UNITED STATES AIR FORCE
AIRCRAFT ACCIDENT INVESTIGATION
BOARD REPORT

KC-46, T/N 17-6028

905TH AIR REFUELING SQUADRON
931ST AIR REFUELING WING
MCCONNELL AIR FORCE BASE, KANSAS

LOCATION: TRAVIS AIR FORCE BASE, CALIFORNIA

DATE OF ACCIDENT: 21 AUGUST 2024

BOARD PRESIDENT: COLONEL DIANE E. PATTON

Conducted IAW Air Force Instruction 51-307

5 June 2025

ACTION OF THE CONVENING AUTHORITY

The report of the Accident Investigation Board, conducted under the provisions of AFI 51-307, *Aerospace and Ground Accident Investigations*, current as of 6 April 2023, that investigated the 21 August 2024 mishap near Travis Air Force Base, California, involving a KC-46A, T/N 17-006028, assigned to the 22nd Air Refueling Wing, McConnell AFB, Kansas, substantially complies with the applicable regulatory and statutory guidance and on that basis is approved.

REBECCA J. SONKISS
Lieutenant General, USAF
Deputy Commander (Convening Authority)

EXECUTIVE SUMMARY
UNITED STATES AIR FORCE
AIRCRAFT ACCIDENT INVESTIGATION

KC-46, T/N 17-006028
TRAVIS AIR FORCE BASE, CALIFORNIA
21 AUGUST 2024

On 21 August 2024, at approximately 0927 hours local time (L), mishap aircraft one (MA1), a KC-46A, tail number (T/N) 17-6028, assigned to the 22nd Air Refueling Wing, McConnell AFB, Kansas, conducted an aerial refueling (AR) mission in the Swiss Air Traffic Control Assigned Airspace (ATCAA) with mishap aircraft two (MA2), an F-15E, T/N 90-0246 and its wingman, both assigned to the 366th Fighter Wing, Mountain Home AFB, Idaho. During the fourth AR attempt of the sortie, MA1 experienced nozzle binding of the boom in MA2's receptacle. Upon release, the boom rapidly flew upward, struck the empennage of MA1, and violently oscillated left and right. The boom striking MA1 and the ensuing forceful oscillations resulted in critical failure of the boom shaft structure, portions of which fell from MA1 in flight. There were no fatalities, injuries, or damage to civilian property. The estimated damages to MA1 are $14,381,303.

The Accident Investigation Board President found, by a preponderance of the evidence, that the cause of the mishap was the Mishap Boom Operator's (MBO) control inputs to the air refueling flight control system, resulting in an excessive fly-up rate of the boom, which struck the aircraft empennage and caused a critical failure of the boom shaft structure. The Board President further found by a preponderance of the evidence that the following factors substantially contributed to the mishap:

- Excessive closure rate and instability of MA2
- The MBO's attempted contact outside the standard AR envelope for MA2
- Mishap Pilot 3's (MP3) failure to recognize and initiate immediate breakaway procedures, which further delayed positive separation from MA1; and
- The MBO's lack of knowledge on boom flight control logic and its effects on the boom flight control surfaces prevented the MBO from recognizing the influence of Flight Control Stick (FCS) inputs and programmed boom limit functions during operations, especially during nozzle binding situations.

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 by the United States or by any person referred to in those conclusions or statements.

SUMMARY OF FACTS AND STATEMENT OF OPINION
KC-46, T/N 17-006028
TRAVIS AIR FORCE BASE, CALIFORNIA
21 AUGUST 2024

TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

3D 3 Dimensional
ACU Actuator Control Unit
AFB Air Force Base
AFE Aircrew Flight Equipment
AFI Air Force Instruction
AFMES Armed Forces Medical Examiner System
AFTO Air Force Technical Order
AIB Accident Investigation Board
ALAS Automatic Load Alleviation System
AMC Air Mobility Command
AMM Aircraft Maintenance Manual
AOC Air Operations Center
APU Auxiliary Power Unit
AR Aerial Refueling
ARS Air Refueling Squadron
ARO Air Refueling Operator
ARW Air Refueling Wing
ARCA Air Refueling Certification Agency
ARCT Air Refueling Control Time
ATCAA Air Traffic Control Assigned Airspace
ARMS Air Refueling Management System
BAMM Boom Actuator Maintenance Mode
BOT Boom Operator Trainer
BP Board President
BPO Basic Postflight
Capt Captain
CAUT Caution
CMCF Central Maintenance Computing Function
Col Colonel
DoD Department of Defense
EICAS Engine Indication and Crew Alerting System
F Fahrenheit
FCIF Flight Crew Information File
FCS Flight Control Stick
FLCS Flight Control System
FPM Feet Per Minute
FS Fighter Squadron
Ft Feet
FW Fighter Wing
G081 Field Maintenance Command & Control
GCI Ground Control Intercept
HUD Heads-Up Display
HFACS Human Factors Analysis and Classification System
IAW In Accordance With
IMU Inertial Measuring Unit
INOP In operative
IP Instructor Pilot
ITR Individual Training Records
K Thousand
KC Tanker/Transport
KCAS Knots Calibrated Airspeed
KTAS Knots True Airspeed
Kts Knots
L Local Time
lbs Pounds
Lt Col Lieutenant Colonel
MA1 KC-46A Mishap Aircraft
MA2 F-15E Mishap Aircraft
Maj Major
MAJCOM Major Command
MC Mishap Crew
MCC1 Mission Crew Chief 1
MCC2 Mission Crew Chief 2
MBO Mishap Boom Operator
MIS Maintenance Information System
MOA Military Operating Area
MP1 Mishap Pilot 1
MP2 Mishap Pilot 2
MP3 Mishap Pilot 3
MS Mishap Sortie
MSL Mean Sea Level
MWSO Mishap Weapon Systems Officer
NM Nautical Miles
NOTAMs Notices to Airmen
OG Operations Group
ONE Operation Noble Eagle
ORM Operational Risk Management
PAN CAM Panoramic Camera
PDL Pilot Director Lights
PHA Physical Health Assessment

PLI	Pre-launch Inspection
PMC	Partially Mission Capable
PR	Pre Flight
PR/BPO	Preflight/Basic Postflight
PRV	Pressure Relief Valve
PSI	Pounds Per Square Inch
QA	Quality Assurance
RAIS	Refueling Alert Indicating System
RNAV	Area Navigation
RTB	Return-To-Base
RVS	Remote Vision System
SAR	Search and Rescue
SII	Special Interest Item
SIB	Safety Investigation Board
TACC	Tanker Airlift Control Center
TCS	Telescope Control Stick
TCTO	Time Change Technical Order
TH	Thru-flight Inspection
T/N	Tail Number
Z	Zulu Time

