UNITED STATES AIR FORCE

AIRCRAFT ACCIDENT INVESTIGATION

BOARD REPORT

B-52H, T/N 60-0047

69TH EXPEDITIONARY BOMB SQUADRON

5TH BOMB WING

ANDERSEN AIR FORCE BASE, GUAM

LOCATION: DEPARTURE END OF RUNWAY 06L, ANDERSEN AIR FORCE BASE, GUAM

DATE OF ACCIDENT: 19 MAY 2016

BOARD PRESIDENT: COLONEL EDWARD F. MARTIGNETTI

CONDUCTED IAW AIR FORCE INSTRUCTION 51-503

EXECUTIVE SUMMARY

AIRCRAFT ACCIDENT INVESTIGATION

B-52H, T/N 60-0047

DEPARTURE END RWY 06L, ANDERSEN AFB, GUAM

19 MAY 2016

On 19 May 2016, at 0832 hours local time (L), a B-52H, tail number 60-0047 [Mishap Aircraft (MA)], assigned to the 69th Expeditionary Bomb Squadron, 5th Bomb Wing, Andersen Air Force Base, Guam, departed the prepared-surface overrun of Runway 06 Left (RWY 06L) during a high-speed, heavy-weight, aborted takeoff. The Mishap Crew (MC), which consisted of the Mishap Pilot (MP), Mishap Co-Pilot (MCP), Mishap Radar Navigator (MRN), Mishap Navigator (MN), Mishap Electronic Warfare Officer (MEW), an augment pilot occupying the Mishap Gunner (MG) station, and an Instructor Weapon System Officer occupying the Mishap Instructor Pilot (MIP) jump seat, were conducting a Higher Headquarters Directed mission. The MC were treated for minor injuries consistent with a ground egress. The MA sustained total damage with a loss valued at $112M. There was no damage to private property.

The MC were cleared for takeoff at 0831L. The MA accelerated within performance standards verified by takeoff and landing data calculated performance for S_1 timing and S_1 decision speed. Approximately three to five seconds after reaching the S_1 speed of 111 knots, the MP, MCP, and MN observed birds in front of the MA at wing level. Shortly thereafter, the MP and MCP observed engine indications for numbers 5, 6, and 7 "quickly spooling back" from the required takeoff setting. The MP also observed high oil pressure indications on the number 8 engine and a noticeable left-to-right yawing motion. Accelerating through approximately 142 knots, the MP simultaneously announced and initiated aborted takeoff emergency procedures. With the throttles set to idle thrust and airbrakes set to six, the MP initiated continuous braking pressure. The MCP deployed the drag chute at 135 knots. The drag chute failed to inflate properly. At 2,500 feet runway remaining, the MP shut off the outboard engines (numbers 1/2 and 7/8). Shortly thereafter, the MP announced the MA and MC were going to depart the prepared surface. The MEW jettisoned the defensive compartment, starboard-side hatch and the MP shut off the inboard engines (numbers 3/4 and 5/6). The MA departed the prepared surface shearing the main landing gear. The MA finally came to a rest slightly canted from runway centerline, right wing down approximately 300 feet from the runway, and subsequently caught on fire. The MC performed emergency aircraft shutdown procedures and safely egressed the MA through the MEW hatch.

The Accident Investigation Board (AIB) President found by a preponderance of the evidence the cause of the mishap was the MP analyzed visual bird activity and perceived cockpit indications as a loss of symmetric engine thrust required to safely attain flight and subsequently applied abort procedures after S_1 timing. The AIB President also found by a preponderance of the evidence the following factors substantially contributed to the mishap: drag chute failure on deployment and exceeding brake-energy limits resulting in brake failure.

SUMMARY OF FACTS AND STATEMENT OF OPINION

B-52H, T/N 60-0047

19 JULY 2016

TABLE OF CONTENTS

COMMONLY USED ACRONYMS AND ABBREVIATIONS

BPO	Basic Post Flight
AAFB	Andersen Air Force Base
AFB	Air Force Base
AFGSC	Air Force Global Strike Command
AFI	Air Force Instruction
AFTO	Air Force Technical Order
BW	Bomb Wing
CBP	Continuous Bomber Presence
EAMXS	Expeditionary Aircraft Maintenance Squadron
EBS	Expeditionary Bomb Squadron
EPR	Engine Pressure Ratio
ER	Exceptional Release
EVS	Electro-Optical Viewing System
GPS	Global Positioning System
IAW	In Accordance With
IMDS	Integrated Maintenance Data System
KIAS	Knots Indicated Airspeed
L	Local
MA	Mishap Aircraft
MC	Mishap Crew
MCP	Mishap Copilot
MEW	Mishap Electronic Warfare Officer
MG	Mishap Gunner
MIP	Mishap Instructor Pilot
MN	Mishap Navigator
MP	Mishap Pilot
MPC	Mishap Preflight Crew
MRN	Mishap Radar Navigator
MSDC	Minimum Speed for Directional Control
NOTAMS	Notice to Airmen
PDM	Post Depot Maintenance
PPP	Pacific Power Projection
PR	Pre-Flight
TC	Team Chief
TCTO	Time Compliance Technical Orders
TOLD	Takeoff and Landing Data
USPACOM	United States Pacific Command
WST	Weapons System Trainer

1. AUTHORITY AND PURPOSE

a. Authority

On 31 May 2016, Major General Michael E. Fortney, Vice Commander, Air Force Global Strike Command (AFGSC), appointed Colonel Edward F. Martignetti to conduct an aircraft accident investigation of the 19 May 2016 mishap of a B-52H aircraft, tail number (T/N) 60-0047, which occurred at Andersen Air Force Base (AAFB), Guam (Tab Y-3 to Y-4). The aircraft accident investigation convened at AAFB, Guam, from 21 June 2016 through 15 July 2016. After receiving technical analysis and mechanical testing from the Air Force Research Laboratory and the Air Force Life Cycle Management Center, the accident investigation re-convened at Barksdale Air Force Base, Louisiana (BAFB) from 11 October 2016 through 21 October 2016. The following appointed board members were present: Lieutenant Colonel Legal Advisor, Major Pilot Member, Captain Pilot Member, Captain Medical Member, Senior Master Sergeant Maintenance Member, Master Sergeant Recorder, and Technical Sergeant Recorder (Tab Y-5 to Y-9).

b. Purpose

In accordance with (IAW) Air Force Instruction (AFI) 51-503, *Aerospace Accident Investigations*, dated 14 April 2015, AFGSC Supplement dated 23 September 2015, this accident investigation board conducted a legal investigation to inquire into all the facts and circumstances surrounding this Air Force aerospace accident, prepare a publicly releasable report, and obtain and preserve all available evidence for use in litigation, claims, disciplinary action, and adverse administrative action (Tab Y-10 to Y-11).

2. ACCIDENT SUMMARY

Figure 1. MA after mishap (Tab Z-3).

On 19 May 2016, at 0832 hours local time (L), a B-52H, tail number 60-0047 [Mishap Aircraft (MA)], assigned to the 69th Expeditionary Bomb Squadron (69 EBS), 5th Bomb Wing (5 BW), Andersen Air Force Base (AAFB), Guam, departed the prepared-surface overrun of Runway 06 Left (RWY 06L) during a high-speed, heavy-weight, aborted takeoff. The Mishap Crew (MC), which consisted of the Mishap Pilot (MP), Mishap Co-Pilot (MCP), Mishap Radar Navigator (MRN), Mishap Navigator (MN), Mishap Electronic Warfare Officer (MEW), an augment pilot occupying the Mishap Gunner (MG) station, and an Instructor Weapon System Officer occupying the Mishap Instructor Pilot (MIP) jump seat (Tab AA-12), were conducting a Higher Headquarters-Directed mission (Tab V-1.3). The MC were treated for minor injuries consistent with the mishap (Tab X-3). The MA sustained total damage with loss valued at approximately $112M. Airfield instrument and approach lighting damage was approximately $1.5M (Tab P-4). There was no damage to private property (Tab P-3).

3. BACKGROUND

The MA was assigned to 5 BW at Minot AFB, ND. The MC was assigned to 69 EBS at AAFB, Guam and conducting Continuous Bomber Presence (CBP) missions under the operational control of U.S. Pacific Command (Tab CC-19).

a. Air Force Global Strike Command (AFGSC)

Air Force Global Strike Command is a major command headquartered at Barksdale Air Force Base, Louisiana, in the Shreveport-Bossier City community. AFGSC is responsible for the nation's three intercontinental ballistic missile wings; the Air Force's entire bomber force, to include B-52, B-1, and B-2 wings; the Long Range Strike Bomber program; and operational and maintenance support to organizations within the nuclear enterprise (Tab CC-3 to CC-7).

b. Eighth Air Force (8 AF)

Eighth Air Force is a Numbered Air Force (NAF) with headquarters at Barksdale AFB, Louisiana, and is responsible for the nation's five bomber wings. Eighth Air Force headquarters has dual responsibilities to AFGSC and United States Strategic Command (USSTRATCOM). As the bomber NAF for AFGSC, 8 AF is responsible for operating and maintaining the AF's bomber force. Designated as USSTRATCOM's Task Force 204, 8 AF provides on-alert, combat-ready bombers to the President (Tab CC-8 to CC-10).

c. Fifth Bomb Wing (5 BW)

The Fifth Bomb Wing is the host wing at Minot AFB, ND, and operates the B-52H Stratofortress aircraft to provide global strike and combat-support capabilities to geographic combatant commanders. The mission of the 5 BW is to defend the United States with safe, secure and effective bombers in support of the President; assure allies with global bomber presence; and deter adversaries with global precision strike anytime, anywhere (Tab CC-11 to CC-14).

d. 69th Expeditionary Bomb Squadron (69 EBS)

The 69 EBS is deployed from Minot AFB to Andersen AFB to support the United States Pacific Command Continuous Bomber Presence (CBP) in order to assure allies and deter adversaries in the Asia-Pacific region. This strategic deterrence mission serves as a visible reminder to allies, partners, and adversaries that the United States is committed to the region and ready to act on a moment's notice. CBP missions from Guam offer persistent, long-range strike capability through expanded loiter times while limiting stress on aircraft and aircrew (Tab CC-19 to CC-20).

e. B-52H – Stratofortress

The B-52 Stratofortress is a long-range, subsonic, jet-powered strategic bomber. The B-52 was designed and built by Boeing, which continues to provide support and upgrades. It has been operated by the United States Air Force (USAF) since the 1950s. The bomber is capable of carrying up to 70,000 pounds of weapons, and has a typical combat range of more than 8,800 miles without aerial refueling (Tab CC-15 to CC-17).

The USAF continues to rely on the B-52 because it remains an effective and economical heavy bomber, particularly in the type of missions that have been conducted since the end of the Cold War in the absence of sophisticated air defenses. The B-52 has the capacity to loiter for extended periods, and can deliver precision standoff and direct-fire munitions from a distance, in addition to direct bombing (Tab CC-15 to CC-17).

f. Bird Hazard Working Group/Bird Aircraft Strike Hazard/Bird Watch Condition

Aircraft collisions with birds and other wildlife annually cause millions of dollars in aircraft damage and may result in loss of aircraft and aircrews (Tab BB-44). However, the 36th Wing (36 WG) reduces these losses through an active Air Force Bird/Wildlife Aircraft Strike Hazard (BASH) reduction program, the Bird Hazard Working Group (BHWG), and the Bird Watch Condition (BWC) (Tabs V-12.1 to V-12.2 and FF-7 to FF-10).

