UNITED STATES AIR FORCE
AIRCRAFT ACCIDENT INVESTIGATION
BOARD REPORT

KC-10A, T/N 83-0080

9TH AIR REFUELING SQUADRON

60TH AIR MOBILITY WING

TRAVIS AIR FORCE BASE, CALIFORNIA

LOCATION: NEAR MOUNTAIN HOME AFB, IDAHO

DATE OF ACCIDENT: 1 NOVEMBER 2016

BOARD PRESIDENT: COL PERRY M. LONG III

Conducted IAW Air Force Instruction 51-503

ACTION OF THE CONVENING AUTHORITY **10 JUL 2017**

The report of the accident investigation board, conducted under the provisions of AFI 51-503, that investigated the 1 November 2016 mishap that occurred near Mountain Home Air Force Base, Idaho, involving KC-10A, T/N 83-0080, assigned to the 60th Air Mobility Wing, Travis Air Force Base, California, complies with applicable regulatory and statutory guidance and on that basis is approved.

\\signed\\

THOMAS J. SHARPY
Major General, USAF
Vice Commander

EXECUTIVE SUMMARY
UNITED STATES AIR FORCE
AIRCRAFT ACCIDENT INVESTIGATION

KC-10A, T/N 83-0080
NEAR MOUNTAIN HOME AFB, IDAHO
1 NOVEMBER 2016

On 1 November 2016, at 1546 hours Zulu time (Z), a United States Air Force KC-10A Extender, tail number 83-0080, the mishap aircraft, assigned to the 60th Air Mobility Wing, departed from its home station of Travis Air Force Base (AFB), California, on a training mission in support of two flights of F-15s and a C-17. The scheduled flight profile was a formation departure from Travis AFB, refueling for approximately one hour with the F-15s, refueling training for approximately 1 hour 15 minutes with the C-17, and approximately one half hour of approach training before landing at Travis AFB. The mishap crew (MC) is assigned to the 9th Air Refueling Squadron, Travis AFB.

At 1632Z, the MC prepared for aerial refueling (AR), and the mishap boom operator (MB) lowered the Aerial Refueling Boom (boom). Immediately after lowering the boom, it began to move erratically, oscillating to the aircraft's right and left in a U-shaped pattern, well outside of its structural limits. After oscillating for approximately two minutes, the boom hoist cable broke. Approximately two minutes later, the gimbal separated from the A-frame gimbal mounts, but remained connected to the fuselage by hydraulic and electrical lines. At 1705Z, the boom completely separated from the aircraft and fell in an open field in Idaho. There were no injuries or fatalities reported with any portion of the mishap. After the boom separated, the MC landed the aircraft at Mountain Home AFB, Idaho without incident. The total monetary value of government loss was $6,529,845.71.

The AIB president found, by a preponderance of the evidence, two causes for this mishap. The first cause of this mishap was a sheared Dual Rotary Voltage Transducer (DRVT) rotary crank that resulted from DRVT rotary bearing misalignment. This provided the aircraft's boom control unit (BCU) with continuous, inaccurate roll position indications. As a result, the BCU compensated with lateral movement commands in both directions, driving the boom beyond its operational and structural limits. The second cause, related to the first, was the MB's failure to turn off the boom flight control switch in a timely manner. Turning off this switch would have disabled the BCU. This would have neutralized the boom flight control surfaces, and prevented the boom from departing the aircraft.

Additionally, the AIB president found, by a preponderance of the evidence, that the failure of maintenance personnel to comply with technical orders prevented the possible detection of an erratically performing D RVT, substantially contributing to the mishap.

United States Air Force Accident Investigation Board Report

Class A Mishap, Near Mountain Home AFB, ID

SUMMARY OF FACTS AND STATEMENT OF OPINION
KC-10A, T/N 83-0080
1 NOVEMBER 2016

TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

80-35	Open Discrepancy
135	KC-135
ADC	Area Defense Counsel
ADF	Automatic Direction Finder
AF	Air Force
AFB	Air Force Base
AFE	Air Flight Equipment
AFI	Air Force Instruction
AFIP	Air Force Institute of Pathology
AFTO	Air Force Technical Order
AIB	Accident Investigation Board
ALAS	Automatic Load Alleviation System
AMC	Air Mobility Command
AMCSUP	Air Mobility Command Supplement
AMW	Air Mobility Wing
AMXS	Aircraft Maintenance Squadron
AR	Aerial Refueling
ARB	Aerial Refueling Boom
ARO	Air Refueling Operator
ARS	Air Refueling Squadron
ATAGS	Advanced Tactical Anti-G System
ATC	Air Traffic Control
BCA	Boom Control Assembly
BCU	Boom Control Unit
BOT	Boom Operator Trainer
BP	Board President
BPO	Basic Post Flight
DCC	Dedicated Crew Chief
DoD	Department of Defense
DRVT	Dual Rotary Voltage Transducer
E & E	Electric and Environmental
EBO	Evaluator Boom Operator
EPR	Enlisted Performance Report
EPS	Emergency Power System
ER	Exceptional Release
FE	Flight Engineer
FLCS	Flight Control System
FTU	Flight Training Unit
ft.	Feet
HF	High Frequency
HFACS	Human Factors Analysis and Classification System
IAW	In Accordance With
IB/IBO/IBO2	Instructor Boom Operator
IFSCS	Instrument and Flight Control System
IP	Instructor Pilot
IPB	Illustrated Parts Breakdown
K	Thousand
kts.	Knots
L	Local Time
LOSA	Line Operation Safety Audit
LVDT	Linear Variable Differential Transducer
MA	Mishap Aircraft
MAJCOM	Major Command
MB	Mishap Boom Operator
MC	Mishap Crew
MCP	Mishap Co-pilot
MD	McDonnell Douglas
MEL	Minimum Equipment List
MFE	Mishap Flight Engineer
MM	Maintenance Member
MOA	Military Operating Area
MP	Mishap Pilot
MXG	Maintenance Group
MXGOI	Maintenance Group Operating Instruction
MXS	Maintenance Squadron
NDI	Non-Destructive Inspection
NM	Nautical Miles
OG	Operations Group
OI	Operating Instruction
Ops Tempo	Operations Tempo
ORM	Operational Risk Management
OSS	Operation Support Squadron
PHA	Preventative Health Assessment
PNS	Plans and Scheduling
Pro Super	Production Superintendent
PSI	Pounds per Square Inch
PST	Pacific Standard Time
Q & A	Question and Answer
QA	Quality Assurance
R2/R-Squared	Removal and Replace
SA	Situational Awareness
SAR	Search and Rescue
Sit-Rep	Situational Report
STP	Status/Test Panel
System 46	Boom System
TBA	Training Business Area
TCTO	Time Compliance Technical Order
TDY	Temporary Duty
T/N	Tail Number
TO	Technical Order
TOD	Technical Order Data
Z	Zulu

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

SUMMARY OF FACTS

1. AUTHORITY AND PURPOSE

a. Authority

On 9 November 2016, Major General Thomas J. Sharpy, Vice Commander, Air Mobility Command (AMC), appointed Colonel Perry M. Long III to conduct an aircraft accident investigation of a mishap that occurred on 1 November 2016 involving a KC-10A Extender aircraft near Mountain Home Air Force Base (AFB), Idaho (Tab Y-2). The aircraft accident investigation was conducted in accordance with (IAW) Air Force Instruction (AFI) 51-503, *Aerospace and Accident Investigations*, at Travis AFB, California, from 11 January 2017 through 14 February 2017. Accident Investigation Board (AIB) members were a Legal Advisor Captain, a Pilot Member Captain, a Medical Member Captain, a Weather Member Captain, an Engineering Member Civilian, a Maintenance Member Chief Master Sergeant, a Boom Operator Member Master Sergeant, and a Recorder Senior Airman (Tabs Y-4, Y-5). Functional Area Experts were two Engineer Civilians, and a Flight Engineer Master Sergeant (Tab Y-6).

b. Purpose

In accordance with AFI 51-503, *Aerospace and Ground Accident Investigations*, this accident investigation board conducted a legal investigation to inquire into all the facts and circumstances surrounding this Air Force aerospace accident, prepare a publicly releasable report, and obtain and preserve all available evidence for use in litigation, claims, disciplinary action, and adverse administrative action.

2. ACCIDENT SUMMARY

On 1 November 2016, at 1546 hours Zulu time (Z), a United States Air Force KC-10A Extender, tail number 83-0080, the mishap aircraft (MA), assigned to the 60th Air Mobility Wing (AMW), departed from its home station of Travis Air Force Base (AFB), California, on a training mission in support of two flights of F-15s and a C-17 (Tabs AA-15 through AA-16). The scheduled flight profile was a formation departure from Travis AFB, refueling for approximately one hour with the F-15s, refueling training for approximately 1 hour 15 minutes with the C-17, and approximately one half hour of approach training before landing at Travis AFB (Tabs AA-6, AA-8, AA-10, AA-15). The mishap crew (MC) is assigned to the 9th Air Refueling Squadron (ARS), Travis AFB (Tabs G-3, G-14, G-22, G-32).

At 1632Z, the mishap crew prepared for aerial refueling (AR), and the mishap boom operator (MB) lowered the aerial refueling boom (ARB, boom) (Tab N-4). Immediately after lowering the boom, it began to move erratically, oscillating to the aircraft's right and left in a U-shaped pattern, well outside of its designed operational and structural limits (Tabs N-4 to N-5, and V-4.4). After oscillating for approximately two minutes, the boom hoist cable broke (Tab N-6). Approximately two minutes later, the gimbal separated from the A-frame gimbal mounts, but remained connected to the fuselage by hydraulic and electrical lines (Tabs N-8, N-15, Z-3). At 1705Z, the boom completely separated from the aircraft and fell in an open field in Idaho (Tabs N-29, S-3 through S-8). There were no injuries or fatalities reported with any portion of the mishap. After the boom separated, the MC landed the aircraft at Mountain Home AFB, Idaho, without incident (Tabs N-30 through N-40). The total monetary value of government loss was $6,529,845.71 (Tab P-2).

3. BACKGROUND

a. Air Mobility Command

Air Mobility Command (AMC) was activated 1 Jun 92, with headquarters at Scott Air Force Base, Illinois, and is one of 10 major Air Force commands. On 1 Oct 16, AMC consolidated with Military Air Command making AMC the oldest major command in the Air Force tracing its history to the establishment of the Air Corps Ferrying Command on 29 May 41. As the air component of the U.S. Transportation Command, AMC is comprised of a Total Force effort to execute rapid global mobility and enable global reach – the ability to respond anywhere in the world in a matter of hours. This is accomplished through AMC's four core mission areas – Airlift, Air Refueling, Air Mobility Support and Aeromedical Evacuation. AMC also provides support to the nuclear enterprise.

Airlift provides the capability to deploy U.S. armed forces anywhere in the world within hours and help sustain them in a conflict. AMC also supports presidential and senior leader airlift. Air Refuelers are the backbone of Global Reach, increasing coalition and U.S. aircraft's range mid-air. Aeromedical evacuation ensures the wounded warriors get the care they deserve and today have sustained the survival rate of 97 percent. In addition to enabling the force to respond to an enemy attack and sustain operations, Rapid Global Mobility brings humanitarian supplies and assistance to those in need who may live in austere locations (Tab CC-2).

b. 60th Air Mobility Wing

The 60th Air Mobility Wing (AMW) is the largest air mobility organization in terms of personnel in the Air Force with a versatile all-jet fleet of C-5M Super Galaxy and C-17 Globemaster III cargo aircraft, and KC-10 Extender refueling aircraft. As the host unit of Travis AFB, California, the wing controls more than $11 billion in total resources, including 6,455 acres, 403 buildings and about 1,320 military family housing units. It handles more cargo and passengers than any other military air terminal in the United States. Travis AFB is the West Coast terminal for aeromedical evacuation aircraft returning sick or injured patients from the Pacific area.