SUMMARY OF FACTS

1. AUTHORITY AND PURPOSE

a. Authority

On 17 October 2024, Lieutenant General Rebecca J. Sonkiss, Deputy Commander, Air Mobility Command (AMC), appointed Colonel Diane E. Patton as Board President (BP) to conduct an aircraft accident investigation of a mishap that occurred on 21 August 2024 involving a KC-46A aircraft at Travis Air Force Base (AFB), California (CA) (Tabs Y-3 to Tab Y-4). The BP conducted the aircraft accident investigation in accordance with Air Force Instruction (AFI) 51-307, *Aerospace and Ground Accident Investigations,* at Travis AFB, CA, from 28 October 2024 through 21 November 2024 (Tab BB-118). Board members included a Legal Advisor (Major), a Pilot Member (Captain), a Boom Operator Member (Staff Sergeant), a Maintenance Member (Technical Sergeant), and a Recorder (Technical Sergeant) (Tabs Y-3 to Y-5).

b. Purpose

In accordance with AFI 51-307, *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 21 August 2024, MA1, a KC-46A, with tail number (T/N) 17-6028, departed Travis Air Force Base, California at approximately 0736L on the first scheduled sortie of an AR mission to support OPERATION NOBLE EAGLE (ONE) (Tab AA-9, Tab AA-32). The MC was from the 931st Air Refueling Wing (931 ARW), McConnell AFB, Kansas, and consisted of the mishap aircraft commander (MP1), the mishap pilot who was flying (MP2), and the mishap boom operator (MBO) (Tab AA-36). MA1 is assigned to the 22nd Air Refueling Wing (22 ARW), McConnell AFB. MA2 was an F-15E, with T/N 90-0246, assigned to the 366th Fighter Wing (366 FW), Mountain Home AFB, Idaho (Tab AA-47). The F-15E crew consisted of the mishap pilot (MP3) and the mishap weapon system operator (MWSO) (Tab AA-46). During the fourth AR attempt of the sortie, MA1 experienced nozzle binding of the boom in MA2's receptacle (Tab CC-5). Upon release, the boom rapidly flew upward, struck the bottom aft portion of MA1, and violently oscillated left and right (Tab J-12, Tab J-15). The boom striking MA1 and ensuing forceful oscillations resulted in critical failure of the boom shaft structure, portions of which departed MA1 in flight (Tab J-15). There were no fatalities, injuries, or damage to civilian property. The estimated damages to MA1 are $14,381,303 (Tab P-3).

3. BACKGROUND

a. Air Mobility Command (AMC)

Air Mobility Command is a Major Command headquartered at Scott Air Force Base (AFB), Illinois (Tab DD-3). AMC provides unrivaled airlift, air refueling, aeromedical evacuation, global air mobility support and Global Mobility Mission Command to project, connect, maneuver and sustain the Joint Force to achieve national objectives (Tab DD-3). The command is composed of more than 110,000 Active Duty, Air Force Reserve, Air National Guard, and civilian employees, and utilizes 13 different airframes (Tab DD-3).

b. 22d Air Refueling Wing

The 22d Air Refueling Wing (ARW) is the host unit of McConnell Air Force Base, Kansas (Tab DD-5). The wing is part of 18th Air Force, a numbered Air Force within Air Mobility Command (Tab DD-5). 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 DD-5).

c. 931st Air Refueling Wing

The 931st Air Refueling Wing (ARW) is an associate unit with the active-duty 22nd Air Refueling Wing (ARW) at McConnell AFB, KS (Tab DD-7). More than 700 air reserve technicians, active guard reserve, traditional reservists and civilians are assigned to the wing (Tab DD-7). The 22nd ARW and 931st ARW share responsibilities for aircraft maintenance, with flying operations conducted by both units, using the KC-46A Pegasus (Tab DD-7).

d. 905th Air Refueling Squadron (ARS)

The 931st Air Refueling Wing reactivated the 905th Air Refueling Squadron on May 4, 2019 (Tab DD-13). It was one of the first squadrons in the Air Force dedicated to the KC-46A Pegasus (Tab DD-13).

e. KC-46A Pegasus

The KC-46A is the first phase in recapitalizing the U.S. Air Force's aging tanker fleet (Tab DD-17). With greater refueling, cargo and aeromedical evacuation capabilities, the KC-46A provides next generation aerial refueling support to Air Force, Navy, Marine Corps and partner-nation receivers (Tab DD-17). The KC-46A is able to refuel most fixed-wing, receiver-capable aircraft (Tab DD-17). The KC-46A is equipped with a refueling boom driven by a fly-by-wire control system, and is capable of fuel offload rates required for large aircraft (Tab DD-17). Its hose and drogue system adds additional mission capability that is independently operable from the refueling boom system (Tab DD-17).

f. Air Refueling Operations

The objective of air refueling operations is to enhance effectiveness by extending the range, payload, or endurance of the receiver aircraft (Tab BB-52). Successful air refueling operations depend on three major factors (Tab BB-52). The first factor is equipment compatibility (Tab BB-52). Aircraft requiring air refueling must be fitted with probes or receptacles and fuel systems compatible with the characteristics of the tanker aircraft (Tab BB-52). The second factor is performance compatibility (Tab BB-52). It is essential for tanker and receiver aircraft performance to be compatible in terms of air refueling speeds and altitudes (Tab BB-52). The last factor is procedural compatibility (Tab BB-52). Tanker and receiver aircraft must employ pre-planned and compatible procedures for rendezvous, making contact, fuel transfer, and departure (Tab BB-52).

g. KC-46A Specific Air to Air Refueling Procedures

For KC-46A air-to-air refueling, the boom operator deploys the boom from the stowed position and extends the telescoping portion of the boom 12 feet to perform an initial flight control check (Tab BB-60). While the receiver aircraft stabilizes in the astern position, the boom operator selects the appropriate Remote Vision System (RVS) scene for environmental conditions on the primary 3D display (Tab BB-60). The RVS Scene Selection Guide located in the Flight Crew Operations Manual (FCOM) may help with selection of the appropriate scene (Tab BB-60). When the boom operator clears the receiver aircraft for contact or provides the radio-silent visual signal, the receiver moves from the stabilized astern position to the boom contact position (Tab BB-60). Closure to contact must be slow and stable (approximately 1 foot per second) with the receiver aircraft stabilizing in the contact position (Tab BB-60). The boom operator will verify that the selected RVS scene remains stable (Tab BB-60). If the scene degrades or visual cues are not discernable, the boom operator will return the receiver aircraft to the astern position and re-evaluate scene selection before clearing the receiver to proceed to the contact position (Tab BB-60). For a successful air refueling contact, the receiver aircraft must maintain the contact position to allow for the boom operator to initiate the contact. Afterwards, for a successful fuel transfer, the receiver must maintain position within the air refueling envelope limits (Tab BB-60).