As outlined in AFI 91-202, *The US Air Force Mishap Prevention Program*, BASH is broken into Phase I and II based on periods of historic wildlife activity. Phase I represents normal, baseline wildlife activity. Phase II represents times of significant increases in local wildlife activity, normally associated with migratory movements, seasonal increases of local wildlife populations, or local land use practices (farming, ranching, or hunting) (Tab BB-46). In addition, Bird Watch Conditions (BWC) is used to increase or decrease awareness for aircrew based on real-time observations. BWC is broken in categories of Low, Moderate, and Severe (Tab BB-45 to BB-46), and is based on observations of local airfield wildlife activity by the Supervisor of Flying (SOF) (Tabs BB-45 and V-7.3).

Observed activity is defined as follows: Low--Wildlife activity on and around the airfield representing low potential for strikes (Tab BB-46); Moderate--Wildlife activity near the active runway or other specific location representing increased potential for strikes (Tab BB-45); and Severe--Wildlife activity on or immediately above the active runway or other specific location representing high potential for strikes (Tab BB-45). BWC Moderate requires increased vigilance by all agencies and supervisors along with caution by aircrews. Supervision and aircrews must evaluate mission need before conducting operations in areas under severe conditions (Tab BB-45). Of note, condition “Severe” or “Moderate” requires action from the installation’s wildlife dispersal team to reduce the BWC to “Low” as soon as possible (Tab BB-45). However, even the most effective techniques for dispersing wildlife from the aerodrome cannot promise long term results or a wildlife-free airfield, especially when considering bird activity (Tab BB-45).

Local conditions that enhance the potential for wildlife/aircraft strikes vary at each installation. The required time and effort necessary to maintain a safe aerodrome will depend upon the severity of the wildlife strike hazard. Although wildlife strikes can never be eliminated, an aggressive, well-planned program developed on the basis of wildlife habits, the environment, and the base mission may limit the potential for these strikes to occur (Tab BB-44).

The 36 WG BASH plans identify local conditions on the airfield attractive to birds, cite measures to reduce these attractions, outline bird dispersal procedures, and specify BWC codes during flying operations (Tab FF-7 to FF-10).

Figure 2: Dove on Runway

The 36 WG BHWG meets in accordance with AFI 91-202 and assists the safety office in drafting and implementing the BASH Plan. Applicable topics covered are: observed and reported bird activity across the aerodrome; airfield bird inspections and surveys; recovered bird remains; bird strikes; and habitat management, which includes dispersal and depredation; migratory patterns; and effectiveness of the program (Tab FF-7 to FF-10). For a more effective program, this information is compiled over several years, both day and night (Tab FF-11). Figure 2 is a single dove recovered on the runway post-mishap. No other bird or wildlife remains were recovered.

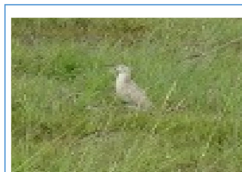

Figure 3: Single Yellow Bittern

At the time of the mishap, Andersen AFB was in BASH Phase 1 and the BWC code was “Low” (Tabs FF-11 and V-7.3). BASH Phase 1 is a period where migratory bird movement patterns historically decrease (Tab BB-46). This phase was effective 1 April 2016 to 31 July 2016 (Tab W-7). The BASH plan specifically identifies multiple species of “migratory birds” often permanently residing on Guam. These species include the Pacific Golden Plover, Yellow Bittern, Island Collared Dove, and Cattle Egret (Tab W-7). BWC code “Low” defines bird activity on and around the airfield as representing a low potential for strikes (Tab BB-46). Flight restrictions, if any, are implemented through BWC during BASH phase 1. The Supervisor of Flying is responsible for establishing and maintaining BWC during normal operations (Tabs BB-45 and V-7.3). Bird activity near the active runway did not represent an increased potential for strikes and did not require an increase to the BWC (Tab V-7.3 to V-7.4).

Testimony revealed the BWC at Andersen AFB only increases to “Moderate” a handful of times throughout the year and for only short durations (Tab V-2.5, V-5.6, V-6.6, V-7.4 and V-13.9). The environmental modifications and active control measures (though dispersal and depredation) reduce wildlife hazards on the airfield (Tab W-10 to W-11, W-15 and W-19). Problem areas are identified and resolved and flying operations are altered with BWC to reduce the risk of bird strikes. (Tabs FF-7 to FF-10 and BB-45). The 36 WG harassment techniques include noise-producing devices, depredation and other methods for effective dispersal (Tab FF-8). Through a seven-year bird-strike analysis at Andersen AFB, the majority of strikes occur during daylight hours (Tab FF-8). Between FY13 and FY15, aircraft operating at AAFB experienced an increase in strikes from six in FY13 to 18 in FY14 and 15 in FY15. This increase in bird strikes directly correlates to the increase in mission ops tempo and a decrease in the number of brown tree snakes caught (Tab FF-8).

The BHWG also identified BASH areas of concern on the airfield. Of those noted are small and varying areas throughout the airfield that contain overgrown grass and weeds in violation of AFI 91-202 (Tab FF-10 and W-12). Specifically, all grass heights in the airfield are required to be maintained at 7-14 inches in height (Tab BB-46). Mowing operations are conducted by civilian personnel as employees of the Navy assigned to the civil engineering squadron (CES). The “grounds” workforce consists of 19 civilians. Of the 19, seven work the airfield daily as the number one priority for mowing operations. They are capable of mowing for only six hours on average since they are also responsible for 34 other priorities which include: the munitions area, the base perimeter, fuel storage area, dog kennels, all the health and safety grass heights on main base, requests in preparation for Distinguished Visitors, as well as other 36 WG requests (Tab W-47)

The BHWG implemented a three-phased approach to address these areas of concern. The first one is currently implemented to identify areas in violation requiring attention and notifying the airfield mowers of those locations. The second, short-term objective is to pursue a waiver to cut grass well below the 7” minimum requirement to prevent weed seeding. This will be followed by an overspray of weed control targeting the over-abundant weed population throughout the airfield. The final, long-term objective is to implement weed control measures until only grass persists on the airfield to then revert back to the 7-14” grass height requirement (Tab FF-10).

Figure 4 displays an area near runway 06L where grass management, though not considered contributory, did contain small areas in violation of AFI 91-202 requiring attention with regard to mowing operations (Tab FF-10, W-12 and W-29). Though the investigation cannot correlate scheduled mowing and grass-height deviations directly to the mishap, post mishap investigation revealed a single, Yellow Bittern nest just off the right side of runway 06L (Figure 4).

Figure 4: Bird Nest Near Runway 06L

4. SEQUENCE OF EVENTS

a. Mission

The mishap mission was planned as a Higher Headquarters-Directed sortie (Tab V-1.1). The MA, call sign MACHO 11, was scheduled to take off at 0830L (Tab AA-6).

b. Planning

As a Higher Headquarters-Directed sortie for deployed B-52H units, the flight was planned using a squadron mission-planning cell. This cell is responsible for creating the MC's mission materials, to include forecast weather, takeoff and landing data (TOLD), airfield notices, weapons documents, and other materials (Tab V-1.2 and V-2.1 to V-2.2). For this mission, the MCP served on the mission-planning cell and created the TOLD for the MC (Tab V-2.2). The MCP received the forecast weather, aircraft configuration, and airfield status (Tab V-2.3). Due to runway rubber removal operations, the normal takeoff runway for heavy-weight aircraft at AAFB, RWY 06R, was closed (Tab V-1.4 and V-2.4). RWY 06L was planned as the active runway (Tab V-1.4). Since RWY 06L is 655 feet shorter in length than RWY 06R, the gross weight of the aircraft was reduced to a 270,000 pound fuel load instead of 290,000 pounds of fuel (Tab V-2.3). This reduction in fuel reduced the aircraft gross weight by 20,000 pounds to account for the shorter runway length. Heavy-weight takeoff procedures are used at aircraft gross weights in excess of 450,000 pounds (Tab BB-50). The MA gross weight at takeoff was approximately 465,000 pounds (Tabs AA-7 and R-9). The TOLD was calculated for an RCR of 23 and 9. RCR is the runway condition reading and a measure of the runway braking action. An RCR of 23 represents a dry runway, whereas an RCR of 9 represents a wet runway (Tab BB-51). Due to the unique bowl shape of AAFB's runways, there are special adjustment charts provided to B-52H aircrews to account for the non-standard runway grade (Tab V-2.2). Based on the supplied information, TOLD was calculated for this mission to include the supplemental adjustments for AAFB (Tab AA-7 and AA-8).

After the creation of products and prior to the sortie, the team chief (TC) briefed the particulars of the mission to the MC (Tab V-1.2 to V-1.3). The MC and Mission Preflight Crew (MPC) received this pre-takeoff brief (PTOB) the day prior to the mishap (Tabs V-1.3 and R-92). The MP, as the Aircraft Commander, conducted the crew briefing in accordance with AFIs and local guidance (Tab V-1.3 to V-1.4). Takeoff and landing data was reviewed but takeoff procedures were not specifically covered, as the 69 EBS was flying "hard crews." This is standard for most sorties while deployed because the same basic crewmembers are present for each flight (Tabs V-1.4, V-1.9, R-37, and R-81). Prior to beginning operations on the island, the MP conducted a thorough briefing on standard sortie events, such as ground operations, takeoff procedures, air refueling and landing procedures. In this manner, these routine items are briefed as "standard" and atypical items on individual sorties are covered in more detail (Tabs V-1.3, V-1.19, V-2.4, V-3.2, V-4.2, V-5.2, and R-37). Though the TOLD calculated numbers may vary, crew actions and takeoff procedures do not vary from 50 knots through S_1 and to S_2 and as such, may be briefed as standard (Tab BB-21 to BB-23).

c. Preflight

On the day of the mishap, the MPC reported for duty, received a briefing from the operations supervisor, and were issued the minimal paperwork required for engine start (Tab V-8.2). The MC reported for duty to 69 EBS and received a weather brief, a pre-flight brief from the operations supervisor, and reviewed all flight and ground currencies necessary to safely complete the planned flight. NOTAMS (Notice to Airmen), airfield status, and bird-watch-condition status ("Low") were also briefed to the MC (Tabs V-1.4, V-2.4, R-59, and R-83). Preflight on the aircraft was normal, with a few minor exceptions. First, it was noted during engine start that several engines were slow to reach idle RPM. While not within prescribed tolerances, this is not uncommon, and after a few minutes, the engine indications returned to normal without maintenance actions (Tab V-8.3 to V-8.4). Additionally, the aircraft navigation model would not accept Global Positioning System (GPS) information (Tab R-51, R-55, R-92, and R-151). At this point in the preflight sequence, the MPC briefed the oncoming MC on the jet status and transferred aircraft control to the MC. The MC concluded GPS was not required for this mission (Tab R-8 and R-55). As required per procedure, the TOLD was reviewed during the taxi to the active runway by the MP, MCP, MRN, and MN (Tab V-1.9 to V-1.10). The TOLD calculated during mission planning was comparable to observed conditions to be used for this flight as the temperature, humidity, pressure altitude, and winds were similar to forecast conditions (Tabs FF-4, FF-6, and V-1.4). The aircraft was within weight and balance limitations (Tab AA-7). The runway was dry (Tabs AA-3 to AA-4, and V-2.4).

d. Summary of Accident

At 08:29.06 MACHO11 contacted the tower ready for an immediate takeoff (Tab N-3). Tower then cleared MACHO11 to line up and wait (Tabs N-3 and R-55). "Line up and wait" is clearance for the aircraft to proceed onto the runway and assume a takeoff position, but is not clearance to take off (Tabs V-1.6, R-8, R-31, R-55, and R-75). As the MA taxied onto the runway, required takeoff checks were completed up to advancing the throttles for takeoff (Tabs V-1.6, R-8, R-51, R-55, and R-75). At 08:30.44, Andersen AFB Tower cleared MACHO11 flight for takeoff, which was acknowledged by the MP. Shortly thereafter the MA began the takeoff roll (Tabs N-3 and R-55).