Part of AMC, the 60th AMW is responsible for strategic airlift and air refueling missions circling the globe. The unit's primary roles are to provide rapid, reliable airlift of American fighting forces anywhere on earth in support of national objectives and to extend the reach of American and allied air power through mid-air refueling. Wing activity is primarily focused in the Pacific and Indian Ocean area, including Alaska and Antarctica. However, the 60th AMW crews can fly support missions anywhere in the world to fulfill its motto of being "America's First Choice" for providing true Global Reach (Tab CC-8).

c. 9th Air Refueling Squadron

The 9 ARS mobilizes and deploys 12 KC-10 aircraft with over 140 combat-ready personnel and equipment to worldwide forward operating locations. The unit ensures global reach for America by generating 24-hour-a-day strategic airlift and aerial-refueling sorties supporting U.S. and allied forces during contingency operations. It also provides training for 24 aircrews tasked to support and sustain Joint Chiefs of Staff directed missions. The unit executes an 8,000+ flying hour program and $580,000 budget. The world's "peerless" air refuelers off-loaded more than 70 million pounds of fuel on over 1,420 sorties last year flying strategic airlift for the Travis Team effort and delivery of over 64,000 tons of critical cargo and passengers (Tab CC-11).

d. 660th Aircraft Maintenance Squadron

The 660th Aircraft Maintenance Squadron (660 AMXS) provides combat-ready maintenance personnel and organizational support to inspect, service, and repair all transient and assigned KC-10 aircraft at Travis AFB. This amounts to 46% of the DoD's inventory of this weapons system. In addition, the squadron generates aerial refueling and strategic airlift missions in support of four active flying squadrons as tasked by AMC. The unit not only maintains aircraft, it also prepares personnel and equipment for worldwide deployment keeping the entire globe within reach of the largest wing in AMC. (Tab CC-13).

e. 60th Maintenance Squadron

The 60th Maintenance Squadron (60 MXS) provides organizational and field-level maintenance, repair, and manufacturing capability for effective on- and off-equipment maintenance, inspection, and refurbishment of C-5, KC-10 and C-17 aircraft. The squadron inspects, services, and overhauls aerospace ground equipment worth over $8 million and effectively manages and stores all base munitions. The unit provides mission capable aircraft in direct support of AMC's global mission (Tab CC-14).

f. KC-10A "Extender"

The KC-10 Extender is an AMC advanced tanker and cargo aircraft designed to provide increased global mobility for U.S. armed forces. Although the KC-l0's primary mission is aerial refueling, it can combine the tasks of a tanker and cargo aircraft by refueling fighters and simultaneously carry the fighter support personnel and equipment on overseas deployments.

Using either an advanced aerial refueling boom, or a hose and drogue centerline refueling system, the KC-10 can refuel a wide variety of U.S. and allied military aircraft within the same mission. The aircraft is equipped with lighting for night operations.

The KC-10's boom operator controls refueling operations through a digital, fly-by wire system. Sitting in the rear of the aircraft, the operator can see the receiver aircraft through a wide window. During boom refueling operations, fuel is transferred to the receiver at a maximum rate of 1,100 gallons (4,180 liters) per minute; the hose and drogue refueling maximum rate is 470 gallons (1,786 liters) per minute. The automatic load alleviation and independent disconnect systems greatly enhance safety and facilitate air refueling. The KC-10 can be air-refueled by a KC-135 or another KC-10A to increase its delivery range (Tab CC-15).

4. SEQUENCE OF EVENTS

a. Mission

On 1 November 2016, the MC was scheduled to fly the MA on a local training mission from Travis AFB (Tab AA-15). The mission was in support of two flights of F-15s and 1 C-17, and finishing with some approach practice before landing back at Travis AFB (Tabs AA-6, AA-10, AA-15).

b. Planning

The MC conducted initial mission planning, checked the weather, reviewed Notices to Airmen, familiarized themselves with applicable Special Instructions, performed fuel planning and completed required forms (Tab AA-16). The MC briefed the mission details at the squadron and at the MA before takeoff, per standard practices (Tab AA-6).

c. Preflight

The crew was comprised of an Instructor Pilot, a Mission Pilot, an Evaluator Flight Engineer, and a Mission Boom operator (Tab K-2). The crew showed at 0450 Local/Pacific time (L)/1250 Zulu time (Z) on Tuesday, 1 November 2016 (Tab AA-8). The MA was reported fully mission capable with a fuel load of 264,000 pounds (Tab AA-6). The flight engineer and boom operator went to the aircraft to perform their preflight duties at approximately 0550L/1350Z while the pilots went to brief the formation at 0545L/1345Z; the pilots stepped to the MA at 0635L/1435Z to perform their preflight duties (Tab AA-8). Nothing of significance was noted during the crew preflight, ground operations, or departure. (Tab AA-4).

d. Summary of Accident

On 1 November 2016, at approximately 0746L/1546Z, the MA, callsign GUCCI 22, took off on a local training mission as the leader of a KC-10 formation from Travis AFB with QUEST 62 and ORCA 24 (Tabs AA-4 and AA-16). GUCCI 22 was planned to continue to the SADDLE Military Operating Area for practice air refueling (AR) (Tab AA-4).

At 0826L/1626Z, the MC began preparing for AR with the scheduled F-15E flight, and began to run the appropriate checklist (Tab N-2).

At 0832L/1632Z, the mishap boom operator (MB) lowered the boom in preparation for AR, and quickly noticed the boom *"going crazy"* (Tab N-5). It quickly began oscillating violently left and right past 30^o (Tab N-5).

At 0833L/1633Z, the MB attempted to stow the boom to no avail (Tab N-5). The MB was able to raise the boom to 10^o, at which time it continued to oscillate left and right to 30^o (Tab N-5). The mishap pilot (MP) noted aircraft yawing approximately $5\text{-}10^o$ and altitude deviations more than 100 ft. in response to boom oscillations (Tabs N-5, V-1.5).

At 0834L/1634Z, the boom hoist cable broke (Tab N-6). The hoist cable is the alternate means for raising the boom (Tab BB-3). The mishap copilot (MCP) terminated AR, cleared the receivers to return to base, and coordinated with Air Traffic Control (ATC) to return to Travis AFB (Tab N-6).

At 0835L/1635Z, the MB exclaimed that the boom movement was *"freaking [him] out,"* and he did not know what to do (Tab N-6). The MB mentioned a checklist for a broken hoist cable, and that there was no ability to control the boom (Tab N-7). After a short discussion among the MC, the mishap flight engineer (MFE) walked to the tail of the aircraft and joined MB in the Air Refueling Operator's station (ARO) (Tab N-7).

At 0836L/1636Z, both rudder fail and elevation fail lights illuminated, the boom completely stopped moving, and the MB ran the *Broken Boom Hoist Cable* checklist (Tab N-8).

At 0837L/1637Z, the MCP declared GUCCI 22 an emergency aircraft with ATC, and requested vectors towards Mountain Home AFB, Idaho (Tab N-8).

At 0839L/1639Z, the boom had stabilized at 4^o left, 14^o elevation, and 2 ft. telescope extension (Tab N-10).

At 0844L/1644Z, the MP and the MB discuss whether the *Flight Controls Do Not Respond to Command Inputs or Control Surfaces Erratic* was the appropriate checklist to run (Tabs N-12 and BB-7).

At 0846L/1646Z, the MB stated, *"[i]t's getting crazy again…I don't know…honestly what's holding it on right now. But it's just trailing behind us."* and then says *"[t]his boom is completely detached, it's still connected some way but it's, everything is ruined"* (Figure 4.1) (Tabs N-14 to N-15, and Z-3). The MP decided to slow the aircraft to attempt to alleviate aerodynamic pressure on the boom (Tab N-15).

Figure 4.1 (Tab Z-3)

At 0847L/1647Z, the MFE returned to the flight deck, and the boom was still stable and attached (Tab N-15).

At 0853L/1653Z, the MP verified with the MB that they had *"gone through every iteration every every possibility of checklist,"* and there was no possible way to raise the boom by normal or alternate means (Tab N-19 to N-20). The MB stated, *"I don't think there's anything I really could have done honestly*" (Tab N-20).

At 0905L/1705Z, the boom departed from the aircraft at a reported position of 42°59'04.7"N 115°33'28.0"W (Figure 4.2) (Tabs N-29, Z-4).

The MC continued to coordinate to land at Mountain Home AFB, Idaho (Tab N-30). The MC landed without incident at 0949L/1749Z (Tab N-38).

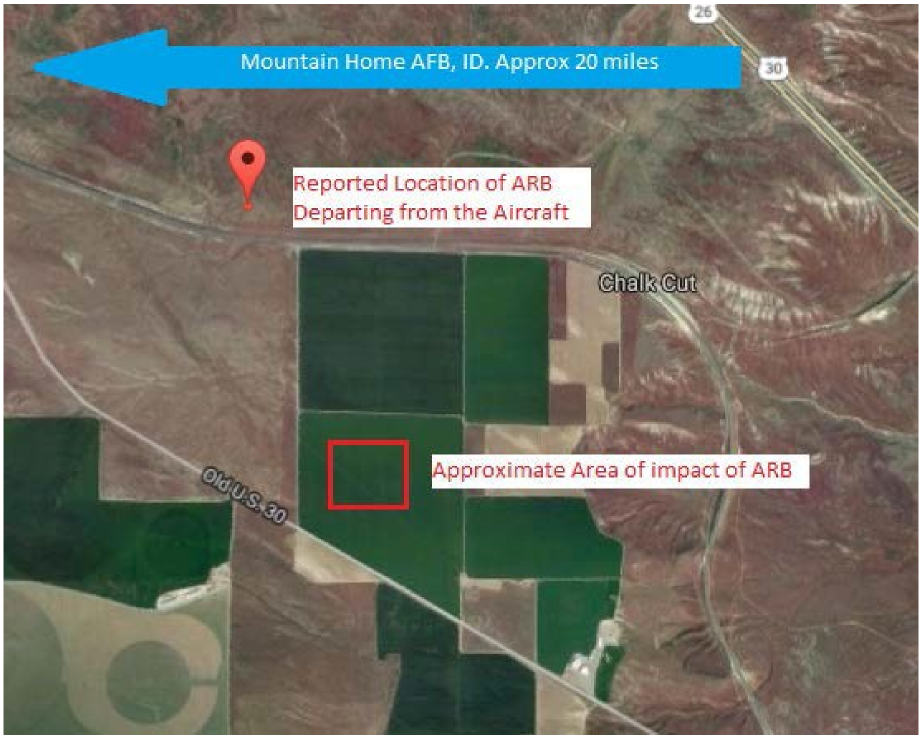

Figure 4.2 (Tab Z-4)

e. Impact

At the time of boom separation, the MA was in a 10-degree bank right turn at 270 knots indicated airspeed, at 42°59'04.7"N 115°33'28.0"W (Tabs AA-4, AA-9, and N-29). The boom fell on an open field; no injuries or fatalities were reported (Tabs S-8, P-2, and X-1).

f. Egress and Aircrew Flight Equipment

The mishap crew landed at Mountain Home and taxied to the ramp without incident (Tabs N-37 through N-40, and AA-4). The crew shut down the aircraft and egressed normally, without the use of emergency egress equipment (Tabs H-2, and N-40).

g. Search and Rescue

Not Applicable

h. Recovery of Remains

Not Applicable

5. MAINTENANCE

a. Unscheduled Maintenance

The following is a list of unscheduled maintenance actions in the boom area on the MA leading up to the mishap:

The MA departed on 11 Oct 16 at 0733L/1533Z for a local training flight (Tab DD-69). The crew cycled the boom twice, contacted the receiver aircraft 10 times, and landed at 1302L/2102Z, and debriefed with the following discrepancy on the associated Air Force Technical Order (AFTO) Forms 781A: *"Boom roll gauge shows 8 degrees right when boom is centered at 0 degrees"* (Tabs D-32, DD-69, DD-75).

