UNITED STATES AIR FORCE AIRCRAFT ACCIDENT INVESTIGATION BOARD REPORT

KC-135R, T/N 63-8877

22D AIR REFUELING WING
McCONNELL AIR FORCE BASE, KANSAS

LOCATION: 6 MILES SOUTH OF CHALDOVAR, KYRGYZ REPUBLIC

DATE OF ACCIDENT: 3 MAY 2013

BOARD PRESIDENT: BRIG GEN STEVEN J. ARQUIETTE

Conducted IAW Air Force Instruction 51-503

ACTION OF THE CONVENING AUTHORITY DEC 3 1 2013

The report of the accident investigation board, conducted under the provisions of AFI 51-503, that investigated the 3 May 2013 mishap that occurred approximately six miles south of Chaldovar, Kyrgyz Republic, involving KC-135R, T/N 63-8877, assigned to the 22 ARW, McConnell Air Force Base, Kansas 67221, complies with applicable regulatory and statutory guidance and on that basis is approved.

BROOKS L. BASH
Lieutenant General, USAF
Vice Commander

EXECUTIVE SUMMARY
AIRCRAFT ACCIDENT INVESTIGATION

KC-135R, T/N 63-8877
6 MILES SOUTH OF CHALDOVAR, KYRGYZ REPUBLIC
3 MAY 2013

On 3 May 2013, at approximately 1448 hours local time (L), a KC-135R, tail number 63-8877, assigned to the 22d Expeditionary Air Refueling Squadron, 376th Air Expeditionary Wing, Transit Center at Manas, Kyrgyz Republic, crashed in the foothills of mountains located 6 miles south of Chaldovar, Kyrgyz Republic. The mishap crew (MC), which consisted of the mishap pilot (MP), mishap co-pilot (MCP), and mishap boom operator (MBO), perished during the accident. The mishap aircraft (MA) exploded inflight, impacted the terrain at three main locations, and burned. The MA was completely destroyed with total loss to government property estimated at $66.3 million. Upon impact, approximately 228 cubic meters of soil were contaminated with jet fuel, and three distinct craters containing a burn pattern were created.

The MA's mission was to refuel coalition aircraft in Afghanistan and then return to the Transit Center at Manas. Immediately after takeoff, the MA experienced an unexpected rapid heading change from the direction of flight known as a crab. During climb, nearly continuous rudder hunting caused the MA's nose to hunt slowly left and right about one degree in both directions. The MP commented on the lateral control challenges and possible series yaw damper (SYD) malfunction but continued the mission without turning off either the SYD or rudder power. Approximately nine minutes into the flight, the MA began a series of increasing yaw and roll oscillations known as a dutch roll, which was undiagnosed by the MC. The MCP attempted to decrease these oscillations using manual aileron controls, as well as two brief attempts with the autopilot. The manual corrective inputs kept the oscillations from growing. The autopilot use further exacerbated the situation, and the oscillations intensified. After the second autopilot use, the MP assumed control of the MA and used left rudder to start a left turn. A subsequent series of alternating small rudder inputs, caused by the MA's dutch roll-induced acceleration forces varying the MP's foot pressure on the rudder pedals, sharply increased the dutch roll oscillations. Within 30 seconds, the MP made a right rudder input to roll out of the turn, exacerbating the dutch roll condition. The cumulative effects of the malfunctioning SYD, coupled with autopilot use and rudder movements during the unrecognized dutch roll, generated dutch roll forces that exceeded the MA's design structural limits. The tail section failed and separated from the aircraft, causing the MA to pitch down sharply, enter into a high-speed dive, explode inflight and subsequently impact the ground at approximately 1448L.

The board president found, by clear and convincing evidence, the cause of the mishap was the MA's tail section separating due to structural overstress as a result of the MC's failure to turn off either the SYD or the rudder power and oscillating dutch roll-induced acceleration forces translating through the MP's feet as the MP used rudder during the unrecognized dutch roll condition. Additionally, the board president found, by a preponderance of evidence, that the dutch roll was instigated by the MA's malfunctioning Flight Control Augmentation System that caused directional instability or rudder hunting which substantially contributed to this mishap. Other substantially contributing factors include insufficient organizational training programs, crew composition, and cumbersome procedural guidance.

SUMMARY OF FACTS AND STATEMENT OF OPINION
KC-135R, T/N 63-8877
3 MAY 2013

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ACRONYMS AND ABBREVIATIONS

17 RS	17th Reconnaissance Squadron
18 AF	Eighteenth Air Force
22 ARW	22d Air Refueling Wing
22 EARS	22d Expeditionary Air Refueling Squadron
22 EARS/ADO	22d Expeditionary Air Refueling Squadron Assistant Director of Operations
22 EARS/CC	22d Expeditionary Air Refueling Squadron Commander
22 MXG	22d Maintenance Group
92 ARW	92d Air Refueling Wing
93 ARS	93d Air Refueling Squadron
93 ARS/CC	93d Air Refueling Squadron Commander
93 ARS/DO	93d Air Refueling Squadron Director of Operations
376 AEW	376th Air Expeditionary Wing
376 AEW/CCV	376th Air Expeditionary Wing Vice Commander
376 EAMXS	376th Expeditionary Aircraft Maintenance Squadron
376 EOG/CC	376th Expeditionary Operations Group Commander
AC	KC-135 Aircraft Commander
AC-MCP	Aircraft Commander for Mishap Co-Pilot
AC-MP	Aircraft Commander for Mishap Pilot
ACP	KC-135 Aircraft Co-Pilot
AF	Air Force
AFB	Air Force Base
AFE	Aircrew Flight Equipment
AFI	Air Force Instruction
AFMAN	Air Force Manual
AFTO	Air Force Technical Order
AIB	Accident Investigation Board
AMC	Air Mobility Command
AOR	Area of Responsibility
ARS	Air Refueling Squadron
ARW	Air Refueling Wing
ATC	Air Traffic Control
ATS INST	Aircrew Training Systems Instructor
BS	Body Station
C-17 AC	C-17 Aircraft Commander
CAOC	Combined Air Operations Center
CE NCOIC	Civil Engineering Noncommissioned Officer in Charge
CO	Carbon Monoxide
CTL	Control
CVR	Cockpit Voice Recorder
DNIF	Duties Not To Include Flying
DoD	Department of Defense
DOD HFACS	Department of Defense Human Factors Analysis Classification System
DoDI	Department of Defense Instruction
DRFT	Drift
ECP	Engineering Change Proposal
ECS	Environmental Control System
EFAS	Engine Failure Assist System
EGT	Exhaust Gas Temperature
EXP	Expeditor
FCAS	Flight Control Augmentation System
FCIF	Flight Crew Information File
FDR	Flight Data Recorder
FPQ	First Pilot Qualification
HPO	Hourly Postflight
IAW	In Accordance With
IMP MX1	Impound Maintainer 1
IMP MX2	Impound Maintainer 2
i.e.	id est (that is)
IB	Instructor Boom Operator
IMPO1	Impound Official 1
IMPO2	Impound Official 2
INST	KC-135 Training Instructor
LVDT	Linear Variable Differential Transformer
LWIT1	Local Witness 1
LWIT2	Local Witness 2
MA	Mishap Aircraft
MAJCOM	Major Command
MBO	Mishap Boom Operator
MBO TR SUP	Mishap Boom Operator's Training Supervisor
MC	Mishap Crew
MCP	Mishap Co-Pilot
MM1	Mishap Maintainer 1
MM2	Mishap Maintainer 2
MM3	Mishap Maintainer 3
MM4	Mishap Maintainer 4
MM5	Mishap Maintainer 5
MM6	Mishap Maintainer 6
MM7	Mishap Maintainer 7
MP	Mishap Pilot
MPF	Mishap Pilot's Friend
MXG	Maintenance Group
NOTAMs	Notices to Airmen
NVGs	Night Vision Goggles
OG	Operations Group
OK	Oklahoma
ORM	Operational Risk Management
PCA	Permanent Change of Assignment
PCS	Permanent Change of Station
PCU	Power Control Unit
PDM	Programmed Depot Maintenance
PE	Periodic Inspection

PIQ	Pilot Initial Qualification
PLAN	Planner
POS	Position
PRD	Pilot Reported Discrepancy
PRO SUP	Production Superintendent
QAI	Quality Assurance Inspector
QVI	Quality Verification Inspection
RADAR	Radio Detection and Ranging
RAF	Royal Air Force
RS	Rudder Station
SAR	Search and Rescue
SC	Section Chief
SCHED	Scheduler
STAN/EVAL	Chief, Standardization and Evaluation
SYD	Series Yaw Damper
TCTO	Time Compliance Technical Order
T/N	Tail Number
T.O.	Technical Order
TX	Texas
U.S.	United States
USAF	United States Air Force
USAFCENT	United States Air Forces Central Command
vs.	Versus
WA	Washington
WXFC	Weather Flight Commander
Z	Zulu

The above list was compiled from the Summary of Facts, the Statement of Opinion, the Index of Tabs, and Witness Testimony (Tab V).

SUMMARY OF FACTS

1. AUTHORITY AND PURPOSE

a. Authority

On 3 May 2013, Lieutenant General Robert R. Allardice, former Vice Commander, Air Mobility Command, appointed Brigadier General Steven J. Arquiette to conduct an aircraft accident investigation of a mishap that occurred on 3 May 2013, 6 miles south of Chaldovar, Kyrgyz Republic (75 miles southwest of the Transit Center at Manas, Kyrgyz Republic) involving a KC-135R aircraft (Tabs Y-3 to Y-4, GG-3). The aircraft accident investigation was conducted in accordance with (IAW) Air Force Instruction (AFI) 51-503, *Aerospace Accident Investigations*, dated 26 May 2010, at the Transit Center at Manas and McConnell Air Force Base (AFB), Kansas (KS) from 10 July 2013 through 28 August 2013. From 29 October 2013 until 22 November 2013, the AIB conducted additional investigation at Scott AFB, Illinois (Tab Y-19). Board members were: Flight Dynamist (Lieutenant Colonel), Pilot Member (Major), Maintenance Member (Major), Test Pilot (Major), Legal Advisor (Captain), Medical Member (Captain), Boom Operator Member (Master Sergeant), Court Reporter (Master Sergeant), and Recorder (Technical Sergeant) (Tab Y-5, Y-17). The following Functional Area Experts were appointed: KC-135 Pilot and Human Factors Expert (Colonel), KC-135 Crew Chief Expert (Chief Master Sergeant), Weather Expert (Master Sergeant), Structural Engineer (Boeing Civilian Contractor), and two Flight Aviation Investigators (Civilians) (Tab Y-8, Y-11, Y-14, Y-18).

b. Purpose

This is a legal investigation convened to inquire into the facts surrounding the aircraft or aerospace accident, to prepare a publicly-releasable report, and to gather and preserve all available evidence for use in litigation, claims, disciplinary actions, administrative proceedings, and for other purposes.

2. ACCIDENT SUMMARY

On 3 May 2013, at approximately 1448 hours local time (L), the mishap aircraft (MA), a KC-135R, tail number 63-8877, assigned to the 22d Expeditionary Air Refueling Squadron (22 EARS), 376th Air Expeditionary Wing (376 AEW), Transit Center at Manas, Kyrgyz Republic, crashed approximately 6 miles south of Chaldovar, Kyrgyz Republic (Tabs K-4, Q-5, Q-7). The mishap crew (MC), which consisted of the mishap pilot (MP), the mishap co-pilot (MCP), and the mishap boom operator (MBO), perished during the accident (Tab Q5 to Q-6). Following the loss of its tail section, the MA exploded inflight and further separated into three main sections, impacted the earth, and burned (Tabs J-28 V-24.2, V-25.2). The three impact points were craters in hilly terrain used for grazing livestock (See Figure 1) (Tab FF-5). Approximately 228 cubic meters of soil were contaminated with jet fuel and each crater contained a pattern of burned grass and trees about 35 meters diameter on average (Tab FF-6 to

FF-11, FF-17). The MA was destroyed upon impact, with total loss to government property estimated at $66.3 million (Tab P-4).

Figure 1. Impact Craters (Tab FF-7 to FF-8, FF-11)

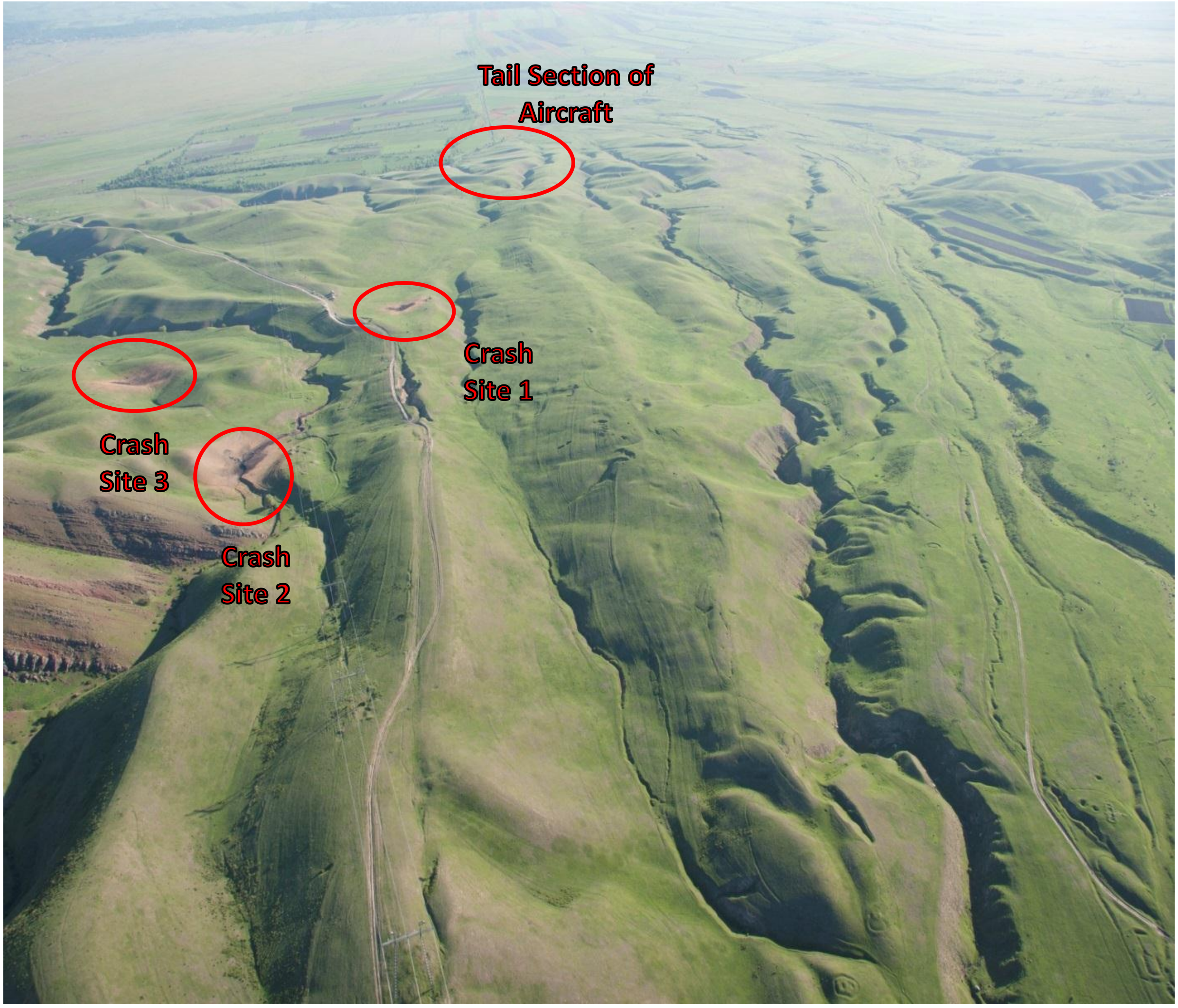

Figure 2. Aerial View of Crash Site (Tab Z-8)

3. BACKGROUND

The MA was assigned to the 22d Air Refueling Wing (22 ARW) at McConnell AFB, KS (Tab Q-7). The MC was assigned to the 93d Air Refueling Squadron (93 ARS) at Fairchild AFB, Washington (WA) (Tab Q-5 to Q-6). The 93 ARS is a squadron within the 92d Air Refueling Wing (92 ARW) (Tab CC-22). Both 22 ARW and 92 ARW align under Eighteenth Air Force (18 AF), the Numbered Air Force (AF) within the major command, Air Mobility Command (AMC) (Tab CC-5).

At the time of the mishap, the MC was deployed to 22 EARS (Tab CC-23). The 22 EARS is assigned to 376 AEW located at the Transit Center at Manas, Kyrgyz Republic (Tab CC-19). The 376 AEW is an expeditionary unit of the United States Air Force Central Command (USAFCENT) (Tab CC-17).

a. Air Mobility Command (AMC)

AMC provides worldwide cargo and passenger delivery, air refueling, and aeromedical evacuation. The command also transports humanitarian supplies to hurricane, flood, and earthquake victims both at home and around the world. AMC's mission is to provide global air mobility (Tab CC-3).

b. Eighteenth Air Force (18 AF)

Eighteenth Air Force presents air mobility forces to combatant commanders. It is charged with carrying out AMC's operational role as Air Forces Transportation, the air component of United States (U.S.) Transportation Command. The mission of 18 AF is to deliver key rapid global mobility solutions through operational expertise and capabilities (Tab CC-5).

c. 22d Air Refueling Wing (22 ARW)

The mission of 22 ARW is to conduct air refueling and airlift operations supporting national objectives worldwide, in any condition or climate using the KC-135 Stratotanker. The 22 ARW has been and continues to be involved in a number of operations providing air refueling, humanitarian airlift, and aeromedical evacuation missions around the globe (Tab CC-10).

d. 92d Air Refueling Wing (92 ARW)

The 92 ARW is dubbed as the "tanker hub of the Northwest" and is capable of maintaining an air bridge across the nation and the world in support of U.S. and allied forces. The 92 ARW's tankers participate in combat operations, humanitarian relief missions, and routinely support special airlift missions in response to world events or international treaty compliance requirements (Tab CC-12).

e. 93d Air Refueling Squadron (93 ARS)

The 93 ARS provides tanker support for routine training, operations, exercises, and worldwide contingencies. Tankers from 93 ARS have refueled combat aircraft for Operations NOBLE EAGLE, IRAQI FREEDOM, and ENDURING FREEDOM (Tab CC-15).

f. U.S. Air Forces Central Command (USAFCENT)

USAFCENT is the air component of U.S. Central Command (USCENTCOM), a regional unified command. USAFCENT is responsible for air operations, either unilaterally or in concert with coalition partners, and developing contingency plans in support of national objectives for USCENTCOM's 20-nation area of responsibility (AOR) in Southwest Asia. Additionally, USAFCENT manages an extensive supply and equipment prepositioning program at several AOR sites (Tab CC-16).

g. 376th Air Expeditionary Wing (376 AEW)

The 376 AEW is the host unit at the Transit Center at Manas, Kyrgyz Republic. The Transit Center at Manas is a transportation and logistics hub at Manas International Airport, near Bishkek, the capital of Kyrgyz Republic. The 376 AEW's around-the-clock missions include aerial refueling of coalition aircraft, airlift of supplies and equipment, movement of coalition personnel, and strengthening of local partnerships (Tab CC-17).

h. 22d Expeditionary Air Refueling Squadron (22 EARS)

The 22 EARS is a KC-135 unit assigned to the 376 AEW at the Transit Center at Manas, Kyrgyz Republic. It is comprised of deployed active duty, guard, and reserve Airmen. Its mission is to provide air refueling supporting forces engaged in combat operations and extend the effectiveness of networked operations. Since the unit's reactivation in 2003, 22 EARS has continuously supported Operation ENDURING FREEDOM (Tab CC-19).

i. KC-135 Stratotanker

The KC-135 Stratotanker provides the core aerial refueling capability for the United States Air Force (USAF) and has excelled in this role for more than 50 years. This unique asset enhances the AF's capability to accomplish its primary mission of global reach. It also provides aerial refueling support to AF, Navy, Marine Corps, and allied nation aircraft. The KC-135 is also capable of transporting litter and ambulatory patients using patient support pallets during aeromedical evacuations (Tab CC-20). The typical crew consists of a pilot, co-pilot, and boom operator (Tab CC-21).

Four turbofan engines power the KC-135 to takeoffs at gross weights of up to 322,500 pounds. A cargo deck above the refueling system can hold a mixed load of passengers and cargo. Depending on fuel storage configuration, the KC-135 can carry up to 83,000 pounds of cargo (Tab CC-20).

