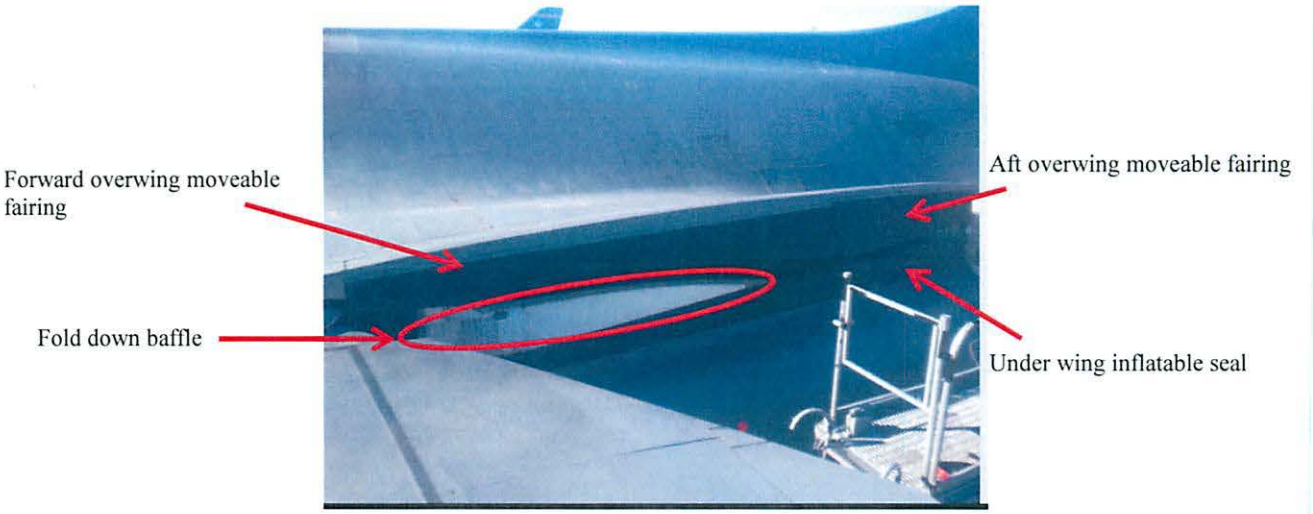


Figure 2. Side View of Left Overwing Fairing (Wing Forward).

During aft wing sweep, only the wing and the fold down baffle move inward into the overwing cavity (see Diagram 1). The overwing fairings house the 4.5-inch main fuel line, the 2-inch fuel cooling loop line, the fuel cooling blower, the overwing fairing fire detection loops, multiple aircraft wire harnesses, and hydraulic lines (Tabs J-38 to J-39 and J-47 to J-49; T.O. 1B-1B-2-27GS-00-1).

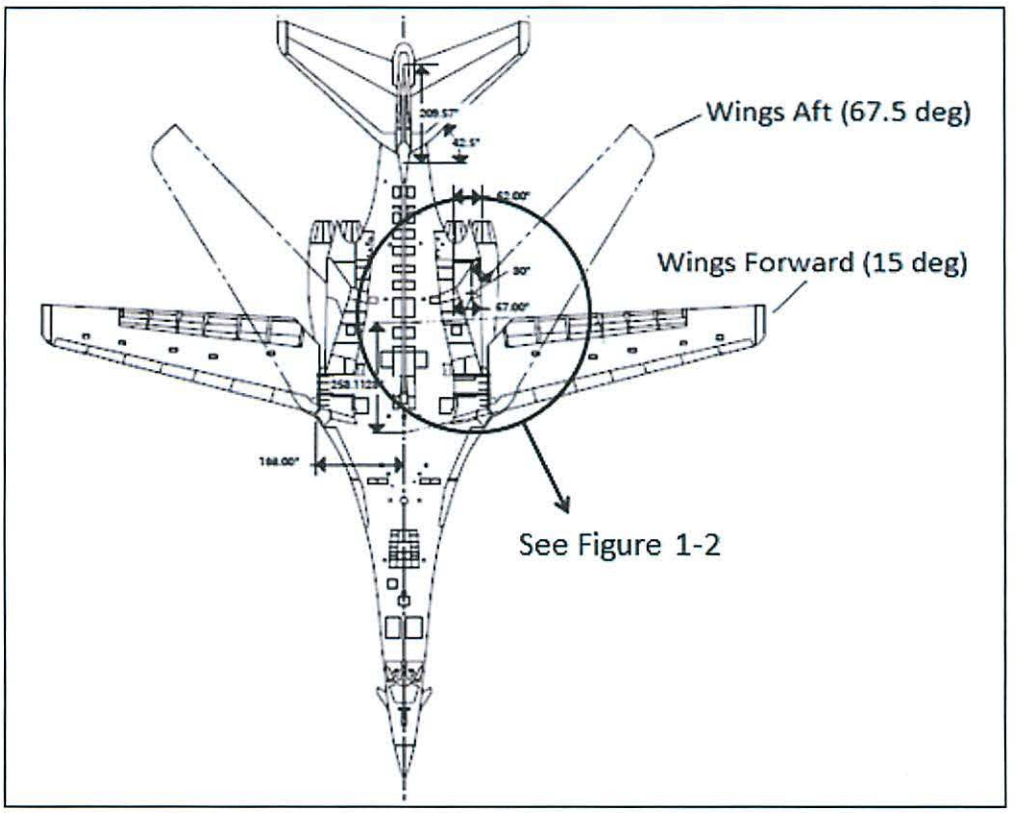
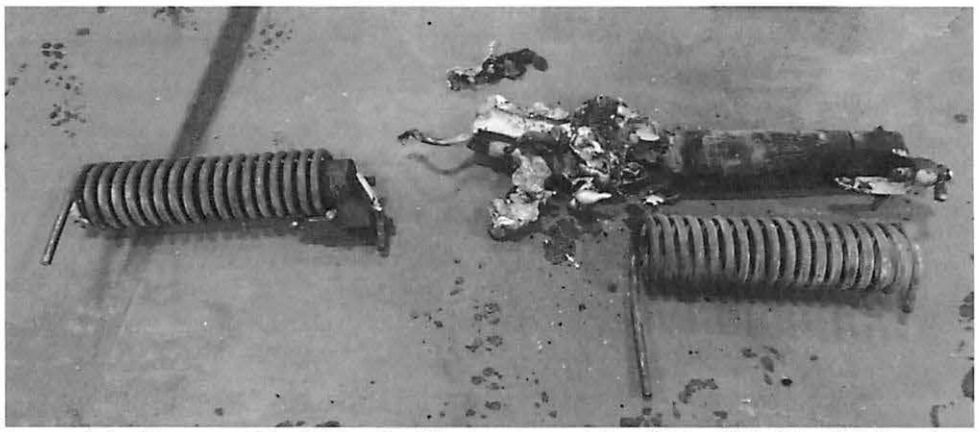


Diagram 1. B-1B Wing Sweep (Tab J-33).

