EXECUTIVE SUMMARY

AIRCRAFT ACCIDENT INVESTIGATION

E-8C, T/N 93-0597

AL UDEID AIR BASE, QATAR
13 MARCH 2009

On 13 March 2009, an E-8C JSTARS, tail number 93-0597, assigned to the 379th Air Expeditionary Wing, experienced a near catastrophic fuel tank over-pressurization during aerial refueling. The mishap aircraft (MA) terminated its mission and returned to Al Udeid Air Base, Qatar. The crew and mission personnel evacuated the aircraft safely without injury. The mishap resulted in damage to the MA in the amount of $25 million dollars. There was no damage to private property.

The mishap occurred during operations in the Area of Responsibility (AOR). The mishap crew (MC) had begun aerial refueling (AR) with a KC-135, when the mishap crew and personnel aboard heard and felt a loud bang throughout the midsection of the aircraft. The MC suspended AR to evaluate the MA to checkout their systems and evaluate the MA for any damage. Finding nothing apparently wrong, the MC re-latched to the tanker and attempted to continue the AR when another series of loud noises and vibrations were heard and felt throughout the aircraft. Personnel aboard the KC-135 observed a stream of vapor and fuel streaming from the MA and alerted the MC. The MC checked for damage through a rear window and observed fuel streaming from at least two holes in the left wing, just inboard of the number two engine. The MC opted to terminate the mission and return to Al Udeid. Maintenance personnel then examined the MA and found that the number two main fuel tank had ruptured, causing extensive damage to the wing of the MA.

The Accident Investigation Board (AIB) President found, by clear and convincing evidence, that the mishap was caused when a civilian subcontractor employee inadvertently left a test plug in the fuel vent system of the MA during recently completed Programmed Depot Maintenance (PDM) performed on the MA.

Additionally, the AIB President found by substantial evidence three factors which contributed to the mishap. First, the PDM subcontractor employed ineffective tool control measures. Second, the PDM subcontractor failed to follow Technical Order (TO) mandated procedures when employing the fuel vent test plug during PDM. Third, due to the relatively short period of time between takeoff and AR, the MC did not have the opportunity to burn a substantial amount of fuel from the number two fuel tank which could have allowed the dive "flapper" valve to open after the tanks excessive air pressure decreased to the point where the flapper valve would open. This explains why this mishap did not occur during ARs conducted between the time the MA left the PDM facility and the time of the mishap.

SUMMARY OF FACTS AND STATEMENT OF OPINION
E-8C, T/N 93-0597, 13 MARCH 2009
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COMMONLY USED ACRONYMS AND ABBREVIATIONS

§	Section
7 EACCS	7th Expeditionary Air Command and Control Squadron
116 ACCS	116th Air Command and Control Squadron
116 ACW	116th Air Control Wing
128 ACCS	128th Air Command and Control Squadron
ACC	Air Combat Command
ACW	Air Control Wing
AEW	Air Expeditionary Wing
AF	Air Force
AFTO	Air Force Technical Order
AOR	Area of Responsibility
AR	Aerial Refueling
CGS	Common Ground Station
CV	Climb Vent
DV	Dive Vent
E-8C	JSTARS Aircraft
EOG	Expeditionary Operations Group
FFCS	Floats and Fuel Cell Services
EMXG	Expeditionary Maintenance Group
EMSG	Expeditionary Mission Support Group
FOD	Foreign Object Damage
FTI	Fixed Target Indicator
IMDS	Integrated Maintenance Data System
ISO	Isochronal
JSTARS	Joint Surveillance and Target Attack Radar System
LCMMC	Lake Charles Maintenance Modification Center
MA	Mishap Aircraft
MC	Mishap Crew
MFE	Mishap Flight Engineer
MM	Mishap Maintainer
MMS	Mishap Maintainer Supervisor
MN	Mishap Navigator
MP	Mishap Pilot
MPT	Mission Planning Team
MXG	Maintenance Group
MTI	Moving Target Indicator
OG	Operations Group
PDM	Programmed Depot Maintenance
SAR	Synthetic Aperture Radar
TCTO	Time Compliance Technical Order
USCENTCOM	United States Central Command
WAS	Wide Area Surveillance
JIMIS	Joint Integrated Maintenance Information System

SUMMARY OF FACTS

1. AUTHORITY, PURPOSE, AND CIRCUMSTANCES

a. Authority

On 9 April 2009, Major General R. Michael Worden, Vice Commander, Air Combat Command (ACC), appointed Colonel (Col) Randall L. Vogel to conduct an aircraft accident investigation of a mishap that occurred on 13 March 2009 involving an E-8C aircraft, tail number (T/N) 93-0597, near Al Udeid Air Base (AB), Qatar (Tabs B-3, C-3 thru C-5). The investigation was conducted at Robins Air Force Base, Georgia (GA) from 22 April 2009 through 7 May 2009. Technical advisors were Col Ronald M. Feder (Legal Advisor), Chief Master Sergeant John M. Menton, (Maintenance), Master Sergeant Brian E. Brown (Recorder), and Technical Sergeant John D. Christian (Fuel Systems Craftsman) (Tabs Y-3, Y-5 and Y-7).

b. Purpose

The purpose of this investigation is to provide a publicly releasable report of the facts and circumstances surrounding the accident, to include a statement of opinion on the cause or causes of the accident; to gather and preserve evidence for claims, litigation, disciplinary, and adverse administrative actions; and for other purposes. This report is available for public dissemination under the Freedom of Information Act (5 United States Code (U.S.C.) § 552).

c. Circumstances

The accident investigation board (AIB) was convened to investigate the Class A mishap involving an E-8C aircraft, T/N 93-0597, assigned to the 128th Air Command and Control Squadron (128 ACCS), Robins AFB, GA with temporary duty assigned to the 7th Expeditionary Air Command and Control Squadron (EACCS), Al Udeid AB, Qatar which occurred during a mission on 13 March 2009 (Tabs B-3).