The KC-46A automatically defines receiver aircraft envelope limits based on the type of receiver aircraft input by the boom operator. Each receiver aircraft has a specifically defined refueling envelope (Tab BB-63). The Boom Actuator Control Unit (ACU) monitors the boom position and rates of motion to remain within each receiver's defined envelope (Tab BB-63). Should the receiver aircraft approach the envelope limits, the boom control system initiates a disconnect prior to the boom exceeding an envelope limit (Tab BB-63). The boom envelope software imposes limits that are set within the mechanical limits of the boom and a disconnect will normally take place before any structural damage occurs (Tab BB-5). Contacts should not be attempted outside the boom contact envelope (Tab BB-5). The largest selectable boom disconnect envelope is 25 degrees left and right roll, 20 to 40 degrees elevation, and 6 to 21 feet telescope extension. Boom disconnect limits are specific to receiver aircraft and are automatically imposed upon the system once the receiver aircraft type is selected by the boom operator (Tab BB-5). If a receiver is not selected, the standard boom disconnect envelope is 10 degrees left and right roll, 25 to 35 degrees elevation, and 6 to 21 feet telescope extension (Tab BB-5).

When contact position is achieved, the boom operator flies the boom to the receiver aircraft's receptacle using the flight control stick (FCS) and extends the boom telescope to make contact (Tab BB-60), locking toggles in the receptacle hold the boom nozzle in contact (Tab BB-60). The receiver then maintains its position within the boom's operating envelope (Tab BB-60). The digital fly-by-wire control system has an Automatic Load Alleviation System (ALAS) (Tab BB-60). The ALAS reduces radial forces on the nozzle and receptacle, thereby permitting a larger AR envelope without nozzle binding (Tab BB-60).

h. Nozzle Binding

Nozzle binding is defined as mechanical impedance on the boom nozzle that keeps it from free flight. This impedance occurs when the boom nozzle is stuck in the receiver's receptacle area, but the boom is not fully engaged by the toggles due to the geometric shape of the receptacle area (Tab BB-115).

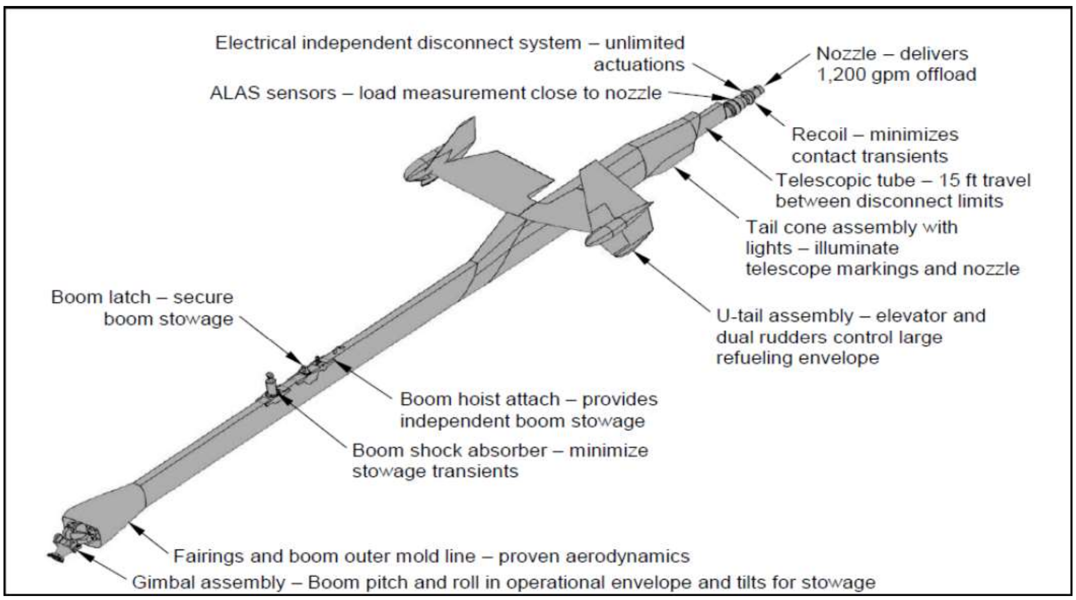

Figure 3.1 Boom Structure (Tab J-8)

i. Breakaway Procedures

A breakaway is an emergency separation of tanker and receiver aircraft in or near the contact position (Tab BB-54). It may be necessitated due to erratic flight by the receiver, a tanker or receiver aircraft malfunction, the receiver under-running the tanker, or an excessive rate of closure between the tanker and the receiver (Tab BB-54). Upon a breakaway being called, the affected tanker and receiver aircraft must immediately disconnect and act in accordance with published guidance to separate (Tab BB-54).

4. SEQUENCE OF EVENTS

a. Mission

On Wednesday, 21 August 2024, the MC was scheduled to fly MA1, call sign WIDE12, on a 618th Air Operations Center (AOC) Tanker Airlift Control Center (TACC) ONE mission from Travis AFB and returning to Travis AFB (Tab AA-30). The mission was in support of one flight of two F-15Es, MA 2 and their wingman, call signs NOBLE41 and NOBLE42, in the SWISS Air Traffic Control Assigned Airspace (ATCAA) track finishing with a landing back at Travis AFB (Tab AA-30).

b. Planning

The MC conducted initial mission planning, checked the weather, reviewed Notices to Airman (NOTAM), familiarized themselves with applicable Special Instructions, reviewed fuel planning via crew papers, and completed the required forms (Tab AA-1 to Tab AA-44). MP1 briefed the mission details prior to arrival at the aircraft IAW the applicable regulations (Tab V-9.3).

c. Preflight

The MC was comprised of a Mission Pilot and acting aircraft commander (MP1), an Instructor Pilot (MP2), and a Mission Boom Operator (MBO) (Tab AA-51). The MC received an alert text at 0330L/1030Z on Wednesday, 21 August 2024 and assembled in the hotel lobby at 0530L/1230Z (Tab V-9.3). MA1 was reported Partially Mission Capable (PMC) with the aircraft not refueled yet due to the fuel truck having nozzle issues (Tab V-11.3 to Tab V 11.4). The MC arrived at the aircraft around 0540L/1240Z to perform preflight duties (Tab V-3.21). Upon arrival at the aircraft, the MC was briefed by the Mission Crew Chief 1 (MCC1) that the boom preflight inspection passed, but previously failed twice (Tab V-3.22). In accordance with maintenance procedures, MCC1 accomplished two rounds of sensor re-rigging and multiple Air Refueling Management System (ARMS) resets (Tab V-3.22). Nothing of additional significance was noted during the MC preflight inspections, ground operations, or departure (Tab V-3.22).

d. Summary of Accident

On 21 August 2024, at approximately 0736L/1436Z, MA1 took off as scheduled (Tab AA-3 to Tab AA-44, Tab V-3.22). MA1 was planned to conduct three sets of Air Refueling Control Times (ARCT) with MA2 and its wingman, both receiver aircraft were F-15Es from the 366th Fighter Wing stationed at Mountain Home AFB (Tab AA-47, Tab V-3.15).