The MA's left aft overwing fairing was found 17 miles north of the main impact site (see Site 7 of Figure 1) (Tab J-54 to J-55). It showed no signs of damage from inflight or ground fire (Tab J-77). As detailed below, a significant fuel leak developed in the left overwing fairing due to a puncture in the 4.5-inch main fuel line (Tab J-78). This leaking fuel detonated when it came into contact with a hot precooler duct, resulting in an over pressure condition in the left overwing fairing (Tab J-78 to J-80). The force from the over pressurization and wind stream caused the left aft overwing fairing to detach from the MA (Tab J-79).

The left forward and aft mandrel spring assemblies from the MA were severely damaged (see Photograph 1) (Tab GG-3 to GG-5).



Photograph 1. Recovered Left Mandrel Spring Assemblies (Tabs GG- 3 to GG-5 and Z-22).

(2) Aircraft Engines

The B-1B is powered by four F101-GE-102 engines attached to the nacelles just aft of the wing pivot (T.O. 1B-1B-2-70GS-00-1). Engine 1 and Engine 2 are located on the left side of the aircraft, while Engine 3 and Engine 4 are located on the right side of the aircraft (T.O. 1B-1B-2-70GS-00-1). The engines are augmented, mixed-flow turbofans, with low and high-pressure sections and a variable exhaust nozzle (T.O. 1B-1B-2-70GS-00-1). The engines produce 15,000 pounds of non-augmented thrust and 30,000 pounds of augmented thrust (T.O. 1B-1B-2-70GS-00-1).

None of the engines from the MA exhibited any evidence of in-flight mechanical or thermal non-containment (Tab J-11 and J-31). In addition, there was no evidence of uncommanded, non-recoverable engine shutdown during flight (Tab J-31). The fire damage found between Engine 1 and Engine 2 is consistent with an in-flight fire, originating *external* to the engines (Tab J-31). All other engine damage is consistent with ground impact and post-impact fire (Tab J-31). The location of the fire external to Engine 1 is marked in Figure 3.

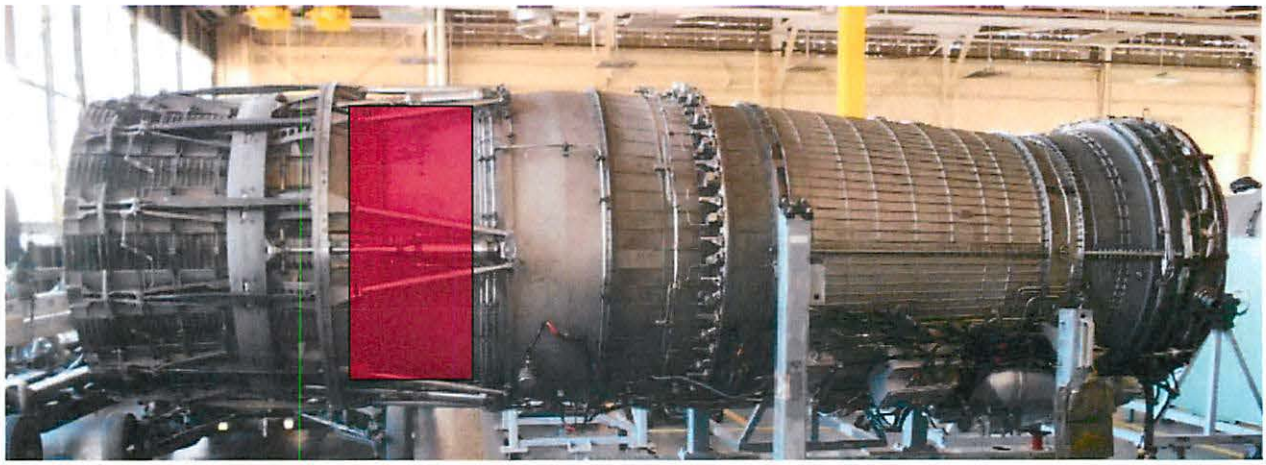


Figure 3. Location of Apparent In-flight Fire Outside of Engine 1 Highlighted in Red on Sample Engine (Tab J-32).

(3) Aircraft Fire Protection System

(a) Fire Detection

The fire detection system indicates overheat or fire conditions in any of the four engine bays, the left or right auxiliary power units, or the left or right overwing fairings (Tab J-47). The overwing fairing sensing elements will indicate a fire when the average element temperature is 350 to 450 degrees Fahrenheit (Tab J-48). The engine sensing elements will indicate a fire when the average element temperature is 1100 degrees Fahrenheit over a 4-inch section inside the engine nacelle (Tab J-48). Crewmembers are notified of a fire via fire warning lights located on the forward crew station center instrument panel (T.O. 1B-1B-2-26GS-00-1).

Shortly after the explosion in the left overwing fairing of the MA, the fire warning light illuminated in the cockpit (Tab V-2.8, V-3.7, V-3.13, and V-4.10). MP1 initiated in-flight emergency procedures IAW the T.O., while MP2 focused on flying the MA (Tab V-2.8, V-3.7, and V-4.10). A few seconds later, at 0914:33L, Engine 2 fire warning illuminated (Tabs J-67, V-1.7, V-1.12, V-3.8 to V-9, V-4.10 to V-4.11, and FF-5). The Engine 1 fire warning illuminated one second later (Tab V-1.8, V-1.12, V-3.8 to V-3.9, and V-4.10 to V-4.11).

(b) Fire Suppression

The B-1B has eight fire extinguishers—two located in each nacelle and two in each overwing fairing containing a fire suppressant agent (T.O. 1B-1B-2-26GS-00-1). All are part of an active fire protection system that provides high discharge rates through pressurization, short feed lines, and large agent container discharge valves (T.O. 1B-1B-2-26GS-00-1). When activated, 90 percent of the fire suppression agent will be discharged in less than one second (T.O. 1B-1B-2-26GS-00-1). The system is designed to operate in a closed environment by shutting fuel valves, air inlets, and exhaust doors, and then using a chemical suppressant to displace air, thereby extinguishing the fire by starving it of oxygen (T.O. 1B-1B-2-26GS-00-1).

Crewmembers arm the fire extinguishers by depressing the associated switch light on the fire warning panel in the cockpit and activate the system by movement of the agent discharge switch

(T.O. 1B-1B-2-26GS-00-1). When the fire suppression system in an overwing fairing is activated, the overwing fairing closes and the associated fuel shutoff valve shuts off, preventing the continued flow of fuel into the overwing fairing (T.O. 1B-1B-2-26GS-00-1).