2. ACCIDENT SUMMARY

During a planned aerial refueling (AR) prior to an operational mission in the United States Central Command (USCENTCOM) Area of Responsibility (AOR), the mishap aircraft (MA), an E-8C, T/N 93-0597, experienced a near catastrophic over pressurization of the number two fuel tank (Tabs J-23 thru J-25; J-34 through J-35). After a series of loud bangs and vibrations during AR, crewmembers of the MA and tanker noticed a stream of fuel flowing from the inboard trailing edge of the left wing. Consequently, the Mishap Crew (MC) elected to abort the mission, declare an in-flight emergency (IFE) and return to base for an uneventful landing and crew evacuation (Tabs B-3 and H-3). The MA damage was valued at approximately $25 million (Tab P-3). There was no damage to private or other government property; there was media interest in the mishap (Tabs O-51 thru O-52).

3. BACKGROUND

a. 116th Air Control Wing

The 116th Air Control Wing (ACW) owns the MA. The 116 ACW is responsible for the worldwide employment of the E-8C Joint Surveillance Target Attack Radar System (JSTARS) aircraft. The 116 ACW is the first Total Force wing, combining more than 2,600 Air National Guard, active-duty Airmen, Army personnel and civilian contractors into a single cohesive unit. The wing trains, mobilizes and deploys combat mission-ready aircraft, aircrews and support to designated theaters of operation and conducts sustained combat support operations to provide uninterrupted command, control, intelligence, surveillance and reconnaissance in support of the joint force air component commander. The 116 ACW is comprised of 116th Operations Group and 116th Maintenance Group. (Tabs CC-7 thru CC-8).

b. 379th Air Expeditionary Wing

The 379th Air Expeditionary Wing (AEW) of the United States Air Force (AF) is located at Al Udeid AB, Qatar. The Wing is one of the largest, most diverse expeditionary wings in the AF, providing combat airpower and support for the Global War on Terrorism and Operations IRAQI FREEDOM and ENDURING FREEDOM, as well as support of Joint Task Force Horn of Africa. The wing and its associate units operate more than 100 aircraft, making the base a large hub for humanitarian airlift activity while providing mission-essential combat power, aeromedical evacuation and intelligence support for three theaters of operations. The 379 AEW is composed of five groups: 379th Operations Group, 379th Maintenance Group, 379th Mission Support Group, 379th Medical Group and 64th Air Expeditionary Group (Tab CC-5).

c. E-8C JSTARS

The E-8C is a long-range, air-to-ground surveillance system designed to locate, classify and track ground targets in all weather conditions. While flying in friendly airspace, the joint Army-AF program can look deep behind hostile borders to detect and track ground movements in both forward and rear areas. It has a range of more than 150 miles (250 km). These capabilities make JSTARS effective for dealing with any contingency, whether actual or impending military aggression, international treaty verification, or border violation.

JSTARS consists of an airborne platform—an E-8C aircraft with a multi-mode radar system and US Army mobile Common Ground Stations (CGSs). The E-8C, a modified Boeing 707, is equipped with a 40-foot long canoe-shaped radome mounted under the forward fuselage which houses a 24-foot side-looking phased array radar antenna. The radar is capable of providing targeting and battle management data to all JSTARS operators, both in the aircraft and in the CGSs, through secure data links. These operators, in turn, can call on aircraft, missiles or artillery for fire support. With a reported range in excess of 150 miles, this radar can cover an estimated 386,100 square miles in a single eight-hour sortie.

The heart of JSTARS is its advanced multimode radar system. From friendly airspace it can detect, locate, track and classify slow moving ground and waterborne targets, low flying aircraft, and rotating antennas deep into hostile territory (Tab AA-9).

4. SEQUENCE OF EVENTS

a. Mission

The mishap mission consisted of one E-8C JSTARS. The mission was scheduled as an operational mission supporting operations in the USCENTCOM AOR (Tab B-3). The planned mission consisted of a takeoff, aerial refueling, sensitive area surveillance and return to Al Udeid AB, Qatar (Tab K-5). The mission was authorized by the 7 EACCS Commander (signing for the Director of Operations) and properly documented on a Crew Flight Authorization Form (Tab K-3).

b. Planning

The mission was planned and briefed by the mission planning team (MPT) IAW 7 EACCS and JSTARS standards. The MPT is manned by one of eight current and qualified crews assigned to the 7 EACCS and crews are scheduled to rotate through MPT on a weekly basis. Crews flying the day's mission arrive two and a half hours prior to their planned launch time and are handed the day's mission materials and briefed information pertinent to execute the mission. The MC followed normal procedures prior the mishap mission (Tab V-4, V-8 and V-16).