The B-52H uses an S_1, S_2 method for determining takeoff performance. The S_1, S_2 system is an acceleration monitor system to check actual aircraft acceleration compared against a precomputed acceleration rate taken from a charted value prior to takeoff. S_1 speed is the computed decision speed which must be reached by the termination of the acceleration check time (S_1 time). S_1 time will determine the decision to takeoff or abort. After the expiration of S_1 time, if the aircraft indicated airspeed is at or above the calculated S_1 speed, the acceleration check is valid and the aircraft should be able to accelerate to the calculated S_2 speed and become airborne. S_2 is the calculated takeoff speed referred to as "unstick" (Tab BB-20).

Additionally, the emergency procedures section of the technical order charts the minimum speed for directional control (V_{MCA}), defined as the speed at which a constant heading can be maintained with full rudder deflection and one-half lateral control authority with all the operative engines at a given amount of thrust. Only one-half lateral control authority is used in order to allow some reserve for maneuvering, gust loads, and dynamic conditions (Tab BB-27). TOLD computes V_{MCA} for 2-engines out, same side, should the emergency arise (Tab AA-7 and AA-10).

The calculated S_1 speed for the mission was 111 KIAS (Knots Indicated Airspeed); the calculated S_1 time was 16.0 seconds. The calculated S_2 (unstick) speed was 158 KIAS. The computed V_{MCA} was 164 KIAS for 2-engines out (same side). These calculations were based on the aircraft gross weight, and the weather and runway conditions. (Tabs AA-3 to AA-4 and AA-7). [The AIB computed the 3-engine out (same side) V_{MCA} of 194 KIAS for these conditions (Tabs AA-10 and BB-28).]

The MP and MCP advanced throttles to the thrust gate shortly after being cleared for takeoff (Tabs V-1.6, V-2.6, R-55, R-75, R-92, and R-121). The thrust gate is a tool used by aircrew to initially position the throttles for takeoff (Tab V-2.6). For this aircraft gross weight and, given the runway and weather conditions, the thrust gate was set to takeoff-rated thrust (TRT) (Tab AA-7 and AA-9). TRT is the maximum thrust rating for B-52 takeoff procedures (Tab BB-26). As takeoff roll commenced, the MCP ensured the aircraft engines were producing the required thrust by verifying each engine was set to the determined Engine Pressure Ratio (EPR) Value of 1.67--viewed at the top of each "engine stack" (Tabs V-2.6, R-55, R-76, and BB-52).

Figure 5. Engine Stack

At approximately 50 KIAS the MN announced over interphone "Airspeed." As the aircraft approached 60 KIAS, the MP announced over interphone "70 knots," and when the aircraft reached 70 KIAS, stated "Now." The MN then replied "Nav is timing." The aircraft continued to accelerate down the runway until 16.0 seconds after the beginning of S_1 timing, at which point the MN announced "Coming up on S_1 timing…Now." (Tabs V-1.6, V-1.10, R-8, R-55, R-75, R-92, and R121)

At S_1 time, the pilot flying the aircraft checks aircraft airspeed and announces to the crew the decision to take off or the decision to abort based on this time-speed relationship (Tab BB-23).

At this point in the takeoff sequence, the MP reviewed his airspeed and engine instruments and determined that the aircraft was meeting the acceleration requirements and announced to the crew "Committed. Your throttles." (Tabs V-1.6, V-2.6, R-51, R-55, and R-75) The MCP then advanced the throttle friction lever to prevent the throttles from moving (Tabs V-1.10, V-2.7, R-55, and R-76 to R-77). About one to two seconds later, the MN saw birds traversing his Electro-Optical Viewing System screen (EVS – a forward facing camera under the nose of the B-52) and announced "Birds" over the interphone (Tabs V-4.4, R-8 to R-9, R-51, R-55, R-75, R-92, and R-121). About the same time, the MP observed "a small flock of birds" moving from left to right in his window at approximate wing level and announced "Birds" while the MCP observed "a handful of birds" moving right to left in his window (Tabs V-1.6, V-2.7, R-4, R-8, R-31, R-51, R-55, R-75, and R-83). The MCP then heard/felt a "couple of thuds" that sounded like something hitting the aircraft (Tabs V-2.7, R-51, R-55, R-75, R-78, R-84, and R-89). The MP then scanned the engine instruments and noted engine indications for #5, #6, and #7 were "quickly spooling back" while also observing the #8 engine oil pressure "spiked" out of the normal pressure range (Tabs

V-1.6, R-4, R-9, and R-31). The MCP also perceived engine indications for #5, #6, and #7 "start[ing] to roll back…starting to go down to zero like the engines were failing" but did not check the oil pressure gauges (Tabs V-2.7, R-51, R-55, R-75, R-77, R-84, and R-89).

"Quickly spooling back" and "Starting to roll back" refer to apparent loss of engine thrust. The MA simultaneous indications were the EPR gauge value decreasing below the takeoff setting of 1.67 and a decrease in the High Speed Rotor (N2) rotations per minute (RPM) on engines #5, #6, and #7 (Tabs V-1.6, V-2.7, R-4, R-9, R-31, R-51, R-55, R-75, and R-77). The MP reported the #5, #6, and #7 EPR needles rolled back towards 1.2 "which is kind of like the cutoff where we don't see anything … we lose data at that point." (Tab R-34) The lowest marked indicator on the round-dial EPR gauges is 1.2 which is where the "needle" rests in a power-off configuration (Tab BB-52).

Additionally, for the B-52H, if oil pressure exceeds the maximum limit on a TF-33 engine, technical order procedures direct the pilot to shut down the engine unless its thrust is necessary to maintain flight. This procedure should be accomplished at the first indication of oil system malfunctions to forestall engine seizure as long as possible (Tabs BB-5).

The MP analyzed visual bird activity correlated with these resultant engine indications as three engines had either failed or, at a minimum, were producing sub-optimal thrust (Tabs V-1.8 and R-9). Associated with these indications was an aircraft yawing motion to the right, which required left rudder to maintain runway centerline (Tabs V-1.15, V-1.18, R-9, and R-38). The bird activity, the engine indicator readings, and the yawing motion of the aircraft, corroborated to the MP that the MA was not producing the required thrust on at least three engines (#5, #6, and #7) (Tab V-1.18). The high oil pressure indicated to the MP an impending engine failure (#8) (Tab BB-5).

Assessing a lack of symmetric thrust, the MP was convinced he could not achieve enough airspeed to safely get airborne and egress all crew members (Tabs V-1.12, R-14, R-31, and R-44). The MP based his opinion on the fact that the MIP was not sitting in an ejection seat which increases the required altitude for bailout from 250 feet above the ground to 500 feet above the ground (Tabs BB-35 and R-34). Additionally, the MP considered the "unstick" speed for the remaining engines at takeoff-rated thrust and the associated asymmetric thrust from the apparent loss of engines #5, #6, and #7 (Tab R-9 and R-14). The MP simultaneously announced and initiated the takeoff abort and noted the airspeed approached "about 142 knots." (Tab V-1.6, R-55, R-75, R-92, R-97, R-121, and R-148) The time lapse from suspecting three-engine failure to applying abort procedures was only a few seconds (Tabs V-1.12, R-33, and R-80). When the MP reduced all throttles to idle thrust, the MP sensed the MA yawing motion ceased and runway centerline was subsequently maintained (Tabs V-1.18 and R-9).

According to the B-52H flight manual, the abort is accomplished by placing the throttles to idle thrust, selecting airbrakes six (this spoils the lift produced by the wings and places more weight onto the wheels of the aircraft, increasing braking effectiveness), releasing the drag chute (a large parachute that deploys behind the aircraft to aid in deceleration) in the appropriate airspeed zone (70-135 KIAS), and applying wheel brakes (Tab BB-32).

Passing Taxiway Golf (Tabs V-1.11 and R-33) (see Figure 6), the MP applied the abort procedures by selecting idle thrust on all eight engines and raising the airbrake lever to position six (Tabs V-1.6, V-1.16, R-9, R-31, R-51, and R-55). The MP then called for the drag chute; however the MP realized that the aircraft was above the maximum drag chute airspeed of 135 KIAS and placed his hand behind the drag chute lever to prevent deployment. The MP accomplished these steps in the abort procedures while simultaneously applying brake pressure in one, continuous application (Tabs V-1.7, V-1.16, R-12, R-31, R-55 and R-75).

The MP applied brakes immediately because, even though "the brakes were going to be hot…going to be in the danger zone," the MP "didn't delay braking because the [MA] was already high speed and further down the runway than the [MC] wanted and the best chance for stopping the [MA] was to get the chute out." (Tab R-35)

As the MA decelerated below 135 KIAS, the MCP deployed the drag chute (Tabs V-1.6, R-9, R-31, R-51, R-55 and R-75). Shortly thereafter, the Supervisor of Flying announced over the radio, "Streamer." (Tabs V-7.5, R-9, R-31, R-51, R-55, R-75, R-148, and R-151) This was to indicate to the MC--who could not see the drag chute--that it did not function as designed and did not inflate properly (Tabs V-7.5, V-1.6, R-51 to R-52, and R-151). Eyewitness testimony reveals the drag chute inflated, then immediately ruptured to what is characterized as a "parachute streamer." (Tab V-7.5 and V-9.2)

As the aircraft continued to decelerate, it continued down the runway. The MIP started announcing to the MP and MCP the distance remaining on the runway, starting with the 3 board (which indicates there are 3000 feet remaining of runway surface, not including the 1000 feet of paved overrun) (Tabs V-6.4, R-9, R-55, R-75, R-92, R-148, and R-151). At about the 2 board, the MP realized the aircraft would not stop within the remaining runway and announced to the MC they were going to depart the prepared surface (Tabs V-1.7, R-9, R-31, R-55, R-75, R-92, and R-121). In accordance with technical order procedures for departing a prepared surface (Tab BB-31), the MP began shutting down engines beginning with numbers 1, 2, 7, and 8 (Tabs V-1.7, R-31, R-58, and R-79). Additionally, at this point the MIP called "hatches, hatches, hatches." (Tabs V-1.7, V-6.4, R-32, R-55, R-75, R-92, R-121, and R-151) This is the call for the MEW and MG to actuate an explosive charge that removes the hatches in the defensive compartment. This provides two locations for the crew to egress the aircraft if the plane is to settle into the terrain, as the crew entry hatch is located underneath the fuselage (Tab BB-31). The MEW then removed the number 6 pin (a safety mechanism to prevent inadvertent hatch actuation) and pulled the handle (Tabs V-5.5, R-135, and R-148). The hatch functioned as designed and departed the aircraft resulting in the sole location for emergency egress (Tabs V-5.5 and R-134).