Both the left nacelle and overwing fire suppression systems of the MA were found empty and damaged at Site 1 (Tab J-77). Analysis of the left overwing fire suppression system showed the main and reserve extinguishers were activated during flight (Tab J-77 to J-78). In addition, analysis of the main left nacelle fire suppression system shows it was activated during flight (Tab J-77 to J-78).

(4) Aircraft Fuel Subsystems

(a) Engine Feed

The engine feed system supplies fuel from the main fuel tanks to the engines (T.O. 1B-1B-2-28GS-00-1). Two boost pumps in each main fuel tank supply positive pressure flow to the cooling loop pump and the two engines on that tank's side of the aircraft (T.O. 1B-1B-2-28GS-00-1). The boost pumps from Tank 6—the main fuel tank—have a rate of 8,000 rotations per minute, with an output pressure of 10 pounds per square inch at 72,000 pounds per hour (T.O. 1B-1B-2-28GS-00-1). These pumps send fuel through the firewall shutoff valves into a 4.5-inch main fuel line that passes through the overwing fairing and connects to the engine feed lines (T.O. 1B-1B-2-28GS-00-1). Because fuel is pumped from the tank, a downstream fuel leak cannot be detected from inside the tank, where fuel quantity is monitored (T.O. 1B-1B-2-28GS-00-1).

The 4.5-inch main fuel line from the MA's left overwing fairing was recovered from the crash site and exhibited extensive damage (Tab J-108 to J-110). Specifically, the line had a v-shaped cut to the top half of the fuel line (Tab J-108 to J-110 and J-122). Analysis suggests the v-shaped cut resulted from impact from an external object (Tab J-109).

An analysis of fuel quantities and IDARS data determined that a fuel leak of approximately 820 pounds per minute (120 gallons) began at 0906:14L, shortly after MP2 began sweeping the wings (Tab J-67, J-78, and FF-4). The fuel leak continued at about the same rate for at least 8.5 minutes, at which time fuel quantity data became unreliable (Tab J-78).

A Suppression/Insulation/Migration (SIM) modification package was previously implemented on the B-1 B fleet (Tab J-47). It included the following: (1) an active fire suppression system in the overwing fairing cavity and bleed air precooler compartment; (2) additional fuel-resistant thermal insulation installed on the engine bleed air ducting, on the bleed air precooler and ancillary hardware, and around the suppression agent bottles and associated wiring; and (3) barriers on the top of the nacelle, which forms the floor of the overwing fairing cavity, and additional drain holes along the inboard boundary layer control walls (Tab J-47). The drain holes attempt to minimize the accumulation of spilled fuel on the top of the nacelle (Tab J-47). The barriers try to direct spilled fuel away from the precooler compartment cover to prevent leakage onto potential hot spots (Tab J-47). The SIM modifications proved ineffective in the MA due to the quantity of fuel that leaked into the left overwing fairing cavity (Tabs J-78 and J-80).

Aircraft fuel ignites at 437 degrees Fahrenheit (Tab J-80). Engine bleed air entering the precooler bay, which can be accessed through the overwing fairing, can exceed this temperature (Tab J-80). Fuel leaking from the 4.5-inch main fuel line in the left overwing fairing could leak into the precooler bay through gaps and seams in the plating above the precooler and ignite if the fuel comes into contact with the hot precooler duct (Tab J-79 to J-80). Unprotected ducting and exposed joints in the precooler bay were observed on the MA wreckage. Ignition of fuel in the precooler bay would likely result in an overpressure condition (Tab J-80).

Fire emanated from the left side of the MA (Tabs J-80, R-29, R-34 to R-35, R-37, R-39 to R-45, and V-4.11). In-flight fire damage was found on the engines, left aft nacelle, Tank 4 (aft portion of aircraft), and the left side of the horizontal stabilizer (Tabs J-74 to J-75 and Z-8 to Z-12).

(b) Fuel Tank Pressurization and Venting System

Pressure control and venting of internal fuel tanks occurs through a common vent line (T.O. 1B-1B-2-28GS-00-1). Overboard venting to accommodate for changes in altitude is controlled by the primary vent manifold in Tank 4 (T.O. 1B-1B-2-28GS-00-1). A valve controlled by engine bleed air senses tank and atmospheric pressure to maintain a safe pressure differential (T.O. 1B-1B-2-28GS-00-1). When the differential is within safe limits, the primary vent valve closes (T.O. 1B-1B-2-28GS-00-1). When pressure differential limits are exceeded, the climb and dive valves remove bleed air to the vent valve, enabling the vent valve to open and thus allowing tank pressure to return to tolerable limits (T.O. 1B-1B-2-28GS-00-1). Vent connections also provide air induction to the engine feed system and relief in the aerial refueling line (T.O. 1B-1B-2-28GS-00-1). The common manifold for Tanks 1 to 4 and Tank 6 have no valves or other obstructions connecting the tanks (Tab J-41).

The ruptured upper skin of Tank 2A, Tank 2B, and Tank 1D found at Site 5 (see Figure 4) indicate an in-flight overpressure condition in the fuel vent system (Tab J-80). Over 90 pieces of Tank 2A and Tank 2B were recovered at Site 5 (J-76). Site 5 is located just under 4.5 miles from the main impact site and approximately 12.5 miles from Site 7 where the left overwing fairing was located (Tab J-54). There was no evidence of ground fire at Site 5, and all of the recovered pieces were relatively clean, lacking any evidence of being involved in a typical hydrocarbon-fed in-flight fire (Tab J-56).