Nearly all internal fuel can be pumped through the flying boom, the KC-135's primary fuel transfer method. The boom operator is stationed in the rear of the plane and controls the boom during inflight air refueling. A special shuttlecock-shaped drogue attached to and trailing behind the flying boom may be used to refuel aircraft fitted with probes (Tab CC-20).

j. Dutch Roll

Dutch roll is a yawing motion of the airplane. It is characteristic of most swept wing airplanes to include the KC-135R. The inherent dynamic stability of the KC-135 will naturally dampen [decrease] a yawing motion, even without corrective input (Tab AA-28 to AA-30). Dutch roll is considered only a nuisance unless allowed to progress to large bank angles. Large rolling yawing motions can become dangerous unless properly damped. Dutch roll is usually induced by rough air or by lateral-directional control (for example in turn entry). The primary means of controlling dutch roll is the yaw damper. Since the yaw damper is normally in use at all times, it eliminates any tendency toward dutch roll. However, if a dutch roll condition develops, the pilot should use the dutch roll recovery procedures (Tab BB-182).

4. SEQUENCE OF EVENTS

a. Mission

On the day of the mishap, the mission of the MA was to conduct air refueling operations in Afghanistan and then return to the Transit Center at Manas later that evening (Tabs K-4, V-23.7). The mission was tasked by the Combined Air Operations Center (CAOC), and the flight was authorized by 22 EARS Assistant Director of Operations (Tabs K-4, V-23.7 to V-23.8).

b. Planning

Mission planning utilized standard procedures from the mission checklist and the AMC standard briefing guide (Tabs V-23.3 to V-23.5, V-32.5). The planned route of flight beginning with navigation waypoints MAAGE, DW, SOMUS, then on to Afghanistan is depicted below in Figure 3. This routing was standard for the type of mission assigned to the MC (Tab V-31.5). The squadron's standard procedures were utilized when constructing the mission package (Tabs V-23.3, V-32.5). The MC reviewed their planned mission and accomplished all required mission items IAW standard procedures (Tabs V-23.8, V-32.5).

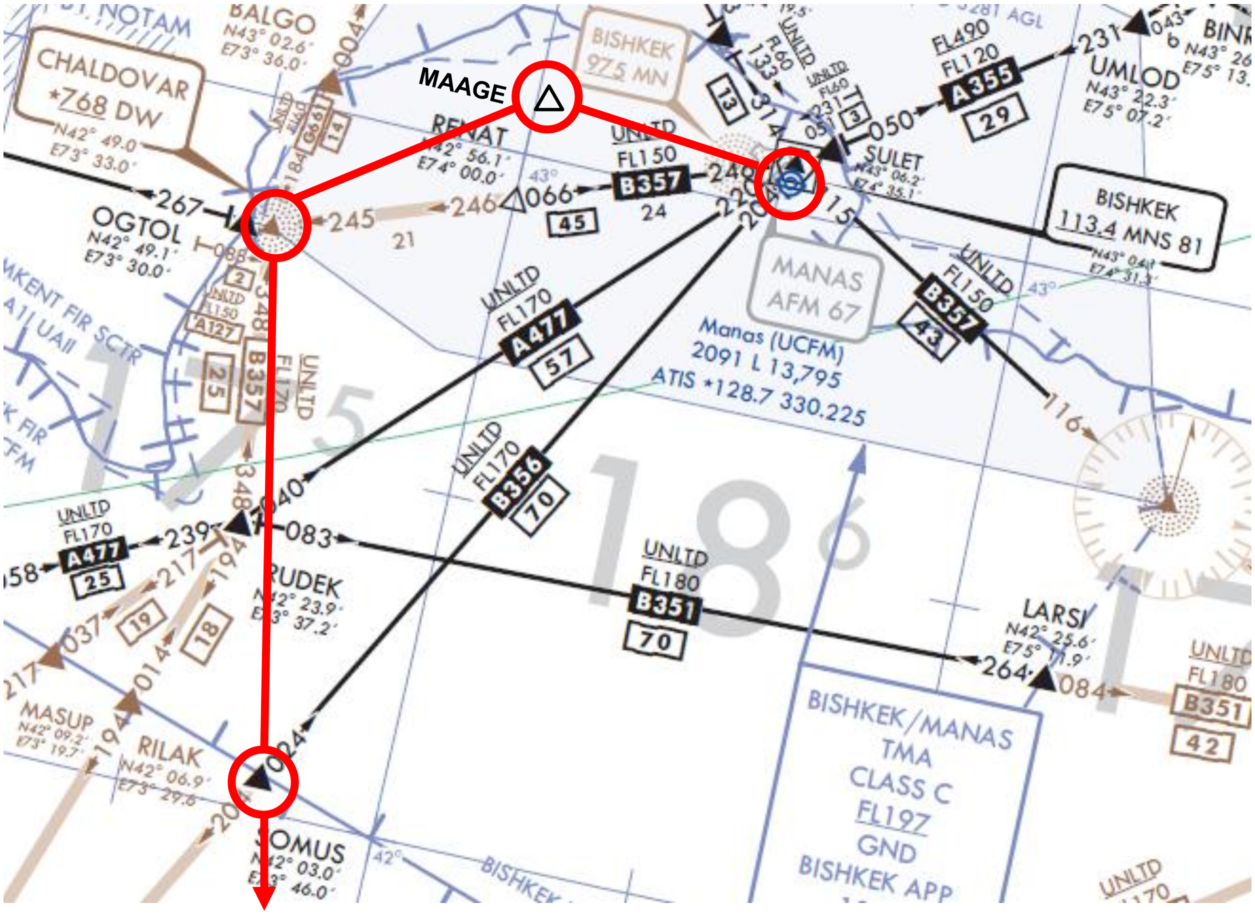

Figure 3. MA Planned Route of Flight (Tab Z-6)

c. Preflight

The MC assembled in the squadron operations room approximately three hours prior to the planned takeoff time (Tab V-23.3 to V-23.4, V-32.4). The completed mission checklist indicates the MC checked current Flight Crew Information Files (FCIFs), Notices to Airmen (NOTAMS), the Air Tasking Order, and mission specific details (Tabs F-2, V-23.3). They also obtained current intelligence and weather briefings and assessed their overall Operational Risk Management (ORM) score as "Low" (Tabs K-6, V-23.3). The MC did not properly adjust the ORM score for isolated thunderstorms on departure and arrival, nor for the heightened bird activity at the airfield. Additionally, the MC did not identify the source of a point taken for a personal factor on the ORM sheet (Tabs F-2, K-6). The MC stepped to the MA on time to begin their preflight (Tab V-7.5). While in the MA, the MC encountered a weather Radio Detection and Ranging (RADAR) fault that would cause the power to cycle on and off throughout the flight (Tab N-4 to N-7, N-9 to N-10). The MC accomplished engine start at 1417L (Tab U-15).

d. Summary of Accident

At 1428L, the MC taxied the MA on the runway and lined up for departure (Tab U-15). Just prior to obtaining takeoff clearance, the MC attempted to troubleshoot the intermittent weather RADAR system; eventually, the MC elected to continue the mission with the system inoperative

(Tab N-4 to N-8). The MC departed at 1437L, 18 minutes prior to the scheduled departure time of 1455L (Tab U-15). Immediately after takeoff, the MP and MCP experienced an unexpected rapid heading change known as a crab in which the MA's nose was pointed at an angle opposite of what would be expected due to the takeoff winds (Tabs N-10, N-13, EE-7, EE-10). The MC did not verbalize any further control difficulties for the next six minutes of flight (Tab N-8 to N-10). However, the nose of the MA hunted left and right about one degree in both directions during the same six minutes (Tab EE-10). The weather RADAR system operated normally for a brief time (about two minutes into the flight) before failing again two minutes later (Tab N-9 to N-10). The MC flew their planned route of flight, except for a one-mile deviation left of course en-route to waypoint DW to avoid cloud buildups (See Figure 4) (Tab N-10 to N-11). The MCP visually identified the building clouds near waypoint DW (Tab N-10 to N-11). At 1446L, the MP reported "clear of the weather" (Tab N-11).

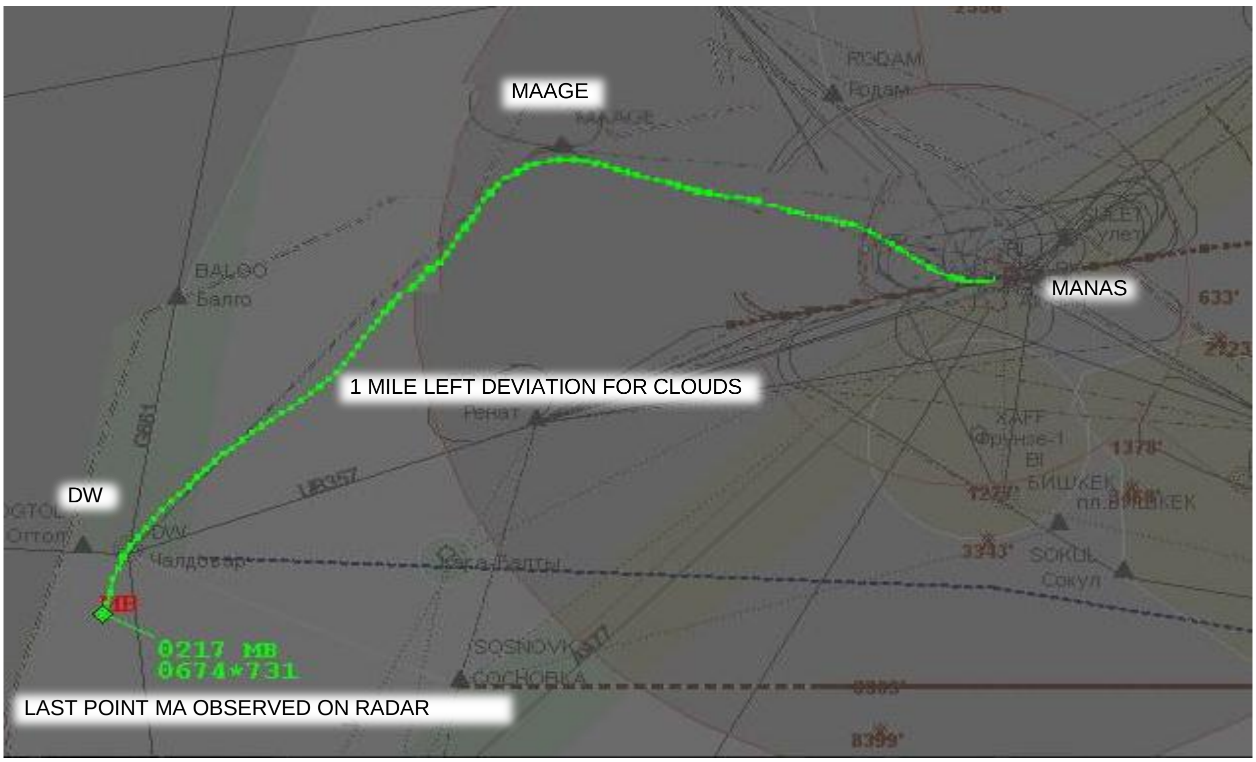

Figure 4. RADAR Plot of MA's Flight Path (Tab Z-3)

Approximately six minutes into the flight, the MP stated the aircraft is "kind of waffling a lot," and the "SYD [series yaw damper] isn't really working" (Tab N-10). The SYD provides automatic control of the yaw axis of the airplane by making corrective rudder inputs (Tab BB-144). The nose of the MA slowly hunted left and right, about one degree each direction, every two and a half seconds as the MA continued climbing on course to waypoint DW (Tab EE-10, EE-12). Approximately nine minutes into the flight, the MA experienced a series of increasing yaw and roll oscillations known as a dutch roll (Tab BB-182). The MA yawed between three degrees left and right and banked between five degrees left and right (Tabs AA-26, EE-8).

The MCP attempted to dampen these oscillations using manual aileron (lateral) controls, as well as two brief attempts with the autopilot. The MCP made corrective inputs and kept the roll oscillations from growing. The first time the MCP engaged the autopilot, it made late inputs and the oscillations increased. The MCP disengaged the autopilot after four seconds (Tab EE-9). As the MA approached waypoint DW, the oscillations, undiagnosed by the MC as dutch roll, grew more pronounced (Tab EE-10). The MP directed the MBO to the wing observation windows to check if anything was, "hanging off our jet?" (Tab N-11). The MBO observed deflection of the left wing spoilers, which was consistent with the MCP's control inputs at the time (Tabs N-12, EE-9). Approximately 10 minutes into the flight, the MC engaged the autopilot again for six seconds, which further increased the MA's oscillations (Tab EE-8 to EE-9). The MP then stated, "I think the SYD is inoperative. Sorry guys, let's turn it off" (Tab EE-3). The MP disengaged the autopilot but not the SYD (Tab EE-5, EE-9).

After the MP stated, "let's turn it off," the MP assumed control of the MA while the MCP made radio calls to Bishkek Air Traffic Control (ATC) (Tabs N-12, EE-5). The MP began a left turn at waypoint DW using left rudder. A subsequent series of alternating small rudder inputs, caused by the MA's dutch roll-induced acceleration forces varying the MP's foot pressure on the rudder pedals, sharply increased the dutch roll oscillations (Tab EE-29 to EE-34). Approximately 11 minutes into the flight, the MP made a right rudder input to roll out of the turn, further exacerbating the dutch roll condition. Ten seconds later, the cumulative effects of the malfunctioning SYD, coupled with autopilot use and rudder movements, generated dutch roll forces that exceeded the MA's structural design limit load factors. This overload caused the tail section to fail and separate in several pieces (Tabs J-28, BB-173, EE-10 to EE-11, EE-29, EE-33 to EE-34). The MA pitched down sharply and entered a high-speed dive (Tab EE-18).

The last point captured on the flight data recorder (FDR) was a nose down attitude of 82 degrees at 21,760 feet (Tab EE-12, EE-18). Around 10,000 feet, the MA exploded into three main sections and fell to the earth, impacting the terrain approximately 1.5 miles southwest of where the tail section of the MA was found (Tabs V-24.2, W-4, Z-8). The three main sections included the cockpit section, the center fuselage section, and the aft section (Tab Z-4).

e. Impact

The MA impacted the terrain at 1448L (0848Z) about 6 miles south of Chaldovar, Kyrgyz Republic (Tabs Q-5, GG-3). In addition to the three main sections mentioned above, the right wing and all four engines fell separately. The rudder, vertical stabilizer, and horizontal stabilizer separated from the MA prior to the explosion (Tab J-28). These relatively lighter aircraft parts were carried by the wind about 1.5 miles northeast of the main crash site (See Figure 5) (Tabs F-19, Z-4 to Z-5). The MA's configuration before breakup was flaps and landing gear up (Tab N-8 to N-9).

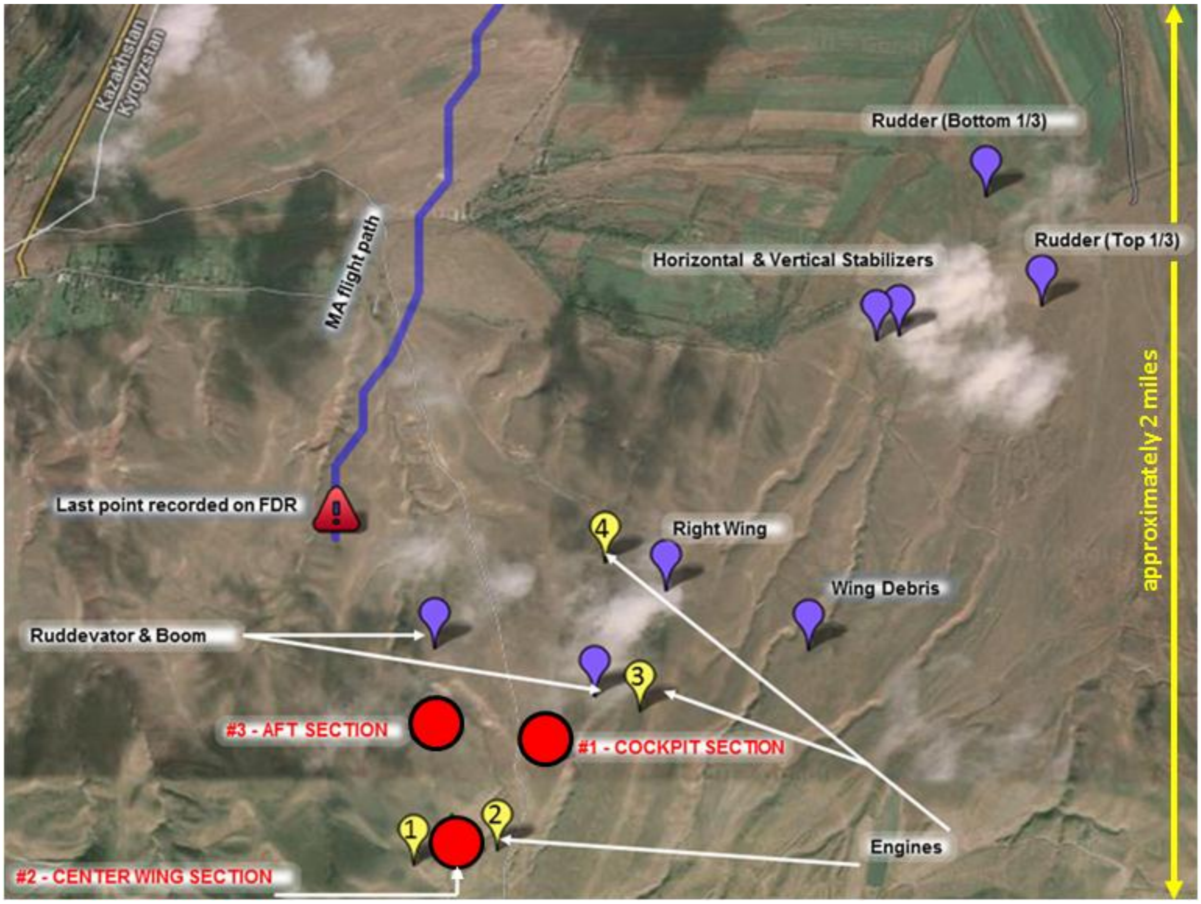

Figure 5. Plot of MA Wreckage (Tab Z-4)

f. Egress and Aircrew Flight Equipment (AFE)

Egress was not possible; the KC-135R is not equipped with parachutes, ejection seats, or any other means of inflight egress (Tab U-13).

g. Search and Rescue (SAR)

The time of the crash was 1448L (Tab Q-5). The MC did not transmit a distress call. The last transmission to ATC was a request for a lower altitude (Tab N-12). Shortly after the MA took off, the RADAR Liaison at Manas International Airport telephoned the 22 EARS Operations (Tab V-38.5). The RADAR liaison indicated that it had lost the MA on RADAR. There were also reports that people had seen a fireball in the sky at about the same location the RADAR liaison lost contact with the MA (Tab V-23.2 to V-23.3). The 376 AEW immediately convened a Crisis Action Team and prepared to dispatch a team of approximately 15 to 20 personnel to the crash site (Tab V-3.3 to V-3.5).

A U.S. Embassy official arrived at the crash scene at approximately two and a half hours after the initial report of the crash and began coordinating with the Kyrgyz first responders (Tab V-3.3 to V-3.4). The 376 AEW's team of 15 responders did not initially know the exact location of the crash site but queried local Kyrgyz people for directions. The remote location, the primitive roads, rainfall, and the waning daylight extended the response time about four hours (Tab V-3.4

to V-3.5, V-36.6). The topography of the crash scene was the foothills of the mountains, which necessitated four-wheel drive vehicles (Tab V-3.5). The team arrived at the crash site at approximately 2300L (Tab V-36.4). Kyrgyz civilians and the Kyrgyz Ministry of Emergency Situations were already on the scene providing security (Tab V-3.6). The U.S. forces experienced some coordination challenges with the local government until the U.S. Embassy was granted permission from the Kyrgyz Commission to access the crash site (Tab V-3.6). On the following day, more waves of personnel and equipment were dispatched to the site to begin the search and recovery operations (Tab V-36.4 to V-36.5).

A team from the Joint Personnel Recovery Center at Bagram Air Base, Afghanistan, led the search and recovery effort for the MC (Tab V-3.6 to V-3.7, V-36.6). Search and rescue dogs from Fairfax County, Virginia, were later brought in to assure full accountability during the search (Tab V-3.6 to V-3.7). Approximately 16 days following the mishap, a Kyrgyz contractor completed transportation of the MA wreckage to Manas International Airport (Tab V-3.7, V-36.7).

h. Recovery of Remains

The remains of the MC were temporarily held in the Mortuary Affairs building at the Transit Center at Manas before being flown to the Armed Forces Medical Examiner System at Dover AFB, Delaware (Tabs V-3.7, X-3). Autopsies were performed on the MC before remains were released to the respective families (Tab X-3).