(1) Air Refueling Contacts

At approximately 0815L/1515Z, MA1 entered the SWISS ATCAA at a flight level of 20,000 ft and prepared for air refueling with MA2 and its wingman (Tabs V-3.3, Tab J-20). During the first set of air refueling, MA2 required multiple approaches and contacts to receive its fuel (Tab V-3.3). According to the MC, MA2 appeared to have some difficulty getting into, and stabilizing in, the contact position. (Tab V-3.3, Tab V-3.22, Tab L-4 to Tab L-11). During MA2's first set of air refueling, the MBO directed MA2 to slow closure and return to astern three times before completing the first contact (Tab L-4 to Tab L-7). At the end of MA2's first contact, MA2 fell off the aft limit, triggering an automatic disconnect (Tab L-7). The second F-15E (MA2's wingman) received all 10,000 pounds of fuel in one contact with no issues to report (Tab V-3.3). The MC elected to stow the boom until the next set of air refueling, approximately 45 minutes later (Tab V-3.3).

Figure 4.1 F-15E Receptacle (Tab J-11)

At approximately 0919L/1619Z, the MC began preparing for their second set of AR with MA2 and its wingman (Tab J-12). During MA2's approach to contact, the MWSO cautioned MP3 not to turn into or climb into MA1 during his approach. (Tab L-9). During the contact, MP3 was told "Forward 4, Down 4," "Down 4," "Forward 4," and "Back 2, Back 4, Back" multiple times by the MBO and MWSO (Tab L-10 to Tab L-11). Despite these verbal corrections, MA2 proceeded inside the inner limit, triggering another automatic disconnect (Tab L-11). Following the disconnect, the MP3 was unsure which limit triggered the automatic disconnect stating it was, "Upper limit for sure, or lower limit I guess," to which the MWSO corrected MP3 and told him that it was the forward limit (Tab L-11, Tab V-6.4 to Tab V-6.5 Tab V-6.18, Tab V-7.4, Tab V-7.7). MP3 and MWSO did not brief special emphasis items for pre-contact/contact positions, techniques to stay in position, axial load (stiff boom) and other considerations with KC-46A AR Operations (Tab BB-109, BB-117, Tab V-6.9).

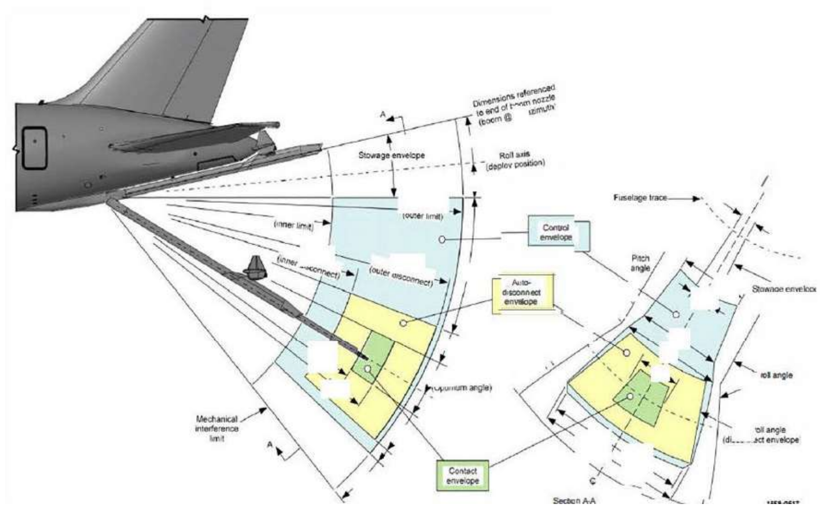

Figure 4.2 Boom Envelope (Tab J-9)

At approximately 0927L/1627Z, MA2 was cleared to contact again to obtain the last 6,500 pounds of fuel (Tab L-11). Upon approach to contact, the MBO did not recognize the receiver moving towards the limit of the boom envelope and attempted receptacle engagement outside the refueling envelope at 41.9 degrees pitch and 10.2 feet telescope length (Tab BB-5, Tab CC-5, Tab J-13). The lowest boom envelope limit is 40 degrees pitch (Tab BB-5). To achieve contact with the receptacle, the MBO was utilizing approximately full "fly down" input of the boom (Tab CC-5). At 09:27:33L/16:27:33.1Z, the boom system advanced to contact status, and immediately triggered a disconnect due to the boom being outside of the refueling envelope limit at approximately 42 degrees boom pitch (Tab CC-5). At the same time, the automated boom elevator tried to fly the boom upward to return to soft envelope limits, building the radial Z (vertical) load on the boom nozzle to -1246 lbs. (Tab CC-5).

During this period, the boom telescope position was compressed to just over 8 feet with normal axial loads and the MBO began to initiate telescope retraction (Tab CC-5). Boom roll position was roughly unchanged, and radial Y (horizontal) loads were normal (Tab CC-5).

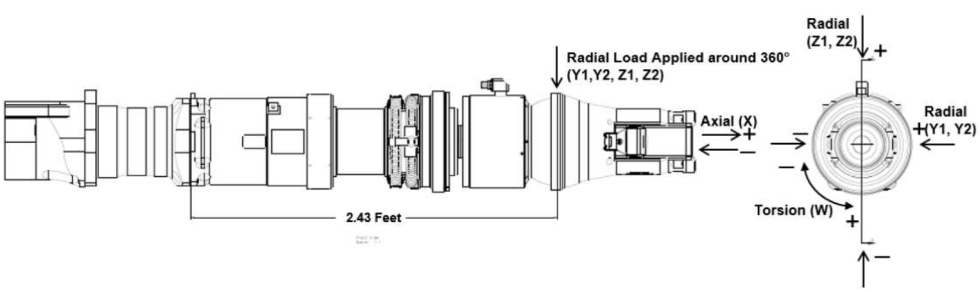

Figure 4.3 ALAS Force Convention Diagram (Tab J-9)

The MBO initially input "fly up" FCS deflection, compounding the ALAS nozzle force reduction inputs and the automated boom system fly up command to soft envelope limits (Tab CC-5). The MBO also induced axial loads of approximately 2500 lbs. as the MBO initiated telescope retraction (Tab CC-5). The boom telescope continued to be compressed as MA2 continued its forward movement (Tab CC-5). Minimum receiver approach during the mishap contact was ~3.75 feet (Tab CC-6). The inner boom envelope limit is 6 feet (Tab BB-5). The MBO increased fly up FCS relative elevation deflection to the maximum value before removing input briefly, re-applying input up to maximum value, and then continued to apply varying levels of fly up FCS relative elevation deflection at less than the maximum value (Tab CC-5). At the start of this period, the radial Z load increased from -1246 lbs. to -2400 lbs. and remained constant at -2400 lbs. for the remainder of the period (Tab CC-5). At this time, the ALAS ELEVATION warning was annunciated, triggering an associated AR Master Warning annunciation, which provides both a visual warning and an audible tone (Tab J-14).