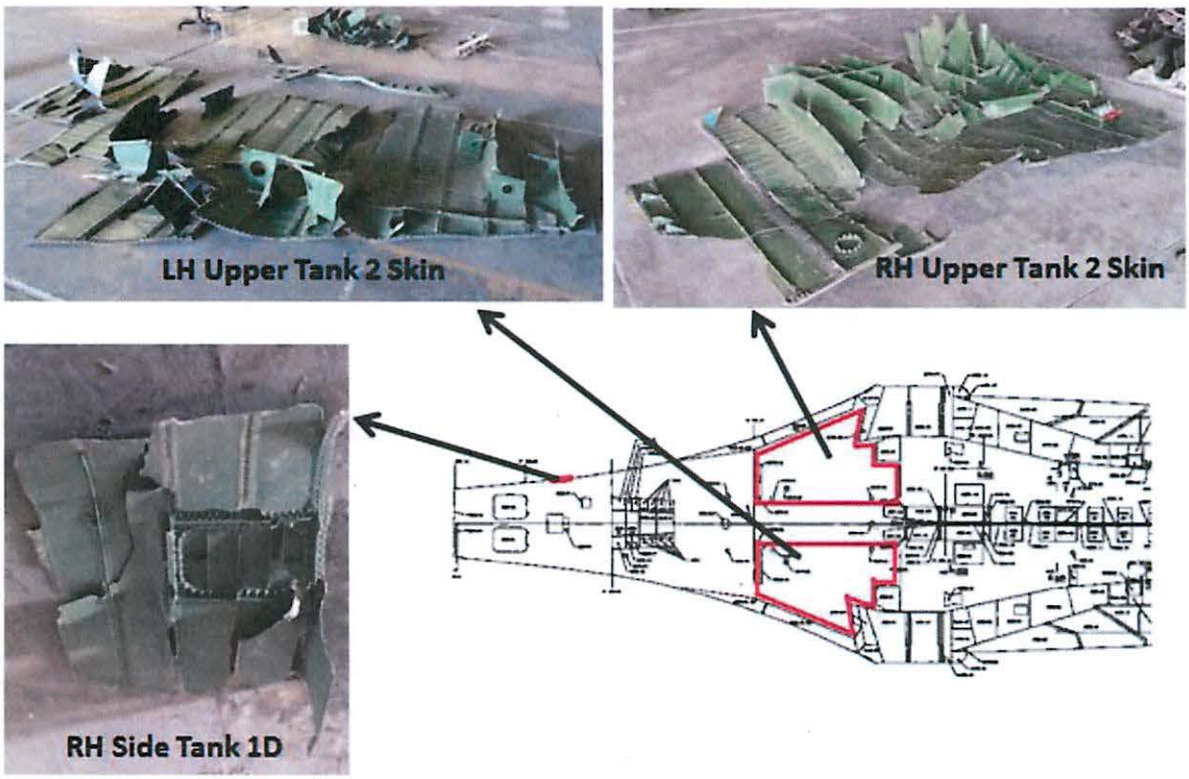


Figure 4. Debris from Tops of Tank 2A and Tank 2B (Tab J-57).

The MC heard a second explosion immediately prior to loss of electrical power, and approximately 1.5 minutes after the first explosion (Tab V-1.8 to V-1.9, V-2.7, V-3.9, V-3.13, and V-4.11). Given the type and condition of debris located at Site 5 and the distance between debris from Site 7 and Site 5, this second explosion was likely from an overpressure condition in Tank 1D, Tank 2A, and Tank 2B (Tab J-80).

(5) Electrical Power Supply Systems

The main electrical power supply comes from three primary alternating current (AC) generators (Generator 1, Generator 2, and Generator 4) (T.O. 1B-1B-2-24GS-00-1). The B-1B has one emergency generator. Under normal conditions, all three primary generators are online (T.O. 1B-1B-2-24GS-00-1). The emergency generator provides a backup source of power for the aircraft (T.O. 1B-1B-2-24GS-00-1). The electrical cables for distributing power to the crew compartment run along the tops of the fuel tanks (T.O. 1B-1B-1 and T.O. 1B-1B-2-24GS-00-1).

The three primary generators convert variable input power from the associated aircraft engine through an accessory drive gearbox (T.O. 1B-1B-2-24GS-00-1). During normal operation, each generator supplies 230 volts/115 kilovolt amperage (KVA) alternating current; the outputs are paralleled and synchronized to supply power to the five distribution buses (T.O. 1B-1B-2-24GS-00-1). Thus, when an engine is shutdown, the associated generator goes offline (T.O. 1B-1B-2-24GS-00-1). The emergency generator is hydraulically driven with an output of 15 KVA (T.O. 1B-1B-2-24GS-00-1).

For a detailed schematic of the electrical system, see Diagram 2.

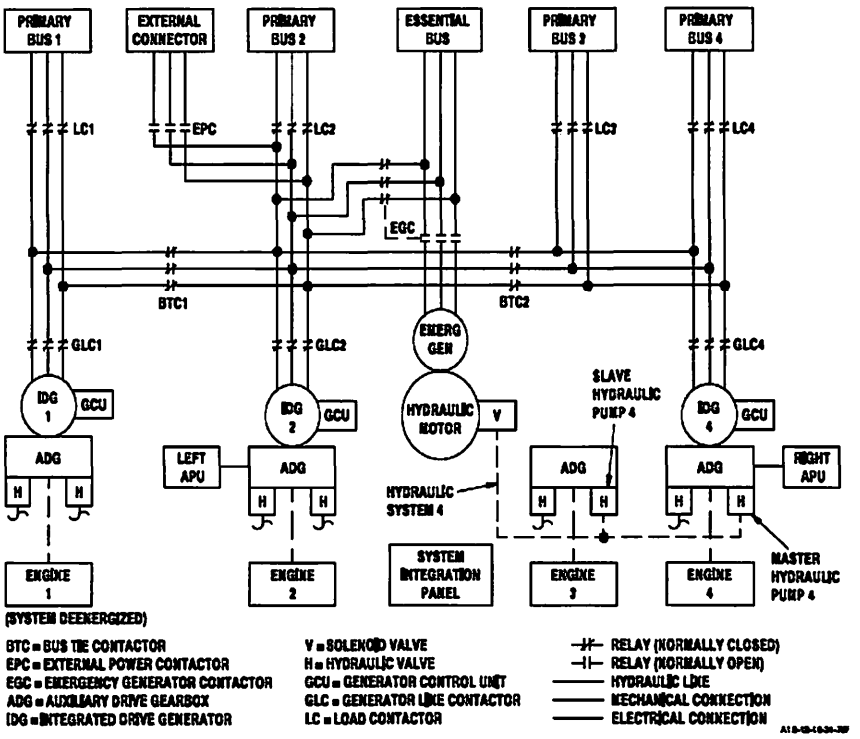


Diagram 2. AC Power Generation (T.O. 1B-1B-1).

After MP1 initiated procedures to address the fires in the left overwing fairing, Engine 1, and Engine 2, the number one and number two AC generators were rendered inoperative, leaving the MA to rely on the number four and emergency AC generators (Tabs J-67, V-3.8, V-3.12, and V-3.18; T.O. 1B-1B-1 and T.O. 1B-1B-2-24GS-00-1). The rupturing of the MA's fuel tanks resulted in the severing of the electrical cables running through the tops of the fuel tanks, causing a complete and permanent loss of electrical power in the crew compartment (Tabs V-1.8 to V-1.9, V-2.7, V-3.9, V-3.13, V-4.11, and FF-7; T.O. 1B-1B-2-24GS-00-1). The loss of electrical power degraded MP2's ability to control the MA (Tabs V-2.9, V-3.8 to V-3.9, and FF-3; T.O. 1B-1B-1 and T.O. 1B-1B-2-24GS-00-1).

