsion engineer, OC-ALC/LPARA, Tinker AFB, OK identified five missing segments of the shroud assembly. (TAB V-246) Most of the distributors in the corresponding area were also missing. The aft rail of the shroud support along with respective "C" clamps was missing as well. Evidence indicated that the rack support structure adjacent to the missing and deteriorated shroud segments allowed the shroud assembly to droop into the blade path of the rotating high pressure turbine wheel. All blades showed signs of rub. (TAB J-4, V-246) Severe foreign object damage (FOD) downstream from the HPT and little or no significant FOD damage upstream of the HPT indicate catastrophic failure occurred at the HPT region (TAB J-2 thru 6, V-246, 247).

Engine monitoring system (EMS) data stored over the eleven month period prior to the mishap was analyzed by General Electric technical consultants during the accident investigation. Analysis indicated a series of trend points that could have predicted problematic conditions in engine performance (TAB S-4, 5, V-249). Specifically, a recent rise in T4B trend points suggested a loss of HPT efficiency due to blade tip wear. This T4B rise was correlated to a compensating decrease in engine fan speed trend points (TAB S-4, 5, V-246). The analysis indicated that diagnostic data was available from the EMS system to alert the engine shop supervisor and the engine manager of decreasing engine performance (TAB V-247, 248, 249). Difficulty in interpreting the highly technical trend data by engine shop personnel was compounded by the absence of a formal engine trend analysis and diagnostic program. No command guidance for a program existed nor was any formal training in data analysis available. A formal trend analysis program had not been established at the unit level. It should be noted that while bulk raw data was available from EMS downloads the technical conclusions drawn from the data were supported through contractor laboratory analysis not routinely available at the field level. Further complicating data analysis was a software anomaly in the ground station software system used for EMS data collection and analysis. The GSS program checks altitude range limits when determining data trend point validity. If base operating altitude is between -500 feet and 5000 feet, the trend point is considered valid for altitude. If the value for altitude is outside of this range (Buckley ANGB - 5560 feet MSL) GSS considers the trend point to be invalid, impacting the program. Corrective action to this anomaly by OC-ALC/LPA modified the software program to correct the deficiency. Distribution for the new software version was announced by message from OC-ALC/LPA 281838Z JUN 93 (TAB H-21). The new software version was received by the 140FW engine manager, but was not found to be installed in the GSS system at the time of the mishap. No sense of urgency or safety of flight implications in announcing the software update was identified to affected units in the OC-ALC/LPA message.

From the time of takeoff on the mishap flight to the initial engine explosion, flight recorder readouts indicated FTIT temperature excursions above the maximum operating limit of 935 degrees centigrade (TAB O-27). One exceedance occurred seconds after lift-off from a single-ship afterburner take-off when the pilot was task loaded with gear retraction, radar target acquisition of his flight lead and join-up geometry. The excursions did not exceed 1000 degrees centigrade for two seconds, the parameter required by aircraft systems to activate the engine warning system (TAB O-54, V-242, 243). The mishap pilot did not identify analog readouts of high engine temperature that occurred during the high task load mission. Activation of the engine warning system at the maximum operating limit could have provided the pilot with time for corrective action and diversion. Analog/digital instrumentation alone cannot be effectively monitored for max operating limits in single seat fighter aircraft during critical phases of flight and high task load employment scenarios. Human factors engineering considerations should be evaluated for adjusting the engine aural warning system of the F-16C/D to activate at the maximum FTIT operating limitation.

General Electric engine technical consultants participated extensively in the accident investigation. According to testimony by the OC ALC propulsion engineer, GE consultants wrote the non-releasable portion of the investigation as to their opinion on the failure scenario and the initiating failure mechanism. (TAB V-256) A potential conflict of interest may exist (TAB V-31) when systematic involvement by a manufacturer is granted in attributing causal factors in a material failure mishap that may be design related (Reference TCTO 2J-F110-597)(TAB O-52).



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1 MARCH 1994

DATE