Simultaneously, the MBO commanded a "Back 4, Back 4, Back 4" followed by an incomplete breakaway call of "WIDE12, BREAK" in accordance with applicable guidance and regulations (Tab L-12). The MBO's breakaway call was interrupted by the AR Master Warning tone (Tab CC-9, Tab L-12). In conjunction with the breakaway call, the MBO pressed the breakaway switch on the Telescope Control Stick (TCS), flashing the Pilot Director Lights (PDL) IAW established procedure (Tab BB-46, Tab V-6.6, Tab V-9.4). While MP3 had reduced power on the right thrust lever in an attempt to reduce forward movement, MA2 did not execute immediate breakaway procedures in accordance with the applicable guidance (Tab BB-65 and Tab BB-113). MP3 stated the breakaway call was cut off and "not perceived real time by myself [MP3] or the MWSO" (Tab BB-60, Tab CC-9, Tab L-12, Tab V-6.18). MP1 and MP2 executed proper breakaway procedures IAW the applicable guidance (Tab BB-44, Tab V-3.4, Tab V-4.4).

(2) Period of Nozzle Binding

The published guidance cautions operators that binding of the boom nozzle in the receiver's receptacle is possible, even with a disconnect signal (Tab BB-61). While nozzle binding can occur in most disconnect positions, it is most likely at high receiver roll and low boom elevation (Tab BB-61). If nozzle binding occurs or is suspected, the guidance directs boom operators to neutralize the boom flight control inputs and avoid abrupt boom flight control inputs (Tab BB-61). During the timeframe from attempted contact outside the boom envelope to release from the receptacle, the boom nozzle became bound in the receptacle (Tab CC-5). MP1 stated the "boom appeared to be stuck in the receptacle" when he observed the air refueling with MA2 through the panoramic camera (PAN CAM) (Tab V-3.3). The MBO applied flight control stick inputs to achieve contact by first applying downward pressure (Tab CC-5, Tab J-13, Tab L-49, Tab V-9.2). Then, in an attempt to clear the nozzle binding, the MBO applied additional flight control stick inputs to track the receiver aircraft (Tab L-49, Tab V-9.7). These actions alternated between counteracting and compounding the automated systems boom envelope soft limit, the "drift to home" function, and ALAS inputs to the boom flight controls (Tab CC-5). The ARMS system did not provide real-time indication or feedback to the MBO on control forces or sensor loads when in contact or during the period of nozzle binding.

The boom pitch position was at approximately 44 degrees at the onset of nozzle binding and slowly returned within the disconnect envelope and then to the center of the boom envelope, at which point nozzle binding ended (Tab CC-5). Throughout the period of nozzle binding, the boom elevator continued to increase deflection up to maximum upward deflection, attempting to fly up the boom at varying rates as the MBO changed their input (Tab CC-5). The elevator deflection decreased by a small value mid-way through the nozzle binding and just before the end of nozzle binding (Tab CC-5). Boom axial loads increased from ~2500 lbs. to ~4100 lbs. as the receiver aircraft continued to compress the boom to ~3.75 feet (Tab CC-6). Throughout the nozzle binding, the MBO continued telescope retraction input, with one small period of reduced input (Tab CC-6). At this point MA1 and MA2 began to separate, thus extending the telescope at an increasing rate and a peak axial load of +7404 lbs. was observed (Tab J-13). The boom telescope length extended to almost 17 feet at the end of the nozzle binding (Tab CC-6).

Just after the start of the nozzle binding the MBO input an FCS relative azimuth (horizontal) command of up to approximately 75% maximum value in an attempt to laterally track MA2's movement; however, most inputs were around 50% or less of the maximum value (Tab CC-6, Tab V-9.7). The boom rudders increased their deflection throughout the period of nozzle binding until they reached maximum deflection and remained there until the end of the nozzle binding period (Tab CC-6). The radial Y (horizontal) nozzle loads initially increased to a positive value of ~700 lbs. before decreasing to a value of -966 lbs. (Tab CC-6).

At 09:27:39.1L/16:27:39.1Z the boom nozzle became free of the receptacle (Tab CC-6). At release, the boom pitch position was 31.8 degrees, and the radial Z, radial Y, and axial load dropped to free-air values (Tab CC-6). The MBO had input commands of telescope retraction deflection of -14 degrees, an FCS azimuth relative deflection of -5 degrees, and an FCS fly up relative deflection of 6.6 degrees (just over half maximum). The boom elevator surface was approximately 2 degrees from maximum at 21.7 degrees upward deflection (Tab CC-6). The boom reached a peak fly up rate of 114 degrees per second (Tab CC-6). A BOOM INOP Refueling Alert Indicating System (RAIS) message was declared during the fly up (Tab J-14). In BOOM INOP status, the flight control surfaces enter a condition where they no longer respond to boom operator or automatic actuator control unit (ACU) commands from the boom control laws (Tab BB-20).

Milestone	Time	Time Delta	Bubble Note
CONTACTS PRIOR TO MISHAP	15:35:07.0	T – 48 Minutes	None
READY	16:27:23.0	T – 10.2 Sec	(A)
CONTACT	16:27:33.1	T – 0.1 Sec	(B)
DISCONNECT	16:27:33.2	T = 0.0 Sec	(C)
VERTICAL NOZZLE LOADING	16:27:34.2	T + 1.0 Sec	(D)
MINIMUM RECEIVER APPROACH	16:27:35.7	T + 2.5 Sec	(E)
TENSION NOZZLE LOADING	16:27:38.5	T + 5.3 Sec	(F)
RELEASE	16:27:39.1	T + 5.9 Sec	(G)
FLY UP	16:27:39.5	T + 6.3 Sec	(H)
FUSELAGE IMPACT	16:27:39.6	T + 6.4 Sec	(I)
OSCILLATORY RESPONSE	16:27:48.1	T + 14.9 Sec	(J)
DEPARTURE	16:27:48.2	T + 15.0 Sec	(K)
COMPLETION	16:27:57.1	T + 23.9 Sec	(L)

Figure 4.4 Mishap Sequence (Tab J-12)

At approximately 09:27:39.6L/16:27:39.6Z, the boom impacted the fuselage 0.5 seconds after release from MA2's receptacle (Tab J-12 and J-15). MP3 observed the boom began to "sway and oscillate back and forth in an obviously uncontrolled manner" after impact (Tab V-6.18).

Figure 4.5 APU Shroud (Tab S-3)

Approximately 8.5 seconds after impact the boom departed MA1 (Tab J-15). The location of boom departure was provided via a mark point from MA2, 35°06'08.0"N 120°16'37.3"W (Tab L-14).