(6) Integrated Data Acquisition Recorder System

IDARS is a compact, solid-state recording system used for collecting, processing, and storing a variety of flight data on the aircraft, including inputs from strain gages, accelerometers, flight control surface position conditioning units, and the central integrated test system. The data provides a time-history file stored in the IDARS until processed for analysis (Tab J-78).

The MA's IDARS data started at 00:00:08.906 and ends at 01:30:25.906 (Tab J-66). Overwing fairing fires are not recorded by IDARS (Tab J-78). Table 2 below is a summary of the information obtained from IDARS (Tab J-66 to J-67).

IDARS Time	Comments
01:10:50.906	Takeoff
01:11:48.906	Wings positioned forward (25 degrees)
01:20:07.906	Throttle back for descent
01:20:09.906	Begin wing sweep aft to 67.5 degrees
01:20:48.906	Wings full aft (greater than 65 degrees)
01:21:02.906	Military Power
01:25:53.906	Begin descent to low level
01:27:14.906	Arrived at low level (approximately 1,000 feet AGL)
01:28:42.906	Full afterburner on all four engines
01:28:51.906	Uncommanded left hand bank
01:28:55.906	Engines drop to intermediate power level
01:28:57.906	Begin climb
01:28:58.906	Engine 2 fire
01:28:59.906	Engine 1 and Engine 2 fire lights illuminate
01:29:10.906	Engine 3 and Engine 4 to maximum augmented thrust
01:29:29.906	Generator 2 offline
01:29:30.906	Fuel data becomes erratic
01:29:35.906	Engine 1 oil pressure low
01:29:40.906	Left hand turn to Ellsworth AFB, right wing begins sweeping forward
01:29:41.906	Generator 1 and Generator 2 offline
01:29:43.906	Hydraulic 2 low pressure
01:29:45.906	Engine 1 oil pressure low, Hydraulic 1 low pressure
01:29:47.906	Engine 2 oil pressure low
01:29:48.031	Lost wing sweep strain gauge (went invalid)
01:30:11.906	Right wing holds for a few seconds at 45 degrees
01:30:20.906	Right wing starts sweeping forward again
01:30:25.906	Last data recorded

Table 2. IDARS Information Summary (Tab J-66 to J-67).

b. Evaluation and Analysis

(1) Engine Investigation Report

All four engines were recovered from the crash site and sent for analysis at the Air Force Life Cycle Management Center at Tinker AFB, Oklahoma (Tab J-5 to J-30). Analysis results for each engine is as follows:

Engine 1. Engine 1 was operating at sub-idle speed at impact. Fire damage to Engine 1 indicated in-flight fire originating outside of the engine. All other damage to Engine 1 was

consistent with high-speed impact. The analysis revealed no in-flight mechanical problems (Tab J-5 to J-11).

Engine 2. Analysis revealed Engine 2 was operating at sub-idle speed at impact. Similar to Engine 1, fire damage to Engine 2 indicated in-flight fire originating outside of the engine. All other damage was consistent with high-speed impact. No evidence of in-flight mechanical problems was found (Tab J-11 to J-17).

Engine 3. Engine 3 was operating at idle to high-idle speed at impact. There was no indication of in-flight fire in or around Engine 3. The damage to Engine 3 is consistent with high-speed impact. The analysis revealed no in-flight mechanical problems (Tab J-17 to J-21).

Engine 4. Analysis showed Engine 4 operated near the intermediate power setting at impact. Similar to Engine 3, there was no sign of in-flight fire damage in or around Engine 4. The damage to Engine 4 was consistent with high-speed impact, and analysis did not reveal any in-flight mechanical issues (Tab J-21 to J-30).

Although the Engine 1 and Engine 2 warning lights came on during flight, analysis of the engines revealed that the fire was external to the engines and not a result of engine failure (Tabs J-31, J-67, V-1.7 to V-1.8, V-1.12, V-3.8 to V-3.9, and V-4.10 to V-4.11).

(2) Overwing Fairing Attachment Fractures Report

The left aft overwing fairing was recovered at Site 7, which was located 17 miles north of the main impact site (Tab J-54 to J-55). Analysis of the overwing fairing by the Air Force Research Laboratory at Wright-Patterson AFB, OH, revealed evidence of overload. However, the analysis failed to reveal any pre-existing defects (e.g., fatigue, corrosion) that would have compromised its ability to function properly (Tab J-86). It showed no signs of being involved in a fire, inflight or ground (Tab J-77).

At approximately 0914L, the MA experienced an initial explosion followed by an uncommanded left bank (Tabs J-67 to J-68, V-1.7, V-2.9, V-3.6 to V-3.7, V-3.13, V-4.7, and FF-5). Shortly after the explosion, the left overwing fairing fire light illuminated (Tab V-2.8, V-3.7 to V-3.8, V-3.13, and V-4.10). The uncommanded left bank likely resulted from the detonation of leaked fuel in the precooler bay, causing an overpressure condition that separated the left aft overwing fairing components (Tab J-79 to J-80). The combination of the over pressurization force and the wind stream caused the overwing fairing to detach from the aircraft (Tab J-79).

(3) Flexible Fuel Line Examination Report

The 2-inch fuel cooling loop line and 4.5-inch main fuel line (see Diagram 3) from the left wing root bay were submitted to the Air Force Research Laboratory at Wright-Patterson AFB, OH, for analysis (Tab J-107). The 2-inch fuel cooling loop line showed evidence of line collapse due to thermal exposure (Tab J-107 to J-108, J-113, and J-115). The 4.5-inch main fuel line showed multiple fractures and melting of the inner layers of the line, likely due to thermal exposure (Tab J-108 to J-109). In addition, the 4.5-inch main fuel line had a v-shaped cut (see Photograph 2) through the exterior braiding and into the inner layers of the line (Tab J-109).

This type of damage suggests the 4.5-inch main fuel line had been cut by impact with an external object (Tab J-109).

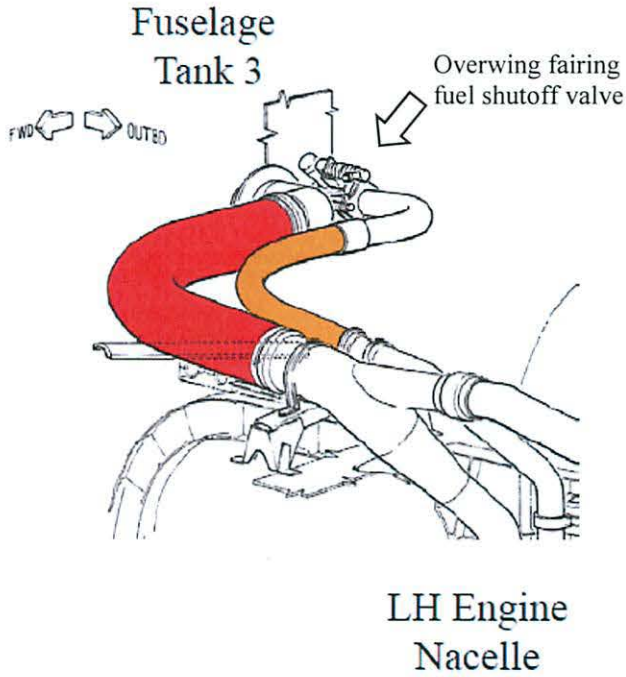


Diagram 3. Two-Inch Fuel Cooling Loop Line (Orange) and 4.5-Inch Main Fuel Line (Red) (Tab J-113).