5. ANALYSIS OF ACCIDENT SEQUENCE

The figures and charts in this section highlight distinct actions of the MC during the accident sequence. All times are indicated in Zulu (Z) in order to align with FDR analysis. The flight characteristics captured by the FDR describe how and when the MA broke apart and crashed. The accident sequence contains a chain of four elements relevant to the overall outcome.

First, the accident sequence began when the MA resumed dutch roll oscillations at 08:46:10Z due to an FCAS failure at which time the MC became concerned about a flight control difficulty symptomatic of dutch roll, but did not diagnose it as dutch roll (Tabs N-10 to N-12, BB-182, EE-8). Second, the MCP attempted to control the oscillations with lateral control wheel inputs and with the autopilot (Tab EE-9). Third, the MC noticed a potential failure of the SYD coupled with their difficulty controlling the MA but failed to turn off either the SYD or the rudder power (Tab N-10 to N-12, EE-5). Lastly, the MP took control of the MA and used the rudder during the dutch roll condition (Tabs N-12, EE-5, EE-11).

a. Identification of Dutch Roll

In Figure 6 below, the blue plot is the MA's roll and the orange plot is the MA's drift angle, or yaw. Positive values indicate rolling/yawing to the right and negative values indicate rolling/yawing to the left (Tab EE-4, EE-8). Beginning with takeoff at 08:37:23Z, the MA experienced a series of uncommanded yaw movements that caused the nose of the MA to oscillate left and right (Tab EE-5, EE-8, EE-10). At around 08:44:33Z, the oscillations dampened out almost entirely, characterized by the flat segment of the orange line in Figure 6 (Tab EE-8). At approximately 08:46:10Z, the MA resumed the oscillations (Tab EE-5, EE-8). The period between 08:46:43Z and 08:47:23Z depicts a clear yawing-then-rolling relationship that is symptomatic of dutch roll (Tabs AA-27, EE-8). Each "peak" of roll occurs about two seconds after each peak of yaw. In this 40-second time frame, eight peaks equate to a period of about five seconds (Tab EE-8).

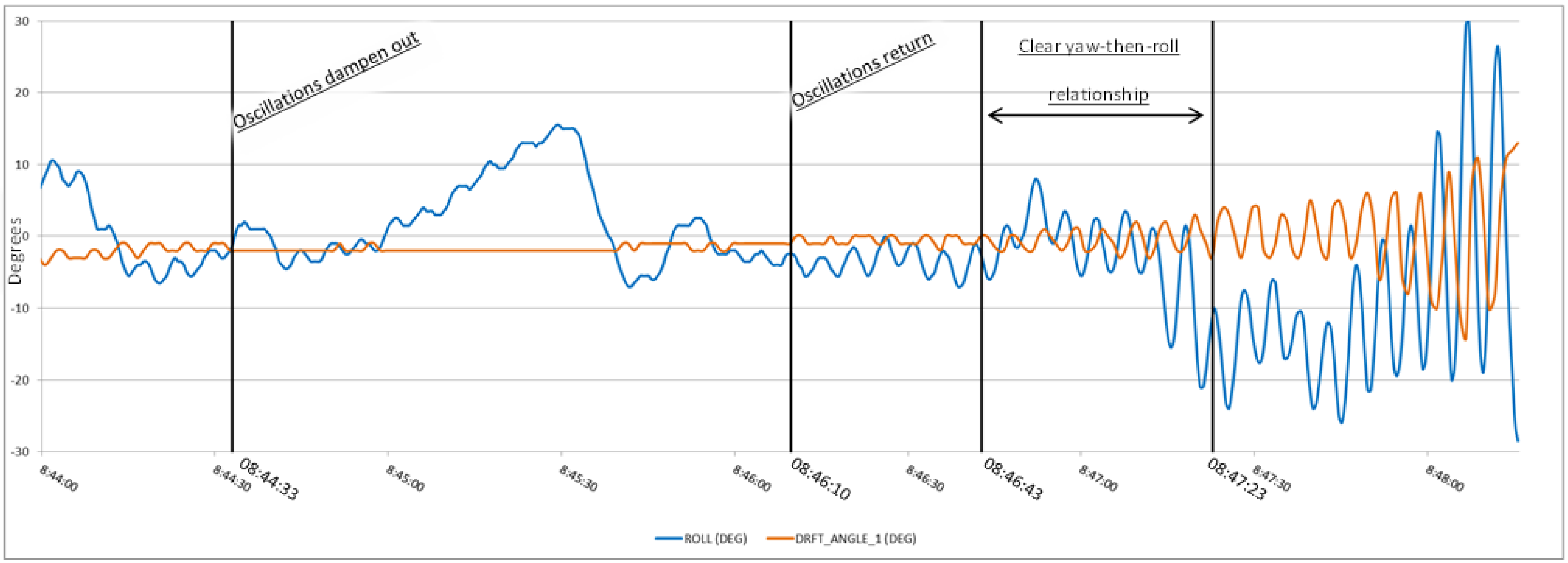

Figure 6. Onset of Dutch Roll of the MA (Tab EE-8)

Figure 7 below illustrates how the KC-135 behaves during dutch roll. The yawing of the aircraft's nose is known as sideslip (Tab AA-26). The FDR indirectly measures sideslip as a drift angle (Tab EE-4). Once the sideslip reaches its peak, the roll develops as depicted in red below in Figure 7 (Tab AA-26). Dutch roll damping is reduced as altitude increases (Tab BB-182). As the MA continued to climb, the amplitude of the dutch roll oscillations increased (Tab EE-8, EE-12).

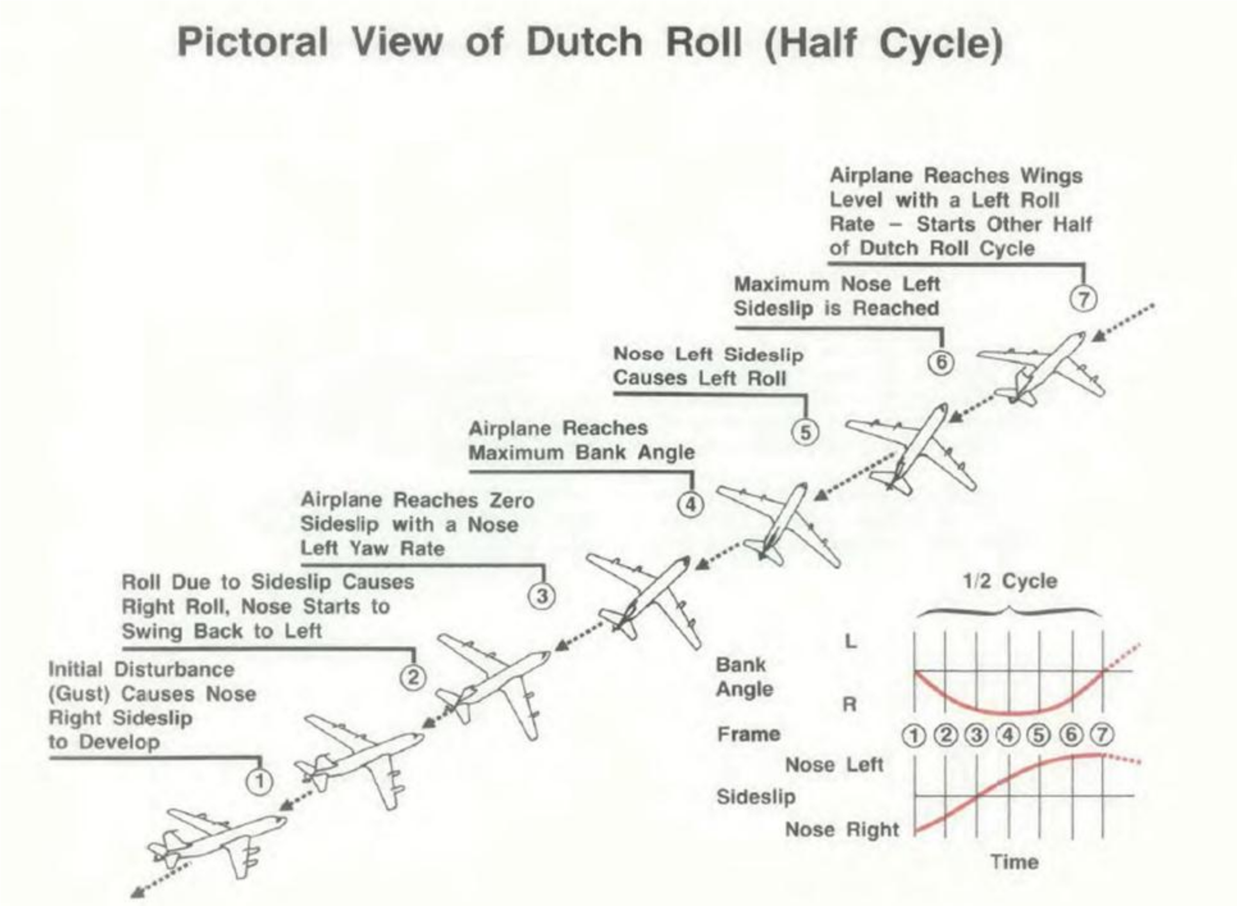

Figure 7. Dutch Roll Illustration (Tab AA-26)

b. Lateral Controls

Proper dutch roll damping technique is to apply corrective control wheel deflections as the aircraft rolls through wings-level (Tab AA-28 to AA-30). The damping technique described in the Technical Order (T.O.) 1C-135(K)R(II)-1, *KC-135R/T Inflight Data,* Change 12, dated 1 April 2012 (Inflight Manual) is to "stop the rising wing at the desired bank angle with aileron. As the wing stops, center the control wheel and prepare to stop the other wing from rising" (Tab BB-171). Figure 8 below illustrates a properly timed input (green dot), a late input (yellow dot), and an out-of-phase input (red dot). The-out-of-phase input occurs after roll has changed direction, and in turn accelerates roll in the opposite direction instead of dampening the roll (Tab BB-171).

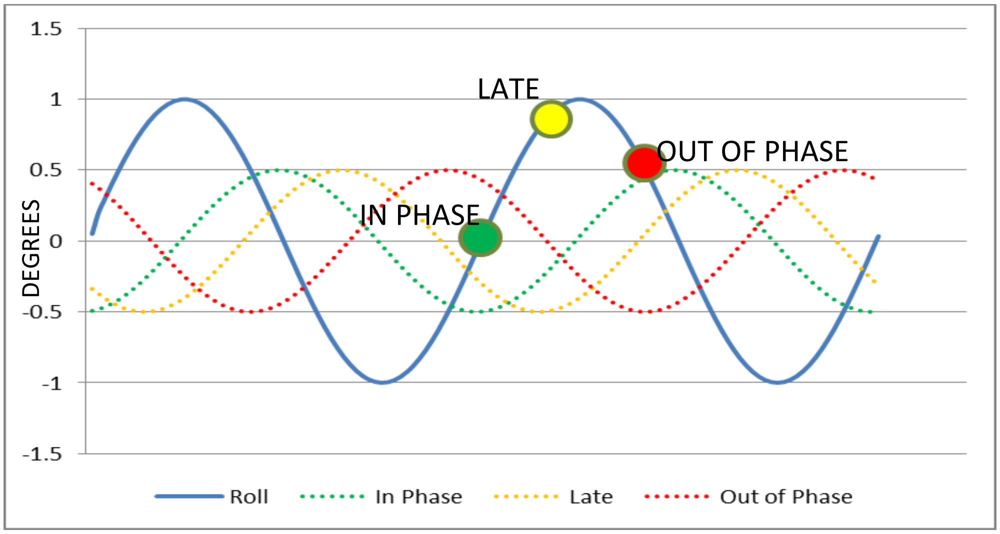

Figure 8. Lateral Input Timing Assessment (Tabs Z-10, EE-9)

The FDR plot of the MCP's inputs is shown below in Figure 9. The yoke inputs of lateral, control, and position (LAT_CTL_POS) are mostly in-phase between 08:46:00Z and 08:47:22Z, except when the autopilot is engaged. Negative values are left yoke movements, and positive values are right yoke movements (Tab EE-4). When the MCP initially engages the autopilot, it makes two late lateral control inputs. The second time the autopilot is engaged it makes one large out-of-phase input before being disengaged by the MP (Tab EE-9).

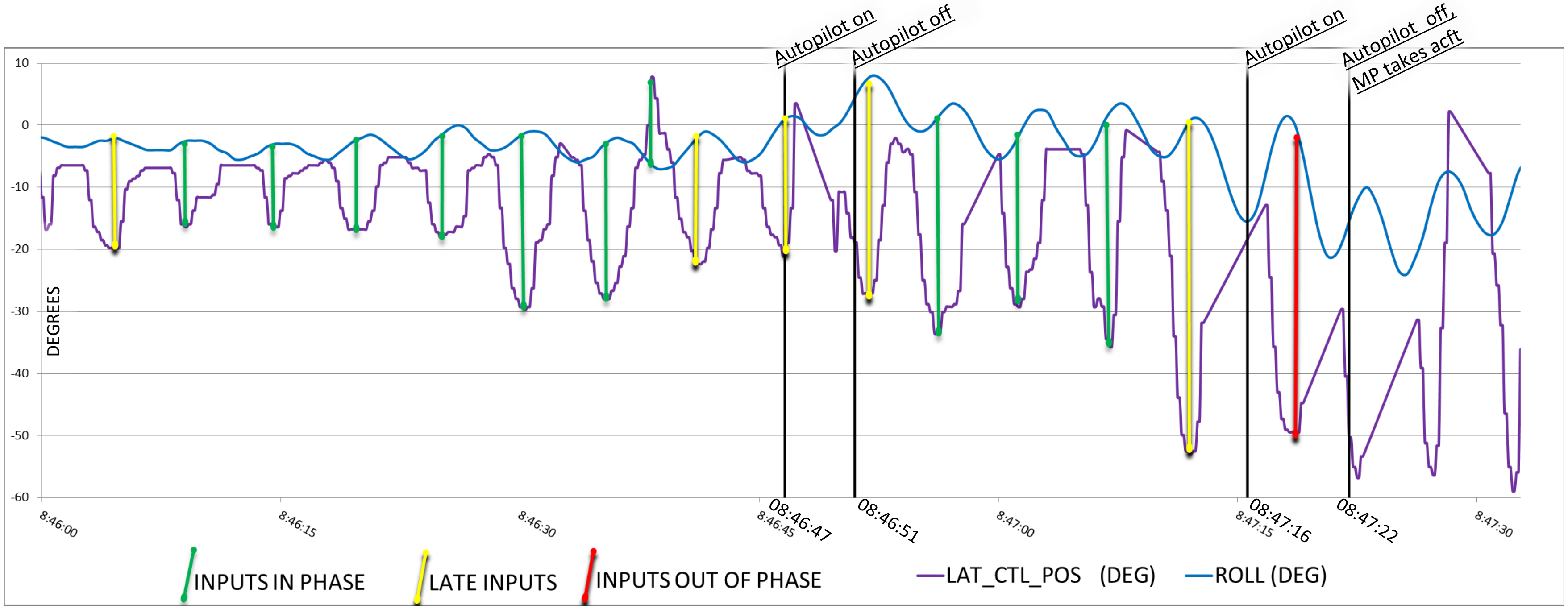

Figure 9. Lateral Inputs Made by MCP & Autopilot (Tab EE-9)

Most of the lateral control inputs accomplished by the MCP resemble the example in Figure 8 regarding the in-phase properly timed inputs. As a trend, the roll oscillations of the MA did not get larger with in-phase inputs. The amplitudes of the inputs appear to be greater than that of the roll. When engaged, the autopilot applied late corrections and in turn generated a larger, steeper roll in the opposite direction (Tab EE-9). Once the MP takes control of the MA, the lateral control inputs can no longer be reliably measured due to the FDR constraints and rudder input (Tab EE-4 to EE-5, EE-9).

c. Diagnosis of SYD Malfunction

Dutch roll occurs in response to a disturbance (Tab AA-26). However, the inherent dynamic stability of the KC-135 will naturally dampen a yawing motion, even without corrective input (Tab AA-28 to AA-30). Slow yaw oscillations were present throughout most of the sortie (Tab EE-5, EE-10). The yaw oscillations demonstrated by the MA indicate the presence of a repeated and vacillating disturbance. Simply put, some force was disrupting the MA in a repetitive manner (Tab EE-5, EE-10).

Figure 10 also depicts a KC-135R flying a similar profile as the MA one day prior to the mishap. The "DRFT_ANGLE_1" field (orange) depicts the steady, non-oscillating behavior of the reference MA's nose about its yaw axis (See Figure 10). The "DRFT_ANGLE_1" of the MA illustrates the key difference between these two flights (See Figure 10). The MA's nose hunted left and right during the mishap flight (Tab EE-5 to EE-6, EE-10).

At 08:43:37Z, the MP stated, "It's kind of waffling a lot, like the SYD isn't really working." The MP also stated that on initial takeoff, the MA immediately crabbed (Tab N-10). At 08:47:29Z, the MP again stated, "I think the SYD is inoperative" (Tab N-12). FDR data shows the SYD was indicating "on" for the entire flight therefore the MC did not disengage either the SYD or the rudder power (Tab EE-5).

The MC diagnosed a directional control problem as well as a problem with the SYD but did not diagnose dutch roll (Tab N-10 to N-12). The *Lateral and Directional Control Difficulty Due To SYD Malfunction* and *Rudder Hunting* sections in the Inflight Manual describe appropriate crew actions in response to these conditions. Rudder hunting is "erratic movement or slow deflection/oscillation of the rudder" (Tab BB-172 to BB-173).

Figure 10 below depicts the yaw oscillations of the MA compared to another KC-135R flying a similar route of flight with all systems operating normally (Tab EE-5 to EE-6, EE-10).

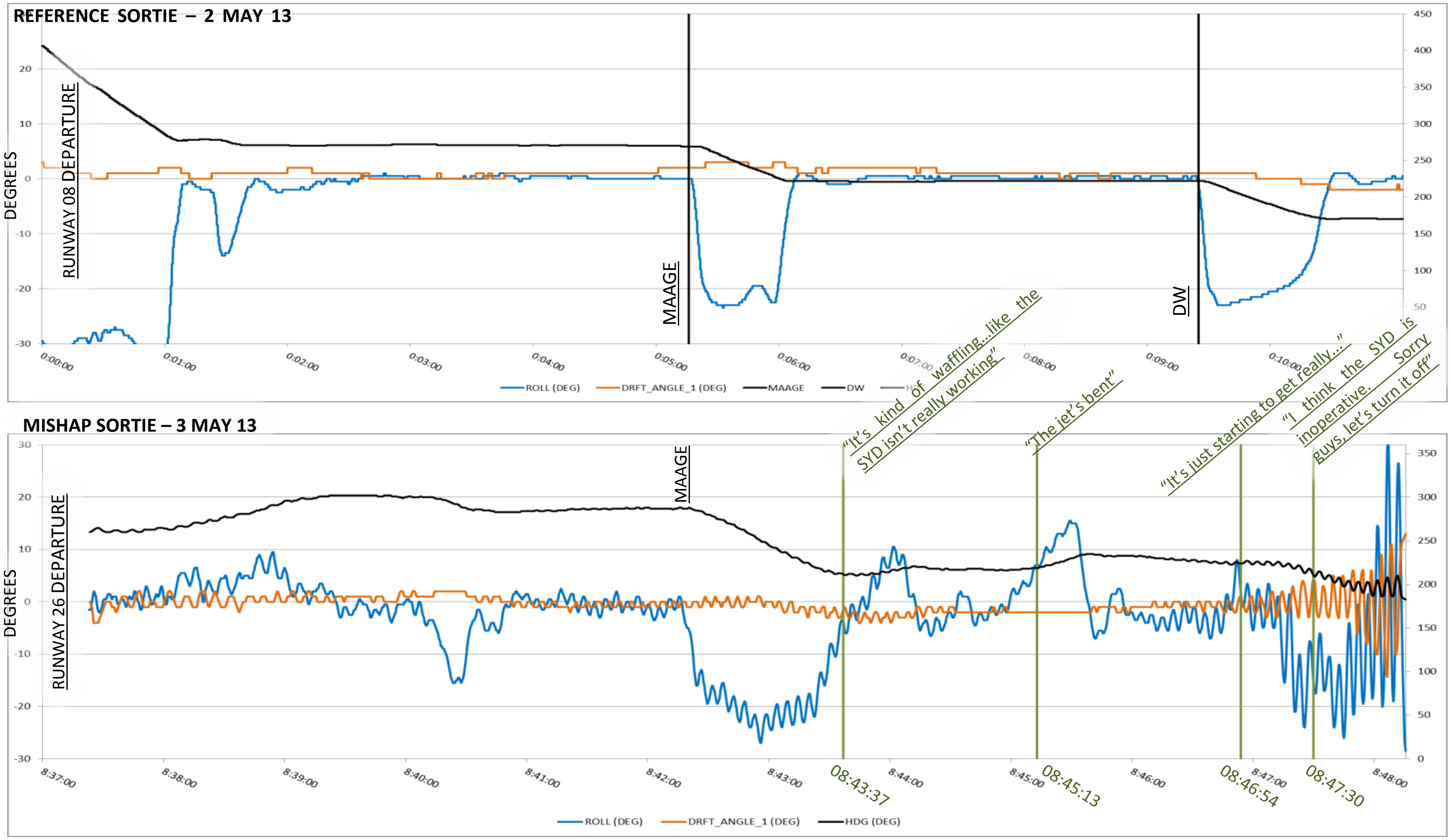

Figure 10. Comparison of Reference Sortie vs. Mishap Sortie on MAAGE Departure (Tab EE-10)

d. Use of Rudder during Dutch Roll

A published safety bulletin states that large, abrupt rudder inputs generate large sideslip angles, which result in an amplified roll rate (Tab AA-5 to AA-6). Sideslip builds before it generates this roll, which creates a time lag before the pilot perceives the roll. If the pilot uses rudder in the opposite direction, large amplitude oscillations can result (Tab AA-6).