(3) Impact Aftermath

Immediately following the boom departure from MA1, the MC received a HYDRAULIC SYSTEM PRESSURE (C Only) Engine Indication and Crew Alerting System (EICAS) message (Tab V-3.4). The checklist drove the MC to utilize ALTERNATE FLAP EXTENSION and ALTERNATE GEAR EXTENSION (Tab V-3.26). Further, MP1 stated after impact, "the boom flight controls were gone, and the auxiliary hoist cable had snapped and was just flapping around in the wind" (Tab V-3.4). The MC elected to use Conference Hotel, an in-flight conferencing procedure that linked the MC directly with representatives from the Air Force Life Cycle and Management Center and Boeing, to ask for additional guidance as this was "Not a scenario that we've ever practiced so we talked to them rather extensively" (Tab V-3.5 and Tab V-3.6). Boeing agreed with the MC's assessment that they would have to land with boom in-trail and had completed all applicable checklists (Tab V-3.6).

MA1 requested that MA2 perform a battle damage assessment (BDA), where MWSO relayed that MA1 only had a single dent on the underside of the aircraft estimated to be 6 inches deep and a foot long (Tab V-3.24, Tab V-4.6, Tab V-14.7, Tab V-3.5). The MC attempted to run the FUEL JETTISON checklist to reduce gross weight under 310,000 lbs. of fuel (Tab V-3.5, Tab V-3.6). The maximum landing weight in the KC-46A is 310,000 lbs. of fuel (Tab V-3.24). The MC received a fuel jettison fault when MP1 armed the fuel jettison switch and were unable to jettison fuel (Tab V-3.25, V-3.5). The MC continued to orbit in the SWISS ATCAA with the plan to burn fuel to reduce gross weight and depart the airspace to land just under the maximum landing weight (Tab V-3.25).

(4) Return to Travis AFB

Upon exiting the SWISS ATCAA, the MC officially declared an In-Flight Emergency (IFE) to get preferential treatment and vectoring back to the planned recovery airfield (Travis AFB) (Tab V-3.25, V-3.6). The MC continued to coordinate to land at Travis AFB, California (Tab V-3.7 to Tab V-3.8). MP1 accomplished the landing from the left seat utilizing an area navigation (RNAV) 21L approach (Tab V-3.7). Emergency Response personnel were dispatched to meet the aircraft on the runway after arrival (Tab V-3.29, V-3.26).

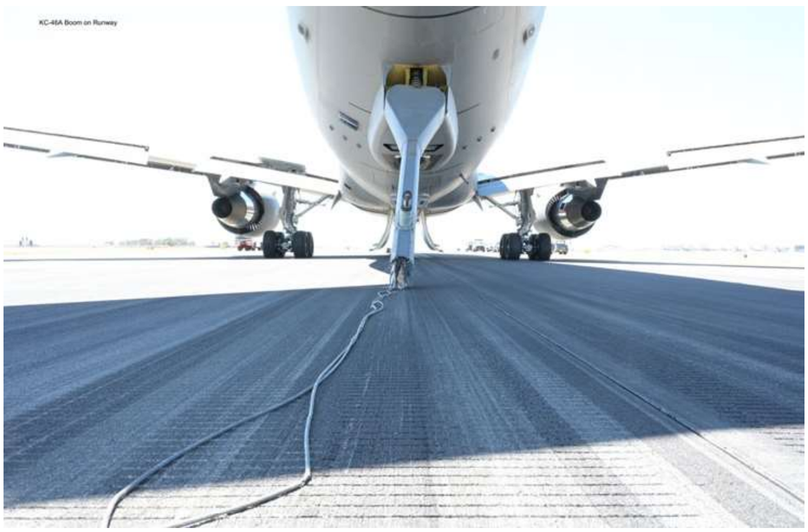

Figure 4.6 T/N 17-6028 after landing (Tab S-4)

Upon landing, MP2 turned on the Auxiliary Power Unit (APU) IAW with the After Landing Procedures (Tab V-3.8, Tab V-3.27). Shortly after shutting down the right-side engine, the MC began to smell unpleasant fumes on the flight deck (Tab V-3.8, Tab V-3.27, Tab V-37). MP2 reached up and shut off the APU bleed switch, which immediately shut down the APU (Tab V-3.8, Tab V-3.9). Shortly thereafter, ground crew plugged their headset in to MA1 and asked the MC not to shut down in order to preserve flight data (Tab V-3.8, Tab V-3.9). The MC turned the APU back on and immediately noticed fumes on the flight deck again (Tab V-3.9). One of the emergency responders on the ground started yelling "shut it [APU] off" (Tab V-3.9, Tab V-3.27). MP1 switched the APU switch to the "off" position and pulled the APU fire switch to immediately shut it off (Tab V-3.8, V-3.27). It was noted from the ground that the damage was considerably more severe than the single 6-inch deep dent initially reported by the MWSO, with some of the damage blocking the APU exhaust, thus causing the fumes on the flight deck (Tab V-3.27). The MC obtained positive control of their controlled items and egressed the aircraft through the emergency bay (Tab V-3.9).


Figure 4.7 APU Shroud (Tab S-5)

e. Impact

The location of the broken boom was provided via a mark point from MA2, at 35°06'08.0"N 120°16'37.3"W (Tab L-14). The boom fell in an open field with no injuries or fatalities reported (Tab S-6).


Figure 4.8 Boom Wreckage (Tab S-6)

f. Egress and Aircrew Flight Equipment (AFE)

Not applicable.

g. Search and Rescue (SAR)

MA2 provided an initial report to the ground control intercept (GCI) controller with a mark point on the approximate location of the dropped boom, 35°06'08.0"N 120°16'37.3"W (Tab L-14). The boom was eventually recovered in a remote location on National Forest Systems lands, within the Santa Lucia Ranger District of the Los Padres National Forest and retrieved by helicopter (Tab CC-11, Tab S-6).

h. Recovery of Remains

Not applicable.

5. MAINTENANCE

a. Forms Documentation

All maintenance actions were recorded on the Air Force Technical Order (AFTO) 781 series forms and equally in the Maintenance Information System (MIS), which is Field Maintenance Command & Control (FMxC2, also referred to as G081) (Tab U-8). Active and historical forms and G081 were reviewed for MA1 for the months since its last "A Check" Inspection, which occurred in July 2024 (Tab U-87 to Tab U-88). There were slight inconsistencies for basic postflight (BPO) inspections documented on the AFTO 781A and AFTO 781H forms. The AFTO 781A forms that were reviewed show BPO inspections being entered as a discrepancy and signed off with the appropriate aircraft maintenance manual (AMM) for the BPO, but the AFTO 781H in the same set of forms indicates that a combined Preflight/Basic Postflight (PR/BPO) for the BPO inspection was accomplished (Tab D-23, Tab U-74 to Tab U-75).