Photograph 2. Damage to 4.5-Inch Main Fuel Line (Tab J-122).

7. WEATHER

a. Forecast Weather

On the day of the mishap, the forecasted weather for takeoff of the MA at Ellsworth AFB, SD, was clear skies, unlimited visibility, and winds variable at five knots (Tab F-3 to F-4). The forecast surface temperature was 73 degrees Fahrenheit, with a freezing level at 13,000 feet AGL (Tab F-3). The altimeter setting was 29.96 inches of mercury and pressure altitude was 3,239 feet MSL (Tab F-3).

The forecasted weather for the Powder River MOA for the date and time of the mishap was clear skies, unlimited visibility, and surface winds 160 degrees at seven knots (Tab F-3 and F-4). The freezing level was 15,000 feet MSL (Tab F-3 and F-4).

b. Observed Weather

Observed weather at the mishap location at the time of the mishap was clear skies, unrestricted visibility, surface winds 160 degrees at seven knots, and freezing level at 15,000 feet MSL (Tab F-5 and F-6). The MC did not report any weather conditions prior to the mishap.

c. Operations

The mission complied with weather requirements (AFI 11-202, Volume 3, *General Flight Rules*, dated 22 October 2010, ACC Supplement, 28 November 2012, paragraph 8.11 and Table 7.1; AFI 11-214, *Air Operations Rules and Procedures*, dated 14 August 2012, paragraph 4.2.7.2; and AFI 11-2B-1, Volume 3, *Flying Operations: B-1 Operations Procedures,* 7 January 2011, paragraph 7.10.2).

There was no evidence that weather contributed to the mishap.

8. CREW QUALIFICATIONS

a. Mishap Pilot 1

MP1 was a fully qualified B-1B Instructor Pilot (IP) and United States Air Force (USAF) Weapons School graduate (Tab G-105). MP1 was also an experienced flight lead in the B-1B (Tab G-103). With the exception of instrument approach, day and night air refueling, night landing, and terrain following at night or in instrument meteorological conditions, MP1 was current in all flight areas, IAW AFI 11-2B-1, Volume 1, *Flying Operations: B-1 Aircrew Training*, 23 December 2011, Table 4.1 (Tabs K-4 to K-5 and FF-3). MP1 completed his most recent instrument and mission qualification checkride in the B-1B on 29 March 12 (Tab G-63). MP1 completed graduation from the Air Force Weapons Instructor Course with outstanding performance on 1 June 2013 (Tab G-105). MP1 had 1,782.4 total flight hours and 1,567 B-1B flight hours (Tab G-4).

At the time of the mishap, MP1's recent flight times were as follows (Tab G-5):

	Hours	Sorties
Last 30 Days	0.0	0
Last 60 Days	4.2	2
Last 90 Days	4.2	2

Table 3. MP1's Flight Times (Tab G-5).

b. Mishap Pilot 2

MP2 was a qualified IP who was an experienced flight lead in the B-1B (Tab G-103). With the exception of unguided bomb hit and visual contour, MP2 was current in all flight areas, IAW AFI 11-2B-1, Volume 1, Table 4.1 (Tabs K-4 and FF-3). MP2 completed his most recent instrument and mission qualification checkride in the B-1B on 30 July 2012 (Tab G-72, G-75 and G-76). MP2 had 2,254.9 total flight hours and 2,013.1 B-1B flight hours (Tab G-20).

At the time of the mishap, MP2's recent flight times were as follows (Tab G-21):

	Hours	Sorties
Last 30 Days	24.2	2
Last 60 Days	97.5	9
Last 90 Days	186.7	16

Table 4. MP2's Flight Times (Tab G-21).

c. Mishap Crewmember 1

MC1 was a qualified Instructor Weapons System Officer (WSO) and USAF Weapons School graduate who was an experienced Multi-Ship Mission Lead in the B-1B (Tab G-104 and G-107). MC1 was current in all flight areas, IAW AFI 11-2B-1, Volume 1, Table 4.1 (Tabs K-5 and FF-3). MC1 completed his most recent mission qualification checkride in the B-1B on 9 August 2012 (Tab G-83 to G-85). MC2 had 1,872.3 total flight hours and 1,696.6 B-1B flight hours (Tab G-34).

At the time of the mishap, MC1's recent flight times were as follows (Tab G-35):

	Hours	Sorties
Last 30 Days	18.5	6
Last 60 Days	18.5	6
Last 90 Days	18.5	6

Table 5. MC1's Flight Times (Tab G-35).

d. Mishap Crewmember 2

MC2 was a qualified Instructor WSO who was an experienced Single-Ship Mission Lead (SML) in the B-1B (Tab G-104). With the exception of unguided bomb hit and Terrain Following, MC2

was current in all flight areas, IAW AFI 11-2B-1, Volume 1, Table 4.1 (Tabs T-5 and FF-3). MC2 completed his most recent qualification checkride in the B-1B on 22 October 2012 and mission qualification on 31 May 2013 (Tab G-92 to G-93 and G-96 to G-97). MC2 had 1,828.2 total flight hours and 1,651.6 B-1B flight hours (Tab G-49).

At the time of the mishap, MC2's recent flight times were as follows (Tab G-50):

	Hours	Sorties
Last 30 Days	25.6	2
Last 60 Days	97.8	8
Last 90 Days	221.6	19

Table 6. MC2's Flight Times (Tab G-50).

There was no evidence that insufficient crew qualifications contributed to the mishap.