c. Preflight, engine start, taxi, takeoff and level off prior aerial refueling

The aircraft commander, Mishap Pilot 1 (MP1), Mishap Pilot 2 (MP2), Mishap Navigator (MN) and Mishap Flight Engineer (MFE) all testified that preflight, engine start, taxi, takeoff and level-off prior to their first planned aerial refueling were uneventful (Tab V-4, V-9, V-16 and V-30).

d. Summary of Accident

On 13 March 2009, the mishap aircraft experienced a near catastrophic rupture to the number two fuel tank within the left wing of the aircraft during AR operations prior to conducting an operational mission in the USCENTCOM AOR. Post accident investigation revealed that a mechanical test plug was left in the climb vent (CV) during Phased Depot Maintenance (PDM) procedures. Such plugs should be removed prior to the AC leaving PDM (Tabs J-19 thru J-35, S-32 thru S-38). The number two fuel tank in an E-8C has two vents, a climb vent (CV), located near the front of the tank, and a dive vent (DV), located near the back of the tank. These vents relieve pressure, ensuring that pressures inside the tank do not grow large enough relative to the outside air pressure to rupture the tank. By design, at least one of these two vents will remain open during all phases of flight (Tab J-37).

Failure to remove a mechanical test plug from the CV would leave the dive vent (DV) as the only working vent for the number two the fuel tank (Tab J-37).

Pre-mission fuel loads (Tab J-57 thru J-59):

Lt Res Tank	#1 Main Tank	#2 Main Tank	Center Tank	#3 Main Tank	#4 Main Tank	Rt Res Tank	Total
2,750	15,150	24,650	23,000	24,650	15,150	2,750	108,100

Estimated fuel loads at the beginning of AR during the mishap mission (Tab J-57):

Lt Res Tank	#1 Main Tank	#2 Main Tank	Center Tank	#3 Main Tank	#4 Main Tank	Rt Res Tank	Total
2,500	14,700	24,200	3,900	24,200	14,700	2,500	86,700

With the main fuel tanks full or nearly full (as with the MA), the DV in each tank automatically closes during takeoff and climb to prevent fuel from spilling out of the vent system (Tab J-37). The CV is designed to be open during these same phases of flight to enable air pressure inside the tank to remain equalized with outside air pressures during the climb (Tab J-37). If the CV is obstructed by the mechanical test plug, the pressure cannot be equalized. Since outside air pressure decreases as altitude increases, this inability to equalize pressure results in increasingly higher pressures within the number two tank as an AC climbs in altitude.

Upon reaching the desired altitude and leveling off, the AC returns to an angle where the fuel will not spill out of the DV, so, by design, the DV should drop open (Tab J-37). If the pressure inside the tank is too high relative to the outside air pressure though, as was the case with the MA, the relatively high internal pressure prevents the DV from dropping open upon level off (Tab J-23). This leaves the AC in a condition with both vents closed and leaves it subject to over pressurization if more fuel is added to the tank.

Consistent with normal AR procedures, the Mishap Flight Engineer (MFE) burned fuel from the center tank from takeoff to AR, and then began burning main tank to engine fuel prior to taking on fuel from the tanker AC (Tabs T-5 thru T-8 and V-31 thru V-32). During this period, only 450 lbs of fuel (1.83% of the tank's fuel) was burned from tank number two before fuel was loaded into it to top it off (Tabs J-57 thru J-59). The relatively small decrease in air pressure caused by the 1.83% decrease in fuel was not sufficient enough to allow the DV to open (Tabs W-12 thru W-14). The MFE continued to burn from the main tanks during AR and periodically topped off the main tanks to keep them relatively full while the center tank filled. As fuel is pumped into the tank that cannot vent, the pressure in the tank rises and can eventually over pressurize the tank, causing it to rupture.

When the MA received approximately 30,000 pounds of its planned 65,000 lbs, the MC heard a loud bang and felt a series of vibrations throughout the aircraft. At first, they thought it might have been the radar equipment located within the canoe shaped radome below the MA which creates a noticeable noise from time to time. However, the radar is normally turned off during AR, and it was quickly confirmed by the MC that the radar was off, eliminating that as the source (Tabs V-5, V-9, V-17 and V-31). MP1 then asked if anyone on the tanker felt a bump or anything unusual; the crew responded in the negative (Tabs V-17 and V-23). The MC elected to

break away from the tanker to try and determine the source of the noise and vibration. The MP1 and MP2 discussed different scenarios such as an engine compressor stall, MA getting hit by ground fire, etc. but found all MA systems were operating normally after disconnecting from the tanker (Tabs V-4).

The tanker reported to the MC that there was an additional pilot (AP) onboard their AC who was in the boom pod, which is in the rear of the tanker and has a window, who could look the MA over to see if he observed any damage or anomalies (Tabs V-5, V-10 and V-17). The MP1 and MP2 repositioned the MA in order for the AP and the boom operator on the tanker to observe the MA's fuselage and wings (Tabs V-5, V-10 and V-17). Neither the additional pilot nor the boom operator saw anything unusual (Tabs V-5, V-10 and V-24). At that time, since all the MA's systems appeared normal and no anomalies were discovered, the MC elected to re-connect with the tanker and resume AR (Tabs V-5, V-10 and V-18).