The sideslip oscillations of the MA represent rudder inputs (some abrupt) and a progressively increasing sideslip. Due to the timing of the input, each peak rudder input (depicted as red bars in Figure 11) occurs in the same direction as the sideslip as depicted in Figure 11. Instead of decreasing the sideslip, the MP's inputs compounded it. At 08:48:14Z, the final rudder input of 11 degrees coincides with the final FDR and cockpit voice recorder (CVR) data indicating failure of the MA's tail section. One second later the MA pitches over at 08:48:15Z (Tab EE-3, EE-11, EE-18).

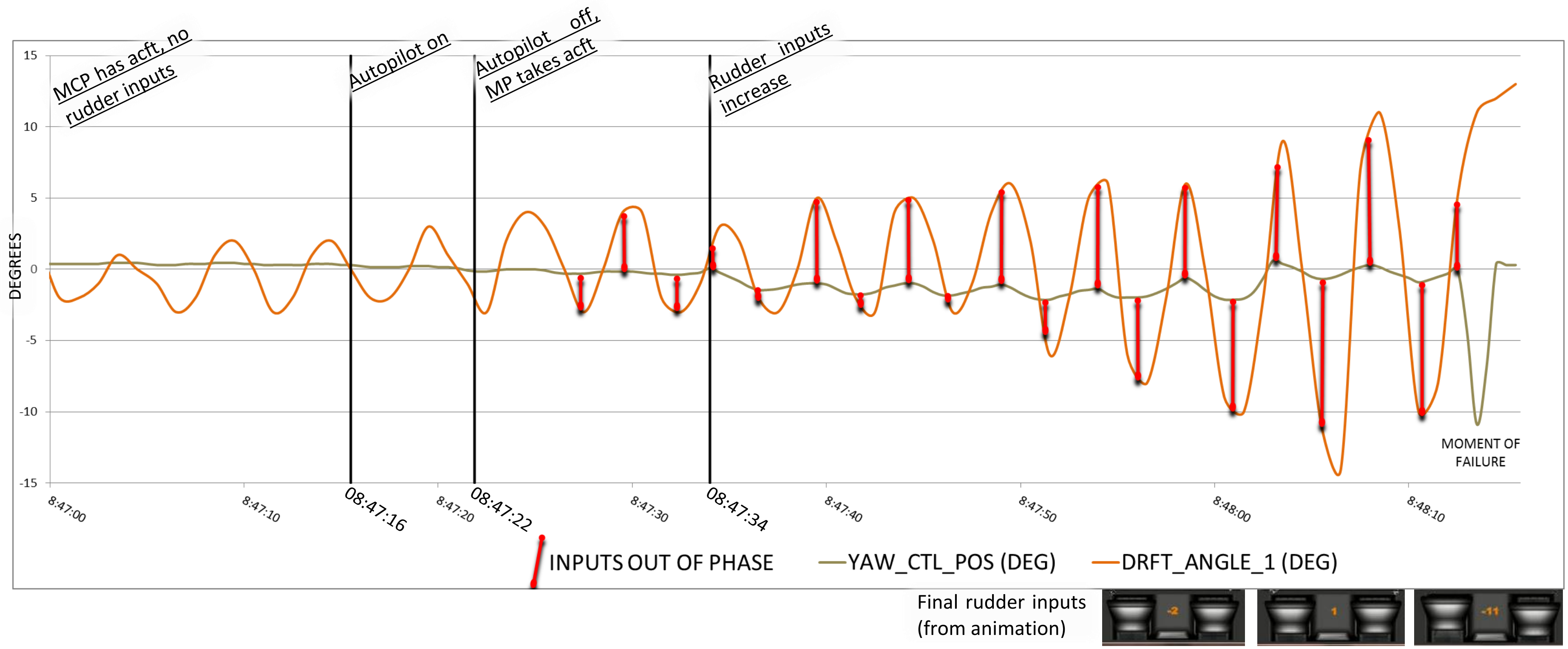

Figure 11. FDR Plot of MP's Rudder Input vs. Sideslip (Tabs Z-7, EE-11)

The MP's rudder response in Figure 11 is analogous to the expected response shown in red in Figure 12. The rudder input is nearly zero between 08:47:00Z and 08:47:34Z, and the sideslip oscillates steadily around plus or minus three degrees. From 08:47:34Z until the end of the flight, rudder inputs correspond with increasing sideslip on each cycle. Figure 12 below depicts the same divergent sideslip tendency when rudder input is applied two seconds late (Tabs AA-28, EE-11). The amplitudes of the building sideslip are indicative of undesirable rudder inputs, as shown below in Figure 12 (Tab AA-28).

If the pilot reacts to an abrupt roll onset with a large rudder input in the opposite direction, the pilot can induce large amplitude oscillations. These large amplitude oscillations can generate loads that exceed the limit loads and possibly the ultimate loads, which could result in structural damage (Tab AA-14). Boeing airplanes are capable of sustaining a single control input, but do not account for input reversal or oscillatory inputs (Tab AA-8). The Inflight Manual contains a warning that states, "The sudden reversal of rudder direction at high rudder deflections, due to improper rudder application or abrupt release, can result in overstressing the vertical fin. This condition could be brought about during recovery attempts from a flight condition induced by a lateral control malfunction" (Tab BB-172). Figure 11 depicts an abrupt application and release of the rudder, as well as a rudder reversal in the final 10 seconds (Tab EE-11).

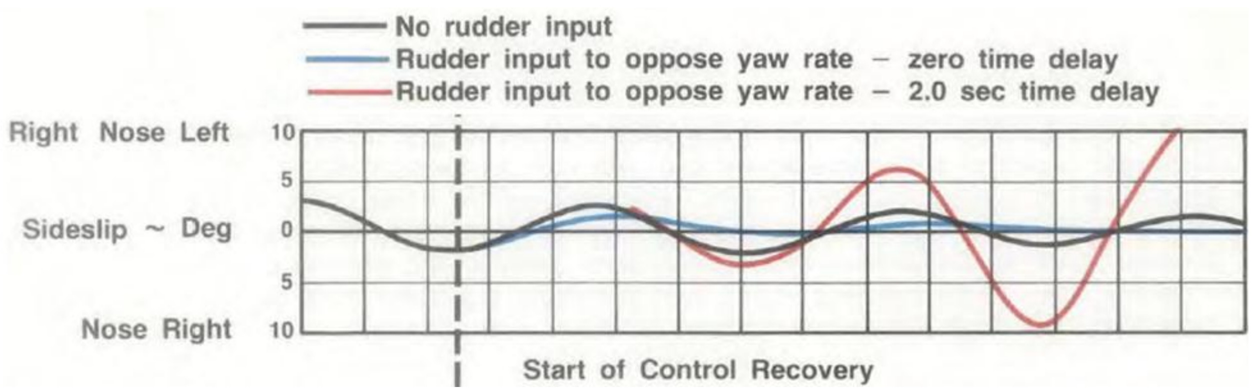

Figure 12. KC-135 Aerodynamic Characteristics Dutch Roll Response (Tab AA-28)

Immediately after the MP assumed control of the MA, rudder inputs are registered in the FDR data. These inputs indicate the MP placed his feet on the rudder pedals and moved them slightly (Tab EE-29). At waypoint DW, a shift in left rudder pedal deflection of 2 degrees occurred which indicates the MP attempted to use rudder to affect a left turn to remain on the MA's flight plan routing (Tab EE-32). This shift is followed by a series of alternating small rudder inputs, caused by the MA's dutch roll-induced acceleration forces varying the MP's pressure on the rudder pedals (Tab EE-29). This continued for 25 seconds and was followed by an abrupt reversal and shift in right rudder pedal deflection of almost 3 degrees (from 2 degrees left rudder to 1 degree right rudder) culminating a 27 degree divergence in drift angle (heading change) in less than one second (Tab EE-32). This shift corresponds with the MP rolling out of a turn to continue on the route of flight. These actions significantly increased the dutch roll due to the amplifying effect of the use of rudder pedal during dutch roll. Ten seconds later, the cumulative effects of the malfunctioning SYD, and out of phase autopilot use and rudder movements, increased dutch roll significantly, exceeding the MA's structural design limit load factors causing structural failure of the tail section (Tab EE-11, EE-32).

The rudder pedal force required to achieve maximum available rudder deflection decreases as airspeed increases. As speed increases, the maximum available rudder deflection can be obtained with comparatively light pedal forces and small pedal deflections (Tab AA-10). The maximum rudder angle attainable for the KC-135R at 320 knots (the approximate speed during the last minute of flight) is about seven degrees (Tab AA-46). For example, the plus or minus two degrees yaw control position (YAW_CTL_POS) that was applied by the MP equates to about one-third of the full rudder available at the time (Tabs AA-46, EE-11). The maximum rudder pedal force calculated prior to the MA's moment of structural failure was less than 40 pounds. The force required to deflect the rudder pedals that created the oscillations directly correlated to the total lateral momentum experienced by the MA due to dutch roll (Tab EE-30).

The FDR measures rudder pedal movement, not actual rudder deflection. Secondary actuator inputs such as the Engine Failure Assist System (EFAS) and SYD are not recorded since they do not move the rudder pedals (Tab EE-4). FDR and CVR data confirm the point at which the MP assumed control of the MA (Tab EE-29). To rule out the probability that a mechanical malfunction caused rudder pedal movement, a detailed analysis of the MA's PCU was conducted (Tab EE-29). This analysis determined whether or not tablock hydraulic piston slippage could cause tablock arm movement, which would in turn move the rudder pedals. Test results revealed the rudder pedals did not move due to slippage of the tablock hydraulic piston. There was very little hydraulic piston back-drive when the tablock arm moved to the limits of the test fixture (Tab J-126 to J-127).

Additionally, a worst-case load analysis was conducted at three points where rudder pedal displacement was noted as significant during the last minute of flight; this included the actual rudder pedal displacement and an additional four degrees of rudder displacement added for possible maximum SYD input. At these three points, the load applied through the tab rod to the PCU tablock arm did not exceed the holding capability of the tablock piston (Tab DD-28 to DD-29). When combining the results from both tests, it is unlikely that the load applied would result in slippage of the tablock piston. Therefore, the rudder pedal movement recorded by the FDR was generated by pilot rudder pedal movement, not slippage within the tablock piston (Tabs J-126 to J-127, DD-28 to DD-29, EE-29).

6. MAINTENANCE

a. Forms Documentation

All maintenance records, the Jacket File historical records, Air Force Technical Order (AFTO) Form 781 Series, AFTO Form 95, Maintenance History Information from the G081 database (Automated Maintenance Information System), and Time Compliance Technical Orders (TCTOs), were reviewed after the mishap. All maintenance actions for the MA were documented on AFTO Form 781 and in the G081database (Tab U-7). The AFTO Form 781 series provides a maintenance, inspection, service, configuration, status, and flight record for the particular aerospace vehicles and trainers for which they are maintained (Tab BB-19). G081 is a maintenance management system and a logistics command and control system for Mobility Air Force fleets. It provides fleet-wide visibility of status and location of aerospace vehicle, discrepancy history, TCTO status, maintenance data documentation history, personnel, back shop production control, training, support equipment, and aerospace ground equipment (Tab BB-21). The most current AFTO Form 781 series are maintained in a binder assigned to each aircraft and kept onboard during flight. As the most recently transcribed AFTO Form 781 Series available are dated 2 May 2013, the AFTO Form 781 series and Aircrew and Mission Flight Data document dated 3 May 2013 were onboard the MA and destroyed in the mishap. A detailed review of all AFTO Form 781 series and a one-year history review of the G081 records for the MA revealed no evidence to suggest maintenance was a factor in the mishap (Tab U-7).

The MA's total aircraft time was 20,611.4 hours. All four engines were F108-100 model number engines. The number one, three, and four engines had 8,783.2 hours total engine time respectively. The number two engine had 11,873.1 hours total engine operating time (Tab J-3). On 23 April 2013, a 60-day Hourly Postflight (HPO) inspection was accomplished on all four engines and no discrepancies were noted (Tabs J-3, U-8). All four engines appeared to have been operating normally at the time of the mishap. There is no evidence to suggest engine failure was a factor in the mishap (Tab J-4 to J-10).

A recurring discrepancy is a system or subsystem malfunction that reappears during the third, fourth, or fifth sortie (or attempted sortie) following its first appearance (Tab BB-13). A review of the historical records did not reveal any recurring maintenance problems (Tab U-8).

TCTOs direct and provide instructions for modifying military systems and end items or performing one-time inspections (Tab BB-23). A review of the records revealed all required TCTOs were accomplished IAW applicable guidance. No TCTOs restricted the MA from flight (Tab U-7).

b. Inspections

Programmed Depot Maintenance (PDM) is an inspection requiring personnel skills, equipment, or facilities not normally possessed by operating locations. Individual areas, components and systems are inspected to a degree beyond specific technical guidance requirements (Tab BB-18). Maintenance personnel at Alabama Aircraft Industries Incorporated in Birmingham, Alabama, a subcontractor of Boeing Aerospace Support Center in San Antonio, Texas (TX), accomplished a PDM inspection for the MA on 27 October 2011 (Tab D-2). The next PDM inspection was scheduled for 27 October 2016. The inspection was completed satisfactorily, and there is no evidence to suggest any items discovered during the inspection were factors in the mishap (Tab U-8).

The Periodic Inspection (PE) is due upon accrual of the number of flying hours, operating hours, or at the expiration of a calendar period specified in the applicable technical guidance (Tab BB-17). The last PE inspection was completed on 27 October 2011 as part of the PDM inspection , and the next inspection was scheduled for 26 October 2013. The PE inspection was completed satisfactorily, and there is no evidence to suggest any items discovered during the inspection were factors in the mishap (Tab U-8).

The 900-hour or 12-month inspection is a minor inspection accomplished between PE inspections. This hourly inspection is required on any individual aircraft that accumulates 900 flight hours or 12 months since the previous periodic inspection. An hourly inspection may be accomplished any time prior to 900 flight hours or 12 months, as directed by local command. This inspection consists of checking certain components, areas, or systems to determine if conditions exist which, if uncorrected, could result in failure or malfunction of a component prior to next scheduled inspection (Tab BB-31). The last scheduled 900-hour inspection was completed on 22 October 2012, and the next inspection was due in 353 hours or 22 October 2013, whichever came first (Tabs D-2, U-8). The 900-hour inspection was completed satisfactorily, and there is no evidence to suggest any items discovered during the inspection were factors in the mishap (Tab U-8).

The HPO consists of inspection requirements based on a predetermined number of calendar days. It shall be accomplished every 60 days (Tab BB-25). The last HPO was completed on 23 April 2013 at McConnell AFB, KS IAW technical guidance. The next HPO inspection was scheduled for 22 June 2013. The HPO was completed satisfactorily, and there is no evidence to suggest any items discovered during the inspection were factors in the mishap (Tab U-8).

The thruflight (between flights) inspection, is accomplished after each flight when a turnaround sortie or a continuation flight is scheduled (Tab BB-16). Mishap Maintainer 3 (MM3) and MM6 accomplished the last thruflight inspection satisfactorily on 1 May 2013 at 0930Z at RAF Mildenhall (Tabs U-8, V-10.5, V-15.5, V-15.9). MM3 inspected the MA IAW technical guidance, and no discrepancies were found during the inspection (Tab U-10). There is no evidence to suggest the thruflight inspection was a factor in the mishap (Tab U-9).

The preflight inspection is a flight preparedness inspection check conducted IAW T.O. 1C-135-6, *Aircraft Scheduled Inspection and Maintenance Requirements*, dated 13 October 2010. A preflight inspection is valid for 72 hours provided the aircraft has not been on the ground for 48 consecutive hours (Tab BB-196). A preflight inspection was accomplished at McConnell AFB, KS on 30 April 2013. No discrepancies were found during the inspection (Tab V-10.5, V-15.5). The MA landed at the Transit Center at Manas, Kyrgyz Republic at approximately 1200Z on 2 May 2013. The last preflight inspection for the MA started at approximately 1230Z on 2 May 2013 and was completed at approximately 1800Z on 3 May 2013. At the completion of the preflight inspection, the MA had been on the ground for approximately six hours (Tab V-5.5 to V-5.7).

A Quality Assurance Inspector (QAI) performed a quality verification inspection (QVI) for the preflight inspection and found three discrepancies; the nose steering valve cover bracket was cracked, the right keel beam bay door was unsecured, and one screw was missing from the right horizontal stabilizer coffin panel. These discrepancies failed the QVI (Tabs U-8, V-6.4 to V-6.5). The preflight maintenance crew returned to the MA and corrected the discrepancies. To prevent further cracking of the nose steering valve cover, a hole was drilled at the end of the crack. The screw was annotated as missing in the forms. MM4, MM5, and MM8 secured the right keel beam bay door (Tabs U-11, V-5.5 to V-5.7). With the exception of the items stated above, the preflight inspection was accomplished IAW proper technical guidance. There is no evidence to suggest any items discovered during this inspection were factors in the mishap (Tab U-8).

During the MC's exterior preflight inspection, personnel noticed a small amount of hydraulic fluid on the ground near the left wheel well. A hydraulic component associated with landing gear door actuation had a small amount of hydraulic fluid dripping from its B nuts; hydraulic maintenance personnel inspected the component, tightened the B nuts and performed a leak check. While pressurizing the hydraulic system to perform the leak check, a small amount of hydraulic fluid discharged from the MA's left wing. It was determined that this discharge was likely the result of the MA draining excess fluid after having been over-serviced. Personnel cleaned up the fluid, and verified that the MA did not have a leak (Tab V-12.6 to V-12.7).

c. Maintenance Procedures

All maintenance procedures accomplished at McConnell AFB, KS and RAF Mildenhall prior to the MA's arrival at the Transit Center at Manas were conducted IAW technical guidance. MM3 and MM6 accomplished the preflight inspection and launch procedures. Maintenance procedures performed by personnel at the Transit Center at Manas during recovery and preflight were performed IAW technical guidance (Tab U-10 to U-11). As stated above, the preflight inspection initially failed a QVI, but all identified issues were corrected and signed off in the MA AFTO 781A Form (Tabs U-11, V-6.7 to V-6.8). All maintenance procedures accomplished on the MA from 30 April 2013 until the day of the mishap were completed IAW the applicable aircraft T.O.s, and there is no evidence to suggest maintenance procedures were factors in the mishap (Tab U-11).

d. Maintenance Personnel and Supervision

Maintenance personnel from the 22d Aircraft Maintenance Squadron at McConnell AFB, KS serviced and performed inspections of the MA prior to deployment and en-route to the Transit Center at Manas. Training records confirmed maintenance personnel were trained and certified on the task they performed on the MA (Tab U-11). Maintenance personnel assigned to the 376th Expeditionary Aircraft Maintenance Squadron (376 EAMXS) performed the preflight inspection and launch of the MA prior to the mishap. With the exception of one individual, MM2, maintenance personnel were trained and certified on all tasks they performed (Tab U-11 to U-12).

MM2, who was a member of the maintenance team that launched the MA on 3 May 2013, was in training and was not officially qualified to launch aircraft (Tab V-12.4 to V-12.5). MM2 is a back shop electrical-environmental journeyman; he had never performed a flightline task for KC-135 aircraft prior to this deployment (Tab V-12.2 to V-12.3). MM1 was supervising MM2's aircraft launch and flight controls training (Tab V-28.11). No sequential aircraft launch procedures are outlined in a specific maintenance T.O. Aircraft ground crews use various technical guidance that discusses ground handling procedures and flight control checks (Tab U-11). MM2 followed available technical guidance during the performance of the task, and he had been briefed by his immediate supervisor of the steps required to perform the task. On two previous occasions, MM2 performed on-the-job training by launching an aircraft under the supervision of a qualified individual (Tab V-12.4 to V-12.5). On 3 May 2013, MM2 was tasked to launch the MA while MM1 supervised the action (Tab V-28.11). MM2 was confident that his training would be completed and signed off; however, the mishap delayed this from occurring (Tabs U-12, V-12.5).