The aircraft continued down the runway and decelerated, but was unable to stop on the remaining runway or the paved overrun. As the aircraft was about to depart the prepared surface, the MP shut down the remaining engines, numbered 3, 4, 5, and 6, prior to exiting the overrun (Tabs V-1.7, R-9, R-36, and R-79).

The MA departed the prepared surface at the departure end of RWY 06L overrun (Tabs V-1.7, R-9, R-93). The MA slid approximately 300 feet, impacting a concrete slab approximately 200 feet from the end of the runway, which sheared a portion of the main landing gear from the aircraft (Tabs S-6 and R-56). The right main tip gear also sheared from the aircraft. The MA came to rest in an upright position, slightly right wing low and caught fire (Figure 1).

After the MA came to rest, the MP activated the abandon light (Tabs V-1.7, R-10, and R-32). The MCP then completed the remaining items on the emergency exit checklist (Tabs V-1.7 and R-10), and the MC evacuated the MA through the MEW hatch (Tabs V-1.7 and R-10). The MEW lowered the escape rope (Tab R-135) and was the first person out of the aircraft (Tab V-5.5). The MP was the last person out of the aircraft (Tabs V-1.7, R-14, R-93, R-148, and R-152). The MC gathered approximately 2000 feet from the aircraft (Tabs V-1.7 and V-1.8).

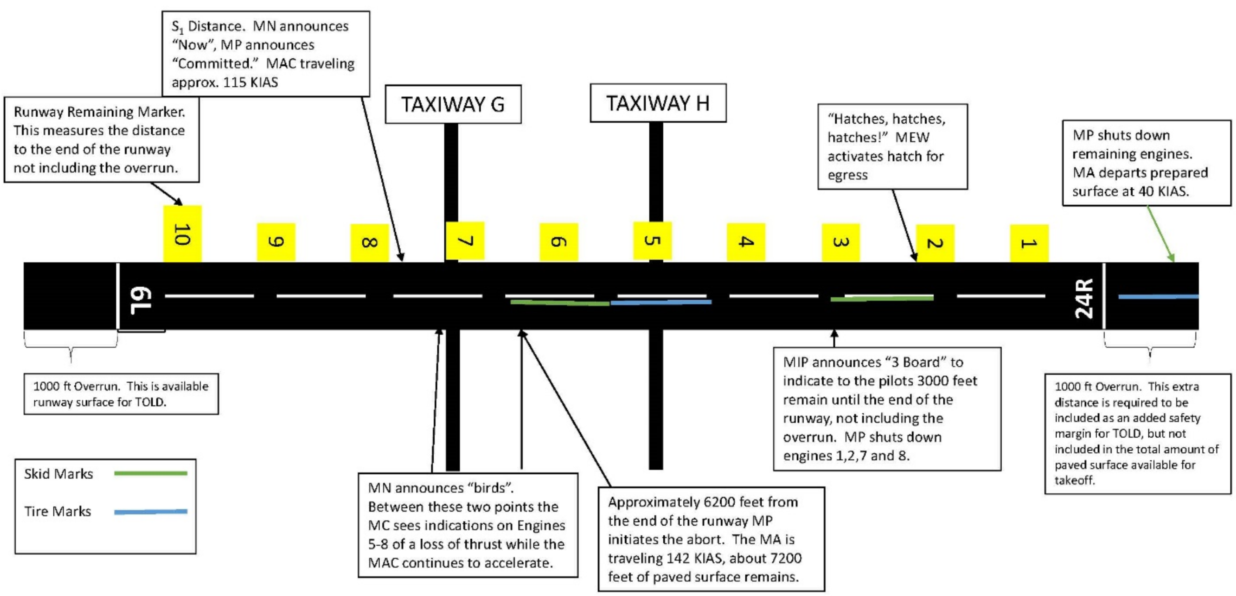

Figure 6: Mishap Sequence of Events

<u>Performance Analysis</u>

High-fidelity data is not available to the Accident Investigation Board due to the B-52H not having any data recording devices installed, such as a crash-survivable data recorder. The absence of available data led the board to use the B-52 Weapons System Trainer (WST) as a tool to evaluate the MA performance through different scenarios, including the abort above S_1 speed. Based upon witness testimony and gathered evidence, the simulator was able to replicate a similar configuration, fuel weight and environmental settings from the day of the mishap. The WST can also replicate such emergencies as engine failures, compressor stalls, or high oil pressure. Because it was not determined at the time of the simulation if the engines had failed entirely or were producing partial thrust, compressor stalls were used to simulate a partial thrust condition. Again, without a data recorder it is impossible to exactly replicate this mishap. The WST scenarios validated several facts to the accident board, which will be discussed after each simulation is described (Tab EE-3 to EE-4).

Three specific scenarios were accomplished in the WST. The first scenario validated the TOLD used by the MC, with an abort occurring at S_1 time and the aircraft at 115 KIAS. No malfunctions were simulated in this scenario. Using the standard emergency procedures described above, the aircraft was stopped approximately 3,200 feet from the end of the runway, not including the 1000 foot paved overrun (Tab EE-3 to EE-4).

The second scenario was used to gather data and verify the testimony from the MC. Compressor stalls were input into the system at approximately 135 KIAS to replicate the MC testimony. The aircraft was then allowed to accelerate to 142 KIAS to replicate the day of the mishap. At this point in the simulation, the aircraft had approximately 6200 feet of runway remaining plus approximately 1000 feet of paved overrun (Tab EE-3 to EE-4). The abort procedures where then executed two times, once with a good drag chute deployment, and once without deploying the drag chute. Brakes were applied in one, smooth application to maximum effort and not changed until the aircraft stopped or departed the prepared surface, as described by the MP (Tab V-1.7). With the drag chute deployed at approximately 135 KIAS, the aircraft stopped prior to entering the overrun. Without the drag chute, the aircraft departed the prepared surface at 50 KIAS. This scenario corroborated to the board that with a failed drag chute, the aircraft could not be stopped on the remaining prepared surface, while a good drag chute may have allowed the MC to stop in the remaining runway (Tab EE-3 to EE-4).

The final scenario involved a continued takeoff with engines #5, #6, and #7 failed. In the WST, the engine failure simulates a complete loss of thrust. With the engines failed, the aircraft became more difficult to control due to the asymmetric thrust. To compensate, the instructor pilots were able to firewall engine four and reduce thrust on engines one and two. This resulted in a liftoff at the minimum speed for directional control (V_{MCA}) approximately 1500 feet from the end of the runway (not including the overrun). The term “firewall” refers to advancing the throttle to its most forward throttle position, creating an amount of thrust beyond TRT. The engine power on numbers 1 and 2 was reduced to minimize the asymmetric thrust condition and make it easier for the instructor pilots to maintain directional control. Differential throttle settings is a technique to maintain directional control, not specifically discussed in the flight manual; however reducing asymmetric thrust is a recommended technical order procedure (Tab BB-34). Gear was immediately retracted and resulted in a climb rate of slightly over 500 feet per minute up to 1500 feet above the ground where this portion of the scenario was terminated. The instructor pilot simulator crew, who prepared for this specific situation, demonstrated the aircraft could safely climb to a minimum safe altitude. This scenario showed the board it may be possible to fly the aircraft with a complete loss of thrust in engines 5, 6, and 7. It did not provide any data on engine number 8 failing (Tab EE-3 to EE-4).

e. Impact

The MA departed the prepared surface at the departure end of RWY 06L overrun (Tabs V-1.17, R-9, R-93). The MA slid approximately 300 feet, impacting a concrete slab approximately 200 feet from the end of the runway, which sheared a portion of the main landing gear from the aircraft (Tabs S-6 and R-56). The right main tip gear also sheared from the aircraft. The MA came to rest in an upright position, slightly right wing low and caught fire in the area of the forward gear wheel well underneath the fuselage (Tab R-93 and Figure 1).

f. Egress and Aircrew Flight Equipment

After the MA came to a complete stop, the MP activated the abandon light (Tabs V-1.7, R-10, and R-32). The MCP then completed the remaining items on the emergency exit checklist (Tabs V-1.7, R-10, R-56, R-75, and R-85), and the MC evacuated the aircraft through the MEW hatch (Tabs V-1.7 and R-10). The MEW was the first person out of the aircraft and lowered the escape rope (Tab V-5.5). The MP was the last person out of the aircraft and counted seven individuals (including himself) running towards the fence line (Tabs V-1.7, R-10, and R-14). Shortly thereafter, the MC were taken by ambulance to the base clinic for evaluation (Tab X-3).

g. Search and Rescue

Immediately following the accident at 08:32.38, Andersen Tower contacted the Fire Department and airfield management (Tabs N-5 and N-10). The Fire Department arrived on scene within minutes and the crew was reported safe and accounted for by 08:38.57. There were no fatalities (Tab N-15).

h. Recovery of Remains

Not applicable.

5. MAINTENANCE

a. Forms Documentation

The 69th Expeditionary Aircraft Maintenance Squadron (69 EAMXS), Andersen AFB, maintained the aircraft forms for the MA. Tracking aircraft maintenance is accomplished via the Integrated Maintenance Data System (IMDS) and the Air Force Technical Order (AFTO) Form 781 series is used to document various maintenance actions. A detailed review of the MA's IMDS and AFTO Form 78ls showed no evidence to suggest any maintenance correlation to the mishap (Tabs D-4 to D-25 and U-184 to U-190).

b. Inspections

A Basic Post-flight/Pre-flight (BPO/PR) is a flight preparedness inspection performed by maintenance personnel prior to flight and is a valid inspection for 72 hours once completed. The BPO/PR inspections are performed IAW Technical Order (TO) 00-20-1, *Aerospace Equipment Maintenance Inspection, Documentation, Policies, and Procedures.* The purpose of the Pre-Flight Inspection is to visually inspect and operationally check various areas and systems of the aircraft in preparation for a flying period. The last PR inspection was completed on 18 May 2016 at 0800L. A BPO inspection was completed after the first sortie of the day on 13 May 2016 at 2130L with no discrepancies identified IAW TO 00-20-1. The Production Superintendent completed an Exceptional Release (ER) prior to the first flight of the day with no discrepancies noted during either inspection. An ER is a forms inspection and is required before flight; it serves as a certification that the authorized individual reviewed the active forms to ensure the aircraft is safe for flight. All scheduled inspections were completed IAW applicable TO guidance and no discrepancies were noted (Tabs D-5 to D-6 and U-18).

c. Maintenance Procedures

In the 24 hours prior to the mishap, pre-flight servicing and routine operational checkouts were performed, to include an engine inlet inspection and liquid oxygen servicing. All servicing and inspection procedures completed on the day of the mishap were IAW applicable aircraft TOs and did not contribute to the mishap (Tabs D-5 to D-6, U-187 and U-189 to U-190).

d. Maintenance Personnel and Supervision

MXG personnel performed all field-level maintenance on Andersen AFB's B-52s. A thorough review of maintenance records for personnel performing maintenance functions on the MA within 24 hours of the mishap revealed no training deficiencies. All maintenance personnel involved in the servicing or inspecting of the MA were qualified and proficient in their duties. Maintenance personnel and supervision did not contribute to the mishap (Tab U-41 to U-168).

e. Fuel, Hydraulic and Oil Inspection Analyses

Pre-mishap joint oil analysis program (JOAP) samples from the MA were normal and no volatiles noted in the spectrum. Post-mishap engine oil samples were taken from the MA and it was found that engines 4 and 8 passed while engines 1, 2, and 7 failed secondary analysis due to insufficient samples and visible particles. Engine 3 had an insufficient sample so the analysis was incomplete. No oil samples were taken from engines 5 and 6 because of the fire (Tab U-34 and U-41). Post-mishap fuel samples from the fuel truck and fuel tanks used to service the MA were normal and the material tested complied with TO 42B-l-1. Post-mishap fuel tested from the left and right outboard fuel tanks were normal; engine 7 fuel strainer and engine 7 fuel pump failed workmanship for visible black particulate matter present in the sample (Tab U-21 to U-33 and U-184). Hydraulic fluid was not analyzed.

f. Unscheduled Maintenance

Unscheduled maintenance is any maintenance action taken that is not the result of a scheduled inspection. It is normally the result of a pilot-reported discrepancy during flight operations or a condition discovered by ground personnel during ground operations. All documented unscheduled maintenance for the MA since programmed depot maintenance (PDM) was reviewed. None of the discrepancies were pertinent to the mishap. The 69 EBS AMX AMU performed all maintenance actions and properly documented IAW applicable technical data (Tabs D-7 to D-11 and U-188).

g. Time Compliance Technical Orders (TCTOs)

TCTOs are the authorized method of directing and providing instructions for modifying military systems and end items or performing one-time inspections. TCTOs are categorized as Immediate Action, Urgent Action, Routine Action, Routine Safety Action and Record. The category determines the compliance period. Historical records showed that all required TCTOs had been accomplished on the MA in accordance with applicable guidance (Tab U-186).