11 Oct 16, Day Shift - This discrepancy was worked by MM1 from the 60 MXS Hydraulics Section (Tab V-10.2). MM1 adjusted the Dual Rotary Voltage Transducer (DRVT) utilizing TO 1C-(K)A- 2-28, task 28-72-05 (Tab D-32). MM1 signed off the write-up with, *"adjusted DRVT-[Operations (Ops)] Check good"* in AFTO 781A (Tab D-32). The MA departed at 1905L on 11 Oct 16/0305Z on 12 Oct 16 for a local training flight (Tab DD-78). The crew attempted to lower and fly the boom, but the boom did not operate properly (Tab DD-84). The boom operator debriefed maintenance personnel and entered the following discrepancy in the AFTO Form 781A: *"Boom was about 4 to 5 degrees to the left and the roll gauge was showing 11 to 12 degrees to the right when lowered"* (Tabs D-35, DD-84).

11 Oct 16, Night Shift - This discrepancy was worked by personnel from the 60 MXS Hydraulics Section, including MM2 (Tab V-11.3). During troubleshooting, the gimbal yoke nut was found to have a broken safety wire, requiring a removal and replacement (R2) of the gimbal and yoke assembly (Tab V-11.3). During the shift, the boom was lowered, associated panels were removed, and the MA was prepared for subsequent work (Tab V-11.3).

12 Oct 16, Day Shift - During the shift, led by MM1, the boom was removed, but the gimbal still required R2 (Tab V-10.5).

12 Oct 16, Night Shift - During this shift, the gimbal assembly was installed by MM2 with a new DRVT (Tab V-12.1). Additionally, while MM2 installed the gimbal and yoke assembly, a portion was evaluated by MM11, a 60 MXG Quality Assurance (QA) evaluator, who noted zero defects (Tabs DD-68, and V-20.1). MM2 gave the task to dayshift with the gimbal installed (Tab V-12.1). This shift did not document their work in the AFTO 781A (Tabs D-35, D-43 to D-45, D-48 to D-52).

13 Oct 16, Day Shift – This shift finished installing the boom assembly, adjusting the DRVT, and signing off all associated discrepancies (Tabs D-46 to D-49, DD-51 to DD-55, and V-13.3). MM3 installed the boom IAW the boom installation TO; a portion was evaluated by MM12, a 60 MXG QA evaluator, who noted zero defects (Tabs D-51 and DD-67).

After boom installation, with the boom in the stowed position, MM9 adjusted the DRVT utilizing the Gimbal Install TO (Tab V-17.1). The boom, gimbal, and all associated discrepancies were signed off by MM3 and MM4, citing Gimbal and Boom installation TOs (Tab D-51). The original boom discrepancy was signed off with the corrective action *"R2'd Boom Gimbal, adjusted DRVT, Leak/Ops [Check] Good"* by MM4 in the "Corrected By" block of the AFTO 781A (Tab D-35).

The parts replaced included Gimbal Assembly (part number NQC6400-503, serial number UAE2015-491) and DRVT (part number AS-784-001, serial number 5150) (Tabs D-35, V-11.7, and DD-108). The organizations, dates, and locations where removal, installation, bench check/testing, repair, and overhaul were completed are located in Tab DD (Tab DD-108).

The MA did not fly from 15-23 Oct 16 due to a scheduled series of inspections, known as an "A-Check" (Tabs V-11.7 and DD-66). On 19 Oct 16, while in A-Check, the MA's Boom Control Unit (BCU) was removed to troubleshoot another aircraft, but was reinstalled on the MA by MM13 and MM14 (Tab D-162). The forms show the corrective action of *"Installed BCU Ops [Check Good]"* (Tab D-162).

The MA departed on 23 Oct 16 at approximately 0827L/1627Z and diverted back to Travis AFB for a discrepancy not associated with the boom (Tabs AA-13 and DD-95). The boom was not cycled during this flight (Tab DD-95).

The MA departed on the same day at 1208L/2008Z to Eielson AFB, Alaska, and the boom was not cycled (Tab DD-94). The MA stayed on the ground in Eielson AFB for six days while awaiting repairs for discrepancies not associated with the boom (Tabs D-81 through D-89 and DD-85).

The MA departed Eielson AFB on 30 Oct 16 at 1009L/1809Z heading for Yokota Air Base on a refueling mission (Tab DD-85). The crew attempted to lower and fly the boom, but the boom did not operate properly (Tab DD-89). The aircraft diverted to Travis AFB for maintenance and landed on 30 Oct 16 at 1601L (31 Oct 16 at 0001Z) (Tab DD-85). The boom operator debriefed maintenance personnel and entered the following discrepancy in the AFTO Form 781A:

> *"During boom lowering, the boom flew to 5 degrees w/ no input by the operator. Small corrections were made to align the boom. The boom then flew uncommanded to 32 degrees or greater. Right structural limit broken with no command inputs made"* (Tab D-90).

30 Oct 16, Day Shift - This discrepancy was worked by MM1 from the 60 MXS Hydraulics Section (Tab V-10.6). MM1 performed a visual inspection of the DRVT and gimbal area, and utilized a camera phone to verify the position of the DRVT indicator pin engagement to yoke tangs (Tab V-10.7).

30 Oct 16, Night Shift - This discrepancy was worked by MM2, who performed a visual inspection of all boom flight controls and the boom flight control area with the help of MM8 (Tabs V-11.9, V- 16.3). MM2 utilized an ARB tester, cycled the flight controls, found loose cannon plugs, and signed off the discrepancy and made the following entry in the "Corrected By" block of the AFTO Form 781A:

> *"Lowered boom check visually all flight control surfaces. Did sensor readouts on STP (Status/Test Panel), all within limits. Hook up ARB tester ran test and sensor read out. Ran preflight and MX Test on boom. Found DRVT and Roll [Linear*

> *Voltage Differential Transducer (LVDT)] cannon plugs on visual inspection. [Re-torqued] cannon Plugs DRVT/LVD*T" (Tabs D-90, V-11.9).

The discrepancy was closed out at 0450, 31 Oct 16 (Tabs D-90, DD-98).

The MA departed Travis AFB on 1 Nov 16 at 0746L/1546Z as described in Sections 2 and 4d of this report (Tab DD-65). The following discrepancy was noted after the mishap in the AFTO Form 781:

> *"Boom uncontrollable in flight shortly after it was deployed. Dual rudder fail, elevation fail lights, different malfunctions indicated throughout period boom was uncontrollable. Boom appeared to detach from gimbal and eventually separated from aircraft"* (Tab D-9).

The aircraft was subsequently impounded for investigation.

b. Inspections

The Combined Basic Postflight/Preflight (BPO/PRE) inspection was completed IAW TO 1C-10(K)A-6WC-1, *USAF K-10A Aircraft Preflight-Basic Post and Thruflight Inspection Work Cards*, and documented in the 781H on 9 Oct 16, 2300Z (1500L) (Tab DD-30).

The BPO Inspection was accomplished IAW TO 1C-10(K)A-6WC-1, *USAF K-10A Aircraft Preflight-Basic Post and Thruflight Inspection Work Cards*, on 20 Oct 16, 0600Z (2200L, 19 Oct) (Tab D-62).

An A-Check was accomplished 20 Oct 16, but was mislabeled as a more extensive inspection called a C-Check due to GO81 error (Tabs D-3 and V-10.6).

c. Maintenance Procedures

For the purposes of this report, this section will discuss maintenance procedures observed during this investigation. Specifically the AIB focused on local debrief processes and identification of repeat/recur discrepancies. The AIB referenced TOs, AFIs, local Operating Instructions (OIs), and witness testimony.

The primary purpose of the aircraft maintenance formal debrief process is to ensure that malfunctions identified by aircrews are properly reported to maintenance personnel and documented per AFI 21-101 Air Mobility Command Supplement, *Aircraft and Equipment Maintenance Management* (Tab BB-34).

"Repeat Discrepancy" is defined as:

> *"[A] Malfunction in a system or subsystem that reappears on the next sortie (or attempted sortie) NOTE: Each consecutive sortie that experiences the malfunction is a Repeat and resets the counter, i.e. there can be several repeats in a row, but not a Recur unless there is at least one flight between malfunctions."* (Tab BB-33).

"Recur Discrepancy" is defined as:

> *"A malfunction that occurs on the second through fourth sortie or attempted sortie after corrective action has been taken and the system or sub-system indicates the same malfunction when operated"* (Tab BB-33).

Per the 60/349 MXG OI, paragraph 16.1.2.2, if a discrepancy is labeled as a second Repeat/Recur, it requires "*lead technician involvement by assisting in troubleshooting and signing off the discrepancy in the 'Inspected By' block of the AFTO Form 781A...*" (Tab BB-39).

The three debrief packets for the MA's previous flights contained numerous errors and omissions (Tabs DD-75, DD-84, DD-93 to DD-95). For example, the packets contained two different types of debrief forms, each at various levels of completion and detail (Tabs DD-75, DD-84, DD-93 to DD- 95). Furthermore, one of the debrief forms was from a different aircraft tail number (Tab DD-92). These debrief packets cover five flights from the initial boom discrepancy on 11 Oct 16 to the last boom discrepancy on 30 Oct 16 (Tabs DD-75, DD-84, DD-93 to DD-95). The Debrief Section did not indicate the boom roll discrepancy as a repeat on 12 Oct 16, even though two flights in a row had similar discrepancies (Tabs DD-75, DD-81, DD-84).