As the MC conducted its pre-flight checks, MM2 called flight control movements over the headset as MM1 stood behind him monitoring (Tab V-12.6 to V-12.7, V-12.11). MM1 left MM2 unsupervised during the flight control checks to discuss the hydraulic leak with Hydraulic Shop members (Tab V-28.7 to V-28.8). Aside from this instance, all individual training records and special certification rosters for all personnel performing maintenance on the MA reflected they were trained and certified to complete all assigned tasks (Tab U-12).

The 376 EAMXS executed split-ramp operations that required flightline supervisors to cover multiple aircraft ramps during launch, recovery, and maintenance actions. The ramps were approximately 400 to 600 meters apart. It took only 45 to 60 seconds at 15 miles per hour to get from one ramp to the next. There were two expediters (personnel in charge of coordinating maintenance procedures during launch and recovery) covering the ramps on the day of the mishap. The MA was the last scheduled KC-135R aircraft to launch, and Expediter (EXP) stayed with the aircraft until its departure (Tabs U-12, V-4.3 to V-4.6). There is no evidence to suggest maintenance personnel and maintenance supervision were factors in the mishap (Tab U-11 to U-12).

e. Fuel, Hydraulic, and Oil Inspection Analyses

All fluids onboard the MA were destroyed in the mishap; consequently, there was no post-accident fluid analysis (Tab U-9). In accordance with T.O. 42B-1-1, *Quality Control of Fuel and Lubricants*, dated 19 November 2012, a burn test was performed on pre-accident fuel samples taken from the servicing fuel trucks. No anomalies were found in any of the samples (Tab U-3, U-9).

f. Unscheduled Maintenance

Unscheduled maintenance is any action taken that is not the result of a scheduled inspection and normally is generated by a pilot-reported discrepancy (PRD) or condition discovered by ground crew personnel. A thorough review of the MA's AFTO Form 781 Series revealed several unscheduled maintenance actions since the last scheduled inspection. On 19 January 2013, maintenance personnel at McConnell AFB, KS replaced a Flight Control Augmentation System (FCAS) computer because the SYD would not engage during flight. The computer was replaced, and it passed an operational check. All unscheduled maintenance actions were completed IAW technical guidance (Tab U-9).

Impoundment is the isolation or control of access to an aircraft or equipment item and applicable historical records so an intensified investigation can be completed. An aircraft is impounded when intensified management is warranted due to system or component malfunction or failure of a serious or chronic nature (Tab BB-14).

On 15 February 2013 at McConnell AFB, KS, the MA was impounded for a PRD of uncommanded flight control movement, or rudder hunting. The aircrew of this flight followed checklist procedures to disengage the SYD, recovered the aircraft at McConnell AFB, and turned it over to maintenance for repairs (Tab V-27.4). After troubleshooting the rudder system, the maintenance crew determined the rudder power control unit (PCU) was defective; therefore, they removed and replaced it (Tab V-27.5). Operational checks, to include rig checks (placement of aircraft components into their correct positions) were accomplished. After the impoundment, the system checked satisfactorily (Tabs U-9, V-14.4, V-14.6, V-27.5 to V-27.7, V-27.11). The MA flew approximately 14 sorties following the impoundment with no repeat or recurring discrepancies noted (Tabs U-9, EE-5).

Additionally, the impoundment procedures as stated in the 22d Maintenance Group (22 MXG) Operating Instruction (OI) 21-101, *Maintenance Procedures*, dated 29 January 2010, were not followed in entirety. The impoundment checklist 22 MXG Form 21-8, *Impoundment Official Checklist*, dated 1 July 2007, was available but not completed. A chronological log was available but did not contain the required information as stated in 22 MXG OI 21-101, paragraph 2.2.2.11 (Tabs U-10, V-27.4, V-27.17 to V-27.19, BB-10 to BB-11). Although these discrepancies show a lack of following procedures, all impoundment maintenance actions were accomplished and documented IAW technical data. There is no evidence to suggest impoundment procedures were a factor in the mishap (Tab U-10).

A thorough review of Impound Official 2 (IMPO2), Impound Maintainer 1 (IMP MX1), IMP MX2, MM7 and the rest of the impoundment crew's training records, with the exception of IMPO1, revealed they were trained and certified to complete all assigned tasks while troubleshooting and repairing the MA during the impound (Tab U-11). IMPO1 was in training during the impoundment of the MA and consequently, was not trained, experienced, or certified on the task (Tabs U-11, V-27.5, V-35.3).

7. AIRFRAME, MISSILE, OR SPACE VEHICLE SYSTEMS

a. Condition of Structures

(1) Rudder

The rudder separated from the MA and landed separately from the vertical and horizontal stabilizers (Tab J-15). It was broken into multiple pieces. The bottom, middle, and top pieces of the rudder failed at the riveted splice joints shown by the red the break lines in Figure 13 (Tab J-88). The middle section of the rudder was not recovered (Tab J-15).

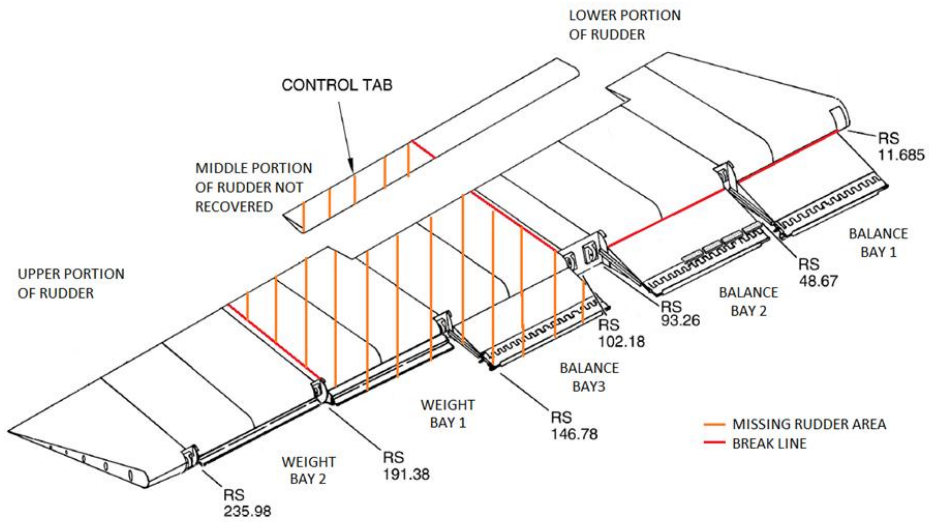

Figure 13. Rudder Shown Laying Flat with Balance Panels and Control Tab (Tab Z-9)

All seven of the vertical stabilizer-rudder hinge assemblies (fittings, bolts and nut plates), located at the Rudder Stations (RS) shown in Figure 13, failed at either the vertical stabilizer or the rudder side of the assembly (Tab J-87).

(2) Vertical Stabilizer

The vertical stabilizer attachment points at Body Station (BS) 1440 and BS 1507, shown in Figure 16, were both intact on the stabilizer side with the pins installed. At BS 1440, the fuselage side fittings had failed just below the fuselage skin (exterior metal sheets of the aircraft's structure) (Tabs J-18, HH-3). At BS 1505, the top of the bulkhead with the complete body side fitting intact was still attached to the vertical stabilizer (Tab J-18).

The vertical stabilizer has a steel splice plate on the left hand side at Fin Station 156 to splice the chord at the aft end of the balance bays (See Figure 14) (Tab J-18). A splice is a joint made in assembly of aircraft components in which all individual parts have to be attached (Tab HH-3). The Fin Station 156 splice plate was deformed to the left and down due to the rudder PCU being torn from the vertical stabilizer as the rudder hinge assemblies and rudder failed (Tab J-86 to J-87). In addition, there was a large rip on the left hand side of the vertical stabilizer where the rudder PCU tore through the skin (Tab J-18). The left and right sides of the vertical stabilizer contained forward to aft skin buckling from the bottom up (Tab J-87). Buckling is an out of plane bending, followed by crushing of material under compressive loads (Tab HH-3).

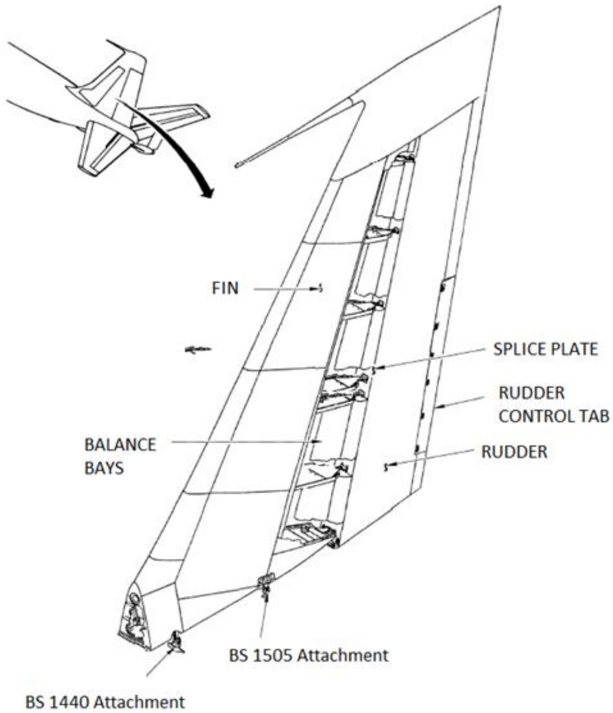

Figure 14. Vertical Stabilizer and Rudder Balance Bays (Tab BB-127, BB-131)

(3) Horizontal Stabilizers with Elevators Attached

The horizontal stabilizers (left hand, right hand and center sections) departed the MA intact along with their respective elevators (Tab J-20). There was no apparent damage to the stabilizer attachment points (Tab J-20). Symmetric outboard "V" shaped skin buckling and tears were present in the left and right horizontal stabilizers upper skins due to ground impact (See Figure 15) (Tab J-20, J-86).

Figure 15. Horizontal Stabilizer Sections and Portion of Aft Fuselage (Tab Z-8)

(4) Aft Fuselage Structure

The fuselage is divided into four sections (Section 41, Section 43, Section 46 and Section 48) (See Figure 16). The wing-to-fuselage attachment structure consists of terminal fittings on bulkheads at BS 620 and BS 820. The horizontal stabilizer surfaces loads are transferred to the fuselage by the stabilizer trim actuator through the lower bulkhead at BS 1505 and the stabilizer hinge fitting through the bulkhead at BS 1592 (Tab BB-95).

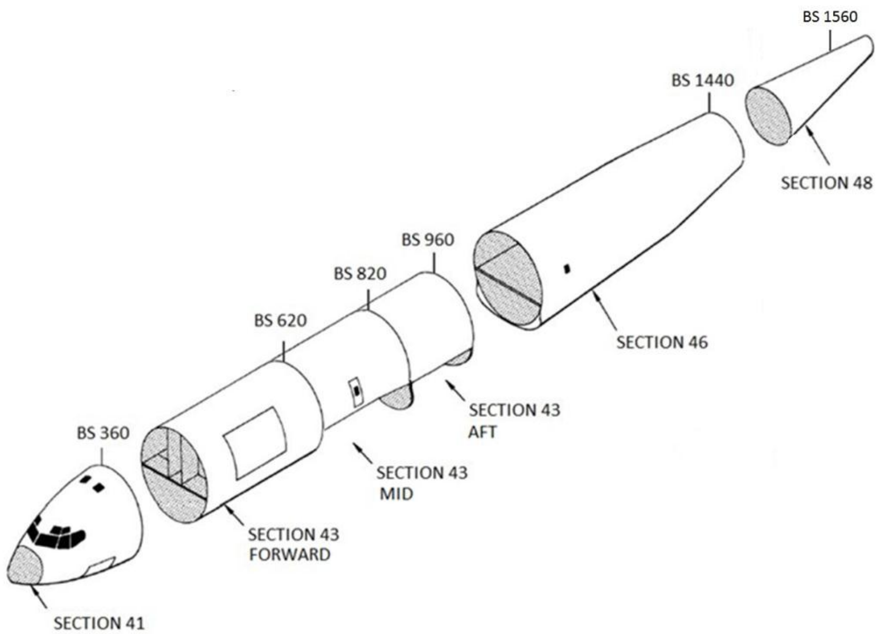

Figure 16. Fuselage Section Breakdown (Tab Z-11)

The MA separated at the Section 46 to Section 48 joint just aft of the BS 1440 bulkhead (Tab J-23). The top of Section 48 remained attached to the vertical stabilizer (Tab J-24). It extended from approximately BS 1440 aft to BS 1560 and spanned multiple stringer bays (Tab J-24, J-85).

(5) Summary of Structural Failures

The rudder, vertical stabilizer and horizontal stabilizer sections, with elevators still attached, (tail section) separated from the MA at about the same time during the mishap (Tab J-28). These parts were recovered in close proximity to one another but were located separate from the other wreckage in the debris field (See Figure 2) (Tabs J-14, J-84, Z-8). The lack of fire damage to any tail section components indicates it was the initial point of failure (Tabs J-28, HH-3). Nearly all the other wreckage parts showed fire damage (Tab J-34).

The structure that failed in Section 48 of the fuselage did so under extreme load. These loads could not be applied unless the vertical stabilizer was firmly attached to the fuselage forward of section 48 prior to the overload (Tab J-29). Following the loss of the stabilizers, the MA would rapidly pitch down. At this point, the MA experienced structural overload beyond design conditions of virtually all components (Tab J-28). This is consistent with the design of conventional swept wing aircraft which dictate a strong nose down pitching moment, normally balanced by the downward force of the horizontal stabilizer (See Figure 17) (Tab J-27 to J-28).

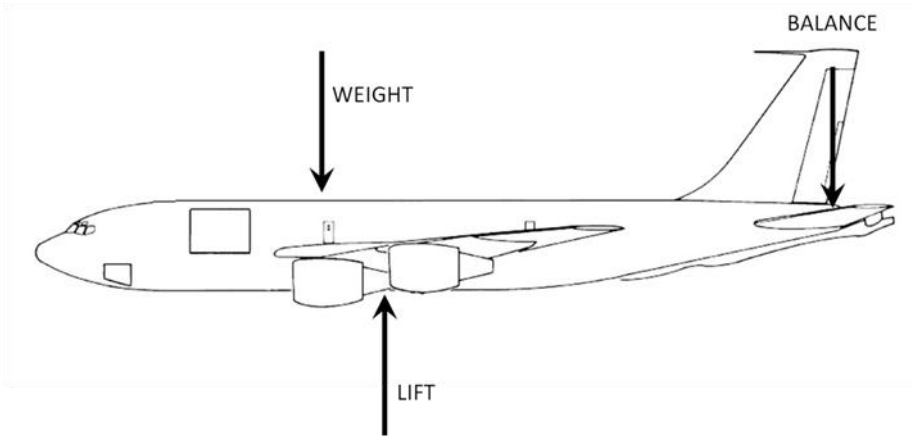

Figure 17. Balancing Stabilizer Load (Tab Z-9).

Structural failure of the wings and fuselage forward of BS 1440 caused the MA to break into four pieces which included three major fuselage sections and the right hand wing. The forward portion of the fuselage separated just forward of the wing near BS 600 (Section 41 and Section 43 Forward). The fuselage broke just aft of the wings near BS 980 (Section 46). The center portion of the fuselage over the wings and main landing gear wheel wells (Section 43 middle and aft) remained with the center wing and most of the left hand wing. (See Figure 16) In addition, all four engines separated from the wings (Tab J-28).

The MA was delivered by The Boeing Company to the USAF on 26 June 1964. Since delivery, the MA has been modified by TCTOs and Boeing engineering change proposals (Tab U-13). PDM maintenance history records for the MA structure indicated no structural defects (Tab U-8).

b. Condition of Systems

(1) Rudder Feel Unit

The feel unit and Q-bellows provide artificial rudder feel for the pilot during hydraulic power-on mode of rudder operation. The feel unit also receives rudder power trim inputs from the control stand and transmits these trim inputs to the rudder power control unit (PCU) (See Figure 20) (Tab BB-44 to BB-45). The amount of feel at the pedal is a function of and proportional to the amount of pedal deflection and aircraft speed. The feel unit and Q-bellows provide feel in the hydraulic power on mode only. The rudder feel forces felt by the pilot in the manual mode of rudder operation (hydraulic power-off) are due to system friction and aerodynamic forces reacting on the rudder tab (Tab BB-45 to BB-46). Wear in the rudder feel unit was found during post-mishap inspection and teardown of the rudder and rudder trim components (Tab DD-13).

The MA's rudder feel unit was manufactured by The Boeing Company (Tab U-13). PDM maintenance history records for the MA indicate no defects were present during the PDM inspection on 27 October 2011 (Tab U-8).

(2) Rudder Power Control Unit

Under normal conditions the rudder is hydraulically positioned through full travel by the PCU (See Figure 18) (Tab BB-45). In addition to the pilots, the FCAS provides automatic rudder control inputs to assist with yaw control of the airplane. The FCAS system consists of an EFAS and SYD. The SYD provides full-time, automatic rudder inputs in response to a broad range of adverse yaw conditions including dutch roll, uncoordinated turns, asymmetric thrust, and other disturbances such as gust or turbulence (Tab BB-144). The SYD deflects the rudder through a secondary rudder actuator inside the PCU. There is no motion in the rudder pedals when the SYD is operating the rudder (Tab BB-67). FCAS components are connected and controlled by an electro-hydraulic sensing, warning and actuation network. The FCAS computer contains both electronic components and circuitry for the EFAS and SYD (Tab BB-144). The MA's SYD and EFAS servo valves were still operational after the mishap (Tab J-125). Several aircraft parts were sent off for analysis. However, the remaining electrical components, including the FCAS computer, were destroyed during the mishap and thus not tested (Tab Q-12 to Q-13, Q-19 to Q-21).

Figure 18**.** Non-Mishap PCU (Tab Z-10)

The PCU main actuator shaft was broken in the vertical plane after the rudder hinges overloaded and subsequently failed (Tab J-35 to J-36). Failure of PCU linkages also occurred including a broken tablock H-assembly (Tab J-125). The outer fork of the main clevis of the lock lever was bent toward the actuator at the bearing rivet (See Figure 19) (Tab DD-12).

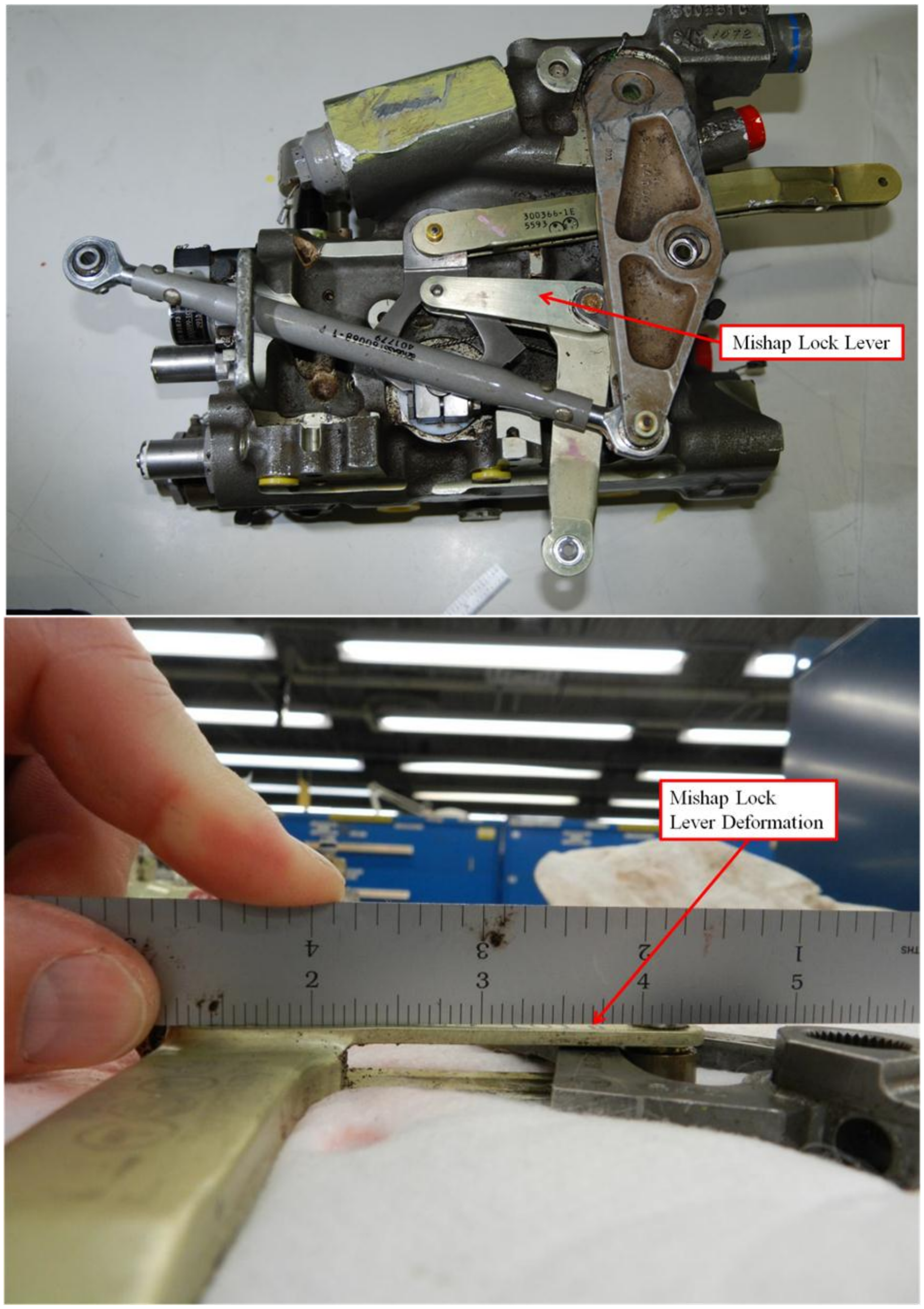

Figure 19. Mishap PCU with Bent Lock Lever (Tab Z-12)

The exact value for “operating force” of the PCU was not recorded on the 40561A Test and Data Sheet; only a checkmark appears in the operating force field (Tab J-135). The mishap PCU was manufactured by Parker Hannifin (Tab U-13).