9. MEDICAL

a. Qualifications

MP1, MP2, MC1, and MC2 were medically qualified for flight duty without restrictions at the time of the mishap. All mishap crewmembers had current annual flight physical examinations (Tab X-3 to X-5).

b. Health

All members of the MC were in good health and had no performance-limiting conditions or illnesses prior to the mishap (Tabs V-1.3, V-1.13, V-2.3, V-3.3, V-4.2 to V-4.3, and X-3 to X-5). The MC sustained injuries consistent with the mishap and were treated at local emergency rooms (Tabs V-1.9, V-2.10, V-3.15 to V-3.16, V-4.14 to V-4.15, and X-3 to X-5).

c. Toxicology

Toxicology tests were conducted on the MC and maintenance members following the mishap. The relevant results were within the Department of Defense limits or consistent with post-mishap treatment (Tab X-3 to X-5).

d. Lifestyle

No lifestyle factors were found to be relevant to the mishap.

e. Crew Rest and Crew Duty Time

Air Force crewmembers must have proper crew rest, as defined in AFI 11-202, Volume 3, *General Flight Rules*, 22 October 2010, ACC Supplement, 9 March 2012, prior to performing in-flight duties. Crew rest is defined in paragraph 9.4.5 and 9.8 as a minimum 12-hour non-duty period before the flight duty period (FDP) begins. Its purpose is to ensure crewmembers are

adequately rested before flight or performing flight related duties (paragraph 9.4.5 and 9.8). During this time, a crewmember may participate in meals, transportation, or rest, as long as he or she has the opportunity for at least eight hours of uninterrupted sleep (paragraph 9.4.5 and 9.8). MP1, MP2, MC1, and MC2 had adequate crew rest prior to the mishap (Tabs R-2 to R-11, V-1.3, V-2.3, V-3.3, V-4.3, and X-3 to X-5).

There was no evidence that medical issues contributed to the mishap.

10. OPERATIONS AND SUPERVISION

a. Operations

The 34 BS has a total of 41 assigned and attached pilots, 24 of whom are experienced (Tab G-103 and G-104). To be considered "experienced," B-1B pilots must meet an AFI mandated level of 1,500 total flight hours and 300 B-1B hours, 1,250 total flight hours and 500 B-1B hours, or 1,000 total flight hours and 750 B-1B hours (AFI 11-2B-1, Volume 1, Table 1.1). The 34 BS has thirty seven WSOs, 24 of whom are experienced (Tab G-103 and G-104). To be considered "experienced," B-1B WSOs must have 1,300 total flight hours and 200 B-1B hours, 1,000 total flight hours and 300 B-1B hours, or 750 total flight hours and 500 B-1B hours (AFI 11-2B-1, Volume 1, Table 1.1). Eighteen of the 41 pilots are qualified as instructors, and 21 of the 37 WSOs are instructors (Tab G-103 and G-104). The 34 BS recently returned from a deployment and had initiated post-deployment reconstitution training (Tab EE-3).

The Operational Risk Management (ORM) level of the mission was eight (Tab EE-5). ORM is a decision-making process to systematically evaluate possible courses of action, identify risks and benefits, and determine the best course of action for any given situation (Air Force Pamphlet 90-803, *Risk Management Guidelines and Tools: Special Management*, 11 February 2013, paragraph 1.1). A score of eight is in the lowest risk category and places the authority to continue the mission with the aircraft commander or flight lead (Tab EE-5 and EE-7). Specific items considered in the ORM assessment included: (1) non-current crewmembers, (2) days since last low altitude flown, (3) days since last flight, (4) mission profile type, (5) defensive maneuvering, and (6) bird condition (Tab EE-5). The operations supervisor on duty was experienced and qualified, IAW the 34 BS Letter of Certification (Tab G-103).

The operations tempo at the time of the mishap was low (Tab G-21, G-35, and G-50).

b. Supervision

The 34 BS Director of Operations reviewed and authorized the mission on the day of the mishap (Tab K-13). In addition, the Commander and Director of Operations for 34 BS attended the mission brief on 16 August 2013 because the mishap mission was the first squadron flight since returning from deployment (TabV-1.4 to V-1.6, V-2.4, V-3.4 to V3.5, and V-4.3). Squadron supervision briefed the MC immediately prior to the MC's departure to the MA on 19 August 2013 (Tabs V-1.5 to V-1.6, V-2.4, V-4.4, and EE-21 to EE-29).

There was no evidence that squadron operations or supervision contributed to the mishap.

11. HUMAN FACTORS

There was no evidence that human factors contributed to the mishap.

12. GOVERNING DIRECTIVES AND PUBLICATIONS

a. Publically Available Directives and Publications Relevant to the Mishap

(1) AFI 11-2B-1 Volume 1, *Flying Operations: B-1 Aircrew Training*, 23 December 2011
(2) AFI 11-2B-1, Volume 3, *Flying Operations: B-1 Operations Procedures,* 7 January 2011
(3) AFI 11-202, Volume 3, *General Flight Rules*, 22 October 2010, Air Combat Command Supplement, 9 March 2012
(4) AFI 11-214, *Air Operations Rules and Procedures*, 14 August 2012
(5) AFI 21-101, *Aircraft and Equipment Maintenance Management*, 26 July 2010, incorporating Change 1, 16 August 2011, including Air Force Guidance Memorandum 4, 19 April 2013
(6) AFI 36-2232, *Maintenance Training*, 22 February 2006
(7) AFI 51-503, *Aerospace Accident Investigations*, 26 May 2010, Incorporating Change 1, 21 June 2010
(8) AFI 51-503, *Aerospace Accident Investigations*, 26 May 2010, Air Combat Command Supplement, 5 September 2013
(9) Air Force Pamphlet 90-803, *Risk Management Guidelines and Tools: Special Management*, 11 February 2013
(10) T.O. 00-5-15, *Air Force Time Compliance Technical Order Process*
(11) T.O. 00-20-1, *Aerospace Equipment Maintenance Inspection, Documentation, Policies, and Procedures*

NOTICE: All directives and publications listed above are available digitally on the Air Force Departmental Publishing Office website at http://www.e-publishing.af.mil.

b. Other Directives and Publications Relevant to the Mishap

The following T.O.s are not publically available and are subject to the Arms Export Control Act of 1976.

(1) T.O. 1B-1B-1, *USAF Series B-1 Aircraft*
(2) T.O. 00-20-1, *Aerospace Equipment Maintenance Inspection, Documentation, Policies, and Procedures*
(3) T.O. 00-5-1, *AF Technical Order System*
(4) T.O. 1B-1B-2-24GS-00-1 and T.O. 1B-1B-2-24GS-00-2, *Electrical Power*
(5) T.O. 1B-1B-2-26GS-00-1, *Fire Protection*
(6) T.O. 1B-1B-2-27GS-00-1, *Flight Controls*
(7) T.O. 1B-1B-2-28GS-00-1, *Fuel*
(8) T.O. 1B-1B-2-53GS-00-1, *Fuselage*
(9) T.O. 1B-1B-2-54GS-00-1, *Nacelles/Pylons*
(10) T.O. 1B-1B-2-70GS-00-1, *Propulsion*

(11) T.O. 1B-1B-6, *Scheduled Inspection and Maintenance Requirements*

c. Known or Suspected Deviations from Directives or Publications

There were no known or suspected deviations from directives or publications.

13. ADDITIONAL AREAS OF CONCERN

There were no additional areas of concern.