The only Time Change Technical Order (TCTO) pertaining to the boom system still open at the time of the mishap was 1C-46(K)A-725, which is a Depot Level TCTO and was not relevant to the mishap (Tab D-32, Tab U-25, Tab U-76). All other TCTOs for the boom system were completed before the date of the mishap. There were six open TCTOs noted for aerial refueling manifolds at the time of the mishap (Tab U-26). At the time of the mishap, one discrepancy remained open, a finding from TCTO 1C-46(K)A-WA-1-876D, requiring inspection of the boom shaft assembly for corrosion (Tab D-7, Tab U-19, Tab U-28, Tab U-80). Subsequently, there was a Technical Assistance Request (Form 107) submitted for the discrepancy. The Form 107 disposition directed maintenance to perform a reinspection of the corrosion every 30 days. This inspection was never documented in aircraft forms or G081 for MA1. Additionally, a wire harness required removal and replacement and was awaiting parts at the time of mishap (Tab D-34, Tab U-27). The historical records did not reveal any recurring maintenance problems.

b. Inspections

MA1 was current on its scheduled inspections, commonly referred to as A Check, which is a scheduled maintenance program that occurs every six months and is organized into inspections that group maintenance tasks by intervals (Tab U-5). The most recent A Check inspection was a 3A inspection, which is the 18-month inspection, and was accomplished on 18 July 2024 with all work cards satisfactorily completed (Tab U-5, Tab U-87 to Tab U-88, Tab U-91 to Tab U-96).

A PR and BPO inspection were documented on the 781H form on 19 August 2024 (Tab D-23, Tab U-13), however, the corresponding 781A forms reflected that only a BPO was conducted on that day (Tab U-76). Forms documentation for the BPO inspection were all completed satisfactorily. The pre-launch inspection (PLI) was accomplished and documented on 20 August 2024 at 0930Z, prior to departing home station IAW applicable regulations (Tab D-23, Tab U-15). The thru-flight inspection (TH) was completed after arrival at Travis AFB on 20 August 2024 at 2000Z and documented on the 781H IAW applicable regulations with no significant findings (Tab D-23, Tab U-21). On the day of the mishap, the PLI was accomplished at 1245Z, documented on the 781H, and was satisfactorily completed (Tab D-23).

The form 107 derived from TCTO 876 required a reoccurring inspection every 30 days for corrosion and to report major changes of findings by submitting an engineering technical request (Tab U-19). There was no documentation of this inspection being accomplished since 25 June 2024 (Tab U-33 to 125). The boom rudder and elevator 1000-flight hour damping function tests were conducted on 24 May 2024, and were satisfactorily completed (Tab U-32).

c. Maintenance Procedures

Upon arriving at Travis AFB on 20 August 2024, MCC1 and MCC2 performed a TH inspection for MA1. MCC2 accomplished the steps of this inspection for the exterior of MA1, to include the boom (Tab V-12.5). This inspection yielded nothing of significance, and they prepared MA1 for the MS scheduled to depart the next day (Tab V-11.3, Tab V-12.5).

During the PLI on the day of the mishap, MCC1 performed the flight deck portion of the PLI. During the boom preflight inspection, the Aerial Refueling Management System (ARMS) test failed twice (Tab V-11.3, Tab V-12.3). This was resolved by utilizing the push to test drains and resetting the ARMS, which resulted in the ARMS test passing. Subsequently, the boom preflight inspection failed for Automated Load Alleviation System (ALAS) roll and ALAS elevation (Tab V-11.4, Tab V-12.12). To correct this, a sensors re-rigging was performed through the Central Maintenance Computing Function (CMCF) and ARMS was re-set once more (Tab V-11.4, Tab V-12.12). These procedures alleviated the first fault message, but the boom preflight inspection had to be re-accomplished. A second sensors re-rigging was accomplished, during which the boom was put into Boom Actuator Maintenance Mode (BAMM), followed by relieving tip pressure (Tab V-11.4, Tab V-12.12). After a third ARMS reset, the boom passed the preflight inspection, completing the PLI and rendering MA1 airworthy IAW applicable guidance and regulations (Tab V-11.5, Tab V-12.13).

d. Maintenance Personnel and Supervision

A review of the individual training records for MCC1 and MCC2 (ITR) showed that both were fully qualified for the PR, TH, PLI inspections. Both were also fully qualified for aircraft launch and recovery operations (Tab T-24, T-25, T-28).

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

Not applicable.

f. Unscheduled Maintenance

There were multiple unscheduled maintenance actions since the last scheduled inspection (Tab U-37 to Tab U-71, Tab U-98 to Tab U-125). Both engines had vibration issues that needed to be lubricated, trimmed and balanced, which was conducted IAW applicable technical orders (Tab U-44 to Tab U-54, Tab U-57 to Tab U-63, Tab U-66, Tab U-101, Tab U-106, Tab U-107, Tab U-110 to Tab U-112, Tab U-113 to Tab U-117). The left engine also had repeat issues with oil quantity fluctuation, which were solved by changing the quantity transmitter (Tab U-67 to Tab U-68, Tab U-70 to Tab U-72, Tab U-113, Tab U-119 to Tab U-124). Several tires had to be changed due to reaching wear limits (Tab U-38, Tab U-97, Tab U-100, Tab U-102). There were several bird strikes and inspections that occurred (Tab U-40 to Tab U-41, Tab U-69, Tab U-102, Tab U-103, Tab U-118 to Tab U-120, Tab U-123). None of these maintenance issues were associated with the boom or controls for the boom (Tab U-37 to Tab U-125). There is no evidence to suggest unscheduled maintenance was a factor in this mishap.

6. AIRFRAME, MISSILE, OR SPACE VEHICLE SYSTEMS

a. Structures and Systems

(1) Aerial Refueling Boom

The KC-46A aerial refueling boom has two aerodynamically faired tubes that attach to the airplane fuselage at the boom fuselage interface. One internal tube telescopes aft from the outer fixed tube during refueling operations. On the top of the outer tube of the boom is an attached U-Tail flight control system. The U-Tail and its flight control surfaces are attached to the outer fixed tube of the boom. The U-Tail flight control surface has a set of rudders with hydraulic actuators, an elevator, and an actuator. The outer tube of the boom has an A-frame with a rudder and elevator for U-Tail flight control. An Aerial Refueling Operator (ARO), commonly referred to as the boom operator, controls the U-Tail flight control system from the Aerial Refueling Operator Station (AROS). An ARO uses the U-Tail to control the boom and to engage its nozzle with the receiver aircraft receptacle (Tab U-3, U-4).

(2) Aerial Refueling Operator Station (AROS)

The AROS control panel is the bottom panel of the center column of the AROS. The panel is a shared panel for the ARO and Aerial Refueling Operator Instructor (AROI) positions. The ARO and AROI panels work in conjunction with each other when the AROS controls position switch is selected to DUAL mode and independently when selected to ARO or AROI. When selected to ARO, the AROI switches are inoperative, but are still illuminated. The panel is back lit and has annunciations of varying intensity with annunciation test capability. Two switches are on this panel. The POSITION switch controls the station activation. When selected to DUAL, all station functions are active on both the ARO and AROI positions. The AROI or right side of the station, as it is oriented on the aircraft, becomes the instructor position as it has micro switch emergency retraction and control of the Flight Control Stick (FCS) functions when the micro switch is pressed and held (Tab U-10).