(3) Flight Data Recorder/Cockpit Voice Recorder

The FDR/CVR system provides a crash-protected environment that enables retrieval of digitally recorded aircraft data (Tab BB-71). All data acquisition and format conversions are accomplished within the FDR/CVR (Tab BB-72). The FDR/CVR data was recovered (Tabs Z-12, EE-4).

c. Evaluation and Analysis

(1) Rudder

There was no evidence that the three sections of the rudder separated while still attached to the vertical stabilizer, as there are no marks indicating contact between rudder sections after separation (Tab J-17). Additionally, the presence of marks along the entire vertical stabilizer indicates the rudder was in one piece in the trailing edge left position at the time of hinge overload (Tab J-36). The rudder broke into pieces after separation from the vertical stabilizer (Tab J-29). The rudder and rudder trim tab fracture surfaces were visually examined. All skin fractures were typical of overload with no evidence of pre-existing failures such as fatigue or stress-corrosion (Tab J-88).

Examination of the failed rudder hinge parts and hardware revealed only evidence of overload, indicating failure above the design ultimate loads (Tab J-17, J-29). No evidence of preexisting failures such as fatigue or stress-corrosion was found (Tab J-88). Analysis was unable to provide a specific load case based on FDR data at which the observed failures would be expected to occur (Tab DD-12).

(2) Vertical Stabilizer

Contact marks within the vertical stabilizer show that the rudder was fully deflected and driven to its extreme limits in both directions (Tab J-29). The deflections occurred with sufficient force to deform the structures (Tab J-36). These marks along with the Fin Station 156 splice plate indicate that the rudder and rudder trim tab assembly departed the MA as one unit at, or in excess of, maximum left rudder travel. All skin fractures of the vertical stabilizer were typical of overload with no evidence of preexisting failures such as fatigue or stress-corrosion (Tab J-87). FDR data shows the MA entered a condition where the applied load to the vertical stabilizer exceeded the design ultimate load. The vertical fin spar chords were identified as possible critical areas when overloaded by the condition experienced by the MA. However, examination of the wreckage reveals the vertical fin spar chords did not fail (Tab DD-12).

(3) Horizontal Stabilizers with Elevators Attached

All spar, rib, and skin fractures of the horizontal stabilizers and elevators were typical of overload with no evidence of pre-existing failures such as fatigue or stress-corrosion (Tab J-86).

(4) Fuselage

Based on wreckage distribution, analysts concentrated on the fracture surfaces associated with stabilizer separation (Tab J-34). The vertical stabilizer, front spar, and attachment fittings at BS 1440 failed due to overload just below the BS 1440 frame chord (Tab J-23, J-25). The vertical stabilizer, rear spar, and attachment fittings at BS 1505 fittings did not fail (Tab J-25). The BS 1505 bulkhead chord failed between S-10 and S-11 on the right hand side due to overload at the

10th fastener below the cutout for the stabilizer center section (Tab J-24, J-25). This is the strongest part of the BS 1505 bulkhead to fail on the right hand side of the MA (Tab J-25).

Visual and laboratory examination of the fracture surfaces associated with the stabilizer fractures, skins, stringers, bulkheads, chords, and fittings showed only failure in overload. No evidence of preexisting damage, corrosion, fatigue, or stress corrosion cracking was identified (Tab J-25, J-36, J-85). Analysis of the aft fuselage (Section 48) that remained attached to the vertical stabilizer showed the vertical stabilizer departed to the left hand side (Tab J-19).

The BS 1505 bulkhead side web fasteners were also identified as a possible critical area when overloaded by the condition seen by the MA. The wreckage shows there was a separation around the BS 1505 bulkhead side web fasteners. Analysis shows that if the fasteners were to shear, the remaining chords and stiffeners would be overloaded and would consequently fail. After failure of the web, chord and stiffeners, the external fuselage skins would likely fail due to overload. Again, the initial failure would occur above design ultimate load (Tab DD-12).

Separation of the MA's fuselage around the vertical tail area caused the remaining fuselage to overload. In short, the remaining fuselage was unable to carry the balancing load of the MA; therefore, the aft fuselage and horizontal stabilizers departed the MA inflight (Tab DD-12).

(5) Rudder Feel Unit

Wear in the rudder feel unit could correlate to an input to the rudder PCU to displace the rudder either left or right from the neutral position. Due to increased Q-bellow input at higher airspeeds, the rudder would be displaced further from the neutral position. Additionally, the Q-bellow force will be constant and not induce an oscillating rudder (Tab DD-13). Analysis of FDR data from the MA's previous flight on 2 May 2013 from RAF Mildenhall to the Transit Center at Manas showed the MA's control wheel position appeared to be oriented to the left indicating a tendency for the MA to roll to right (Tab EE-6). Although the MA had a tendency to roll to the right, the flight on 2 May 2013 was uneventful (Tabs V-20.7, EE-6). FDR data indicates the MA experienced this same tendency to roll to the right on the day of the mishap (Tab EE-5). There is no evidence to suggest the wear in the rudder feel unit caused the MA's rudder to oscillate during the mishap flight.

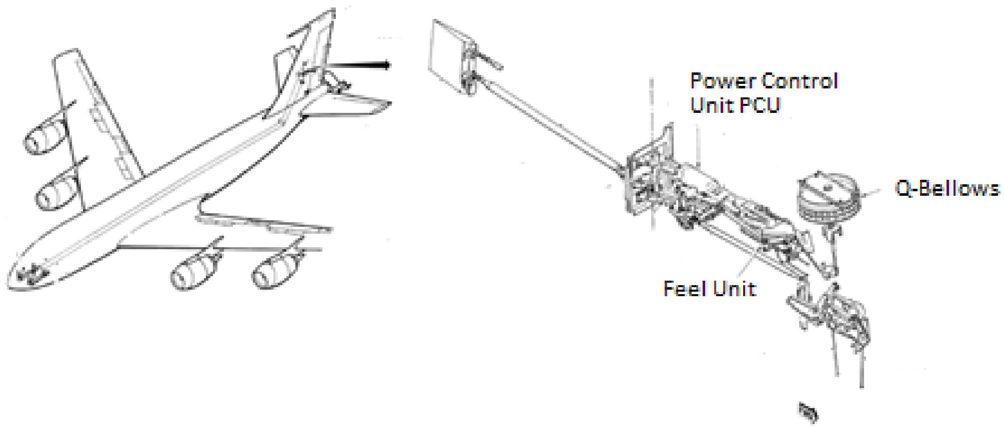

Figure 20. Rudder Control Equipment (Tab BB-47)

(6) Power Control Unit Analysis

PCU testing showed the operating force at the Pilot Input Arm to cause main actuator movement was five pounds in one direction and six pounds in the other. The limit is five pounds but newly overhauled actuators normally require around one pound of input to operate. Hysteresis is the lag in response exhibited by a body reacting to changes in the forces affecting it (Tab HH-4). The PCU failed the electrical accuracy and hysteresis test (Tab J-128).

Due to the severe nature of the mishap, it is not possible to know if the damage to the lock lever occurred during flight or as a result of the mishap. However, the contact marks on the lock lever roller would indicate that the lock lever could have been bent and rubbing on the input arm cam during flight (Tab DD-12 to DD-13).

In at least one case, an aircraft has passed the Flight Control Augmentation System's SYD Built-in-Test and experienced unscheduled rudder movements (Tab DD-4). The PCU for that aircraft had a bent lock lever (Tab DD-9). To operate correctly the PCU linkage must be free of any binding or interference and requires a minimum force to both start and stop the movement of the main actuator. A bent lock lever can contribute to restricting the movement of the PCU linkage with the effect being rudder hunting in flight (Tab DD-9). When the SYD commands a rudder input to offset aircraft yaw, the system expects an immediate response. A delay or lack of rudder movement causes a dead zone in the relationship between aircraft yaw and rudder position, with the result being less effective yaw control. In addition, if the rudder tends to overshoot, it will induce a yaw in the opposite direction. Continuation of this PCU performance will cause a yaw limit cycle oscillation that will remain until the SYD is turned off (Tab DD-5).

To rule out the probability that a mechanical malfunction caused rudder pedal movement, a detailed analysis of the MA's PCU was conducted (Tab EE-29). This analysis determined if tablock hydraulic piston slippage could cause tablock arm movement, which would in turn move the rudder pedals. Test results showed very little hydraulic piston back-drive when the tablock arm moved to the limits of the test fixture (Tab J-126 to J-127).

Additionally, a worst-case load analysis was conducted at three points where rudder pedal displacement was noted as significant in the last minute of flight; this included the actual rudder pedal displacement and an additional four degrees of rudder displacement added for possible maximum SYD input. At these three points, the load applied through the tab rod to the PCU tablock arm did not exceed the holding capability of the tablock piston (Tab DD-28 to DD-29). When combining the results from both tests, it is unlikely that the load applied would result in slippage of the tablock piston. Therefore, the rudder pedal movement recorded by the FDR was generated by pilot rudder pedal movement, not slippage within the tablock piston (Tabs J-126 to J-127, DD-28 to DD-29, EE-29).

(7) Flight Data Recorder

Examination of flight data for the MA from the time of its impoundment on 15 February 2013 until the mishap flight shows no evidence of dutch roll or uncommanded rudder movements based on aircraft roll, aircraft drift angle, and lateral acceleration (Tab EE-5). However, during the flight just prior to the mishap flight, the control wheel position appears to be dominantly oriented to the left indicating the MA's tendency to roll to the right due to the worn rudder feel unit (Tab EE-6). In addition, a comparison flight with a similar flight plan to the MA was reviewed (Tab EE-10). Erroneous data or noise was found in the lateral control position channel on all flights reviewed (Tab EE-4). Portions of the lateral control position data were deemed erroneous and were removed from the analysis (Tab EE-5). Information from the FDR data relevant to the mishap is discussed in Section 5, Analysis of Accident Sequence, of this report.

8. WEATHER

a. Forecast Weather

On the day of the mishap, departure weather at Manas International Airport was forecast to be clear, with no ceiling or visibility restrictions. Winds were forecast out of the Northeast at 10 knots. The forecast pressure elevation on the field was 2,064 feet. En-route, isolated thunderstorms were forecast in southwestern Kyrgyz Republic and northern Tajikistan, with broken cloud decks between 12,000 feet and 20,000 feet (Tab F-2).

b. Observed Weather

The weather on takeoff was as forecast, though the winds were out of the Southwest at 14 knots (7 meters per second), gusting to about 18 knots (9 meters per second) (Tab N-13). The MC observed the forecast broken cloud deck as follows: The MCP engaged the engine anti-ice system as the MA climbed through 12,300 feet (Tabs N-10, EE-5). The MP reported clear of the weather climbing through 21,500 feet (Tabs N-11, EE-12). The MC deviated southeast of course en-route to waypoint DW due to visually identified cloud buildups (See Figure 4) (Tab N-11). Additionally, a USAF C-17A crew, who took off 15 minutes before the MA, observed cloud buildups near waypoint DW using their onboard weather RADAR as well as visually (Tabs R-46, V-34.5). The C-17A crew did not experience any turbulence (Tabs R-48, V-34.5). Two low-intensity rainclouds are shown on the base RADAR return at the time and location of the mishap (Tab V-2.11). The return indicates they had light rain that would have been below the MA's altitude (Tabs V-2.5, W-4 to W-5). After the mishap, witnesses on the ground reported seeing darkened skies and light rain showers, with the base of the clouds even with the tops of the nearby mountains (Tab V-24.1, V-25.1, V-25.4).

c. Space Environment

Not applicable.

d. Operations

Operations of the MA were conducted within prescribed operational weather limitations, with one exception (Tabs F-2, BB-203 to BB-207). Due to the intermittent functioning of the onboard weather RADAR system, the MA was required to remain clear of clouds (Tabs N-4 to N-7, N-9, N-10, BB-239). The broken cloud deck between 12,000 feet and 20,000 feet made the MA unable to comply with this restriction (Tab F-2).

9. CREW QUALIFICATIONS

a. Mishap Pilot

(1) Qualifications

The MP completed undergraduate pilot training at Laughlin AFB, TX, on 12 March 2010 (Tab T-37). The MP initially qualified in the KC-135 as a first pilot (FPQ) on 2 September 2010, at Altus AFB, Oklahoma (OK) (Tab T-38). He completed all phases of the Global Readiness Aircraft Commander Course on 25 April 2012 (Tab T-56). The MP completed in-unit training as a KC-135 aircraft commander at Fairchild AFB, WA, on 26 February 2013 (Tab G-48). The MP completed his initial aircraft commander mission evaluation on 28 February 2013 (Tab T-19).

(2) Summary of Training

During KC-135 initial qualification training, the MP was described as highly motivated and extremely dedicated (Tab T-38). After flying as a FPQ, the MP entered an in-unit aircraft commander upgrade training program on 6 November 2012 (Tab G-48). While in training for aircraft commander upgrade, it was noted that the MP needed to work on establishing solid limits and taking control of the aircraft from the co-pilot, if warranted (Tab T-41). No comments in the subsequent training report indicated the weakness was addressed prior to the MP becoming a certified aircraft commander (Tab T-42). The MP's strengths included general knowledge, aircraft control, checklist procedures, situational awareness and decision-making. No weaknesses were noted (Tab G-48). The MP's evaluation was graded Qualification Level One. No discrepancies were noted on aircraft commander mission evaluation (Tab T-19 to T-20).

(3) Recent Activity

After upgrading to aircraft commander, the MP flew three flights and two simulator events prior to deploying on 17 April 2013 (Tabs G-9, X-4). After arriving at the Transit Center at Manas, the MP completed seven combat sorties (Tab T-45 to T-52).

The MP's flight time for the KC-135R and KC-135T 90 days prior to the mishap (includes primary, secondary and other in aircraft only) (Tab G-6).

MP	Hours	Sorties
Last 30 Days	66.3	8
Last 60 Days	76.2	11
Last 90 Days	83.8	14

(4) Career Highlights

Prior to his KC-135 flying career, the MP garnered the Flying Training Award by distinguishing himself with the best flying scores in his undergraduate pilot training class. Noted as demonstrating the highest standards of initiative, bearing and appearance, the MP was set to excel as a military aviator (Tab T-37). At the conclusion of KC-135 initial qualification training, the MP achieved an academic score of 96 percent and earned an outstanding performance on his initial simulator evaluation (Tab T-27 to T-28, T-38). The MP became an accomplished KC-135 pilot with 144 combat sorties (Tab G-5). As an FPQ, he was recognized twice by 376 AEW as being a member of the crew of the month for helping safely recover aircraft with multiple system malfunctions. Described as a peerless aviator, the MP was ranked number one of six pilots by his flight commander (Tab T-68). Additionally, the MP was certified to fly a tail dragger propeller plane, and he frequently flew this type of private aircraft during his off-duty time. The MP flew an experimental tail dragger, an RV-8, which he owned and operated out of a local airport near Fairchild AFB, WA (Tab V-26.6).

b. Mishap Co-pilot

(1) Qualifications

The MCP completed undergraduate pilot training at Vance AFB, OK, on 13 August 2010 (Tab T-39). The MCP was initially qualified in the KC-135 on 13 April 2011, at Altus AFB, OK (Tab T-40). The MCP flew as a FPQ until 16 February 2012, at which time she assumed duties not to include flying (DNIF) status (Tab X-4). While DNIF, the MCP lost flying qualification because she could not complete her periodic evaluation (Tab T-30). She started an in-unit requalification program at Fairchild AFB, WA, on 5 December 2012 and concluded training on 25 February 2013 (Tab G-65). The MCP completed all requalification evaluation events on 7 March 2013 (Tab T-29).

(2) Summary of Training

After KC-135 initial qualification training, the MCP was assessed as being highly qualified to fulfill the duties as a KC-135 crewmember (Tab T-40). The MCP's in-unit requalification training consisted of four simulator and three flight events (Tab G-23, G-66). Additionally, the MCP completed a simulator and flight evaluation (Tab G-66, T-29). At the conclusion of training, the MCP's strengths consisted of aircraft control, attitude, and crew resource management. No weaknesses were noted (Tab G-65). The MCP's evaluation was graded Qualification Level One. The evaluator noted commendable performances for simulated engine out procedures, circling approach procedures and missed approach procedures (Tab T-29 to T-30).

(3) Recent Activity

After requalifying as an FPQ, the MCP logged three KC-135 simulator events prior to deploying on 17 April 2013 (Tabs G-23, X-4). After arriving at the Transit Center at Manas, the MCP completed seven combat sorties (Tab T-45 to T-52).

The MCP's flight time for the KC-135R and KC-135T 90 days prior to the mishap (includes primary, secondary and other in aircraft only) (Tab G-22).

MCP	Hours	Sorties
Last 30 Days	66.3	8
Last 60 Days	69.8	9
Last 90 Days	77.3	11

(4) Career Highlights

The MCP distinguished herself during KC-135 initial qualification training as a highly motivated and extremely dedicated pilot by achieving a 95.4 percent academic score (Tab T-40). At Fairchild AFB, WA, she earned the 92d Operations Group Eagle Officer of the Quarter award for authoring four higher headquarters awards promoting Women's History Month. During flight, she identified and resolved a critical engine oil malfunction and helped safely recover a KC-135 aircraft. Lauded as a superior leader with the drive and ability to succeed at any task, she ranked number one of three company grade officers in the 93 ARS Awards and Decorations Flight (Tab T-69).

c. Mishap Boom Operator

(1) Qualifications

The MBO initially qualified in the KC-135 as a boom operator on 5 April 2002, at Altus AFB, OK (Tab T-13). On 4 October 2005, he completed instructor qualification at Altus AFB, OK (Tab G-69). On 12 May 2009, the MBO transitioned into the MQ-1B Unmanned Aerial System (UAS) as a sensor operator and was initially qualified at Creech AFB, Nevada (Tab T-11). On 13 October 2009, he was initially qualified in the MQ-9 UAS (Tab T-9). He completed instructor qualification for the MQ-1B and MQ-9 on 9 April 2010 and 19 June 2010, respectively (Tab T-5, T-7). On 27 September 2012, the MBO transitioned back to the KC-135 as a boom operator and started concurrent in-unit instructor requalification and mission certification training at Fairchild AFB, WA. He completed requalification training on 4 February 2013 and mission certification training on 21 February 2013 (Tab G-71).

(2) Summary of Training

The normal period for KC-135 requalification training and mission qualification is 90 days. The MBO received a training waiver to extend the period an additional 60 days (Tab T-57). At the conclusion of training, the MBO's noted strengths were aircrew experience and checklist discipline. Aircraft systems knowledge was noted as a weakness (Tab G-72). The MBO received a Qualification Level of One on the flight evaluation. The MBO's ability to instruct was identified as noteworthy during the evaluation. No discrepancies were noted (Tab T-3 to T-4).

(3) Recent Activity

After completing in-unit training on 21 February 2013, the MBO accomplished two flight and two simulator events prior to deploying on 17 April 2013. After arriving at the Transit Center at Manas, the MBO completed seven combat sorties (Tab T-45 to T-52).

The MBO's flight time for the KC-135R and KC-135T 90 days prior to the mishap (includes primary, secondary, instructor, and other in aircraft only) (Tab G-37).