6. AIRFRAME, MISSILE, OR SPACE VEHICLE SYSTEMS

a. Structures and Systems

The MA departed the prepared surface by approximately 300 feet and sheared the front main landing gear and the right tip gear resulting in the number 5, 6, 7, and 8 engines dragging into the ground (Tab U-172, U-174, and U-177). The main part of the fuselage from the cockpit back to the tail just in front of the drag chute door, to include the vertical and horizontal stabilizer, was completely destroyed by fire (Figure 3). All four main landing gear tires and brakes burned with the fuselage (Figure 4). The number 3 and 4 main fuel tanks were damaged by fire along with engines #5, #6, and #7 (Tab U-170 to U-172, U-174 to U-178, and U-182). The right external fuel tank was also damaged and detached from the right wing of the aircraft during the departure from the prepared surface (Tab U-182 to U-183). Also, most of the right wing was damaged by the fire along with the flaps and flap wells (Tab U-183 to U-184). The left wing had damage to both engine pods and fire damage to the number 1 and 2 main fuel tanks (Tab U-176 to U-177). Both engine pods had damage as did the number 1, 2, 3, and 4 aircraft engines and the inboard, and part of the outboard flaps (Tab U-176 to U-177). There was also fire damage to the left side of the leading edge of the wing between the number 1 engine and the external tank (Tab U-176 to U-177). The left external fuel tank was also damaged and detached from the left wing of the aircraft.

Figure 7. Aircraft Wreckage

Figure 8. Cockpit Remains

1.   Brakes and Antiskid

Each wheel of the main landing gear has hydraulic brakes of a segmented rotor multiple-disc type with cerametallic brake linings. Braking is accomplished by either pilot applying toe pressure on the rudder pedals (Tab BB-7).

The left main-body hydraulic system provides hydraulic pressure to the left brake system while the right-side brakes are provided pressure from the right main-body system. There is an accumulator for each main gear system, located in each main wheel well, which provides system pressure, or to preload the system, if brake pressure is bled down (Tab BB-7).

The antiskid system consists of a skid detector on each main gear well, a dual antiskid valve for each gear, and a relay unit for each main gear. When any wheel is in a skid condition, a signal is transmitted by the skid detector unit through the relay unit to actuate the valve, shutting off pressure to the brake. After a time delay, brake pressure is then restored to the wheel (Tab BB-11 to BB-12).

The brakes merely stop the wheels from turning but stopping the aircraft is dependent on friction of the tires on the runway. This frictional force is dependent on the load imposed on the wheels; optimum braking action cannot be expected until the tires are carrying heavy loads. The tendency of the tires to skid decreases when the full weight of the aircraft is on the wheels. Optimum braking occurs with approximately a 15-20% rolling skid; that is, the wheel continues to rotate but has approximately 15% to 20% slippage on the surface so that the rotational speed is 80% to 85% of the speed that the wheel would have were it in a free roll. As skidding increases, the effectiveness of braking decreases so that at a 75% skid, the friction is only 60% of the optimum and at a full skid it is even lower. This is because of two reasons: as the tires skid, the rubber scuffs off tiny pieces of the tire which act as tiny rollers under the tire; and secondly, the heat generated by the friction melts the rubber, which acts as a lubricant between the runway surface and the tire (Tab BB-12).

The military specification to which the brakes are designed requires that they provide for only one maximum refused-takeoff stop. This is to minimize the weight on the braking system. The brakes themselves are designed to absorb a maximum energy of 298 million foot-pounds total for all eight brakes. Above this energy absorption, the brakes become ineffective and this number represents the stopping-capability limit. Tire explosions and hydraulic fires can result from lower levels of brake-energy absorption. At 230 million foot-pounds accumulation and above, fire and tire explosion are imminent, and above 150 million foot-pounds, tire explosion and fire are possible (Tab BB-14 to BB-16).

Using charts provided in T.O. 1-B-52H-1-1, the braking energy absorbed by the MA can be calculated. By applying the aircraft gross weight, airspeed at brake application, pressure altitude, and runway temperature, the braking energy calculated on the MA exceeds the capabilities of the supplied chart. Interpolating "off the chart," a value of approximately 335 million foot-pounds can be estimated, above the maximum limit of brake failure (Tab BB-15). If the drag chute worked as designed, a value of 295 million foot-pounds can be estimated, providing some validation of the simulator crew's ability to stop before the end of the runway surface when the drag chute was effective (Tabs BB-15 and EE-3).

Figure 9. Brakes and tires showing evidence of overheating and fire

Referring to Figure 6, the skid marks followed by the tire marks on the runway are consistent with proper anti-skid system operations. Additionally, the lack of tire marks from approximately 2,000 feet remaining until the end of the runway suggests the brakes absorbed the maximum prescribed energy during the abort and were no longer effective (Figure 6). All brakes show signs of heat stress and fire (Figure 9).

2. Drag Chute

The B-52H is equipped with a 44-foot, ribbon-type drag chute for deceleration during the landing roll. The drag chute provides considerable deceleration force over the first portion of the landing roll while the wheel brakes have a small decelerating effect because the wheels are lightly loaded due to lift generated by the wings. As the aircraft decelerates, the drag chute becomes less effective while the brakes become more effective as lift decreases. Optimum braking action cannot be expected until the tires are carrying heavy loads (Tab BB-12). The drag chute will be deployed at airspeeds above 70 KIAS up to the maximum deployment speed of 135 KIAS (Tab BB-32). In the landing run section of the flight manual, there is guidance which states that all landings should be planned from a standpoint as though the drag chute was not installed. The drag chute should only be considered an aid to braking and a means of reducing tire and brake wear (Tab BB-17). In normal operation, the drag chute is deployed during the landing rollout at speeds between 100 and 115 KIAS (Tab J-31). Emergency takeoff abort procedures direct drag chute deployment regardless of aircraft gross weight (Tab BB-18).

The MA drag chute, identification number MD-29, was reportedly manufactured by Pioneer Aerospace Corporation (Tab J-93). MD-29 had 29 deployments with no malfunctions prior to the mishap. The drag chute is limited to 160 deployments and is required to be inspected fully every 90 days (Tab J-31). The AFTO 391, *Parachute Log*, was destroyed by fire. No known deficiency reports exist for MD-29 (Tab J-31) which indicates no maintenance actions were required on this chute.

b. Evaluation and Analysis

Most of the MA was destroyed by the fire. However, some components were recoverable and intact enough for analysis. Engines 5, 6, 7, and 8 (TF 33-P103) were sent to the Air Force Life Cycle Management Center (AFLCMC) at Tinker AFB for analysis along with the number 8 engine firewall shutoff valve, actuator motor and the wiring harness. Several parts of the drag chute were sent to the Air Force Research Laboratory (AFRL) at Wright-Patterson AFB for analysis (Tab J-89).

The AFLCMC Teardown Deficiency Reporting (TDR) facility conducted borescopes, metallurgical analysis, and engine teardown to determine the status of the engines and engine components. Additionally, the TDR examined the engines for outside influences to include bird remains. Each engine exhibited fire damage to the external components and internal damage to the blades and stators due to debris ingestion from impacting the ground. Engine #5 did not rotate freely due to the amount of debris ingested during the mishap while engines #6 and #7 rotated freely. The internal sections of the engines had minor nicks and salt deposits, dirt, and fire retardant present. The N1 compressor blades and stators did not show signs of compressor stalls. The combustion sections were seated properly and the fuel manifolds showed regular spray patterns. Beyond normal wear-and-tear within technical order limits, the borescope and teardown found no defects or other abnormalities detected on the three engines inspected. There was no evidence of any organic material being processed through the engines. All of the debris found in the engine consisted of pieces of coral, dirt, and grass that was processed through the engines when they contacted the ground. The lack of discrepancies beyond fire damage and dirt and debris ingestion indicates the engine cores were operating as designed (Tab J-60 to J-64, J-66 to J-69 and J-72).

The AFRL conducted visual and mechanical analysis of the drag chute remnants that had not burned. This analysis revealed at least five suspension lines failed in high-speed overload which caused the main canopy to rip along two gores and deflate completely. Mechanical testing of the recovered suspension lines indicated they had degraded in service, failing to meet the required 4,000 lb. minimum breaking load. No pre-existing damage to the webbing (abrasions, cuts, burns, etc.) was observed. The analysis suggests failure of the drag chute's main canopy most likely was preceded by failure of the suspension lines in high-strain rate overload. This is supported by the fact that two suspension lines were the first objects to depart the aircraft and by fractographic evidence that indicates these failed at high strain rate. Failure of suspension lines would affect the loading on the main canopy so that some gores carry more load and others less, which would cause the canopy to tear if the loading is significantly imbalanced. The suspension lines failed at loads significantly below the required 4,000 lb. minimum. Mechanical testing revealed fibers within the suspension line webbing were breaking under repeated loads. The cumulative effect of the fibers breaking over many drag chute deployments would reduce the strength of the webbing below the requirement. The fact that at least five suspension lines fractured at or near the same area suggests that the applied loads at these locations were higher than expected and exceeded the breaking strength of the suspension lines (Tab J-28, J-31 and J-33 to J-34).

7. WEATHER

a. Forecast Weather

Weather conditions at takeoff time were forecast to be 29 degrees Celsius, with winds from 070 degrees at 12 knots. The minimum altimeter setting was 29.89, with broken clouds at 1500 feet above the ground and a scattered cloud layer at 2500 feet above ground level, and seven statute miles of visibility (Tab FF-3 to FF-5).

b. Observed Weather

Weather conditions at takeoff were a temperature of 28 degrees Celsius with winds from 070 degrees at 16 knots. The altimeter setting was 29.92, with scattered clouds at 1500 feet above the ground and 10 statute miles of visibility (Tab FF-6).

c. Space Environment

Not applicable.

d. Operations

The mission was flown IAW weather requirements defined in AFI 11-202 Vol. 3, *General Flight Rules*. These observed weather conditions are typical at Andersen Air Force Base at this time of year. There was no visible precipitation and the runway was dry (Tabs AA-3 to AA-4, FF-6 and V-2.4).