22 November 2013

BRIAN A. HUMPHREY, Colonel, USAF
President, Accident Investigation Board

STATEMENT OF OPINION

B-1B, Tail Number 85-0091
Broadus, Montana
19 August 2013

Under 10 U.S.C. § 2254(d) the opinion of the accident investigator as to the cause of, or the factors contributing to, the accident set forth in the accident investigation report, if any, 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

I find by clear and convincing evidence that a displaced fold down baffle in the left overwing fairing caused the mishap. The underwing fairing fold down baffle became detached for an unknown reason at one or more points sometime prior to the initiation of an aft wing sweep. During the sweep, the wing pushed the detached fold down baffle into the 4.5-inch main fuel line, resulting in a v-shaped cut to the top half of the fuel line. The leaking fuel ignited and caused multiple catastrophic detonations throughout the aircraft.

I developed my opinion by analyzing factual data from Air Force directives and guidance, engineering technical analysis, witness testimony, flight data, flight simulations, animated simulations, technical analysis of post-crash aircraft components, and information provided by subject matter experts.

2. BACKGROUND

On 19 August 2013 at 0856:50L hours the mishap aircraft (MA), a B-1B,Tail Number 85-0091, assigned to the 34th Bomb Squadron, 28th Bomb Wing, Ellsworth Air Force Base (AFB), and containing four crewmembers, departed Ellsworth AFB on a training mission.

Following takeoff, Mishap Pilot 2 (MP2) leveled off at an initial altitude of 20,000 feet (Flight Level 200), and the mishap crew (MC) performed a level off check to ensure normal aircraft system performance. At 0905:42L, MP2 initiated a descent to 10,000 feet Mean Sea Level and swept the wings from the forward to the aft position. During this wing sweep, the MA developed a fuel leak in the 4.5-inch main fuel line found in the left overwing fairing cavity. Due to the location of the fuel leak and the duration of the sortie, the MC could not detect the fuel leak. Approximately 7,000 pounds (1,000 gallons) of fuel leaked into the overwing fairing while the MC continued their training mission.

At 0914:26L, the leaking fuel migrated through seams in the precooler bay access panels and detonated following contact with exposed portions of a hot precooler duct. The MC perceived the detonation as a loud noise from the left hand side of the MA. The detonation caused an uncommanded left bank of approximately 15 degrees. The left overwing fire light illuminated in

the cockpit. Ignited fuel streamed down the left side of the MA, extending one to two times the length and four times the width of the MA.

MP2 pulled the throttles back to an intermediate power setting, and Mishap Pilot 1 (MP1) activated the main left overwing fairing fire suppression system. The left overwing fire light remained illuminated. Thirty seconds after the first attempt to extinguish the fire, MP1 activated the reserve fire suppression system. MP1's efforts to extinguish the fire failed for two reasons: (1) the fire suppression agent was no longer being discharged into a closed system (the high velocity airflow entering the exposed overwing fairing prevented the fire suppression chemicals from being effective), and (2) the fire had extended beyond the reach of the fire suppression system, trailing down the side of the MA.

Two engine fire lights also illuminated in the cockpit. However, the fire lights were not the result of engine fire but, instead, were activated in response to the intense heat generated by ignited fuel streaming near the engines. Following MP1's attempts to extinguish the apparent fire in Engine 1, the fire light went out for unknown reasons. The Engine 2 fire light remained illuminated.

The ignited fuel streaming down the left side of the MA heated fuel Tank 4, located in the aft portion of the MA, to a temperature that exceeded 437 degrees Fahrenheit, the temperature at which jet fuel will automatically ignite. As MP2 began a climbing left turn to execute an emergency return to Ellsworth AFB, the fuel tank detonated, resulting in an overpressure condition that propagated through the MA fuel venting system. This initiated a cascade of catastrophic detonations in additional MA fuel tanks. The explosions severed the electrical cables, cut power to the crew compartment and severely degraded MP2's ability to control the MA. With no options left to remedy the situation, and with marginal control over the MA, MP1 ordered the crew to eject.

The forward fuselage separated from the MA due to compromised structural integrity resulting from the multiple fuel tank explosions. The forward fuselage came to rest embedded in a ravine wall approximately 0.5 miles from the aft portion of the fuselage. The aft fuselage impacted 24 miles east of Broadus, Montana.

3. CAUSE

The wings of the B-1B move from a forward position to an aft position to increase the aircraft's performance at different speeds. During a wing sweep, the only moving parts in the overwing fairing cavity are the wing and the fold down baffle. The wing normally sweeps clear of the fuel lines located in the overwing fairing cavity, and I found no evidence to suggest that the wing of the MA came in contact with the fuel line. The fold down baffle helps provide a smooth surface for air to pass over the wing. During an aft wing sweep, the fold down baffle folds flat, allowing the wing to sweep over the top.

At some time prior to MP2's initiation of the wing sweep, the left fold down baffle became detached at one or more points, preventing it from folding as the wing swept aft. Because the fold down baffle was detached, the wing pushed the fold down baffle into the overwing fairing

cavity where the tapered edge of the fold down baffle cut a v-shaped hole in the 4.5-inch main fuel line.

I considered whether the left underwing fold down baffle may have detached due to the failure of the forward mandrel spring assembly, as a possible substantially contributing factor but could not so conclude. The fold down baffle attaches to the underwing fairing at four points. Mandrel spring assemblies (forward and aft) form two of the attachment points, providing the pressure necessary to push the fold down baffle into place as the wings sweep. A forward and an aft mandrel spring assembly recovered at the crash site are consistent in form and fit with those found in the left overwing fairing cavity. Both assemblies showed evidence of structural overload, along with significant damage from exposure to fire. Of note, the forward mandrel spring assembly was missing the spring component, the interior tube was gouged and crushed, and the sheared forward mounting plate was co-mingled with a mass of melted aluminum. Thus, the cause and timing of the detachment of the left fold down baffle remains unknown.

Despite minor documentation irregularities, I found no evidence that maintenance personnel, practices, or procedures substantially contributed to the mishap. My review of the MA's maintenance records showed that all inspections of the MA were completed in accordance with technical orders. My interviews with maintenance members who worked on the MA immediately prior to takeoff on 19 August 2013 and during the last major inspection on 19 March 2013 did not reveal any issues related to the cause of the mishap.

In addition, I found no evidence that the MC caused, could have prevented, or substantially contributed to the loss of the MA. My interviews of the MC and review of information from the Integrated Data Acquisition Recorder System showed that the MC responded appropriately to the known conditions on the MA.

4. CONCLUSION

I find by clear and convincing evidence that a displaced fold down baffle in the left overwing fairing cavity caused the mishap.

22 November 2013

BRIAN A. HUMPHREY, Colonel, USAF
President, Accident Investigation Board

INDEX OF TABS