MBO	Hours	Sorties
Last 30 Days	66.3	8
Last 60 Days	77.7	10
Last 90 Days	82.3	11

(4) Career Highlights

The MBO distinguished himself during Operations ENDURING FREEDOM and IRAQI FREEDOM as a boom operator instructor and sensor operator evaluator by amassing 170 combat and 29 combat support sorties in the KC-135 and 904 combat support sorties in the MQ-1B/MQ-9 UAS (Tabs G-36, T-70). As the 17th Reconnaissance Squadron (17 RS) Non-Commissioned Officer in Charge of Standardization and Evaluations, the MBO led 16 people and was responsible for 171 initial, annual and upgrade evaluations. Lauded by squadron and wing leadership, he was recognized on two occasions for exemplary job performance. Outstandingly professional, he was awarded 17 RS Non-Commissioned Officer of the Quarter in 2011 (Tab T-70).

10. OPERATIONS AND SUPERVISION

a. Operations

The operations tempo at 22 EARS on the day of the mishap was low to average (Tab V-7.5, V-23.7). Most deployed KC-135 aircrews averaged 40 sorties every 60 days (Tab V-22.7). The

MC's operations tempo was similar to the deployed aircrew average, and they flew a total of seven times at the Transit Center at Manas since their arrival on 17 April 2013 (Tab T-45 to T-51). The MC flew all seven sorties as a "hard crew", meaning they flew together for the duration of their deployment (Tabs T-45 to T-51, V-23.6). The MC's experience level was taken into consideration when their home station squadron leadership tasked them to deploy together (Tab V-21.7). Leadership assessed the MP's aviation skills and general knowledge of KC-135 aircraft systems and operational procedures as above average. The MCP's aviation skills and general knowledge level were assessed as average (Tab V-21.8 to V-21.9). The MBO was assessed as having above average aviation skills (Tab V-21.9). The experience level of the MC and final crew composition did not raise any concerns for squadron leadership (Tab V-21.8).

b. Supervision

The primary mission of 22 EARS is to provide air refueling support for forces engaged in combat operations and extend the effectiveness of networked operations (Tab CC-19). The CAOC is responsible for tasking 22 EARS for missions. Initial notification of mission taskings occurs the day prior. The mission schedule is finalized approximately 12-14 hours prior to mission execution (Tab V-23.4). Missions are dispatched through squadron scheduling and execution functions (Tab V-31.5). Updated unclassified mission scripts are posted in crewmembers' dormitories the night before their flight (Tab V-23.4). The 22 EARS planner alerts the aircraft commander approximately one hour prior the crew show time (Tab V-23.3, V-32.4). Crews arrive at the squadron and follow 22 EARS Mission Checklist. The checklist guides the crew through pre-mission and post-mission actions and includes an Operational Risk Management (ORM) worksheet (Tab K-6, V-23.3). The checklist is signed by the planner verifying that various pre-mission and post-mission tasks were accomplished and to account for classified paperwork (Tab V-32.5 to V-32.6).

ORM at 22 EARS was completed via the ORM worksheet. The ORM worksheet indicated the level of risk assessed by the aircraft commander (Tab K-6). If the risk assessed was low, then review of the ORM to ensure its completion resided at the level of the staff planner (Tab V-32.5). If risk levels are elevated above the level of low, additional oversight is necessary (Tab V-22.6). Approval authority for ORM risk level follows: Low--aircraft commander, Medium--director or assistant director of operations, High--squadron commander and Severe--operations group commander (Tab K-6).

11. MEDICAL

a. Qualifications

At the time of the mishap, all members of the MC had current annual physical examinations and were medically qualified for flight duty without restrictions (Tab X-4 to X-5).

b. Health

A review of a 72-hour history and 14-day history for the MP and all available medical records documenting the MP, MCP and MBO's health and well-being prior to the mishap revealed no evidence to suggest a medical condition, medication or fatigue for the MC was a factor in the mishap. A review of the 72-hour and 14-day histories for the Mishap Ground Crew (MM1, MM2, MM3, MM4, MM5, MM6, QAI, EXP, and PRO SUP) revealed no evidence to suggest a medical condition, medication or fatigue for the Mishap Ground Crew was a factor in the mishap (Tab X-4 to X-5).

c. Pathology and Toxicology

On 4 May 2013, post-mishap toxicology specimens were obtained from Mishap Ground Crew members. Blood and urine specimens were sent for examination for volatiles (including alcohol) and drugs. All specimens tested from Mishap Ground Crew were negative (Tab X-5).

During autopsy, toxicology specimens were obtained from the remains of the MP, MCP, and MBO. The MC's specimens were sent for examination for carbon monoxide (CO), cyanide, volatiles (including alcohol) and drugs. Specimens for the MP, MCP and MBO were not adequate for detection of CO or cyanide (Tab X-3).

Medical examiners at the Armed Forces Medical Examiner System at Dover AFB, Delaware, completed autopsy reports for the MC. Based on the evidence, the MP, MCP and MBO died of multiple non-survivable injuries sustained during the accident. There was no evidence of acute medical issues, drugs or alcohol (Tab X-3).

d. Lifestyle

No lifestyle factors were found to be relevant to the mishap (Tab X-4 to X-5).

e. Crew Rest and Crew Duty Time

AFI 11-202, Volume 3, *General Flight Rules*, dated 22 October 2010, requires aircrew members to have proper "crew rest" prior to performing flight duties. AFI 11-202 defines normal crew rest as a minimum 12-hour non-duty period before the designated flight duty period begins. During this time, an aircrew member may participate in meals, transportation or rest, as long as they have the opportunity for at least eight hours of uninterrupted sleep (Tab -4 to BB-5).

Based on review of 22 EARS Operations desk scheduling for the MP, MCP and MBO, no crew rest or crew duty time requirements were violated or found to be factors in the mishap. There is no evidence to suggest fatigue was a factor in the mishap (Tab X-4 to X-5).

12. HUMAN FACTORS

a. Introduction

Department of Defense Human Factors Analysis and Classification System (DOD HFACS) implements portions of Department of Defense Instruction (DoDI) 6055.07, *Accident Investigation, Reporting, and Record Keeping,* dated 6 June 2011 (Tab BB-209). The DoDI directs DoD components to "provide for the cross-feed of mishap data that involves like equipment or similar operations among the DoD Components and U.S Coast Guard. That cross-feed should include applicable information about…human performance threats, hazards, and human error” (Tab BB-237). Human Factors is not just about humans. It is about how features of people’s tools, tasks and working environment systemically influence human performance. James Reason's “Swiss Cheese” model describes the levels at which active failures and latent failures/conditions may occur within complex operations. This model is designed to present a systematic, multidimensional approach to error analysis (Tab BB-209).

Mishaps are rarely attributed to a single cause, or in most instances, even a single individual. The goal of a mishap or event investigation is to identify these failures and conditions in order to understand why the mishap occurred and how it might be prevented from happening again. The DOD HFACS is used to accurately capture the complex layers of human error in context with the individual and mishap or event (Tab BB-209).

Crew coordination during an emergency requires the full, coordinated effort of each crewmember. Emergency procedures should be practiced at every opportunity so the crew will become proficient in every procedure (Tab BB-170).

Human factors were extrapolated from FDR/CVR data, witness testimony, ATC and RADAR logs, flight training records and the reconstruction of the accident through a simulator. There is an inherent level of uncertainty assumed in the human factors cited below.

b. Applicable Factors

(1) AE103 Procedural Error

Procedural Error is a factor when a procedure is accomplished in the wrong sequence or using the wrong technique or when the wrong control or switch is used. This also captures errors in navigation, calculation or operation of automated systems (Tab BB-210).

The Inflight Manual contains a chapter on emergency procedures. This section is arranged in two subsections, within each of these subsections, the procedures are divided into two categories, critical and non-critical. These procedures constitute the minimum required steps to be taken by a crewmember to ensure survival. When an airborne emergency occurs, the following rules always apply: 1) Fly The Airplane: Establish a safe airspeed, attitude, and thrust setting. Maintaining airplane control is paramount. 2) Stop – Think – Collect Your Wits: Make a thorough evaluation of each emergency prior to initiating corrective action (Tab BB-170).

The Inflight Manual’s *Dutch Roll Recovery Procedures* warnings section states that pilots should “not attempt to damp dutch roll manually with the rudder” and “improper excitation and recovery techniques cause higher than normal cumulative stresses in the vertical stabilizer…” (Tab BB-171). Also, the “sudden reversal of rudder direction at high rudder deflections, due to improper rudder application or abrupt release, can result in overstressing the vertical fin” (Tab BB-172).

The MP assumed control of the MA approximately one minute before the MA’s moment of failure (Tab EE-5, EE-11). When the MP took control of the MA it was in a pronounced dutch roll, as shown by widely divergent sine waves (See Figure 6 and Figure 11) (Tab EE-8, EE-11). The MP used rudder to roll in and out of a turn at waypoint DW. Additionally, during the turn, the MA experienced a series of alternating small rudder inputs. These alternating small rudder inputs, caused by the MA's dutch roll-induced acceleration forces varying the MP's foot pressure on the rudder pedals, sharply increased the dutch roll oscillations (Tab EE-29). The MP's use of rudder was not in compliance with the Inflight Manual dutch roll procedure and the warnings regarding use of rudder and rudder reversal due to overstressing the vertical fin (Tab BB-171 to BB-172).

(2) OP004 Organizational Training Issues/Programs

Organizational Training Issues/Programs are a factor when one-time or initial training programs, upgrade programs, transition programs or other training that is conducted outside the local unit is inadequate or unavailable and this creates an unsafe situation (Tab BB-216).

Dutch roll recognition and recovery training is only accomplished in the simulator during the Pilot Initial Qualification (PIQ) course and is not re-accomplished in the simulator during upgrade and continuation training (Tab AA-19 to AA-20, AA-32). The proficiency level required for dutch roll recognition is "familiarization," meaning each pilot must only discuss this topic and is not required to perform the maneuver (Tab V-40.5). The KC-135 simulator dutch roll profile is planned in straight and level flight at flight level 390, a gross weight based on 100,000 pounds of fuel and a speed of .77 mach (Tabs V-40-6, AA-49). The Inflight Manual prohibits pilots from practicing dutch roll recognition and recovery in the aircraft, specifically stating "intentionally-induced dutch roll and aerobatics of any kind are strictly prohibited" (Tab BB-171, BB-180).

After KC-135 PIQ, dutch roll recognition and recovery procedures are not included in aircraft commander upgrade training or continuation training (Tabs V-19.4 to V-19.5, V-40.4 to 40.5, AA-19 to AA-20, AA-40). Pilots accomplish the continuation simulator profiles during aircraft commander upgrade (Tabs G-48 to G-62, T-55). The aerodynamic malfunctions reviewed during upgrade and continuation training focus on other rudder issues such as unscheduled rudder deflections (Tab V-19.4 to V-19.5, V-40.9). These malfunctions are single episodes; an instructor can put in unscheduled rudder deflection right or left and you could choose between those two, but it's not a continuous or variable input (Tab V-19.5).

Insidious onset of dutch roll is impossible to replicate in KC-135 simulator training due to mechanical limitations (Tab AA-47 to AA-48). In order to have a flight simulator enter a dutch roll phenomenon, simulator instructors utilize two predominant techniques. The first has one of the pilots push the rudder in about three inches and pop it out and the other involves activating a programmed simulator malfunction, such as hard over-rudder, for a couple seconds, and then take it out which will also induce rolling motions and bank angles of 45 degrees or more roll (Tab V-40.6). The flight simulator dampens dutch roll on its own with little pilot input (Tab AA-47 to AA-48). The simulator cannot reproduce dutch roll in a continuous motion (Tab V-19.4 to V-19.5). Dutch roll recovery procedure calls for ensuring the SYD is on. However, there is no training profile in which the SYD is completely inoperative or where the SYD is providing erroneous inputs (Tab AA-19 to AA-20). A former KC-135 Instructor Pilot and current simulator operator, who experienced severe dutch roll in flight, confirmed the current simulator training does not reproduce a severe dutch roll (Tab V-19.2 to V-19.3, V-19.6 to V-19.7).

The MP did not receive any instruction on dutch roll recognition or recovery procedures during upgrade or continuation training (Tabs G-48 to G-62, T-55 to T-56).

The MCP had recently requalified for FPQ duties (Tabs G-23, T-29). The MCP performed local requalification training; however, dutch roll recognition and recovery procedures are not required. The MCP did not perform dutch roll recognition or recovery during recent requalification simulator training (Tabs G-64 to G-66, AA-19 to AA-20, AA-40).

Boom operators are not required to receive any training on dutch roll recognition or recovery (Tab AA-20).

(3) SP002 Crew/Team/Flight Makeup/Composition

Crew/Team/Flight Makeup/Composition is a factor when, in the opinion of the investigator, the makeup of the crew or of the flight should have reasonably raised obvious safety concerns in the minds of crewmembers involved in the mission, or in any other individual directly related to the scheduling of this mission (Tab BB-214).

Each crewmember assigned positions on the MC had recently requalified or upgraded (Tabs G-9, G-65, G-71, T-3, T-29). The MP upgraded within two months prior to deployment (Tab G-9). The MCP had four aircraft flights over an approximate 15-month period prior to deploying due to a 10-month DNIF period (Tabs G-23, X-4). The MBO returned from an approximate 3.7-year period of operating UAS and requalified in the KC-135 six weeks prior to deploying (Tab G-39 to G-40).

The MP had a grand total of 1427.7 hours flying time prior to deploying on 17 April 2013 (this includes primary, secondary, other, and student time) (Tabs G-5, G-9 to G-10, X-4). The MP had 1,048.7 total flying hours in KC-135 (this includes primary and secondary pilot time only) (Tab G-5). The MP was upgraded to aircraft commander on 28 February 2013 (Tab T-19). The MP had been an aircraft commander for 49 days from time qualified until date of deployment on 17 April 2013 (Tabs T-19, X-4). The MP had 9.9 hours as an aircraft commander and 14 hours of simulator time from the date of qualification until date of deployment on 17 April 2013 (this includes primary and secondary pilot time only) (Tabs G-9 to G-10, X-4).

The MCP was initially qualified as an FPQ on 13 April 2011 and was actively flying for approximately 10 months prior to being placed on DNIF status on 16 February 2012 (Tabs T-31 to T-32, X-4). Once on DNIF status, the MCP remained DNIF for nearly 10 months (Tab X-4). The MCP was returned to flying status for five months prior to deploying on 17 April 2013 (Tab X-4). The MCP had a grand total of 573.1 hours flying time prior to deploying on 17 April 2013 (this includes primary, secondary, other, and student time) (Tabs G-21, G-23, X-4). The MCP had 296.6 total flying hours in the KC-135 (this includes primary and secondary pilot time only) (Tab G-21). The MCP requalified as an FPQ on 7 March 2013 (Tab T-29). The MCP had been an FPQ for 41 days from date of requalification until date of deployment on 17 April 2013 (Tabs G-23, X-4). The MCP had 0.0 aircraft flying hours, and 12 hours of simulator time as an FPQ from time of requalification until date of deployment on 17 April 2013 (this includes primary and secondary pilot time only) (Tab G-23).

The MBO had 3,351.2 total hours as a KC-135 boom operator and 1,802.5 total hours as a sensor operator (Tab G-36). The MBO had recently requalified as an instructor boom operator (IB) after nearly four years out of the aircraft where he performed duties as sensor operator in a UAS (Tabs G-40, T-15). The MBO requalified as an IB on 15 February 2013 (Tab T-3). The MBO required a waiver for concurrent instructor requalification training. The lack of formal training availability at Altus AFB, OK, led to a local IB requalification (Tab T-15 to T-16). The MBO had been an IB for 61 days and had 11.4 hours (this includes primary, secondary, and instructor time only) as a boom operator and 8 hours of simulator time from the date of requalification until date of deployment on 17 April 2013 (Tabs G-40, X-5).

(4) OP003 Procedural Guidance/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 an unsafe situation (Tab BB-215 to BB-216).

The Inflight Manual procedures state in separate sections that rudder should or should not be used depending on if there is a rudder malfunction or if there is a dutch roll phenomenon (Tab BB-171, BB-173). Additionally, the Inflight Manual has the following multiple, physically separated sections addressing ways to troubleshoot lateral control difficulty (Tab BB-166 to BB-169).

(a) There are 21 emergency procedures discussing lateral control difficulties referencing the rudder, and they are spread out over 177 pages between 3-37 and 3-214 (Tab BB-166 to BB-169).

(b) Relevant information on dutch roll damping characteristics is located on page 6-21, but does not exist in the *Dutch Roll Recovery* procedures paragraph on page 3-37. Specifically, the information that increased altitude reduces natural dutch roll dampening is omitted on page 3-37 of the Inflight Manual (Tab BB-171, BB-182).

(c) The Inflight Manual procedure for *Lateral/Directional Control Difficulty Due to Yaw Damper Malfunction* states, "adequate rudder authority should be available to counteract any yaw induced by a yaw damper failure" provided no additional failures occur such as loss of an engine (Tab BB-172). Under the *Unscheduled Roll* description, it states that the "roll control force is adequate to counteract the effect of any single component malfunction, such as unscheduled full rudder deflection…" (Tab BB-179). The guidance to use the rudder that is implied under the *Lateral/Directional Control Difficulty Due to Yaw Damper Malfunction* is not in alignment with the *Unscheduled Roll* description and the warning to not use rudder that is stated in the *Dutch Roll Recovery* procedures on page 3-37 of the Inflight Manual (Tab BB-171 to BB-172, BB-179).

Additionally, the FCAS description states "pilots can override the FCAS inputs or establish a different reference point by applying rudder pedal force" (Tab BB-144). However, when the yaw and roll induced by a yaw damper failure develops into a dutch roll, this guidance does not align with the warning stated in *Dutch Roll Recovery* procedures on page 3-37 of the Inflight Manual (Tab BB-171).

The boldface warning for *Unscheduled Rudder Deflection* is “Rudder Power – OFF” and applies when the rudder moves uncommanded. The procedure for *Rudder Hunting* directs disengagement of the EFAS, then the SYD, and then the powered rudder. Rudder hunting is erratic movement or slow deflection/oscillation of the rudder, yet the first step of the *Rudder Hunting* procedure does not match that of the boldface (Tab BB-170, BB-173, BB-176).

(d) The checklist for *Dutch Roll Recovery* states that “the primary means of controlling dutch roll is the yaw damper…engage or attempt to engage the yaw damper any time dutch roll is recognized, even when the yaw damper is assumed to be on” (Tab BB-171). However, the checklist for *Lateral and Directional Control Difficulty Due to Yaw Damper Malfunction* states, “to disengage the yaw damper, set the yaw damper switch to OFF” (Tab BB-172). The Inflight Manual does not consider the possibility that the SYD itself is causing the control difficulty (i.e. dutch roll) as shown by its lack of being addressed in the Dutch Roll Recovery checklist (Tab BB-171).

(e) The boldface warning for *Unscheduled Rudder Deflection* is located on page 3-207 (Tab BB-170, BB-176). The paragraph that immediately follows is for Creeping Stabilizer, which is unrelated to the rudder. A pilot would have to flip backwards 123 pages to page 3-84 for the Rudder Malfunction Analysis paragraph, thus using up valuable time in a potentially emergent situation (Tab BB-173).