After the 12 Oct 16 flight the MA flew twice on 23 Oct 16, and even though the boom was not deployed on either of those flights, this cleared the "Repeat" discrepancy before the 30 Oct 16 flight (Tabs DD-75, DD-84, DD-86, DD-94, DD-95). The boom issue on 30 Oct 16 was the third flight of the MA after an attempted corrective action had been taken to resolve the boom roll problem (Tab DD-109). Upon return from this flight, home station debriefed the MA with boom roll issues, but it was not identified as a "Recur" discrepancy (Tab DD-93). The crew completed an AMC Form 97 *AMC In-Flight Emergency and Unusual Occurrence Worksheet*, which noted an "*audible bang,"* but no related notes were included on the debrief form (Tabs V-24.3 and AA-2). The Flying Crew Chief, MM15, aboard the aircraft filled out the debrief form in flight prior to the discrepancy, but did not change the form or attend the debrief (Tabs V-24.1 to V-24.2). Despite an air abort, fuel jettison, and divert home due to boom controllability issues and broken structural limits, the debrief forms for the MA showed no evidence of a major discrepancy or Repeat/Recur (Tabs V-24.3, DD-93, and DD-109). The debrief form from 12 Oct 16 did have "Yes" circled in the "repeat/recur" discrepancy block, but the form does not specify which one of multiple issues identified that day caused the air crew to report a repeat/recur (Tabs DD-80, DD-81 and DD-84). In addition, these discrepancies were not captured in the GO81 database or AFTO Form 781A's as a "Repeat" on 12 Oct 16 or a "Recur" on 30 Oct 16 (Tabs DD-80 through DD-81, DD-88 through DD-90, and DD-97 through DD-98).

d. Forms Documentation

The 60 MXS Hydraulics Section utilizes anecdotal, hand-written turnover logs, which do not reference TO task, item number, or page number to ensure the oncoming shift knows which specific steps to complete (Tab V-10.11, V-11.24 to V-11.25). TO 00-20-1, paragraphs 5.7.3.16.7 and 5.7.3.16.7.1 dictate that incomplete tasks be documented in a specified manner in the AFTO 781A (Tab BB-36 to BB-37). The gimbal and yoke assembly installation required greater than four shifts to accomplish, but all jobs were signed off during one shift on 13 Oct 16 (Tabs D-43 through D-54, and V-13.3 to V-13.4 and V-15.3 to V-15.4).

e. Maintenance Personnel and Supervision

All Training Business Areas (TBAs) for applicable technicians were reviewed with no significant training deficiencies identified (Tabs T-2 through T-122). However, none of the qualified technicians interviewed had previously removed or replaced a gimbal yoke assembly or a DRVT (Tabs V-11.12, V-15.3, V-20.2). These maintainers gained certification through academic study, not on aircraft (Tabs V-11.12, V-15.3, V-20.2). A data query from the Maintenance Information System revealed that in from 2011 to 2017, there have been eight gimbals and two DRVTs replaced on the entire KC-10A fleet (Tab DD-107).

f. Fuel, Hydraulic, Oil, and Oxygen Inspection Analyses

Not Applicable

6. AIRFRAME SYSTEMS

a. Normal Operation of the Boom

The KC-10 boom assembly (Figure 6.1) consists of a telescopic refueling boom equipped with bilateral rudders and a trailing elevator (flight control surfaces) to assist with elevation and roll control while in flight (Tab BB-17). The Boom Flight Control System is an integrated closed-loop, fly-by-wire system that utilizes a repurposed McDonnell Douglas MD-80 autopilot box called the BCU (Tabs BB-17 and EE-5). The flight control actuation system consists of the following (Figures 6.1 and 6.2):

- The BCU (Tab BB-17).
- An elevation/roll hand controller, which includes a flight control stick and a Boom Control Assembly (BCA), gives artificial feedback to, and translates command inputs from, the boom operator (Tab BB-17).
- Linear and rotary position transducers constantly provide the BCU with the elevation and roll position of the boom (Tab BB-17).
- Accelerometers control and report rate of boom movement to the BCU (Tab BB-17).
- Nozzle load sensors provide load feedback to the BCU to prevent overload of the boom nozzle when in contact with receiver aircraft (Tab BB-17).
- Elevator and rudder actuators provide hydraulic force to move the flight control surfaces when commanded (Tab BB-17).
- Boom control force selector (BB-17).
- Various electrical switches and lights provide both the boom operator and BCU with necessary information in regards to the status of boom performance (Tab BB-17).
- An STP displays built-in-test information from the BCU for boom operator and maintenance personnel use on the ground (Tab BB-18).

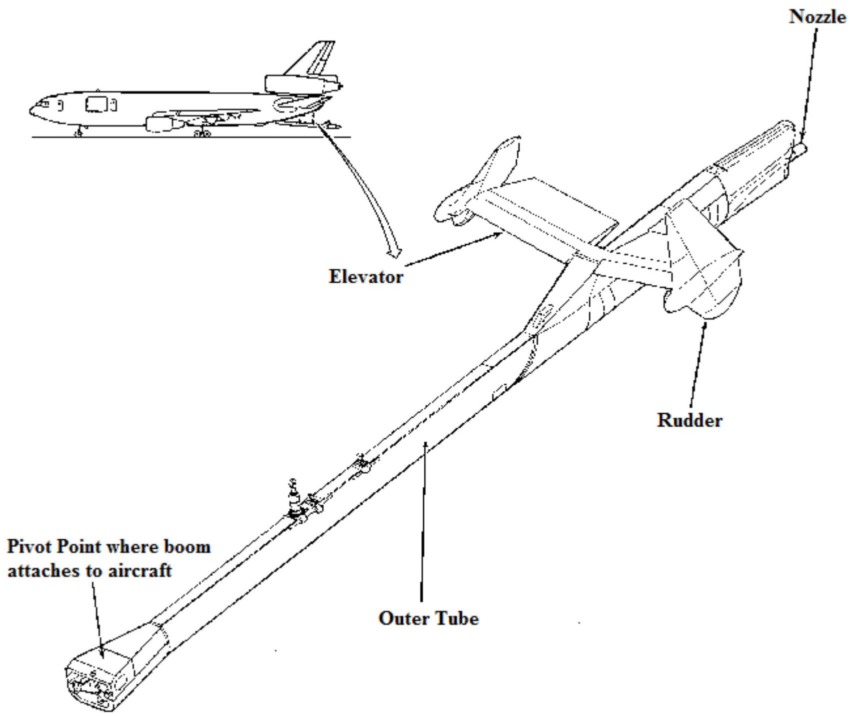

Figure 6.1 (Tab BB-20)

In order to control the boom, the boom operator uses the flight control stick atop the BCA, which consists of two elevation linear voltage differential transducers (LVDT), two roll LVDTs, one elevation torque motor, and one roll torque motor (Tab BB-17). The LVDTs translate linear boom flight control stick movement to electronic elevation and roll commands, then send them to the BCU, which in turn, commands the boom flight controls (Tab BB-17). The automatic load alleviation system (ALAS) provides automatic control of the boom when the boom is in contact to a receiver aircraft (BB-18). ALAS measures the boom forces at the nozzle and commands the control stick to a position that will alleviate the load (Tab BB-17 to BB-18). In short, whether the boom is being manually flown by the boom operator or automatically flown by ALAS, the BCU sends electrical command signals to the flight control surface actuators (Tab BB-17 to BB-18).

In addition to the BCA elevation and roll LVDTs, there are more sensors located on the boom gimbal and yoke assembly that continually monitor the boom's position (Figure 6.2) (Tab BB-17). A single DRVT, located in the gimbal yoke housing, senses boom roll by translating rotational movement into voltage, and sending that voltage signal to the BCU, similar to the LVDTs (Tab BB-17). The boom accelerometer, located near the end of the outer fuel tube, detects boom angular roll rates (Tab BB-17).

The gimbal and yoke assembly is located on the underside of the tail and attaches the boom assembly to the aircraft (Tabs BB-23 and EE-3). The assembly consists of a gimbal housing, a yoke, a yoke retainer, and roller bearings (Tab EE-3). The gimbal unit allows the boom to move freely throughout the normal operational range (Tab EE-3). The boom assembly attaches to the gimbal yoke assembly using two lugs (Tab EE-3). The gimbal housing then attaches to the aircraft structure using two more lugs (Tab EE-3).

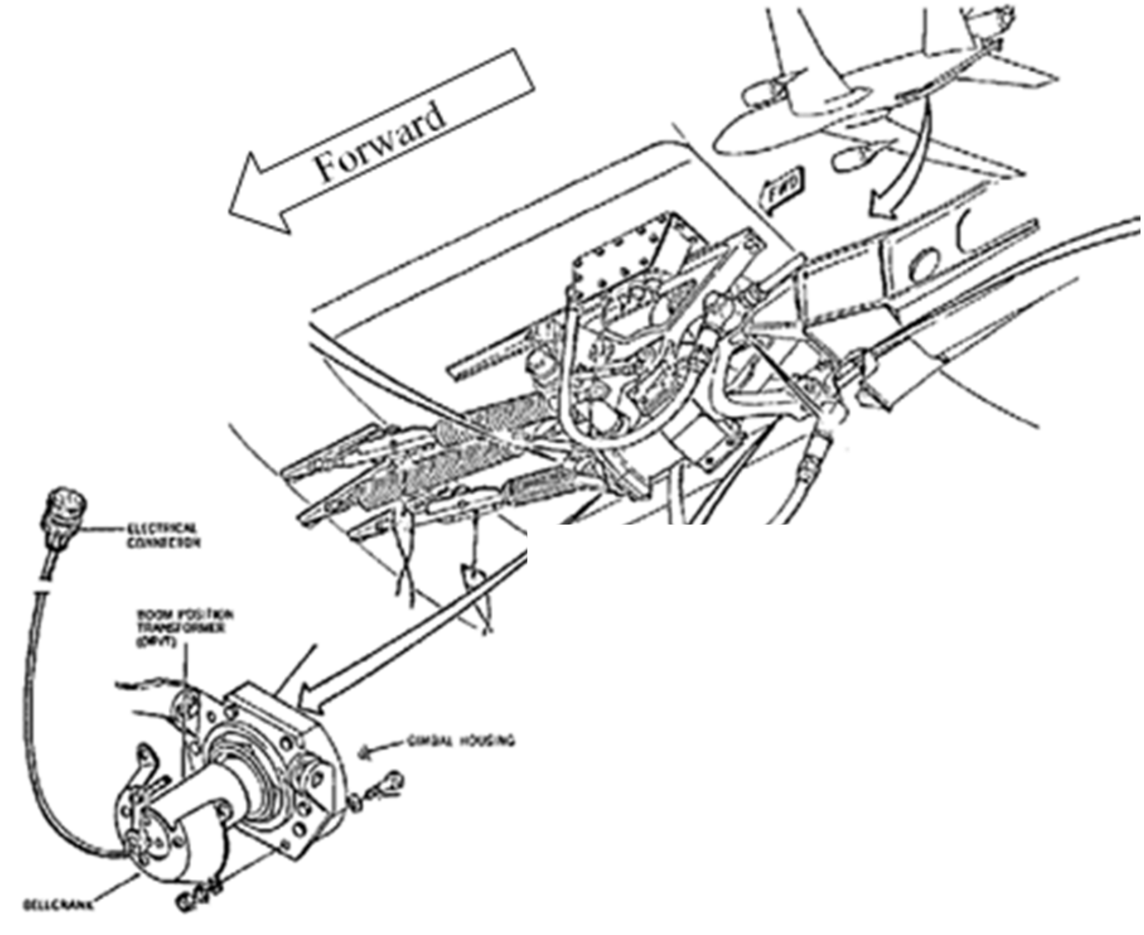

Figure 6.2. (Tab BB-23)

Normal system operation of the boom flight controls is as follows:

In free-flight mode, the boom operator makes command inputs using the flight control stick (Tab BB-17). If ALAS is engaged the nozzle load sensor can also provide command inputs to track a receiver aircraft during coupled flight (Tab BB-17). Each LVDT corresponds to a single channel that is fed to the BCU (Tab BB-21). Dual elevation LVDTs and dual roll LVDTs command movement in their respective axes (Tab BB-21). The command data goes from the LVDTs to the BCU, where they are compared and translated to flight control surface movement only if each input channel is within a specified tolerance of its pair (Tabs BB-18 and EE-21). The BCU constantly monitors command inputs, the movement of the flight control surfaces, and boom position using a dual channel feedback feature (Tab BB-21). If the channels disagree with each other, or are not within a specified tolerance, the BCU shuts down the power to the associated flight control surface (Tabs BB-18 and EE-21). Once the BCU shuts down a flight control surface, or the flight control switch is turned off, the surface goes into the faired or power-off mode and neutralizes in the airstream (Tab BB-18).

b. KC-10 Boom Normal Flight Procedures

Prior to flight, the boom operator conducts preflight checks of flight control surfaces, control circuits, and ancillary components of the boom (Tab V-4.3). Once in flight and prior to receiver aircraft contact, the boom operator goes to the ARO compartment and initiates a 22-step checklist, the *Boom Operator Preparation for Contact* Checklist (Tab BB-12). This checklist includes opening the sighting window, lowering the boom, and performing another flight control check (Tabs BB-12 to BB-14). If this flight control check is successful, then in-flight refueling may begin (Tab BB-14).