8. CREW QUALIFICATIONS

a. Mishap Pilot

The MP was a current and qualified Aircraft Commander in the B-52H. The MP had 796.4 total hours in the B-52H: 387.1 primary hours, 330.7 secondary hours, and 78.6 other hours. Of the 796.4 total hours flown, 122.8 hours were as an Aircraft Commander. All necessary flight currencies were up to date and all required training for the planned mission was current IAW AFI 11-2B-52 V1, *B-52 Aircrew Training*. MP performed his last instrument/qualification evaluation on 18 December 2015. He was rated “Qualified” (Tab G-26).

MP’s flight time for the 90 days before the mishap was as follows (Tab G-5):

	Hours	Sorties
Last 30 Days	26.5	3
Last 60 Days	65.2	8

Last 90 Days	91.9	10

b. Mishap Copilot

The MCP was a current and qualified Pilot in the B-52H. MCP had 420.7 total hours in the B-52H, 195.3 primary hours, 195.3 secondary hours, and 30.1 other hours. All necessary flight currencies were up to date and all required training for the planned mission was current IAW AFI 11-2B-52 Volume 1, *B-52 Aircrew Training*. MCP performed his last instrument/qualification evaluation on 26 April 2016. He was rated "Qualified" (Tab G-29).

MCP's flight time for the 90 days before the mishap was as follows (Tab G-8):

	Hours	Sorties
Last 30 Days	15.3	2
Last 60 Days	54.0	7
Last 90 Days	80.7	9

c. Mishap Radar Navigator

The MRN was a current and qualified Weapons System Operator in the B-52H. MRN had 345.6 total hours in the B-52H: 329.6 primary hours and 16.0 other hours. All necessary flight currencies were up to date and all required training for the planned mission was current IAW AFI 11-2B-52 Volume 1, *B-52 Aircrew Training*. MRN performed his last qualification/mission evaluation on 27 April 2015. He was rated "Qualified" (Tab G-38).

MRN's flight time for the 90 days before the mishap was as follows (Tab G-17):

	Hours	Sorties
Last 30 Days	26.5	3
Last 60 Days	77.9	9
Last 90 Days	111.2	12

d. Mishap Navigator

The MN was a current and qualified Weapons System Operator in the B-52H. MN had 404.5 total hours in the B-52H: 400.0 primary hours and 4.5 other hours. All necessary flight currencies were up to date and all required training for the planned mission was current IAW AFI 11-2B-52 Volume 1, *B-52 Aircrew Training*. MN performed his last qualification/mission evaluation on 10 March 2016. He was rated "Qualified" (Tab G-41).

MN's flight time for the 90 days before the mishap was as follows (Tab G-20):

	Hours	Sorties
Last 30 Days	21.1	3
Last 60 Days	49.0	6
Last 90 Days	78.6	9

e. Mishap Electronic Warfare Officer

The MEW was a current and qualified Instructor and Evaluator Electronic Warfare Officer in the B-52H. MEW had 1049.5 total hours in the B-52H: 982.1 primary hours, 4.9 secondary hours, 51.0 instructor hours, and 11.5 other hours. All necessary flight currencies were up to date and all required training for the planned mission was current IAW AFI 11-2B-52 Volume 1, *B-52 Aircrew Training*. MEW performed his last instrument/qualification evaluation on 10 March 2016. He was rated "Qualified" (Tab G-35).

MEW's flight time for the 90 days before the mishap was as follows (Tab G-14):

	Hours	Sorties
Last 30 Days	25.5	4
Last 60 Days	64.2	9
Last 90 Days	90.9	11

f. Mishap Gunner

The MG was a current and qualified Aircraft Commander in the B-52H, added to the crew as an augment pilot for the anticipated long duration sortie. MG had 761.4 total hours in the B-52H: 341.1 primary hours, 334.6 secondary hours and 85.7 other hours. All necessary flight currencies were up to date and all required training for the planned mission was current IAW AFI 11-2B-52 Volume 1, *B-52 Aircrew Training*. MG performed his last instrument/qualification evaluation on 18 December 2015. He was rated "Qualified" (Tab G-44).

MG's flight time for the 90 days before the mishap was as follows (Tab G-23):

	Hours	Sorties
Last 30 Days	29.2	4
Last 60 Days	67.7	9
Last 90 Days	94.9	12

g. Mishap Instructor Pilot

The MIP was a current and qualified Instructor and Evaluator Weapons Systems Officer in the B-52H, added to the crew as an augment navigator for the anticipated long-duration sortie. MIP had 1321.5 total hours in the B-52H: 350.9 instructor hours, 895.4 primary hours, 3.3 secondary hours and 71.9 other hours. All necessary flight currencies were up to date and all required training for the planned mission was current IAW AFI 11-2B-52V1, *B-52 Aircrew Training*. MIP performed his last qualification/mission evaluation on 2 June 2015. He was rated "Qualified" (Tab G-32).

MIP's flight time for the 90 days before the mishap was as follows (Tab G-11):

	Hours	Sorties
Last 30 Days	26.5	3
Last 60 Days	72.0	9
Last 90 Days	97.6	12

Aircrew composition was in accordance with AFI 11-2B-52 volume 3, *B-52 Operations Procedures* (Tab BB-49). There is no evidence to suggest insufficient crew qualifications were a factor in this mishap.

9. MEDICAL

a. Qualifications

The MC were medically qualified for flight duties at the time of mishap. Each member of the MC had a current annual flight physical exam and DD Form 2992 medically clearing them for flight. Three members of the mishap crew had current aeromedical waivers for medical conditions unrelated to the mishap (Tab X-3).

b. Health

The MC were all in good health prior to the mishap. Of note, the MEW was medically cleared for flight duties one day prior to the mishap after recovering from an acute, minor illness. There is no evidence that this illness contributed to the mishap. Medical record review revealed that the MC sustained only minor injuries consistent with the mishap and ground egress from the MA. (Tab X-3).

c. Pathology

Toxicology testing (urine drug screen and blood alcohol level) was performed on the MC, pre-flight crew, supervisor of flying, and maintenance members. All results were negative (Tab X-3).

d. Lifestyle

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

e. Crew Rest and Crew Duty Time

AFI 11-202 Volume 3, *General Flight Rules,* paragraph 2.1, provides guidance regarding the required crew rest prior to an aviator beginning flight duties. Crew rest is important to mitigate fatigue and ensure an aviator is properly rested prior to flight or performing flight-related duties. Aviators are required to have, at minimum, a 12-hour non-duty period before their flight duty period begins. This 12-hour non-duty period may include time for meals, transportation, and rest. The flight duty period begins when the aviator reports for the mission, briefing, or any official duty. The flight duty period ends when the engines shut down at the completion of the mission (Tab BB-40).

Witness interviews and review of 72-hour and 14-day histories for all members of the MC revealed compliance with the 12-hour, uninterrupted non-duty period. The MC had adequate crew rest and were within crew duty day at the time of the mishap (Tabs V-1.20, V-2.17, V-3.6, V-4.6, V-5.7, V-6.6, V-13.7, R-16 to R-27, R-60 to R71, R-94 to R-105, R-108 to R-119, R-122 to R-132, R-136 to R-146 and R-155 to R-166).

10. OPERATIONS AND SUPERVISION

a. Operations

The 69 EBS experienced a relatively steady operations tempo at the time of the accident. Due to demand from USPACOM, there was a larger number of operational missions tasked to the squadron for this deployment. However, as the demand for higher headquarters' missions increased, squadron supervision applied a commensurate decrease in the number of local flying sorties. This ensured the total number of monthly sorties flown by the 69 EBS remained consistent with programed flying hours and 36 MXS maintenance production capacity. As such, the ready-crews in the squadron, such as the MC, were flying at a pace to meet normal currency requirements and proficiency levels, but not so much to induce fatigue (Tab V-4.6, V-5.5, V-6.6 and V-7.6).

b. Supervision

The 69 EBS provided supervision for the flight. The MC was flying at the appropriate rate for an inexperienced level as defined by crew station in AFI 11-2B-52 Volume 1 and the Ready Aircrew Program Tasking Message. Experience levels are defined by flight hours and is a method used to regulate training requirements (Tab BB-41). The "hard crew" of the MC was the MP, MCP, MRN, MN, MEW, and the Instructor Weapon System Officer in the MIP station (Tab R-81). This crew composition was IAW AFI 11-2B-52 Volume 3 since the only additional aircrew restriction levied by supervision is to ensure inexperienced dual-seat navigators (the MRN and MN; Tab G-17 and G-20) must fly under the supervision of an experienced dual-seat navigator or instructor on all sorties with weapons, and to the maximum extent possible on all other sorties (Tab BB-49). There are no restrictions for pilot composition based on experience level (Tab BB-49). The augmented pilot (MG) was aboard due to the long-duration of the mission (Tab V-13.1). The MC was qualified in all aspects to perform the assigned mission (Tab G25 to G45). The Operational Risk Management (ORM) assessment addressed experience level by station and was determined for the mission and briefed, with mitigation measures, and approved at the appropriate level (Tab AA-5). The crewmembers occupying the MG and MIP stations do not have technical order-directed crew duties while occupying those stations during takeoff (Tabs BB-21 to BB-23 and V-1.20).

11. HUMAN FACTORS

a. Introduction

The Department of Defense Human Factors Analysis and Classification System describes how human factors can contribute to mishaps and provides a systematic approach to determining applicable human factors involved in a mishap. These factors can be causal or contributory. Causal factors are defined as “deficiencies which, if corrected, would likely have prevented or mitigated damage and/or injury.” Contributory factors are “independent events/conditions that do not directly result in damage and/or injury, but are integral to the progression of the mishap sequence.” (Tab BB-47 to BB-48)

b. Applicable Factors

1. OP003 Provided Inadequate Procedural Guidance or Publications

Procedural Guidance/Publications is a factor when written direction, checklists, graphic depictions, tables, charts or other published guidance is inadequate, misleading or inappropriate and this creates a potential unsafe situation (Tab BB-48).

Contributing to this accident is ambiguous technical order procedures on whether to abort or continue the takeoff after S_1 time. Stated as a Warning in the technical order: “Takeoff will not be aborted after S_1 unless, in the opinion of the pilot, the emergency renders the aircraft definitely unsafe to attain emergency bailout altitude. In those cases where the pilot attempts to abort after S_1, he must accept the fact that he will probably fail to stop within the confines of the runway.” (Tab BB-23) Stated as a Note in the technical order performance manual: “In those cases where the decision to stop or go may be borderline, experience shows in general that more difficulty is experienced in attempting a stop than in attempting to continue. This might be expected because of failure of drag chute or brakes to work properly or because of runway conditions different from those assumed in the flight manual. Because of these considerations, it is recommended that emphasis be placed on continuing the takeoff in borderline cases.” (Tab BB-24) Additionally, with loss of engines on one side creating asymmetric thrust, the pilot flying must achieve the V_{MCA} (the minimum speed for directional control), which is normally faster than S_2, to avoid reduction of the maneuvering margin to the point of absolute control limits (Tab BB-29). The minimum speed for directional control is defined as the speed at which a constant heading can be maintained with full rudder deflection and one-half lateral control authority with all of the operative engines set to a given amount of thrust. Only one-half lateral control authority is used in order to allow some reserve for maneuvering, gust loads, and dynamic conditions (Tab BB-27).