Shortly after MC started taking on fuel for the second time, they heard and felt another series of bangs and vibrations and again disconnected from the tanker (Tabs V-5, V-10 and V-18). As the MA pulled back from the tanker, both the additional pilot and the boom operator from the tanker observed a large plume of vapor or liquid coming out of the left inboard wing near the number two engine (Tabs V-5 and V-10). They advised the MC of their observation. Looking out their rear window, the MC verified the large leak and also observed two relatively large holes near the top, inboard trailing edge of the left wing (Tabs V-5, V-10, V-18 and V-34 thru V-35). At that time, the MC decided to abort the mission.

After discussing their options, the MC elected to return to Al Udeid AB (Tabs V-10 and V-18 thru V-19). During their decent into Al Udeid, the MP1 and MP2 performed a controllability check during flap extension and found a need for slight aileron trim adjustment (Tab V-6 and V-19). MC declared an IFE and successfully landed and evacuated the MA after the MA stopped (Tabs V-5 thru V-6, V-11 thru and V-19 thru V-20 and V-35).

e. Impact

Not applicable.

f. Life Support Equipment, Egress and Survival

Not applicable.

g. Search and Rescue

Not applicable.

h. Recovery of Remains

Not applicable.

5. MAINTENANCE

a. Forms Documentation

Every Air Force aircraft has a detailed set of records, paper or electronic, that details the maintenance history of the aircraft. The Air Force Technical Order (AFTO) 781 series of forms are the paper records, additionally electronic records are managed in the Integrated Maintenance Data System (IMDS). The MA's AFTO Forms 781 and IMDS data were reviewed for accuracy and completeness to determine the condition of the MA during the 30 days prior to the mishap. At the time of the mishap, the MA's total flight time was 54,089.5 hours (Tab D-11). There were no relevant open discrepancies, time change items, or overdue or pending Time Compliance Technical Orders (TCTO) for the MA.

This aircraft recently returned from PDM; thus the contractor's PDM forms were available for review. These forms are not Air Force forms and originate from the subcontractor, Floats and Fuel Cell Services (FFCS). Numerous leaks in all fuel tanks had been repaired and the tanks were checked for leaks. Examining the records for the number two tank repairs showed the documentation as incomplete, since documentation required by the Warner Robins Air Logistics Center (WR-ALC) Technical Requirements documents for tool control was not accomplished (Tab O-47).

b. Inspections

PDM was completed, and the MA returned to Warner Robins on 7 January 2009. The last in support of ISO Minor inspection was completed on 21 November 2007. A preflight inspection was completed on 13 March 2009 (Tab D-11 thru Tab D-13).

c. Maintenance Procedures

Relevant maintenance procedures were performed at the Lake Charles Maintenance Modification Center where the MA underwent overhaul and numerous routine fuel tank repairs.

Tab H, Section 3, Technical Data, of the WR-ALC Technical Requirements Documents requires that all maintenance conform to the applicable directives and Tech Orders (T.O.s) listed in Tab C of the WR-ALC Technical Requirements Document. The two primary publications used were T.O. 1-1-3, Inspection and Repair of Aircraft Integral Tanks and Fuel Cells, and T.O. 1E-8C-12, JSTARS Integrated Maintenance Information System (JIMIS) (Tab W-15 and W-16).

A mechanical test plug was found in the CV system of the number two tank. Contract requirements and maintenance technical manuals specifically require this mechanical test plug to have streamers attached and documentation entered in work control documents. Specifically T.O. 1-1-3, Section 2.7.6.4 requires "Remove Before Refuel/Defuel" streamers to be attached to equipment such as test plugs that could affect venting, fueling, defueling or transferring of fuel (Tab T-21). This requirement is mirrored in Tab H, Section 9.6, of the WR-ALC Technical Requirements Documents (Tab W-18). A properly installed streamer is designed to alert

mechanics that the plug is installed and shall be removed before refuel/defuel. The mechanical test plug found in the CV did not have a streamer.

T.O. 1E-8C-12 provides the guidance to properly perform the maintenance procedure that required the mechanical test plug to be installed. Task 280082 of this T.O. instructs the mechanic how to prepare the tank for the pressure check. Task 280090 instructs the mechanic how to restore the tank to an operational status (Tab T-9 thru T-16). Step 5 of this task directs the mechanic to remove the mechanical test plug (Tab T-19).

The company that performed the fuel tank maintenance has its own safety checklist for fuel tank entry, the FFCS Safety Checklist (Tab D-12). Item 11 on this document requires that the maintenance supervisor ensure that tools and equipment entering and leaving fuel tanks are documented on the Tool Inventory Checklist, FFC Services Form FFCS-105. The mechanical test plug a piece of equipment requiring such documentation. The Tool Inventory Checklist did not show the mechanical test plug as having been installed into the number two fuel tank (Tab D-63 thru D-68).

The Lake Charles Maintenance Modification Facility (LCMMF) has internal guidance for Foreign Object Damage (FOD) prevention and tool control. The document is LC-M-0501M (Tab D-75 thru D-79). Prevention of Foreign Objects/Foreign Object Damage. Section Two of this document covers tool control. One requirement of this section is that personal or company issued toolboxes must be inventoried daily, at the beginning and end of shift, as a minimum, to ensure all tools are accounted for (Tab D-75). The mechanical test plug is one of the accountable tools.