The checklist includes the following key steps:

- Steps 1-11 direct the boom operator to open the sighting window and power up hydraulics to the flight controls (Tab BB-12 to BB-13). The boom operator keeps the boom in view using the boom sighting window and angled mirrors (Figure 6.6) (Tab BB-22).
- Step 12 directs the boom operator to turn on the flight control switch, activating the BCU (Tab BB-13). The boom is still stowed at this point (Tab BB-13).
- Step 19 directs the boom operator to lower the boom and check the boom flight controls (Tab BB-13). Under normal operation, the boom operator lowers the boom from its stowed position to its refueling position through the following two steps (Tabs BB-13, BB-14):
  - A lever is moved to *Lower*, and a hydraulically controlled cable (hoist cable) lowers the boom to approximately 0° elevation (Tabs BB-3, BB-14).
  - An electronic switch (*Boom Elevation Position Switch*) is moved to the *Refuel* position, and the BCU lowers the boom to its centered position (Tab BB-14). The normal, centered position of the boom, in reference to the aircraft's fuselage, is 0° left and right and 30° down from level, depicted in Figure 6.4 (Tabs Z-5, BB-14).
- Step 20 directs the boom operator to perform a flight control check, which consists of flying the boom first left and right to 25° roll, then up to 18° and down to 40° elevation (Tab BB-14). Figures 6.3 and 6.5 below depict 25° Right and Left (with respect to the aircraft) with corresponding gauge and flight control stick position (Tabs Z-6, Z-7).

Figure 6.3 (Tab Z-6)

Figure 6.4 (Tab Z-5)

Figure 6.5 (Tab Z-7)

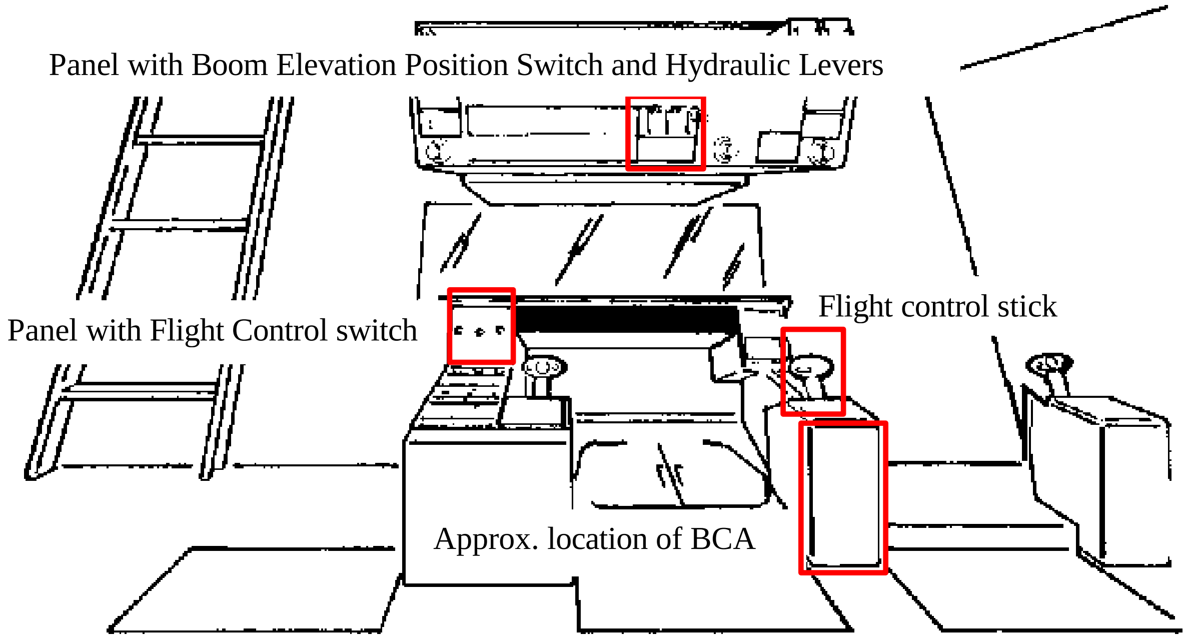

Figure 6.6 (Tab BB-22)

After AR, the boom operator stows the boom using the *Post Air Refueling* checklist, which consists of the following key steps:

- Step 1 directs the boom operator to stow the boom
  - The *Boom Elevation Position Switch* is moved to the *Stow* position, and commands the BCU to raise the boom from 30° elevation to approximately 0° elevation (Tab BB-15)
  - Then, a lever is moved to the *Raise* position, which commands the hydraulically controlled hoist cable to raise the boom from 0° elevation to the stowed position (Tab BB-15).
- Step 2 directs the boom operator to turn off the flight control switch (Tab BB-15)
- The remainder of the checklist is not applicable to this investigation.

Under normal operations, both the flight control system and the boom hoist cable work together to control the boom (Tab BB-15). In abnormal situations, the boom operator can use either system independently to stow the boom (Tabs BB-7, BB-8). For example, if the hoist cable is broken, the boom operator can fly the boom to the stowed position (Tab BB-8). Likewise, if the flight control switch is off, the boom operator can use the hoist cable to winch the boom to the stowed position (Tab BB-7). If neither system is operational then the flight crew may consider landing with the boom in trail (BB-9).

c. Structures and Systems post-mishap: Evaluation and Analysis

A majority of the boom's external components landed in a field approximately 20 miles east of Mountain Home AFB (Figures 4.2, 6.7) (Tabs S-3, Z-4). The Safety Investigation Board sent the following components for analysis:

- Flight data recorder / cockpit voice recorder (Tab Q-2)

- Boom gimbal and yoke assembly with the DRVT (Tab Q-2)
- BCA (Tab Q-2)
- BCU (Tab Q-2)
- Hoist Cable (Tab Q-2)
- A-Frame (Tab Q-2)
- All accelerometers, LVDTs (Tabs Q-2, Q-3)
- Wiring Harnesses (Tab Q-3)
- Window Heat Controller (Tab Q-3)

Only the structures deemed relevant to the mishap by the AIB are discussed in this section.

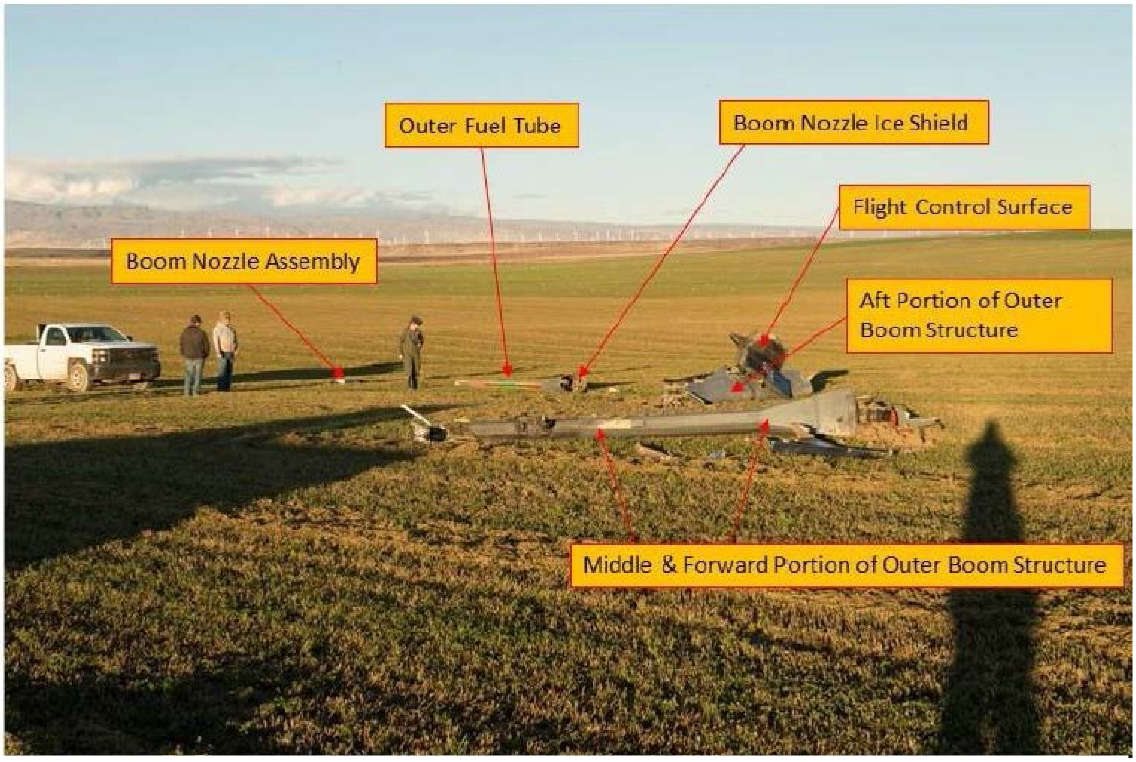

Figure 6.7 (Tab S-3)

(1) Gimbal and Yoke Assembly with the Dual Rotary Voltage Transducer

Detailed analysis of the aerial refueling boom gimbal assembly by Boeing demonstrated the following findings:

- Complete fractures of the gimbal housing assembly, yoke retainer and support fittings were found obliterated due to mechanical damage from impact and were therefore of little use for analysis (Tabs J-212, S-3, and S-4).

- Undamaged regions demonstrated either a rough, grainy texture consistent with tensile or bending overload or a flat, smooth appearance consistent with shear or compressive overload (Tabs J-210 through J-211).
- In addition, the positioning stud of the DRVT (DRVT indicator pin) was found to be displaced to one side of the yoke retaining slots with associated damage found on DRVT housing from the same side due to contact with the stud (Tab J-211).
- The bellcrank arm was twisted and the DRVT housing end cap was damaged, which resulted in a deflection of the indicator pin approximately 6 degrees to the left (Figure 6.8) (Tab J-211 and J-223).
- The DRVT housing was pulled away from the forward flange by approximately 0.16 inches (Tab J-211). As a result, the transducers within the DRVT housing were found to be intact, but separated from their anchoring points and hanging only by its wires (Tab J-211).
- There was evidence of reworking at the forward end of the yoke assembly with the original tabs positioned diametrically opposite (180º) to the "newer" tabs (Tab J-211).
- Witness marks were found along the inner surface of the two tabs extending 0.09 inches, indicating the depth of the DRVT pin engagement (Tab J-211).
- Damage along the forward faces of the tabs suggests contact with the DRVT pin as it came out of the slot in both directions with multiple strikes, suggesting more than one instance of contact (Tab J-211).
- Damage to inner surface of the yoke assembly along the upper right-hand quadrant was found due to contact with the lockwire as it articulated with the yoke nut (Tab J-211).
- Metallurgic analysis demonstrated no material abnormalities associated with fracture sites (Tabs J-210 to J-212).
- Breakaway torque was attempted at the yoke nut during initial disassembly, but was discontinued after a significant torque was achieved without movement of the nut (Tab J- 211).