The first ambiguity is the MP must make a quick decision based on his opinion that the aircraft is definitely unsafe (not controllable in flight). The second is the probability of the MA achieving and maintaining minimum speed for directional control with a loss of engines on the same side. Both of these must be balanced against stopping the MA within the confines of the runway above S_1, the third ambiguity.

- The S_1 S_2 acceleration monitor system uses a timed acceleration check between two indicated airspeeds to be compared against a precomputed acceleration rate using charted values. This virtually eliminates wind error while minimizing airspeed indicator calibration error. Excellent crew coordination is essential when performing the acceleration check (Tab BB-20). S_1 is the computed decision speed which must be reached by the termination of the acceleration check time. This speed does not commit the aircraft to takeoff rather, the end of the acceleration check time will determine the decision to takeoff (committed) or abort. S_2 is the takeoff indicated airspeed commonly referred to as “unstick” at which point the aircraft generates sufficient lift for sustained flight (Tab BB-20).

- The technical order provides clear guidance when to "commit" or "abort" up to the termination of the acceleration check time. The S_1, S_2 system is airborne-centric above $S_{1,}$ yet the guidance suggests aborting may be appropriate above S_1. The technical order does not provide definite situations during a compounding or catastrophic emergency where an abort would be more appropriate at any point during takeoff roll at airspeeds between S_1 and S_2 (Tab BB-24). The technical order specifically addresses the fact that safe takeoffs can be made on 7 engines at intermediate and heavy gross weights with throttles at TRT (Tab BB-33). In emergency situations with less than 7 operative engines, the decision is based solely on the opinion of the pilot flying, while maintaining aircraft control, to analyze the situation and take the appropriate action (Tabs BB-23, V-1.3 and V-1.11).

- The V_{MCA} is defined as the speed at which a constant heading can be maintained with full rudder and one-half lateral control authority with all operative engines at a given amount of thrust. Only one-half lateral control authority is used in order to allow some reserve for maneuvering, gust loads, and dynamic conditions (Tab BB-27). As a balance of a reasonable amount of data for a pilot to consider during the dynamic conditions of a normal takeoff, the standard from mission planning is to compute V_{MCA} for 2-engines out, same side, should the emergency arise (Tabs AA-7 to AA-10).

In summation, the guidance in the technical order to remain committed after S_1 with asymmetric thrust is an interpretation by the pilot to do so only if the he believes the aircraft can achieve V_{MCA} up to emergency bailout altitude. This guidance and accepted procedures only accounts for the loss of two engines on one side.

To counter the summation, established recurrent training and upgrade courses, as well as local training requirements, mitigate the technical order procedure's ambiguity. In accordance with AFI 11-2B-52, Vol 1, *Aircrew Training*; AFI 11-2B-52, Vol 3, *Operations Procedures*; and the Ready Aircrew Program (RAP) Tasking Message (RTM), aircrew practice myriad emergency procedures to include heavy-weight takeoff aborts in the Weapon System Trainer (Tabs BB-41 to BB-42, and V-1.19). The MP accomplished this scenario in the WST two months prior to deploying to AAFB which was approximately 5 months prior to this mishap (Tabs V-1.13 and R-39).

According to testimony, the MP analyzed the engine indications as the "loss of three engines and going to lose a fourth engine, which is one of the very few things [the MP] would abort for after $S_{1.}$" (Tab V-1.6) The MP perceived the MA was not flyable based on recurrent and upgrade training accomplished in the WST (Tabs V-1.11 to V-1.12 and R-152). The MP recalled from his recent upgrade "Decision WST" which simulates the scenario of a heavy-weight aircraft losing "that much thrust, especially on one side, and never goes well." (Tab V-1.11 to V-1.12) The MP's experience from training indicates the possible outcome is "a descending turn" if the MA were to achieve unstick speed (Tab V-1.12). Additionally, the MP determined, based on timing, the MA had enough runway remaining to stop if the drag chute functioned properly (Tab V-1.13). The MP understood that if the drag chute did not deploy properly, the MA would probably depart the prepared surface (Tab V-1.11). In the decision matrix to continue or abort, the MP determined the MC would have to egress the aircraft regardless of the decision and determined aborting was the safer situation of the two choices (Tab V-1.12 to V-1.13). The MCP recalled from his training with “high gross weight” and “lose three or four engines on one side,” the typical outcome is “you can get maybe two hundred, three hundred feet in the air in about thirty degrees of bank pretty much uncontrollable to almost uncontrollable at the point.” (Tabs R-83 and R-85)

According to the technical order, the pilot should be aware that an emergency warranting abort consideration after S_1 is passed must, in his opinion, be more crippling than an engine failure (Tab BB-24). The procedures between S_1 and S_2 highlight a contributory factor of real-time, split-second decision making required by all members of the B-52H aircrew during unanticipated emergency abort procedures; however, local training programs and procedures mitigate this factor.

2. PE201 Seating and Restraints

Seating and Restraints is a factor when the design of the seat or restraint system, the ejection system, seat comfort or poor impact-protection qualities of the seat create an unsafe situation.

The MC was comprised of seven aircrew: the basic crew compliment plus one instructor Weapons System Office (WSO) and one augment Pilot. The aircraft has 6 ejection seats plus one additional non-ejection seat in the pilot station, the navigator station and the defensive compartment. The aircraft technical order mandates a minimum altitude for ejection of 250 Above Ground Level (AGL) for the navigator station downward ejection seats and a minimum of 500 AGL for the manual bailout of non-ejection seat personnel (Tab BB-35 to BB-36).

As stated in the B-52H technical order, “takeoff will not be aborted after S_1, unless, in the opinion of the pilot, the emergency renders the aircraft definitely unsafe to attain emergency bailout altitude. In those cases where the pilot attempts to abort after S_1, the aircraft will probably fail to stop within the confines of the runaway.” (Tab BB-33)

The MP aborted after the expiration of S_1 timing, and the MA departed the prepared surface. As discussed in section 11.b.1. of this report, this decision was made within technical order procedure. Testimony revealed the MP did not believe the MA would attain enough airspeed to accelerate and then climb to 500 AGL to allow all crew members to abandon the aircraft safely (Tabs BB-35 to BB-36 and R-34). The accepted practice of placing crew members in non-ejection seat positions in the aircraft is used so long as the appropriate safety, communications, and survival equipment is provided (Tab BB-49).

12. GOVERNING DIRECTIVES AND PUBLICATIONS

a. Available Directives and Publications Relevant to the Mishap

(1) AFI 51-503, *Aerospace Accident Investigations*, 14 April 2015

(2) AFI 51-503, *Aerospace Accident Investigations*, 14 April 2015, Air Force Global Strike Command Supplement, 23 September 2015

(3) AFI 11-202, V3, *General Flight Rules*, 7 November 2014

(4) AFI 11-2B-52 Volume 1, *B-52 Aircrew Training*, 6 Nov 15

(5) AFI 11-2B-52 Volume 3, *B-52 Operations Procedures*, 24 Sep 12

(6) AFI 91-202, *The United States Air Force Mishap Prevention Program*, 24 Jun 15

(7) AFI 91-204, *Department of Defense Human Factors Analysis and Classification System*, Attachment 6, 12 Feb 2014

(8) Air Force Pamphlet 91-212, *Safety: Bird/Wildlife Aircraft Strike Hazard (BASH) Management Techniques*, 1 February 2004

(9) AFTTP 3-3.B-52, *Combat Aircraft Fundamentals B-52*, 23 May 2015

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. 00-20-1, *Aerospace Equipment Maintenance Inspection, Documentation, Policies, and Procedures*

(2) T.O. 42B-1-1-WA-1, *Quality and Control of Fuels and Lubricants*

(3) T.O. 1B-52H-1, *Flight Manual*, Change 10, 1 November 2012, incorporating Change 10 1 November 2015

(4) T.O. 1B-52H-1-1, *Supplemental Flight Manual,* Change 6, 1 November 2015

(5) Air Force Global Strike Command Guidance Memorandum to AS-16 RAP Tasking Message, B-52, 11 Feb 16

(6) T.O. 14D1-3-232, *Drag Chute Assembly*, 24 April 2015

(7) 36 WG OPLAN 91-212, *Bird/Wildlife Aircraft Strike Hazard Plan*, January 2015

26 January 2017

EDWARD F. MARTIGNETTI, Col, USAF
President, Accident Investigation Board

STATEMENT OF OPINION

B-52H, T/N 60-000047

DEPARTURE END RWY 06L, ANDERSEN AFB, GUAM

19 MAY 2016

Conducted IAW Air Force Instruction 51-503

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

On 19 May 2016, at 0832 hours local time (L), a B-52H, Tail Number (T/N) 60-0047 [Mishap Aircraft (MA)], assigned to the 69th Expeditionary Bomb Squadron, 5th Bomb Wing, Andersen Air Force Base (AAFB), Guam, departed the prepared-surface overrun of Runway 06 Left (RWY 06L) during a high-speed, heavy-weight, aborted takeoff. The Mishap Crew (MC), which consisted of the Mishap Pilot (MP), Mishap Co-Pilot (MCP), Mishap Radar Navigator (MRN), Mishap Navigator (MN), Mishap Electronic Warfare Officer (MEW), an augment Pilot occupying the Mishap Gunner (MG) station, and an Instructor Weapon System Officer occupying the Mishap Instructor Pilot (MIP) jump seat, were conducting a Higher Headquarters' Directed mission. The MC was treated for minor injuries consistent with the mishap. The MA sustained total damage with loss valued at approximately $112M. Airfield instrument and approach lighting damage was approximately $1.5M. There was no damage to private property.

The MC was cleared for takeoff on AAFB's RWY 06L at 0831L for an operational mission supporting U.S. Pacific Command objectives. The MA accelerated within performance standards through the calculated S_1 Speed and Distance (normal acceleration check speed, time and distance computed for aircraft gross weight and weather conditions). The MP announced "Committed," to the MC. Approximately 3-5 seconds later, the MP, MCP, and MN observed a small number of birds transitioning in front of the MA approximately at wing level. Shortly thereafter, the MCP heard and felt "a couple of thuds" on the starboard side of the MA. The MP and MCP observed engine indications for numbers 5, 6, and 7 "quickly spooling back" from the takeoff setting. The MP also observed high oil pressure indications on the number 8 engine. The MP felt a noticeable yawing motion from left-to-right (toward the engines indicating abnormal thrust conditions) and began flight control inputs to arrest the motion. The MP simultaneously announced and initiated aborted takeoff emergency procedures. The fastest airspeed observed was 142 knots (kts). After setting the throttles to idle thrust and airbrakes to six, the MP initiated continuous braking pressure. The MP felt the yawing motion neutralize when the throttles were set to idle thrust and maintained runway centerline. The MP called the MCP to deploy the drag chute then physically delayed this action until the MA airspeed was within limitations. Decelerating through 135 kts (the maximum drag chute deployment speed), the MCP deployed the drag chute. The MC did not feel the noticeable tug of the drag chute inflating and was informed over radio the drag chute failed. Eyewitness testimony reveals the drag chute inflated then immediately ruptured to what is characterized as a "parachute streamer." The MIP announced distance remaining (does not include the 1,000-foot overrun) at the 3,000-foot and 2,000-foot runway remaining identifiers. At 2,500 feet runway remaining, the MP shut off the outboard engines (numbers 1, 2, 7 and 8). Shortly thereafter, the MP announced the MA and MC were going to depart the prepared surface of RWY 06L at which time the MIP announced "hatches, hatches, hatches." At this call, the MEW jettisoned the hatch on the starboard side of the defensive compartment. As the MA crossed onto the runway overrun, the MP shut off the inboard engines (numbers 3, 4, 5 and 6) while continuing breaking actions. The MA departed the prepared surface at approximately 40 kts. After sheering the main landing gear and right-wing tip gear, the MA finally came to rest slightly canted from runway centerline, with the right wing down, approximately 300 feet past the end of the runway. The MA subsequently caught on fire. The MC performed emergency aircraft shutdown procedures and safely egressed the MA through the MEW hatch.