Mishap maintenance supervisor 1 (MMS1) and mishap maintainer 1 (MM1) both testified to a tool control process being used at LCMMF. MMS1 testified to an inventory being accomplished at the end of each job but not a daily inventory. MM1 testified to a daily inventory as well as an inventory when a job is completed. Both individuals testified that tools are shadowed in the box and tracked on tool inventories. The mechanical test plug is such a shadowed and tracked tool. Both individuals testified that there were no missing or lost tools while working on 93-0597 (Tabs R-17, R-19 thru R-20, R-28 thru R-29, R-31, and R-38, thru R-39).

MM1 performed desealing and sealing maintenance in the number two main tank (Tab D-36 through D-39). Comparing these maintenance actions with the tool control inventories showed that there are no records of MM1 taking any tools into the number two main tank (Tab D-63 through D-68). Desealing and sealing maintenance requires tools, including a mechanical test plug, be taken into the tank in order to complete the task and check for leaks following the repair actions.

FFCS Form 100, Safety Checklist, line 11, requires that the inspector check to "ensure tools and equipment entering and leaving fuel tanks gets documented on the Tool Inventory Sheet." This form is signed by MMS1; the dates align with the period that fuel cell maintenance was performed by MM1 on 93-0597 (Tab D-57 through D-62).

According to the documentation, LCMMF has prior tool control deficiencies. In May 2007, LCMMF was evaluated IAW AFJI 10-220 (Tab O-15 thru O-27). The evaluation found that tool control procedures were not being followed. In particular, tools that were taken to the aircraft were not being documented (Tab O-21). In January 2008, LCMMF was again evaluated in accordance with Air Force Joint Instruction (AFJI) 10-220 (Tab O-3 thru O-12). Once again, it was noted that the facility had deficiencies with tool control (Tab O-7 and O-8).

d. Maintenance Personnel and Supervision

Individual training records of all maintenance personnel who performed relevant maintenance procedures on the MA prior to the mishap were reviewed. As the maintainers who performed the relevant maintenance were not Air Force members, they do not have Individual Training Records, AF Forms 623. Instead, they have a mixture of FFC Services and Federal Aviation Administration training requirements and documentation. Training records indicate that personnel had been trained and were qualified to perform the relevant maintenance (Tab G-43 thru G-116).

e. Fuel Inspection Analysis

There was no indication of fuel contamination or that a fuel condition contributed to the mishap (Tab J-20).

f. Unscheduled Maintenance

The AFTO Forms 781 and IMDS data revealed there were no relevant unscheduled maintenance procedures performed in the 30 days prior to the mishap.

6. AIRCRAFT AND AIRFRAME

a. Condition of Aircraft and Airframe Systems

(1) Landing Gear System

There was no visible indication of landing gear damage.

(2) Engines

Engine numbers 1-4 operated normally throughout the mishap and rotated freely. A borescope inspection was not required as the engines were not damaged in the mishap.

(3) Avionics

There was no visible indication of avionics system damage.

(4) Flight Controls

There was no visible indication of flight control system damage.

(5) Electrical Systems

There was no visible indication of electrical system damage.

(6) Fuel System

The MA suffered visible damage to the left wing. Externally, the aircraft appeared undamaged except for visible deformation of the lower wing skin at the aft row of fasteners in the forward spar chord, and five missing rivets on the lower wing skin and two missing rivets on the upper wing skin. Internally, the aircraft suffered extensive internal damage to the number two main tank. The extent of the damage was complete severance of the connectivity between the upper and lower wing panels through the interspar ribs. Additionally, the failed fasteners allowed significant fuel leaks to occur. A complete description of the damage is reported in Tab J-6 through J-15.

b. Testing

(1) Number Two Main Tank

An internal visual inspection of the number two main tank was conducted and damage was evident as noted in Section 6a.(6). A visual inspection of the number two main tank system components revealed only a single fuel system discrepancy with a dump tube pulled free from the supporting clamp (Tab J-22). All other fuel system components internal to the number two main (included piping, fill and shutoff valves, shutoff switches, sense lines, vent plumbing, quantity probes, and wiring) were visually inspected with no discrepancies noted (Tab J-4 and J-22).

(2) Internal Component Testing

The following checks or tests were conducted at the request of the Northrop Grumman team.

Sense lines for auto shutoff switches/fill valve were pressure tested. No discrepancies were noted (Tab J-47). Air pressure supplied by a ground cart was applied to the refueling manifold through use of a single point ground refueling test port. The pressure supplied by the cart was 50 psi, though the exact pressure seen at the manifold was not able to be measured. The system was observed for audible signs of leakage through the piping, connections, or valves in number two main. No signs of leakage were detected (Tab J-45).

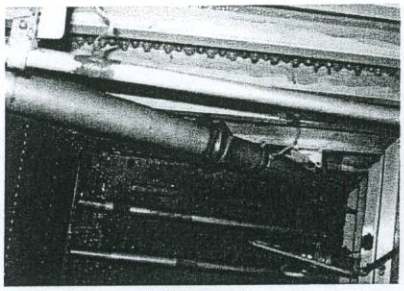
A connectivity check was conducted on all electrical connections regarding number two main fuel tank's fuel system. No discrepancies were noted (Tab J-49 thru J-50).