The AIB disassembled both the mishap DRVT and a DRVT from the supplier to compare rotary bearing alignment and other internal components (Tab EE-12). Detailed analysis of the DRVTs by the AIB Engineering and Maintenance Advisors demonstrated the following findings (Tabs EE- 12 through EE-19):

- The DRVT rotary bearing assembly was oriented 120° clockwise placing the internal mechanical stop in the 4 o'clock position looking from the face view or 8 o'clock position (240°) if viewing from internal view when removed (Figure 6.9) (Tab EE-13).
- The misalignment was out of design specifications, and was found to have put the mechanical stop in the normal range of motion of the rotary crank (Figure 6.9) (Tab EE-14).
- The rotary crank sheared and the rotary crank mechanical stop was damaged (Tab EE-15).
- With the rotary crank sheared, DRVT rotary drive shaft cannot fully engage the rotary crank (Figure 6.11) (Tab EE-15).

The AIB also analyzed the gimbal and yoke assembly after its return from Boeing, and found the following:

- The yoke tang bearing insert introduced an additional .132” of length to the original end of the yoke (Tab EE-5).
- The internal diameter of the yoke decreased by .293” due to the yoke tang bearing insert (Tab EE-5).
- At .277” in length, the yoke tangs were nearly half the size they should have been per drawing specifications (Tab EE-9).
- The bearing shaft length was 1.214” which is above design limits (Tab EE-9).
- The mishap yoke was short one thread from *design sp*ecifications (Tab EE-9).

(2) Boom Control Unit

After the incident, the BCU was sent to Honeywell for teardown and analysis (Tab Q-2). The BCU passed functional tests and no physical defects were identified in their report (Tabs EE-23 through EE-24).

(3) Boom Control Assembly

Detailed analysis of the BCA by Aero-K Inc. and Frazier Aviation Inc. demonstrated the following findings (Tabs Q-2, EE-20):

- Initial inspection of the BCA revealed that the red wire to the roll feedback motor was disconnected (Tabs J-193, and EE-20).
- The crank assembly binds the support frame when the elevation motor is engaged (Figure 6.12) (Tabs J-190, EE-20, Z-22).
- All four pitch and roll LVDTs failed the voltage bench test (Tabs J-194, EE-20, EE-21).

The following are figures referenced in this section.

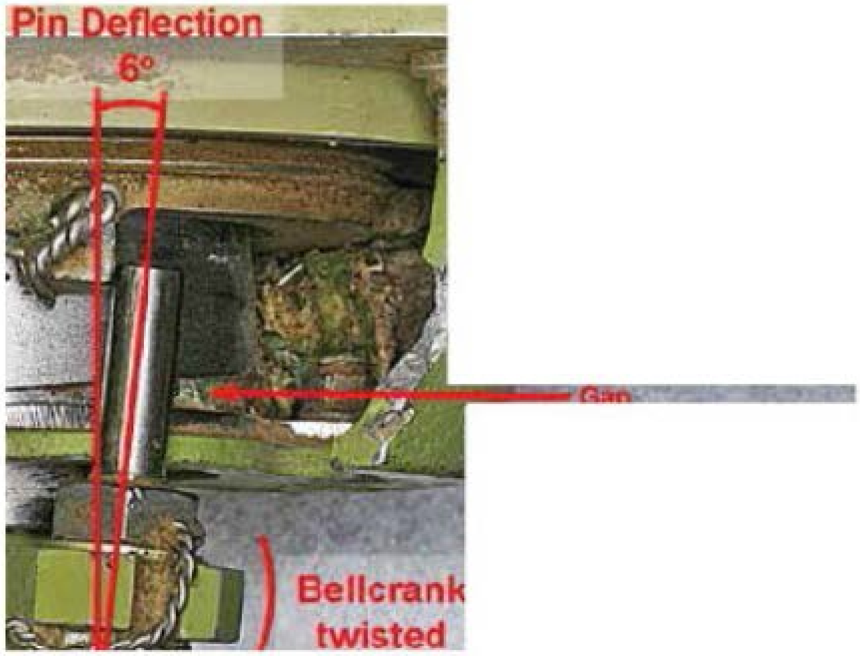

Figure 6.8 (Tab J-223)

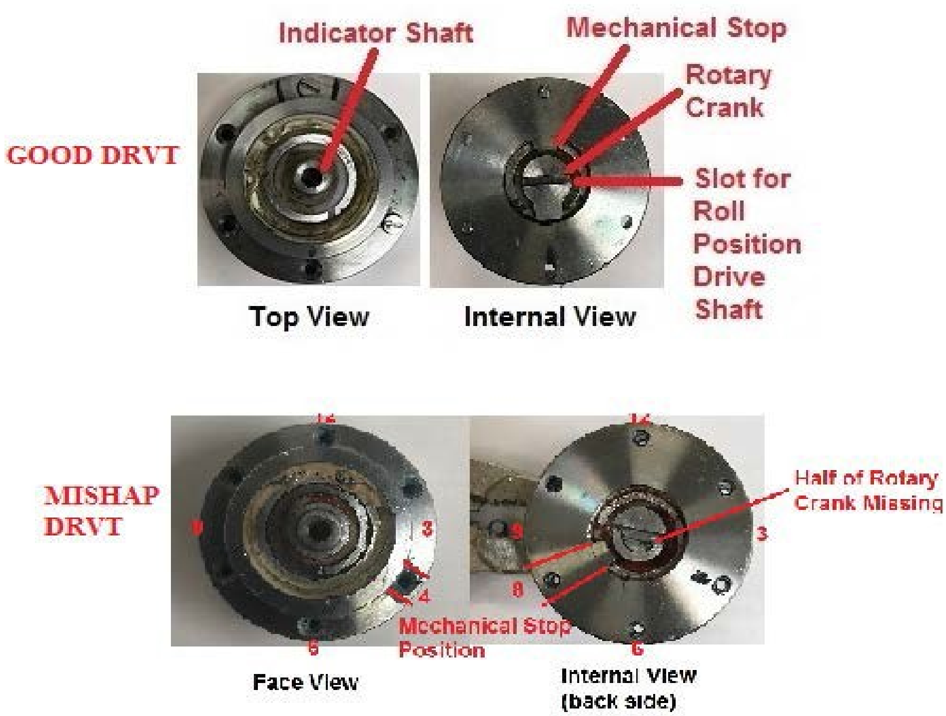

Figure 6.9 (Tabs EE-13, EE-14)

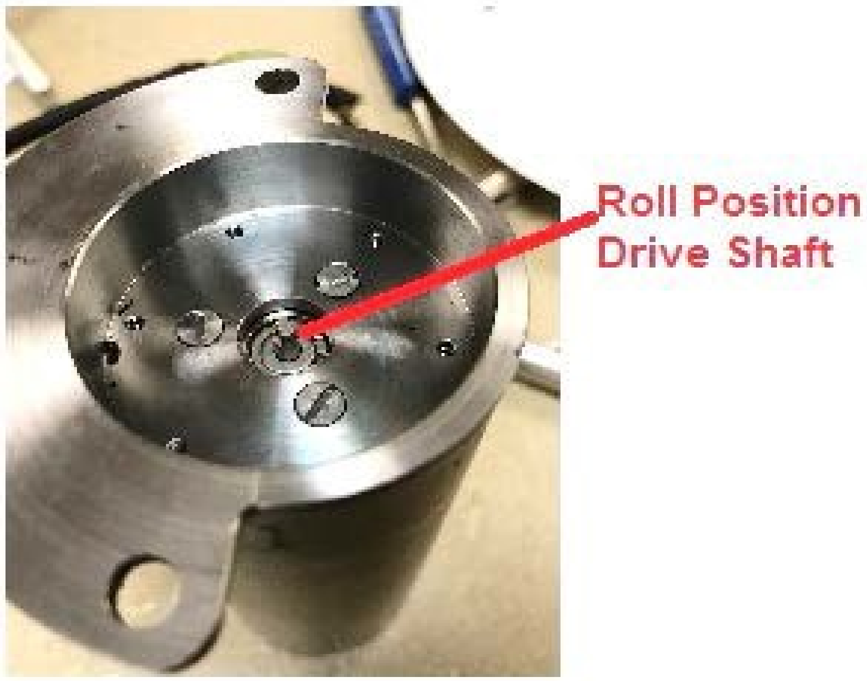

Figure 6.10 (Tab EE-13)

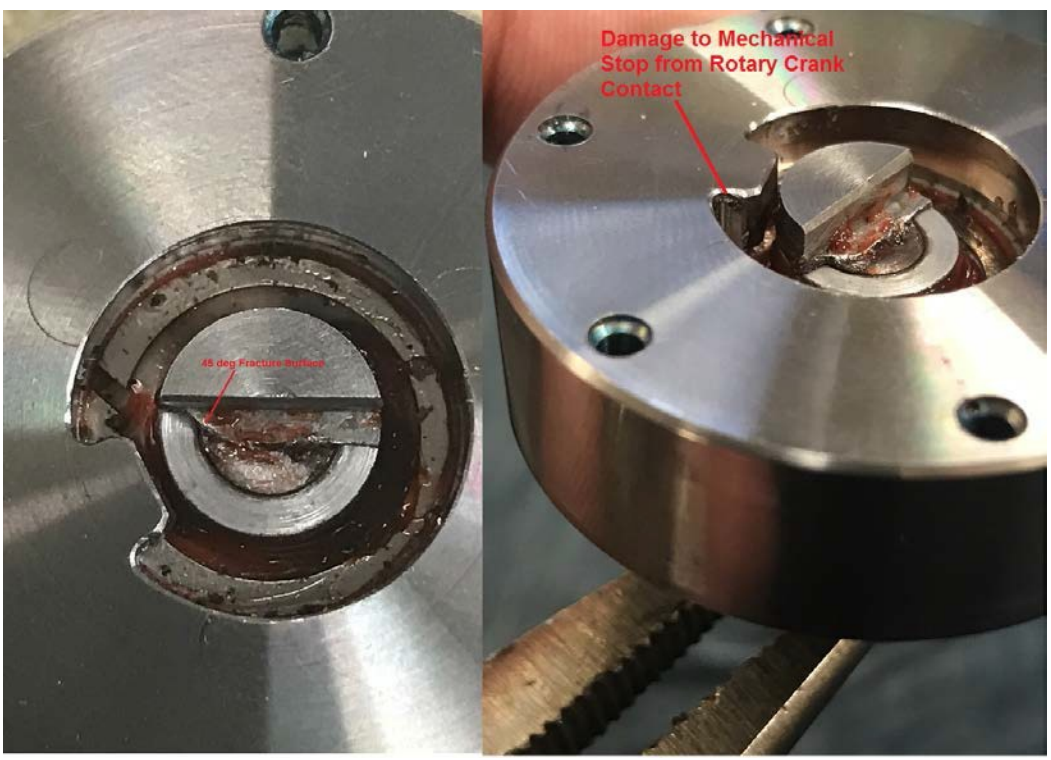

Figure 6.11 (Tab EE-16)

Figure 6.12 (Tab Z-22)

The AIB also analyzed the BCA after its return from Frazier Aviation Inc., using an ARB tester, and found the following:

- Individual LVDT measurements were out of tolerance design specification (Tab EE-21).
- Each LVDT voltage output was within tolerance of its corresponding LVDT when tested using the Boeing ARB Tester (Tab EE-21).
- Voltage differences, when centered, would bias (or lean) the flight control stick to command the boom to the aircraft left (Tab EE-21).