I find by a preponderance of the evidence the cause of the mishap was the MP analyzed visual bird activity and perceived cockpit indications as a loss of symmetric engine thrust required to safely attain flight and subsequently applied abort procedures after S_1 timing. I also find by a preponderance of the evidence the following factors substantially contributed to the mishap: drag chute failure on deployment and exceeding brake-energy limits resulting in brake failure.

I developed my opinions based on post-mishap analysis of factual data from aircraft-specific technical orders, historical records, Air Force directives and guidance, engineering technical analysis, witness testimony, simulation of the mishap, and a visit to the mishap site.

2. CAUSE

The MP analyzed apparent bird ingestion and high oil pressure indications on the starboard side of the MA as an eventual, and complete, loss of symmetric thrust and determined minimum speed for directional control (V_{MCA}), 194 KIAS, could not be attained. In the opinion of the MP, these perceived engine indications rendered the aircraft as unsafe to attain emergency bailout altitude. The MP determined this altitude accounting for the MIP not occupying an ejection seat. Technical guidance states in cases where the pilot attempts to abort after S_1, the aircraft will probably fail to stop within the confines of the runway. The MP applied abort procedures after S_1.

The B-52H uses the S_1, S_2 method to determine Takeoff and Landing Data. The S_1, S_2 method is an acceleration monitor system to verify aircraft acceleration. Actual aircraft performance is compared to a precomputed acceleration rate. S_1 speed is the decision speed that must be reached by the termination of the acceleration-check time (S_1 time). S_1 time will determine the decision to takeoff or abort. If the aircraft does not achieve S_1 speed at the expiration of S_1 time, the aircraft is not performing in accordance with technical data and the takeoff should be aborted. If the aircraft meets or exceeds S_1 speed at the expiration of S_1 time, the aircraft is operating within performance standards. Normally, takeoffs will not be aborted when the aircraft exceeds S_1 time and speed.

At the expiration of S_1 time, the MP announced "Committed," to the MC. According to technical order procedures, at S_1 time the pilot checks airspeed and announces to the crew his decision to takeoff or abort. Analysis showed the MA exceeded S_1 speed at the expiration of S_1 time. Additionally, testimony revealed the highest speed the MA accelerated to during the takeoff roll was 142 kts, a full 31 kts above calculated S_1 speed, yet 16 kts below S_2 and 52 kts below V_{MCA}.

The MN observed a bird in the Electro-Optical Viewing System (EVS) screen and the MP and MCP visually observed a small number of birds flying at approximately wing level. The MCP heard and felt “a couple of thuds” from the starboard side of the aircraft. The MP and MCP testified to engine indications for numbers 5, 6, and 7 “quickly spooling back” from the takeoff setting. This was observed on the Engine Pressure Ratio (EPR) and core Revolutions per Minute (RPM) gauges for each engine. Additionally, the MP applied flight-control inputs to arrest a MA yawing motion toward the starboard side. The MP also observed high oil pressure indications on the number 8 engine.

At the time of the mishap, the AAFB Bird Aircraft Strike Hazard (BASH) model was Phase 1. Migratory bird movement patterns historically decrease during BASH Phase 1. Additionally, the Bird Watch Condition (BWC) was Low. BWC Low defines normal bird activity in and above the airfield with a low probability of hazard.

Post-mishap engine analysis was conducted by the Air Force Life Cycle Management Center (AFLCMC) at Tinker AFB for analysis along with the number 8 engine firewall shutoff valve, actuator motor and the wiring harness. The AFLCMC Teardown Deficiency Reporting (TDR) facility conducted borescopes, metallurgical analysis, and engine teardown to determine the status of the engines and engine components. Additionally, the TDR examined the engines for outside influences to include bird remains. Each engine exhibited fire damage to the external components and internal damage to the blades and stators due to debris ingestion from impacting the ground. Engine #5 did not rotate freely due to the amount of debris ingested during the mishap while engines #6 and #7 rotated freely. The internal sections of the engines had minor nicks and salt deposits, dirt, and fire retardant present. The N1 compressor blades and stators did not show signs of compressor stalls. The combustion sections were seated properly and the fuel manifolds showed regular spray patterns. Beyond normal wear-and-tear within technical order limits, the borescope and teardown found no defects or other abnormalities detected on the three engines inspected. There was no evidence of any organic material being processed through the engine. All of the debris found in the engine consisted of pieces of coral, dirt, and grass that was processed through the engines when they contacted the ground. The lack of discrepancies beyond fire damage and dirt and debris ingestion indicates the core engine was operating as designed.

For the B-52H, if oil pressure exceeds the maximum limit on a TF-33 engine, technical order procedures direct the pilot to shut down the engine unless its thrust is necessary to maintain flight. This procedure should be accomplished at the first indication of oil system malfunctions to forestall engine seizure as long as possible.

The MP analyzed the situation and perceived symmetric, takeoff-rated thrust would not be maintained and the minimum speed for directional control could not be attained with three engines indicating reducing performance and a fourth engine indicating a potential shutdown or seizure. The technical order provides clear guidance when to “commit” or “abort” up to the termination of the acceleration check time. The S_1, S_2 system is airborne-centric above S_1 yet the guidance suggests aborting may be appropriate above S_1. The technical order does not provide definite situations where an abort would be more appropriate at any point during takeoff roll at airspeeds between S_1 and S_2. Relying on heavy weight, emergency procedures training experience in the B-52 simulator, the MP weighed the opinion of definitely attaining emergency bailout altitude (accounting for the non-ejection seat MIP) against the probability of failing to stop within the confines of the runway. The MP maintained aircraft control, analyzed the situation, and took action in accordance with technical order procedures.

3. SUBSTANTIALLY CONTRIBUTING FACTORS

(a) Drag Chute Failure on Deployment

The B-52H is equipped with a 44-foot ribbon-type drag chute for deceleration during the landing roll. The drag chute provides considerable deceleration force over the first portion of the landing roll while the wheel brakes have a small decelerating effect because the wheels are lightly loaded. As the aircraft decelerates, the drag chute becomes less effective while the brakes become more effective. Optimum braking action cannot be expected until the tires are carrying heavy loads. The drag chute is an aid to braking and a means of reducing tire and brake wear. The drag chute will be deployed at airspeeds above 70 kts. The maximum deployment speed is 135 kts. Emergency takeoff abort procedures direct drag chute deployment regardless of aircraft gross weight.

During the abort, the MP applied brakes immediately because, even though the brakes would heat quickly into the charted "danger zone," the MP realized the best chance for stopping the MA was to deploy the drag chute, requiring a deceleration to 135 kts or less. During the 4-second deployment process, the MA drag chute inflated then immediately blew out to a resultant streamer. Post-mishap analysis was conducted at the Air Force Research Laboratory (AFRL) at Wright-Patterson AFB. The AFRL conducted visual and mechanical analysis of the drag chute remnants that had not been burned. This analysis revealed at least five suspension lines failed in high-speed overload which caused the main canopy to rip along two gores and deflate completely. Mechanical testing of the recovered suspension lines indicated they had degraded in service, failing to meet the required 4,000 lb. minimum breaking load. No pre-existing damage to the webbing (abrasions, cuts, burns, etc.) was observed. The analysis suggests failure of the drag chute's main canopy most likely was preceded by failure of the suspension lines in high-strain rate overload. This is supported by the fact that two suspension lines were the first objects to depart the aircraft and by fractographic evidence that indicates these failed at high strain rate. Failure of suspension lines would affect the loading on the main canopy so that some gores carry more load and others less, which would cause the canopy to tear if the loading is significantly imbalanced. The suspension lines failed at loads significantly below the required 4,000 lb. minimum. Mechanical testing revealed fibers within the suspension line webbing were breaking under repeated loads. The cumulative effect of the fibers breaking over many drag chute deployments would reduce the strength of the webbing below the requirement. The fact that at least five suspension lines fractured at, or near, the same area suggest that the applied loads at these locations were higher than expected, and exceeded the breaking strength of the suspension lines.

At the high end of airspeed envelope, and at a heavy gross weight, the MA did not have the considerable deceleration force provided by the drag chute over the first portion of the abort. Additionally, because the wheels were lightly loaded due to lift generated by the wings, the wheel brakes were less effective at the beginning of the abort. The aircraft braking system is not designed for high-speed, heavy-weight aborts initiated above S_1 with a compounding drag chute malfunction. Technical order procedures for aborted takeoffs above 70 kts require drag chute deployment regardless of gross weight. Based on aircraft simulation and known drag chute performance, this malfunction substantially contributed to the MP's inability to stop the MA within the confines of the runway.

(b) Heavy Gross Weight Braking Action Exceeding Brake Energy Limits resulting in Brake Failure

Brakes, themselves, merely stop the wheels from turning, but stopping the aircraft is dependent on the friction of the tires on the runway. This frictional force, in turn, is dependent on the load imposed on the wheel. Optimum braking occurs with approximately a 15% to 20% rolling skid; that is, the wheel continues to rotate but has approximately 15% to 20% slippage on the surface so that the rotational speed is 80% to 85% of the speed that the wheel would have were it in a free roll. The military specification for the B-52H brake design requires they provide for only one maximum refused-takeoff stop. Under such a condition, it is likely the brake-energy limits will be exceeded.

The B-52H brake-energy limit is 298 million foot-pounds total for all eight brakes. This is the maximum energy the brakes can absorb before becoming ineffective and is the stopping capability limit. Above 230 million foot-pounds accumulation, fire and tire explosion are imminent. According to technical data, the brake-energy charts are the best possible estimate to assess heat-energy absorption. Using the MA gross weight, speed at brake application without drag chute, weather conditions, and adjustments for runway slope, the MA brake-energy accumulation exceeded charted technical data of 325 million foot-pounds. Interpolation off the chart suggests upwards of 335 million foot-pounds accumulation of brake energy for the MA. Evidence of the termination of rolling skid prior to the end of the runway, the extreme brake energy absorbed under the abort conditions, and the speed at which the MA crossed the end of the runway and then the end of the prepared surface, I conclude the brake energy limits on the MA were exceeded and the MA brakes were ineffective even though the MP continued brake pressure throughout the entire abort. Because the MA exceeded the stopping capability limits of its brakes with runway remaining, and still moving at approximately 40 kts airspeed, the MA departed the prepared surface. This resultant failure substantially contributed to the MP's inability to stop the MA within the confines of the runway.

4. CONCLUSION

I find by a preponderance of the evidence the cause of the mishap was the MP analyzed visual bird activity and perceived cockpit indications as a loss of symmetric engine thrust required to safely attain flight and subsequently applied abort procedures after S_1 timing. I also find by a preponderance of the evidence the following factors substantially contributed to the mishap: drag chute failure on deployment and exceeding brake-energy limits resulting in brake failure.

26 January 2017

EDWARD F. MARTIGNETTI, Col, USAF
President, Accident Investigation Board

INDEX OF TABS