The number two main tank outboard vent (i.e. dive vent) flapper assembly was inspected in place and manipulated to determine ease of movement. No binding or restriction was noted

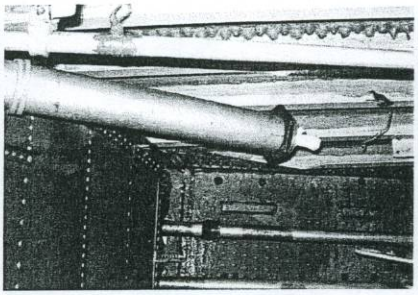
(Tab J-31).

Flow through the vent system for number two main tank was checked by supplying low pressure air from a ground air conditioning cart via a 12 inch flexible supply duct. With the lower access holes (reasonably) blocked, air flow was checked at the wing tip vent exit point. With the dive vent flapper open, relatively strong flow was observed. With the vent manually held in the closed position, all flow ceased.

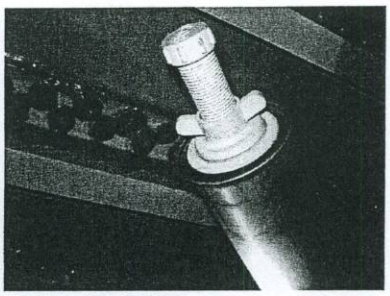
In order to borescope the tubing associated with the inboard vent (i.e. climb vent) to check for obstructions, the vent "horn" was disconnected from the tubing at the nearest joint. When the joint was disassembled, a mechanical test plug was observed installed in the outboard section of tubing. Subsequent research determined that it was an expandable test plug used to retain pressure in the tank during pressure tests. It was marked with a tool control number (8252) that was traced to Northrop Grumman's Lake Charles LCMMF PDM facility. After the plug was removed, the previous test was redone. This time, no significant change in airflow was detected with the dive vent flapper in the closed position (Tab J-31).



Climb vent Installed



Climb vent Removed



C.O.B. Plug

All major components in the number two main fuel tank were removed and sent off for analysis (Tab J-9 thru J-15). The following components were removed from the aircraft for a bench check to be conducted at an approved facility in the U.S. Fuel quantity gage - number two main (from the Flight Engineer panel), total fuel quantity gage (from the FE panel), number two main fuel fill valves, number two main fuel quantity probes, number two main primary automatic fuel shutoff switch (i.e. pilot valve), number two main secondary automatic fuel shutoff switch (i.e. float switch), number two main "dive vent" flapper assembly, and number two main "climb vent" horn assembly. As of the writing of this report, test results for these were all unavailable except for the number two main "dive vent" flapper valve. Sufficient testing was completed on this component to determine that it did not contribute to the mishap (Tab P-3). The remaining components would have no bearing on the cause of the mishap.

7. WEATHER

a. Forecast Weather

At scheduled takeoff time, the forecast weather at Al Udeid AB, Qatar was winds variable at 6 knots, a surface temperature of 85° F with unlimited visibility (Tab F-3).

b. Observed Weather

At the time of the mishap (approx 1735Z), both the KC-135 and E-8C reported smooth air throughout the entire flight (Tab F-5).

c. Space Environment

Not applicable.

d. Conclusion

Weather was within limits for the mission. There is no evidence weather was a factor in the mishap.

8. CREW QUALIFICATIONS

a. Training

According to squadron training records, all members of the MC were current, qualified and mission ready in their respective positions (Tabs G-3 thru G-31). There is no indication crew qualifications were relevant to the mishap.

b. Experience

Mishap Pilot 1 (MP1) was a 33-year-old Senior Pilot and Flight Examiner with a total of 3,648.1 flight hours (of which 1,942.7 hrs were in the E-8C). MP1 was a previously qualified Aircraft Commander (AC) on the E-3B/C. MP1's 30/60/90 day look-back (97/185.2/198 hours and 10/17/19 sorties), Flight Evaluation Folder (FEF), and training records were unremarkable. MP1 occupied the left seat for the mission and was the pilot flying (PF) during most of the mishap sequence (Tab G-3).

Mishap Pilot 2 (MP2) was a 40-year-old Command Pilot and AC with a total of 4,177.1 flight hours (of which 1,488.3 hrs were in the E-8C). MP2 was a previously qualified Instructor Pilot (IP) in the B-1 and E-8C. The AIB reviewed MP2's 30/60/90 day look-back (97/193/193 hours and 10/18/18 sorties), flight evaluation folder (FEF), and training records. MP2 occupied the co-pilot (right) seat for the mishap mission and was the pilot not flying (PNF) during the mishap sequence. MP2's FEF was unremarkable. MP2 was the Aircraft Commander during the first half of their rotation at a Forward Deployed Location and MP1 assumed the roles during the second half, effective 1 Mar 09 (Tab G-10).

Mishap Navigator (MN) was a 45-year-old Master Navigator with a total of 4,726.2 flight hours (of which 1,589 hrs were in the E-8C). MN was previously qualified on the B-52G/H and the B-1. The AIB reviewed MN's 30/60/90 day look-back (97/185.2/190.1 hours and 10/17/18 sorties), flight evaluation folder (FEF), and training records, all of which appeared unremarkable (Tab G-24).

The E-8C mishap Flight Engineer (MFE) was a 42-year-old Flight Engineer with a total of 3002.2 flight hours (all were in the E-8C). The AIB reviewed MFE's 30/60/90 day look-back (97/185.2/188.5 hours and 10/17/18 sorties), flight evaluation folder (FEF), and training records, all of which appeared unremarkable. MFE was at the flight engineer panel during the entire flight (G-17).