7. WEATHER

a. Forecast Weather

The weather forecast for the mishap called for an overcast deck from 5,000 ft. to 12,000 ft., broken clouds from 12,000 to 22,000 ft., and scattered clouds from 22,000 to 26,000 ft. (Tab F-11). Visibility from 22,000 to 26,000 ft. was forecast at three nautical miles (NM) in-cloud and seven NM out-of-cloud (F-11). Winds from 17,000 to 25,000 ft. were forecast out of the Northwest at approximately 20 miles per hour (Tab F-11). Light to occasional moderate turbulence was forecast for the AR track for the duration of the mission. Icing and thunderstorms were not forecast (Tab F-11).

b. Observed Weather

On the day of the mishap, the MP reported the ceiling and visibility to be unlimited with no weather hazards (Turbulence, icing, and thunderstorms) (Tabs AA-4, V-1.4).

c. Space Environment

Not Applicable

d. Operations

Observed weather, cloud ceilings, and visibility were well above the minimums required by AFI 11-2-KC10v3, *KC-10 Operating Procedures*, to conduct the mission, and the MC conducted the mission within its prescribed operational weather limitations (Tab BB-41). No evidence suggests weather was a factor in the mishap.

8. CREW QUALIFICATIONS

All crewmembers were qualified for their respective crew positions (Tabs G-188, G-189, G-190). At the time of the mishap, all necessary flight currencies and training requirements were accomplished and verified by the scheduling authority (Tabs G-11, G-12, G-13, G-20, G-21, G-29, G-30, G-31, G-39, G-40, G-41, G-42, AA-16). There is no evidence to suggest crew qualifications were a factor in this mishap.

a. Flying History/Crew Qualification Table

Table 8.1 illustrates the flight history up to 90 days prior to the mishap, the highest qualification held, and evaluation expiration date:

	Highest KC-10 Qualification held	Expiration of Evaluation	1-30 days prior		31-60 days prior		61-90 days prior	
			Hours	Sorties	Hours	Sorties	Hours	Sorties
MP	Mission Pilot	Feb 2017	0.0	0	7.3	2	21.1	5
MCP	Instructor Pilot	Dec 2017	3.6	1	20.5	2	34.5	6
MFE	Evaluator Flight Engineer	July 2017	5.3	1	0.0	0	0.0	0
MB	Mission Boom Operator	Sept 2017	0.0	0	93.9	14	95.9	15

Table 8.1 (Tabs G-6, G-17, G-25, G-35, G-45, G-111, G-140, G-153, G-188, G-189, G-190)

9. MEDICAL

a. Qualifications

At the time of the mishap, the MC was medically qualified for flying duties IAW AFI 48-123, *Medical Examinations and Standards*. Furthermore, all electronic medical records and the paper charts were reviewed for all involved maintenance members (Tab FF-2).

All maintenance members were found to have current Periodic Health Assessments (PHAs) with no variance in their baseline health. (Tab FF-2)

b. Health

Toxicology reports of the MC and involved maintenance members were reviewed and all were negative for ethanol, amphetamines, barbiturates, benzodiazepines, cannabinoids, cocaine, opiates, phencyclidine, and sympathomimetic amines (Tab FF-2).

c. Pathology

Not Applicable

d. Lifestyle

Mishap 72 hour – 14-day histories of the MC demonstrated a significant lifestyle change of only the MP that included a newborn infant at home (Tab R-12). While the MP denied a significant lifestyle change despite this additional responsibility, he did report sleeping for approximately 6 hours the night prior to the incident (Tab R-6, R-10). No evidence suggests that lifestyle factors for the MC were found to be relevant to the mishap.

e. Crew Rest and Crew Duty Time

There is no evidence to indicate crew rest was a factor in the mishap. MC appears to have been in compliance with AFI 11-202v3, *General Flight Rules*, which requires a minimum of 12 non-duty hours prior to a flight, including an opportunity for at least eight hours of uninterrupted sleep (Tab BB-54). The MC was leaving from their home station of Travis AFB with a crew show time of 0520L Tuesday, 1 Nov 16 (Tab AA-8). Per AFI 11-202v3 the MC was required to enter crew rest at 1720L Monday, 31 Oct 16 (Tab BB-43). MP, MCP, MFE, and MB all completed 72-hour/14 day histories, none of which indicated a lack of opportunity for adequate crew rest (Tab R-3 to R-42).

10. OPERATIONS AND SUPERVISION

There is no evidence to suggest operations and supervision were a factor in the mishap.

a. Operations

The MC was schedule to fly a routine local training mission, departing from and returning to their home station of Travis AFB (KSUU), and complied with all applicable local guidance (Tab K-2).

b. Supervision

The 9 ARS leadership ensured all flight members were current and qualified for the mission (Tabs AA-18, AA-19).

11. HUMAN FACTORS ANALYSIS

a. Introduction

Human Factors describe how our interaction with tools, tasks, working environments, and other people influence human performance. This report includes an analysis of the human performance variables that contributed to this mishap. Interviews with personnel involved in the air refueling mission, including the MC, maintenance personnel and other involved individuals, as well as, the Department of Defense (DoD) Human Factors Analysis and Classification System (HFACS) model were used to present a systematic, multidimensional approach to mishap analysis.

The AIB found elements of each of the following human factors across operations and maintenance personnel throughout the investigation:

b. Checklist Error (DoD HFACS AE102)

When an individual makes a checklist error or fails to run an appropriate checklist that results in an unsafe situation. The MB ran the inappropriate checklist for the situation (Tabs BB-7 to BB-8). MM2 did not formally document or "sign off" the TO steps he had completed while installing a new gimbal and DRVT assembly (V-11.11 to V-11.12). Then on the following shift, MM3 and MM4 failed to perform the TO step of lowering and moving the boom to test that the DRVT had been properly installed (Tabs V-14.3 to V-14.4).

c. Task Misprioritization (DoD HFACS AE202)

Individual fails to recognize, based on accepted prioritization techniques, the tasks needed to manage the immediate situation. The MB prioritized raising the boom using normal procedures before addressing the erratic flight controls (BB-7, BB-8).

d. Necessary Action – Delayed (DoD HFACS AE204)

When individual selects a course of action but elects to delay execution, and the delay, leads to an unsafe situation. The MB delayed step 3 of the *Flight Controls do not Respond to Command Inputs or Control Surfaces are Erratic* checklist, which directs him to turn off the flight control switch (Tabs BB-7, N-5, N-6).

e. Technical/Procedural Knowledge (DoD HFACS PC405)

When an individual was adequately exposed to information but did not absorb it. Lack of knowledge implies no deficiency in training. Based off of testimony, the AIB identified an overall lack of experience regarding gimbal and yoke assembly installation (Tabs V-11.12, V-15.3, V-20.2). The MB did not appear to remember the existence of the *Flight Controls do not Respond to Command Inputs or Control Surfaces are Erratic* checklist when the boom was *"going crazy"* (Tabs N-5 to N-7).

f. Limited Recent Experience (DoD HFACS SP003)

Supervisor selects an individual whose experience is not sufficiently current to permit safe mission execution. Based off testimony of multiple maintenance members, the AIB identified an overall lack of experience regarding gimbal and yoke assembly installation (Tabs V-11.12, V-15.3, V-20.2).

g. Limited Total Experience (DoD HFACS SP004)

Supervisor selects an individual who has performed a specific mission or task either infrequently or rarely. Based off testimony of multiple maintenance members, the AIB identified an overall lack of experience regarding gimbal and yoke assembly installation (Tabs V-11.12, V-15.3, V-20.2).

h. Proficiency (DoD HFACS SP005)

When an individual is not proficient in a task, mission or event. Based off testimony of multiple maintenance members, the AIB identified an overall lack of experience regarding gimbal and yoke assembly installation (Tabs V-11.12, V-15.3, V-20.2).

12. GOVERNING DIRECTIVES AND PUBLICATIONS

a. Publically Available Directives and Publications Relevant to the Mishap

- AFI 51-503, *Aerospace Accident Investigations*, 14 April 2015 (Version of the AFI at the time this board convened)
- AFI 48-123, *Medical Examinations and Standards*, 29 November 2016
- AFI 11-202, Volume 3, *General Flight Rules*, 10 August 2016
- AFI 36-2201, *Air Force Training Program*, 15 September 2010
- AFI 11-2KC10_AFGM1, Volume 3, *KC-10 Operating Procedures*, 30 August 2011, Change 1: 9 August 2015, Guidance Memorandum 23 March 2015
- AFI 21-101 Air Mobility Command Supplement, *Aircraft and Equipment Maintenance Management*, 9 February 2016

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

b. Other Directives and Publications Relevant to the Mishap

- TO 1C-10(K)A-1, *Flight Manual, USAF Series KC-10A Aircraft*, 15 December 2008, Change 6: 1 June 2012, ISS-168, 9 August 2016
- Air Force Forms 623, *Individual Training Record Folder,* 1 October 1996
- Air Force Forms 797, *Job Qualification Standard Continuation/Command Job Quality Standards, Staff progress records and Staff certifications*, 1 August 2002
- TO 1C-10(K)A-2-28, *Maintenance Manual Organizational, Fuel, USAF Series KC-10A Aircraft*, 01 July 2015, Change 5 - 2 December 2016
- TO 1C-10(K)A-6WC-1, *USAF KC-10A Aircraft Preflight-Basic Post and Thruflight Inspection Work Cards*, 15 November 2003, Change 38, 15 November 2016

- TO 00-20-1, *Aerospace Equipment Maintenance Inspection, Documentation, Policies, and Procedures*, 11 July 2016

c. Known or Suspected Deviations from Directives or Publications

- TO 00-20-1, *Aerospace Equipment Maintenance Inspection, Documentation, Policies, and Procedures*, paragraphs 5.7.3.16.7.1 & 5.7.3.16.7.2 (Tabs BB-47, BB-48)
- TO 1C-10(K)A-2-28, task 28-71-04, paragraph 3B, *Gimbal Install*, step 17 (Tab V-17.1)

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23 JUNE 2017

PERRY M. LONG III, Colonel, USAF
President, Accident Investigation Board

STATEMENT OF OPINION

KC-10A, T/N 83-0080
NEAR MOUNTAIN HOME AFB, IDAHO
1 NOVEMBER 2016

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 1 November 2016, at 1546 hours Zulu time (Z), a United States Air Force KC-10A Extender, tail number 83-0080, the mishap aircraft, assigned to the 60th Air Mobility Wing, departed from its home station of Travis Air Force Base (AFB), California, on a training mission in support of two flights of F-15s and a C-17 (Tab AA-15). The scheduled flight profile was a formation departure from Travis AFB, refueling for approximately one hour with the F-15s, refueling training for approximately 1 hour 15 minutes with the C-17, and approximately one half hour of approach training before landing at Travis AFB (Tab AA-6, AA-8, AA-10, and AA-15). The mishap crew (MC) is assigned to the 9th Air Refueling Squadron, Travis AFB (Tab G-3, G-14, G-22, and G-32).