13. GOVERNING DIRECTIVES AND PUBLICATIONS

a. Publically Available Directives and Publications Relevant to the Mishap

(1) AFI 11-2KC-135, Volume 3, *KC-135 Operations Procedures*, 18 September 2010
(2) AFI 11-202, Volume 3, *General Flight Rules*, 22 October 2010
(3) Air Force Manual (AFMAN) 11-248, *Flying Operations*, 19 January 2011
(4) AFI 21-201, Air Mobility Command Supplement, *Aircraft and Equipment Maintenance Management*, 11 February 2011
(5) AFI 51-503, *Aerospace Accident Investigations*, 26 May 2010
(6) AFI 91-204, *Safety Investigations and Reports*, 24 September 2008
(7) DODI 6055.07, *Accident Investigation, Reporting, and Record Keeping*, 6 June 2011

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

b. Other Directives and Publications Relevant to the Mishap

(1) 22 MXG Operating Instruction 21-101, *Maintenance Procedures*, 29 January 2010
(2) KC-135R/T Command Aircraft Systems Training (CAST), 30 March 2005

(3) T.O. 00-20-1, *Aerospace Equipment Maintenance Inspection ,Documentation, Policies, and Procedures*, 1 April 2013
(4) T.O. 00-5-1, *AF Technical Order System*, 15 January 2013
(5) T.O. 1C-135-6WC-1, *Preflight/Post-Flight/Hourly Post-Flight Inspection Workcards*, 1 August 2006 (Change 16 - 29 March 2013)
(6) T.O. 1C-135-6WC-2S-15, Operational Supplement, *Periodic Inspection Workcards*¸ 24 October 2012
(7) T.O. 1C-135-6WC-2, *Periodic Inspection Workcards*, 1 August 2006 (Change 17 - 31 July 2012)
(8) T.O. 1C-135-6WC-7, *Hourly Inspection Workcards*, 1 August 2006 (Change 4 - 31 July 2012)
(9) T.O. 1C-135(K)(I)-1, *KC-135R/T Flight Manual Reference Data*, 1 July 2003 (Change 13 - 1 April 2012)
(10) T.O. 1C-135(K)(II)-1, *KC-135R/T Flight Manual Inflight Data*, 1 July 2003 (Change 12 - 1 April 2012)
(11) T.O. 1C-135(K)R-2-8GA-1, *Flight Control Systems*, 12 December 2003 (Change 23 - 1 December 2012)
(12) T.O. 1C-135-2-11-40-3, *Flight Control Set and Flight Control Augmentation Systems*, 1 January 2008 (Change 13 - 1 September 2012)
(13) T.O. 1C-135-2-11-40-7, *Flight Monitoring*, 1 January 2008 (Change 12 - 15 January 2013)
(14) T.O. 1C-135-3-1, *Structural Repair Instructions Introduction*, 31 January 2013 (Change 1 - 15 June 2013)
(15) T.O. 1C-135-3-2, *Structural Repair Instructions Fuselage*, 31 January 2013
(16) T.O. 1C-135-3-3, *Structural Repair Instructions Wings*, 31 January 2013
(17) T.O. 1C-135-3-5, *Structural Repair Instructions Empennage*, 31 January 2013
(18) T.O. 1C-135-5-1, *Basic Weight Checklist, Maintenance Data, Loading Data, and Fuel Loading Data*, 15 October 2009 (Change 2 - 15 December 2012)
(19) T.O. 1C-135-6, *Aircraft Scheduled Inspection and Maintenance Requirements*, 13 October 2010
(20) TCTO 1C-135-776, *Modification of Station 1505.87 Bulkhead Side Webs*, 28 February 1969
(21) T.O. 42B-1-1, *Quality Control of Fuel and Lubricants*, 19 November 2012

c. Known or Suspected Deviations from Directives or Publications

(1) Approximately 45 seconds before the moment of structural failure, the MP used the rudder to roll in and out of the turn at waypoint DW. At this time, the MA was in a pronounced dutch roll condition, undiagnosed by the MC as dutch roll, which had been exacerbated by alternating rudder movements (Tab EE-8, EE-11). The Inflight Manual states, "If the yaw damper is inoperative, manual recovery is to be accomplished by the use of lateral control inputs only…Attempts at manual rudder application (both deliberate and inadvertent) have historically resulted in a more serious situation" (Tab BB-171).

Additionally, a warning on page 3-37 of the Inflight Manual, *Dutch Roll Recovery Procedures* states, "Manual damping of dutch roll is to be accomplished only with lateral (aileron) control. Do not attempt to damp dutch roll manually with the rudder...Improper excitation and recovery techniques cause higher than normal cumulative stresses in the vertical stabilizer and engine struts" (Tab BB-171).

(2) The MP applied left then right rudder inputs to affect the turn at waypoint DW (Tab EE-11). The application of right rudder was a sudden swap from left rudder pedal deflection, which generated a large slideslip angle that ultimately caused the tail section to fail. The Inflight Manual states, "The sudden reversal of rudder direction, at high rudder deflections, due to improper rudder application or abrupt release, can result in overstressing the vertical fin. This condition could be brought about during recovery attempts from a flight condition induced by a lateral control malfunction" (Tab BB-172).

(3) In the procedure for *Lateral/Directional Control Difficulty Due to Yaw Damper Malfunction*, the Inflight Manual states, "To disengage yaw damper, set the yaw damper switch to OFF" (Tab BB-172). Flight data indicates the SYD remained "ON" during the entire flight and was engaged at the time of the mishap. The MC deviated from the procedure by leaving the SYD engaged (Tab EE-3, EE-5).

(4) The MA demonstrated yaw oscillations symptomatic of rudder hunting, as described in the Inflight Manual (Tabs BB-173, EE-10). The procedure for rudder hunting is to sequentially disengage the autopilot, EFAS, SYD, and the powered rudder until the oscillations stop (Tab BB-173). The MC did not disengage the SYD or powered rudder (Tab EE-5).

(5) In accordance with the Inflight Manual, the procedure for an unscheduled rudder deflection is to disengage the powered rudder (Tab BB-176). The MA experienced yaw oscillations symptomatic of unscheduled rudder deflection. The MC did not disengage the powered rudder (Tab EE-5).

(6) The Inflight Manual states, "Dutch roll is most evident at low indicated airspeeds, during turns, and at high altitudes; during these conditions a longer period of time is required to damp the oscillations" (Tab BB-182). The MC noticed a SYD malfunction at approximately 14,000 feet, but continued towards their target altitude of 32,000 feet into an environment where dutch roll damping authority is reduced and made a turn at waypoint DW further decreasing dutch roll dampening (Tabs N-10 to N-12, EE-12).

14. ADDITIONAL AREAS OF CONCERN

Not applicable.

20 December 2013

STEVEN J. ARQUIETTE
Brigadier General, USAF
President, Accident Investigation Board

STATEMENT OF OPINION

KC-135R, T/N 63-8877
6 MILES SOUTH OF CHALDAVOR, KYRGYZ REPUBLIC
3 MAY 2013

Under 10 U.S.C. § 2254(d), the opinion of the accident investigator as to the cause of, or the factors contributing to, the accident set forth in the accident investigation report, if any, may not be considered as evidence in any civil or criminal proceeding arising from the accident, nor may such information be considered an admission of liability of the United States or by any person referred to in those conclusions or statements.

1. OPINION SUMMARY

On 3 May 2013, at approximately 1448 hours local time (L), a KC-135R, tail number 63-8877, assigned to the 22d Expeditionary Air Refueling Squadron, 376th Air Expeditionary Wing, Transit Center at Manas, Kyrgyz Republic, crashed in the foothills of mountains located 6 miles south of Chaldovar, Kyrgyz Republic. The mishap crew (MC), which consisted of the mishap pilot (MP), mishap co-pilot (MCP), and mishap boom operator (MBO) perished during the mishap. The mishap aircraft (MA) exploded inflight, impacted the terrain at three main locations, and burned. The MA was destroyed with total loss to government property estimated at $66.3 million. Upon impact, approximately 228 cubic meters of soil were contaminated with jet fuel, and three distinct craters containing a burn pattern were created in the terrain during the crash.

I find, by clear and convincing evidence, the cause of the mishap was the MA's tail section separating due to structural overstress as a result of the MC's failure to turn off either the SYD or the rudder power and oscillating dutch roll-induced acceleration forces translating through the MP's feet as the MP used rudder during an undiagnosed dutch roll condition. The MP's use of the rudder during a dutch roll condition was contrary to warnings in Technical Order (T.O) 1C-135(K)R(II)-1, KC-135R/T Inflight Data, Change 12, dated 1 April 2012 (Inflight Manual) that prohibit rudder use in this manner. Further, I find, by a preponderance of evidence, that dutch roll was instigated by the MA's FCAS malfunctions causing directional instability or rudder hunting, which substantially contributed to this mishap. Other substantially contributing factors include insufficient organizational training programs, crew composition, and cumbersome procedural guidance.

I developed my opinion by analyzing the available factual data from historical records, which included Air Force guidance and directives, aircraft T.O.s, engineering analysis, witness testimony, and information provided by technical experts. Additionally, I used the MA's flight data recorder (FDR) and cockpit voice recorder (CVR) information from the Crash-Survivable Memory Unit, computer-generated simulations, and profile reconstruction in a KC-135 simulator to determine the sequence of events.

2. SEQUENCE OF EVENTS

The MA's mission was to refuel coalition aircraft in Afghanistan and then return to the Transit Center at Manas. Immediately after takeoff, the MA experienced an unexpected rapid heading change from the direction of flight known as a crab. During climb, nearly continuous rudder hunting caused the MA's nose to hunt slowly left and right about one degree in both directions. The MP commented on the lateral control challenges and possible series yaw damper (SYD) malfunction, but continued the mission without turning off the SYD or rudder power. Approximately nine minutes into the flight, the MA began a series of increasing yaw and roll oscillations known as dutch roll, which was undiagnosed by the MC. The MCP attempted to decrease these oscillations using manual aileron controls, as well as two brief attempts with the autopilot. The manual corrective inputs kept the oscillations from growing. The autopilot use further exacerbated the situation and the oscillations intensified. After the second autopilot use, the MP assumed control of the MA and used left rudder to start a left turn. A subsequent series of alternating small rudder movements, caused by the MA's dutch roll-induced acceleration forces varying the MP's foot pressure on the rudder pedals, sharply increased the dutch roll oscillations. Within 30 seconds, the MP made a right rudder input to roll out of the turn, further exacerbating the dutch roll condition. The cumulative effects of the malfunctioning SYD, coupled with autopilot use and rudder movements, generated dutch roll forces that exceeded the MA's design structural limits. The tail section failed and separated from the aircraft, causing the MA to pitch down sharply, enter into a high-speed dive, explode inflight and subsequently impact the ground at approximately 1448L.

3. CAUSE

The cause of the mishap was the MA's tail section separating due to structural overstress as a result of the MC's failure to turn off either the SYD or the rudder power and oscillating dutch roll-induced forces translating through the MP's feet as the MP used rudder during the unrecognized dutch roll condition.

The MC's failure to turn off either the SYD or the rudder power was contrary to the Inflight Manual procedure for correcting rudder hunting. Per the Inflight Manual, the procedure is to sequentially disengage the autopilot, EFAS, SYD, and the powered rudder until the oscillations stop. Flight data indicates the SYD was engaged the entire flight. The MC deviated from the procedure by leaving the SYD engaged.

The MP's use of rudder during a dutch roll was contrary to the Inflight Manual that prohibits rudder use in this manner. Rudder movements overstressed the tail section and initiated the MA's breakup sequence that caused the crash. The rudder inputs of the MP were causal in the failure of the tail section.

The MP and MCP diagnosed a directional control problem as well as a problem with the SYD. The *Lateral and Directional Control Difficulty Due To SYD Malfunction* and *Rudder Hunting* sections in the Inflight Manual describe appropriate crew actions in response to these conditions. The Inflight Manual contains warnings that state:

> "Manual damping of dutch roll is to be accomplished with lateral (aileron) control. Do not attempt to damp dutch roll manually with the rudder…the sudden reversal of rudder direction at high rudder deflections, due to improper rudder application or abrupt release, can result in overstressing the vertical fin. This condition could be brought about during recovery attempts from a flight condition induced by a lateral control malfunction."

The MA was in dutch roll, but still in a flyable condition, when the MP took control of the MA. In the last minute of the mishap flight, the MP applied and varied the left rudder pressure multiple times, then reversed pressure to the right pedal. These rudder pedal movements, confirmed by the FDR data analysis, reveal the growing sideslip oscillations of the MA represent the application and multiple variations of left rudder pressure, as well as an abrupt right rudder reversal in the final 10 seconds leading to a progressively increasing sideslip. Due to the timing of the rudder inputs, each peak rudder input occurs in the same direction as the sideslip. Instead of decreasing the sideslip, the MP's rudder pedal movements compounded it. The final rudder input of 11 degrees coincides with the structural failure of the tail section and end the of the FDR / CVR data, about one second before the MA pitches over.

4. SUBSTANTIALLY CONTRIBUTING FACTORS

I find by a preponderance of evidence that the following four factors substantially contributed to the mishap:

a. Flight Control Augmentation System (FCAS) Malfunctions

Power control unit (PCU) testing post-mishap identified three areas of concern related to PCU performance. First, the operating force to cause main actuator movement was beyond acceptable limits. Second, the PCU also failed the electrical accuracy and hysteresis test that is generally performed after overhaul. Lastly, during teardown inspection, the PCU was found to have a bent lock lever. Contact marks on the lock lever roller indicates the lock lever was bent and rubbing on other components during flight. In at least one other case, an aircraft that experienced unscheduled rudder movements was reported to have all three of these conditions. To operate correctly, the PCU linkage must be free of any binding or interference and requires a minimum force to both start and stop the movement of the main actuator. A bent lock lever contributed to restricting the movement of the PCU linkage with the effect being rudder hunting in flight. This condition could have been eliminated by disengaging either the SYD or the rudder power.

Under normal conditions, the rudder is hydraulically positioned through full travel by the PCU. In addition to the pilots, the FCAS provides automatic rudder control inputs to assist with yaw control of the airplane. The FCAS system consists of a computer, an EFAS, and SYD. The SYD provides full time, automatic rudder inputs in response to a broad range of adverse yaw conditions including dutch roll, uncoordinated turns, asymmetric thrust and other disturbances such as gust or turbulence. The SYD deflects the rudder through a secondary rudder actuator inside the PCU. There is no motion in the rudder pedals when the SYD is operating the rudder. FCAS components are connected and controlled by an electro-hydraulic sensing, warning and actuation network. The FCAS computer contains both electronic components and circuitry for the EFAS and SYD. The FCAS computer was destroyed during the mishap and thus not tested.

Increased friction in the PCU, due to the bent lock lever, caused erratic movement of the primary actuator. Since the secondary actuator was moving as commanded by the FCAS, the SYD appeared to the MP and MCP to be on and functioning. However, due to the erratic primary actuator, the rudder was not moving as the SYD was commanding it. Additionally, wear in the rudder feel unit caused a constant uncommanded rudder deflection, resulting in the MA's tendency to roll to the right as confirmed by FDR and CVR data from the mishap flight and FDR data reviewed from flights prior to the mishap. While the worn rudder feel unit caused the MA to roll to the right, there is no indication that it caused the dutch roll.

To rule out the probability that a mechanical malfunction caused the rudder pedal movement recorded by the FDR, a detailed analysis of the MA's PCU was conducted. This analysis examined whether tablock hydraulic piston slippage could cause tablock arm movement, which would in turn move the rudder pedals. Test results showed very little hydraulic piston back-drive when the tablock arm moved to the limits of the test fixture.

Additionally, a worst-case load analysis was conducted at three points where rudder pedal displacement was noted as significant in the last minute of flight; this included the actual rudder pedal displacement and an additional four degrees of rudder displacement added for possible maximum SYD input. At these three points, the load applied through the tab rod to the PCU tablock arm did not exceed the holding capability of the tablock piston. When combining the results from both tests, it is unlikely that the load applied would result in slippage of the tablock piston. Therefore, the rudder pedal movement recorded by the FDR was generated by pilot rudder pedal movement, not slippage within the tablock piston.

b. Organizational Training Programs

The organizational training of lateral control difficulty, to include dutch roll recognition and recovery, appears to be insufficient. KC-135 initial training programs, upgrade programs, and continuation training fall short of fully training aircrew in dutch roll recognition and recovery. Dutch roll recognition and recovery training is only required as a familiarization event in the simulator during the Pilot Initial Qualification (PIQ) Course and it is not included in upgrade or continuation training. The Inflight Manual strictly prohibits crewmembers from practicing dutch roll recognition and recovery in the aircraft due to the inherent danger. Boom Operators are not required to receive any training on dutch roll recognition. The MC received a total of 10-15 minutes of recognition and recovery training several years prior to the mishap. Computer based training is provided during PIQ; however, it is not provided during upgrade or continuation training.

The KC-135 simulator does not accurately recreate the unstable dutch roll flight regime experienced by the MC. The simulator does not replicate the severity of dutch roll and any attempts to instigate a dutch roll in the simulator are easily dampened with little to no pilot input. Insidious onset of dutch roll is currently not possible to replicate in the simulator because a continuous or variable rudder input cannot be programmed. Only one-time failures like "hard over rudder" can be programmed into the simulator to start dutch roll. Since the malfunction of rudder hunting cannot be programmed, it is not practiced in the simulator.

There is no training profile in which a malfunctioning SYD provides erroneous inputs. Crews are taught to ensure the SYD is placed to “On” for dutch roll recovery. However, if the SYD is not working properly this procedure is not a suitable recovery technique. The KC-135 simulator dutch roll profile during PIQ is planned in straight and level flight and at a gross weight based upon 100,000 pounds of fuel. The MA was climbing, turning, and at considerably higher gross weight (based on fuel load of 175,000 pounds at the time of the mishap), all of which reduce dutch roll dampening. The MC appears to not have been adequately trained for the dutch roll recognition and recovery; they experienced a condition they had not encountered in training.

c. Crew Composition

The MC was a qualified, but minimally experienced, crew. The MCP had very little recent (and overall) experience in the KC-135, which warranted a higher level of supervision. The MP had too little experience as an aircraft commander to fulfill this role. The MP was slow to assume control of the MA as the MCP experienced challenges with maintaining lateral control. The MBO, viewed as an experience-level balancing factor, lacked recent KC-135 experience and had a documented weakness in systems knowledge. Each crewmember assigned to positions on the MC had recently requalified or upgraded. This occurrence, coupled with the relative lack of recency for the MCP and MBO, contributed to untimely and inappropriate responses to the MA's malfunctions. The MP had approximately 10 hours of aircraft commander time prior to deploying. The MCP had four aircraft flights over an approximate 15-month timeframe prior to deploying due to a 10-month period of duties not including flying. The MBO returned from an approximate 3.7-year period of operating unmanned aerial systems and requalified in the KC-135 six weeks prior to deploying.

The MC's lack of experience and recency enabled a series of crew coordination decisions that distracted from mission accomplishment and ultimately contributed to the mishap:

(1) The MC's inexperience appears to have led to a slow and partial diagnosis of the MA's lateral control malfunction, as they did not run checklist procedures fully. The CVR statements made by the MC indicate that they had all the cues to diagnose a rudder hunting condition. The MC failed to recognize this condition and therefore failed to run the procedure. The procedure would have disengaged the faulty SYD, and the MCP's lateral inputs would have restored the MA to coordinated flight. Of note, the MA had previously experienced a similar system malfunction that led to a rudder hunting condition and impoundment in February 2013. The crew of that flight followed checklist procedures to disengage the SYD, recovered the aircraft, and turned it over to maintenance for repairs.

(2) The MC attempted to climb to their planned altitude of 32,000 feet with a known or suspected flight control malfunction. Dutch roll damping is reduced at high altitudes. The MC demonstrated a judgment error by attempting to climb to this unfavorable flight envelope with their symptoms.

(3) The MP, being a new aircraft commander, delayed taking control of the MA from the MCP until the MA's unstable flight envelope had progressed beyond the MCP's flying skill abilities. During the MP's aircraft commander upgrade course, an instructor

noted that the MP needed to work on establishing solid limits and taking control of the aircraft from the co-pilot, if warranted. During the mishap flight, instead of taking control of the MA as the dutch roll worsened, the MP told the MCP to "use the autopilot if you can't handle it."

(4) The MC's inexperience led them to rely on the autopilot to make timely inputs in an unstable flight regime. Although the Inflight Manual does not explicitly prohibit autopilot use in dutch roll, the system is incapable of making the precisely timed inputs that are required to counteract dutch roll. Both times the MC engaged the autopilot the oscillations grew worse.

(5) The MP did not comply with the Inflight Manual, which prohibits both the use of rudder during dutch roll and reversing rudder inputs inflight. These actions subsequently overstressed the MA's tail section.

d. Procedural Guidance

The layout of key information in the *Emergency Procedures* section of the Inflight Manual is disjointed and cumbersome. Procedures for lateral control difficulties associated with the rudder span 177 pages. The most critical procedure, the boldface warning for *Unscheduled Rudder Deflection*, contains no subsequent guidance. The appropriate procedure to accompany the boldface is *Rudder Malfunction Analysis*, which is located 123 pages earlier in the manual. Dutch roll damping characteristics are located on page 6-21, displaced over 300 pages from the *Dutch Roll Recovery Procedures*. The disjointed organization of these procedures detracted from the MC internalizing and acting upon critical information. The MC's incomplete analysis of the suspected SYD failure prevented them from applying the appropriate procedures when they encountered a lateral control difficulty that grew into a pronounced dutch roll condition. Consequently, the MC failed to recognize a worsening situation in a timely fashion.

5. CONCLUSION

After a comprehensive investigation into this mishap, I find, by clear and convincing evidence, the cause of the mishap was the MA's tail section separating due to structural overstress as a result of the MC's failure to turn off either the SYD or the rudder power and oscillating dutch roll-induced forces translating through the MP's feet as the MP used rudder during an unrecognized dutch roll condition.

Further, I find, by a preponderance of evidence, that the dutch roll was instigated by the MA's FCAS malfunctioning causing directional instability or rudder hunting, which substantially contributed to this mishap. Other substantially contributing factors include insufficient organizational training programs, crew composition, and cumbersome procedural guidance.

20 December 2013

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