All crewmembers were well qualified for their duties.

9. MEDICAL

The medical records of four personnel were provided for review to the Medical Investigator. The summary of findings is outlined below. The records were reviewed to determine medical fitness for duty at the time of the mishap, medical conditions that may have contributed to the mishap, the presence of medications that may have contributed to the mishap, lifestyle concerns, and any factors that may have impacted crew rest or crew duty time.

a. Qualifications:

Aircrews are required to have a preventive health assessment (PHA) annually. To be medically qualified for flying duties, the Airman must meet the physical standards set forth in AFI 48-123V3 Attachment 4 and have a valid, signed AF Form 1042, *Medical Recommendation for Flying or Special Operational Duty*. The records were reviewed for information located on the AF Form 1042, the Department of Defense (DD) Form 2216E, *Hearing Conservation Data*, the DD Form 2766, *Adult Preventive and Chronic Care Flow sheet*, and medical care documentation (Tab X-11).

The crew had current and valid AF Forms 1042 signed by a flight surgeon at the time of the mishap. A review of the medical records did not reveal any medical conditions that would have disqualified him from flying duties (Tab X-11). All crewmembers had a current and valid AF Form 1042 signed by a flight surgeon at the time of the mishap. A review of the medical records did not reveal any medical conditions that would have disqualified any of them from flying duties (Tab X-11).

b. Health:

A comprehensive review of the available medical records of the four personnel listed in above did not reveal any health conditions that may have been causal or significantly contributory to the mishap (Tab X-11).

c. Pathology/Toxicology:

Blood and urine samples were collected after the mishap IAW AF policy and sent to the Armed Forces Institute of Pathology for toxicological examination. The blood was screened for carboxyhemaglobin saturation and ethanol. Carboxyhemaglobin testing was performed using spectrophotometry with a limit of quantification of 1%. Carboxyhemaglobin saturations of 0-3% are expected for non-smokers, and saturations of 3-10% are expected for smokers. Saturations of more than 10% are considered elevated and are confirmed by gas chromatography. The blood was also examined for the presence of ethanol with a detection cutoff of 20 mg/dL. The urine was screened for amphetamines, barbiturates, benzodiazepines, cannabinoids, cocaine, opiates and phencyclidine by immunoassay or chromatography.

Tests revealed carbon levels were normal and neither drugs nor alcohol were found in the urine of the MP1, MP2, MN and MFE (Tab X-11).

d. Lifestyle:

No lifestyle factors were relevent to the mishap (Tab X-11).

e. Crew Rest/Crew Duty Time:

Crew rest and crew duty time were within prescribed limits. There is no indication crew rest is relevant to the mishap (Tab X-11).

10. OPERATIONS AND SUPERVISION

a. Operations

Not applicable in the accident.

b. Supervision

Not Applicable.

11. HUMAN FACTORS

There were no relevant MC human factors. The MC actions were timely and appropriate.

12. GOVERNING DIRECTIVES AND PUBLICATIONS

a. Primary Operations Directives and Publications

(1). T.O. 1E-8C-1, Flight Manual, USAF Series, E-8C Aircraft, 12 January 2007 with Change 3 dated 05 August 2008

(2). T.O. FE's Checklist

(3). AFI 11-421, *Aviation Resource Management*, 1 November 2004

(4). AFI 51-503, *Aerospace Accident Investigations*, 16 July 2004

(5). AFI 91-204, *Safety Investigations and Reports*, 24 September 2008

(6). Air Force Pamphlet 91-211, *USAF Guide to Aviation Safety Investigation,* 23 July 2001

b. Maintenance Directives and Publications

(1). T.O. 1E-8C-12, JIMIS

(2). T.O. 1-1-3, *Inspection and Repair of Aircraft Integral Tanks and Fuel Cells,* 31 August 2006 with Change 4 dated 15 November 2008

(3). Warner Robins AIR LOGISTICS CENTER, TECHNICAL REQUIREMENTS DOCUMENT, AIRCRAFT DEPOT WORK REQUIREMENTS, TAB H, 13 August 2008

(4). LC-M-0501M Prevention of Foreign Objects/Foreign Object Damage, Lake Charles Maintenance Modification Center, 06August 2007

(5). AFI 21-101_ANGSUP_1, *Aerospace Equipment Maintenance Management*, 29 June 2006 with ANG Supplement dated 14 April 2008

NOTICE: The AFIs listed above are available digitally on the AF Departmental Publishing Office internet site at: **http://www.e-publishing.af.mil.**

c. Known or Suspected Deviations from Directives or Publications

There are no known or suspected deviations from directives or publications by crew members or others involved in the mishap mission. Contractor maintenance deviations are discussed in Section 5.

13. NEWS MEDIA INVOLVEMENT

There was media interest following the mishap (Tab O-51 thru O-52).

14. ADDITIONAL AREAS OF CONCERN

None.

RANDALL L. VOGEL, Colonel, USAF
President, Accident Investigation Board

STATEMENT OF OPINION
E-8C, T/N 93-0597 ACCIDENT
13 MARCH 2009

Under 10 U.S.C. 2254(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 the accident, nor may such information be considered an admission of liability of the United States or by any person referred to in those conclusions or statements.