At 1632Z, the MC prepared for aerial refueling (AR), and the mishap boom operator (MB) lowered the Aerial Refueling Boom (boom) (Tab N-4). Immediately after lowering the boom, it began to move erratically, oscillating to the aircraft's right and left in a U-shaped pattern, well outside of its structural limits (Tabs N-4 to N-5, and V-4.4). After oscillating for approximately two minutes, the boom hoist cable broke (Tab N-6). Approximately two minutes later, the gimbal separated from the A-frame gimbal mounts, but remained connected to the fuselage by hydraulic and electrical lines (Tabs N-8, N-15, and Z-3). At 1705Z, the boom completely separated from the aircraft and fell in an open field in Idaho (Tabs N-29, and S-3 through S-8). There were no injuries or fatalities reported with any portion of the mishap. After the boom separated, the MC landed the aircraft at Mountain Home AFB, Idaho without incident (Tabs N-30 through N-40). The total monetary value of government loss was $6,529,845.71 (Tab P-2).

I find, by a preponderance of the evidence, two causes for this mishap. The first cause of this mishap was a sheared Dual Rotary Voltage Transducer (DRVT) rotary crank that resulted from DRVT rotary bearing misalignment. This provided the aircraft's boom control unit (BCU) with continuous, inaccurate roll position indications. As a result, the BCU compensated with lateral movement commands in both directions, driving the boom beyond its structural limits.

The second cause, related to the first, was the MB's failure to turn off the boom flight control switch in a timely manner. The boom oscillated violently for approximately two minutes before the boom hoist cable broke (Tabs N-5 to N-6). Then the boom continued to oscillate violently for approximately two additional minutes before the boom components and structures became so damaged that they failed and triggered multiple warning lights (Tabs N-6 to N-8). Turning off the boom flight control switch would have disabled the BCU (Tabs EE-5 and V-5.7). This would have neutralized the boom flight control surfaces, and prevented the boom from departing the aircraft.

Additionally, I find, by a preponderance of the evidence, that the failure of maintenance personnel to comply with technical orders prevented the possible detection of an erratically performing DRVT, significantly contributing to the mishap.

2. CAUSE

a. Sheared DRVT Rotary Crank

Upon review of photographs of the face of the installed DRVT from 30 Oct 16 and from the Safety Investigation Board that were taken after the incident, the AIB identified the DRVT rotary bearing to be misaligned (Tab EE-12 through EE-19). To further investigate and confirm this observation, the AIB compared the alignment of the mishap DRVT to another DRVT from supply, and discovered that the mishap DRVT's rotary bearing was installed 120^{o} out of alignment (Tab EE-13). With this misalignment, the DRVT's internal mechanical stop would have obstructed the crank's normal operational range of motion (Tab EE-14 through EE-16). The DRVT comes fully assembled from the manufacturer, and this condition was not identified during any prior maintenance activity (Tab V-11.5 and 11.11).

On the 30 Oct 16 flight (the flight prior to the mishap), the boom was lowered in accordance with (IAW) normal operating procedures (Tab AA-2). This was the first time the boom was lowered during flight after the DRVT, gimbal and yoke assembly replacement on 13 Oct 16 (Tabs D-81 through D-89, DD-66, DD-85, DD-89, DD-94, DD-95, and V-11.5). As the boom lowered, it drifted to aircraft left approximately 10^{o}-15^{o} (Tab V-5.3 and V-5.4). Based off of post-mishap analysis by the AIB, it was determined that the Boom Control Assembly (BCA) had a voltage bias in the roll axis to the aircraft's left and the gimbal yoke assembly was out of design specification tolerances (Tab EE-22). In my opinion, this drift was due to a combination of both of these conditions.

At this point, I believe the approximate 10^{o}-15^{o} lateral drift caused the rotary crank to contact the internal mechanical stop and shear. This caused intermittent mechanical engagement of the DRVT rotary drive shaft, destroying the integrity of the connection between the physical position of the boom and the electrical signal sent by the DRVT to the BCU. This condition would send an electrical position signal to the BCU that would not match the physical position of the boom, but was translated as valid. On this flight, this caused the boom to move rapidly to aircraft right beyond the structural limit (Tab AA-2). The instructor boom operator (IBO) turned off the Flight Control Switch, removing the BCU from flight control inputs and allowing the boom to neutralize slowly behind the aircraft (Tab V-7.2). The IBO then raised and stowed the boom by alternate means using the boom hoist cable (Tab V-7.2). After the aircraft returned, the crew informed maintenance of the boom's actions (Tab V- 7.2).

According to testimony and AFTO 781A entries, maintenance accomplished the following:

> *"Lowered boom check visually all flight control surfaces. Did sensor readouts on STP (Status/Test Panel), all within limits. Hook up ARB tester*

> *ran test and sensor read out. Ran preflight and MX Test on boom. Found DRVT and Roll LVDT cannon plugs on visual inspection. [Re-torqued] cannon Plugs DRVT/LVDT"* (Tab D-90).

Despite half of the rotary crank missing, the rotary drive shaft remained static and engaged with the crank while the boom was stowed (Tab EE-22). As a result, the DRVT sent valid electrical signals to the BCU during STP and ARB preflight tests and showed no fault indications. Therefore, the aircraft was returned to Mission Capable Status, and was next flown on 1 Nov 16 (Tab DD-66).

During the mishap flight on 1 Nov 16, as the MB lowered the boom, it abruptly rolled to aircraft right and started the erratic, U-shaped oscillations (Tab V-4.4). Due to the damage to the DRVT rotary crank on the previous flight, the rotary shaft could not stay engaged, causing intermittent engagement between the two components (Tab EE-22). This condition would persist as the BCU sought to match the physical position of the boom with the electrical feedback from the compromised DRVT. Since the BCU deemed all input and output signals as valid and within design limits during the entire sequence, it did not signal a fault (Tab N-5). The BCU gave flight control inputs until the flight controls were at full deflection, rapidly forcing the boom past its lateral structural limits (Tab V-4.4). The BCU continued to command inputs to the boom flight controls to "chase" the varying position signals being sent by the mechanically damaged DRVT. As a result, the gimbal housing struck the A-frame repeatedly, leading to structural overload and failure of its attachment points (Tab J-116 through J-118 and J-212).

b. The MB Failed to Turn Off the Flight Control Switch in a Timely Manner

During the boom lowering process, the mishap boom operator (MB) stated, "*the boom is going crazy right now…it's moving left to right past 30^{o}*" (Tab N-5). At this point, the boom was oscillating erratically (Tab V-4.4). About two minutes later, the hoist cable broke (Tab N-6). The MB stated, *"I don't know what to do honestly … I have no control over this boom"* (Tab N-6). Based off the situation he was observing, two checklists would apply:

1) *Flight Controls do not Respond to Command Inputs or Control Surfaces are Erratic* (Applicable Steps) (Tab BB-7)
   - Step 1: disconnect the boom from receiver aircraft (if applicable) (Tab BB-7)
   - Step 2: retract the boom telescope (if able) (Tab BB-7)
   - Step 3: turn off the flight control switch (BCU control) (Tab BB-7)
   - Step 4: stow the boom using the hoist cable (Tab BB-7)

2) *Broken Boom Hoist Cable* (Applicable Steps) (Tab BB-8)
   - Step 1: Stow the boom (Tab BB-8)
   - This checklist requires the boom operator to hand-fly the boom to the stowed position (Tab BB-8).
   - The BCU must be on for this checklist to be completed (Tab BB-8).

In my opinion, the flight control surfaces were erratic, and the MB should have begun the *Flight Controls do not Respond to Command Inputs or Control Surfaces are Erratic* checklist immediately. He would have turned off the flight control switch (Step 3) before the hoist cable broke, which occurred approximately one minute and nineteen seconds after he verbalized the boom *"going crazy"* (Tabs N-5, N-6, and BB-7). With the flight control switch still on, the boom continued to move uncontrollably left and right past structural limits, eventually overloading the hoist cable, and weakening the boom attachment structure to failure (Tabs N-4, N-8, J-99, J-118, and J-212). The MB's failure to turn off the flight control switch in a timely manner ultimately led to the boom departing the aircraft.

3. SUBSTANTIALLY CONTRIBUTING FACTORS

a. Failure of Maintenance Personnel to Comply with Technical Orders

The 60th Maintenance Squadron (MXS) Hydraulics Section depended on informal hydraulics turnover logs and word of mouth instead of recording the completed task steps properly in the AFTO 781As (Tabs V-10.11, V-11.24, V-11.25, and V-13.5). This caused a violation of TO 00-20- 1, *Aerospace Equipment Maintenance Inspection, Documentation, Policies, and Procedures,* paragraphs 5.7.3.16.7.1 & 5.7.3.16.7.2 (Tab BB-36 to BB-37). Additionally, the time required to remove and replace the gimbal assembly and to remove and reinstall the boom spanned over four shifts (Tabs D-38, D-46 to D-49, D-51 to D-55, and V-13.3). The failure to annotate accomplished tasks properly, coupled with the length of time required to accomplish these maintenance procedures handicapped the successful completion of the corrective actions for this discrepancy.

Finally, the maintenance team did not complete Technical Order (TO) 1C-10(K)A-2-28, task 28-71-04, paragraph 3B, *Gimbal Install* (Tab V-14.3 to V-14.4). The *Gimbal Install* task refers the maintenance member to install the boom IAW a different task (task 28-71-06). Maintenance personnel failed to refer back to the primary task (*Gimbal Install*), thereby failing to complete all applicable steps for a gimbal installation. Specifically, it appears that they did not perform step 17, which instructs maintenance personnel to conduct a DRVT polarity test by lowering the boom onto a maintenance dolly and moving it to aircraft left (Tabs V-14.4 and BB-27). If the team had referred back to the primary task and completed the remaining steps, they would have had an opportunity to detect the faulty component 17 days before the day of the mishap. In my opinion, the lack of compliance with applicable TOs, and reliance on informal hydraulics turnover logs and word of mouth played an important role in this mishap. However, its correction would not, by itself, have prevented the mishap.

4. CONCLUSION

I find, by a preponderance of the evidence, two causes for this mishap. The first cause of this mishap was a sheared DRVT rotary crank that resulted from DRVT rotary bearing misalignment. This provided the aircraft's BCU with continuous, inaccurate roll position indications. As a result, the BCU compensated with lateral movement commands in both directions, driving the boom beyond its structural limits.

The second cause, related to the first, was the MB's failure to turn off the boom flight control switch in a timely manner. Turning off this switch would have disabled the BCU. This would have neutralized the boom flight control surfaces, and prevented the boom from departing the aircraft.

Additionally, I find, by a preponderance of the evidence, that the failure of maintenance personnel to comply with technical orders prevented the possible detection of an erratically performing DRVT, substantially contributing to the mishap.

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23 JUNE 2017

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