1. OPINION SUMMARY

The mishap occurred while en route to a surveillance mission within the Central Command Area of Responsibility. Upon level-off, the mishap aircraft (MA) rendezvoused with an Air Force tanker to receive its planned 65,000 pound aerial refueling (AR) on-load. After receiving approximately 30,000 pounds of fuel, the mishap crew (MC) heard and felt a series of loud bangs vibrations within the MA. After feeling the first bang and vibrations, the mishap pilot (MP1) separated from the tanker and the vibration went away. After evaluating and finding no physical damage or system abnormalities onboard the MA, MP1 re-rendezvoused with the KC-135T to receive the rest of the planned fuel after which time MC again heard and felt a series of bangs and vibrations and then found fuel streaming from the inward trailing edge of the left wing. The crew aborted, adjusted gross weight to a safe landing weight, declared an in-flight emergency and landed and evacuated the MA after stopping at the end of the runway. There were no injuries. The MA damage was valued at approximately $25 million.

I find by clear and convincing evidence that the mishap was caused by severe over pressurization of the number two fuel tank due to an obstructed climb vent tube that was blocked by a mechanical test plug left in a vent tube during Programmed Depot Maintenance (PDM) at Lake Charles Maintenance Modification Facility (LCMMF).

I find that three factors substantially contributed to the mishap. First, Floats and Fuel Cells Services (FFCS), a subcontractor to Northrop Grumman who performed fuel tank service to the number two tank during PDM, had ineffective tool control procedures. No evidence was found that FFCS was aware the mechanical plug was missing from their tool kit. Second, FFCS failed to follow technical order procedures which would have prevented them from inadvertently leaving the mechanical plug in place following fuel cell servicing. Specifically, they failed to attach a streamer to the mechanical test plug which would have highlighted the plug was still in place during reassembly and they failed to properly document the test plug was installed in their maintenance forms. Third, due to the relatively quick AR shortly after takeoff, the MC did not have a chance to burn a substantial amount of fuel from the number two fuel tank prior to AR which, if they had, would have allowed the dive valve to open and prevent a buildup of pressure during AR. Although this was a contributing factor, the MC followed proper techniques and procedures during AR and were not at fault. This last contributing factor explains why a similar mishap did not occur during ARs conducted between the time the MA left the PDM facility and the time of the mishap.

2. DISCUSSION OF OPINION

a. Cause

The mishap was caused by the mechanical test plug erroneously left in place inside the number two main fuel tank climb vent during PDM at LCMMF that allowed air pressure to build to a point where the tank ruptured and failed during AR. There is no warning system within the fleet's fuel tanks to let the crew know this hazardous condition existed so the MC had no way of knowing the tank was about to fail before it did. The MC followed proper techniques and procedures during the AR.

b. Contributing Factors

I find substantial evidence that FFCS, a subcontractor to Northrop Grumman who performed fuel tank service to the number two tank of the MA during PDM had ineffective tool control procedures. No evidence was found that FFC was aware the mechanical test plug was missing from their tool kit. Tool control at LCMMF is covered by LC-M-0501M, Prevention of Foreign Objects/Foreign Object Damage. It requires the accountability of all tools daily, at the beginning and end of each shift. FFCS performed desealing and sealing maintenance in the number two main tank. Form FFCS 100, Safety Checklist. Line 11 requires that the inspector check to "Ensure tools and equipment entering and leaving fuel tanks get documented on the Tool Inventory Sheet." There is no record of FFC Services mechanics taking any tools into the number two main tank as would be required for performing either for the repair or leak check.

I find substantial evidence that FFC failed to follow technical order (T.O.) procedures which would have prevented them from inadvertently leaving the mechanical plug in place following fuel cell service. The T.O. 1E-8C-12, Task 280090, Vent System Pressure Test Restoration, Step 5 requires the plug be removed from the tank vent. The task specifically requires that the 2 ½ inch plug be removed before the vent horn is reassembled. Also in T.O. 1-1-3 para 2.7.6.4 a yellow streamer that stats "Remove Before Refueling/Defueling" was not attached to aid in identification that a plug was in place.

I find substantial evidence the MC did not to burn a substantial amount of fuel from the number two fuel tank prior to aerial refueling (AR) which would have eventually allowed a secondary valve to open and prevent a buildup of pressure during AR. Given the fuel load at takeoff and the relatively small amount of fuel the MA burned during the short period between takeoff and AR, only fuel from the center tank was used until the MA was configured for AR where the MFE configured it burn fuel from the main wing tanks. Normal procedures are to burn center tank until drained unless fuel quantity adjustments needed to be made in the main or reserve tanks. Since takeoff fuel quantities in all wing tanks of the MA met AR criteria, no adjustments were necessary so burning only the center tank prior to AR is consistent with normal techniques and procedures for AR; therefore, the MC was not at fault. It does, however, explain why previous air refueling did not result in a mishap.

Tests of various components of the MA were ordered by the Safety Investigation Board. Test results made available to the AIB are discussed. Test results for some parts have not yet been reported but are not of such a nature as would affect my analysis or findings.

Whether these parts functioned as designed would not have prevented this mishap from occurring. Accordingly, I am able to complete this report and find by clear and convincing evidence that this mishap occurred solely as a result of the mechanical vent plug that was left in the climb vent.

RANDALL L. VOGEL, Colonel, USAF
President, Accident Investigation Board