(3) ARMS Controls Panel

The ARMS controls panel is the third physical panel down from the top and fourth control panel on the left side of the AROS console on both ARO and AROI stations. The panel is edge-lit and has annunciations of varying intensity with annunciation test capability. There are three switches on this panel. An ARMS RESET removes power from the following components/systems:

- Aerial Refueling Control Computers (ARCCs)
- Signal Data Converter Network (SDCN) System
- Control Stick Electronic Control Units (ECUs)
- Aerial Refueling Boom (ARB)
- Centerline Drogue System (CDS)
- Wing Aerial Refueling Pods (WARP)

When power returns, the ARMS systems are in default air/ground mode (Tab U-11). The boom control system design utilizes the Aerial Refueling Control Computer (ARCC) as the basis of the fly-by-wire closed loop system and incorporates automatic load alleviation during coupled flight. The automatic disconnect system anticipates exceedance of a spatial envelope limit and initiates disconnect in sufficient time to assure separation at the limit (Tab U-12).

(4) Damage to the Boom Structure

During the mishap the two faired tubes broke just aft of the boom shock absorber, along with all associated wire harness and hydraulic lines that run through the boom. Somewhere between contact with the aircraft fuselage and ground impact the U-Tail was damaged, breaking the rudder structure and the mount that holds it. The telescope was separated from the boom structure and to this date has not been recovered. The actuator for the elevator was damaged and ripped from its mounting point (Tab Z-3).

Figure 6.1 Boom Wreckage (Tab Z-3)

(5) Damage to the Aircraft

The Boom Hoist cable ripped out of the cable end attached to the boom and was left trailing during the remainder of the mission (Tab S-7).

Figure 6.2 Boom Hoist Cable (Tab Z-4)

The tail cone of the aircraft was damaged during the mishap, which resulted in the Auxiliary Power Unit (APU) exhaust duct not allowing the gases to release as normal (Tab S-9). When the MC turned on the APU upon landing to provide power for emergency ground crews, the damage resulted in insufficient release of the gases (Tab V-3.27).

Figure 6.3 APU Shroud Damage Closeup (Tab Z-5)

The breaking of the boom caused a loss of the center hydraulic system due to the hydraulics lines being severed (Tab Z-6).

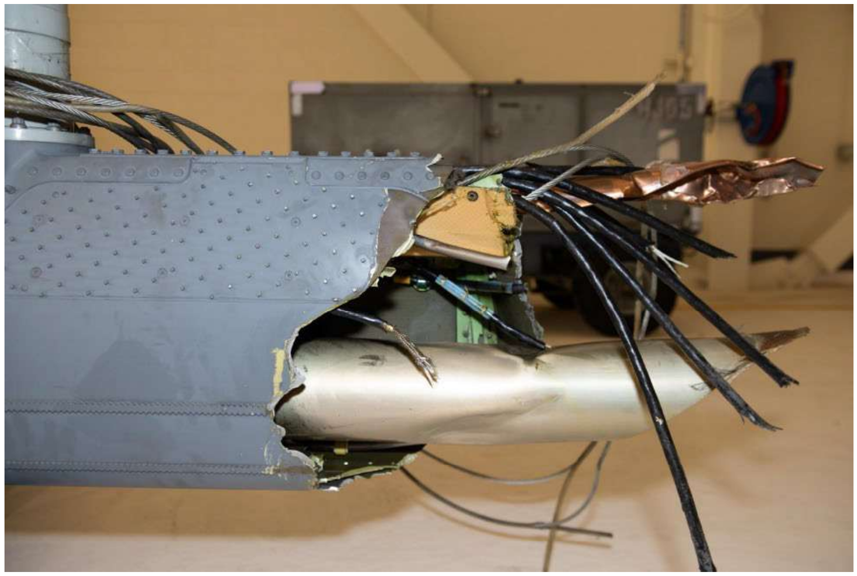

Figure 6.4 Boom Damage Closeup (Tab Z-6)

7. WEATHER

a. Forecast Weather

The forecast on for the SWISS ATCAA track on 21 August 2024 was winds from the south-west at 35 knots with clear skies and a visibility of 7 statute miles (Tab F-12, F-11) The temperature at Travis AFB was forecasted to be 60 degrees Fahrenheit (F) at takeoff and 80 degrees F at landing (Tab F-3). There was no icing, thunderstorms, or turbulence in the forecast or hazard report (Tab F-12). All forecasted weather was well within operating limitations for the MS (Tab F-3)

b. Observed Weather

The observed weather at the time of the mishap was consistent with the forecasted weather described above (Tab F-2, Tab V-3.22, Tab V-6.4, Tab V-6.14).

b. Space Environment

Not applicable.

c. Operations

There is no evidence to suggest that the MS operated outside prescribed operational limits with respect to weather conditions (Tab F-3).

8. CREW QUALIFICATIONS

a. Mishap Pilot 1 (MP1)

The MP1 is a qualified KC-46A Pilot with 2157 combined hours in the KC-135 and KC-46A (Tab T-7). The MP1 was initially qualified in the KC-135 on 17 March 2016 and in the KC-46A on 14 August 2020 and was current for air refueling operations on the day of the mishap (Tab G-4 to G-5).

The MP1's recent flight time is as follows (Tab G-7):

	Hours
30 days	11.6
60 days	32.4
90 days	49.6

b. Mishap Pilot 2 (MP2)

The MP2 is a qualified KC-46A Senior Pilot with 5286.5 combined hours in the KC-135 and KC-46A (Tab G-24, Tab G-218). The MP2 was initially qualified in the KC-135 on 23 October 2013 and in the KC-46A on 7 April 2020 and was current for air refueling operations on the day of the mishap (Tab G-140 to G-141).

The MP2's recent flight time is as follows (Tab G-143):

	Hours
30 days	6.7
60 days	13.4
90 days	20.7

c. Mishap Pilot 3 (MP3)

The MP3 is a qualified F-15E Pilot with 505.9 hours in the F-15E (Tab T-7). The MP3 was initially qualified in the F-15E on 17 October 2022 and was current for air refueling operations on the day of the mishap (Tab G-232 to G-239).

The MP3's recent flight time is as follows (Tab T-3)

	Hours
30 days	3.0
60 days	26.1
90 days	51.3

d. Mishap Weapons System Operator (MWSO)

The MWSO3 is a qualified F-15E Weapons System Officer with 265.4 hours in the F-15E (Tab T-7). The MWSO was initially qualified in the F-15E on 28 July 2022 and was current for air refueling operations on the day of the mishap (Tab T-6, T-8 to T-12).

The MWSO's recent flight time is as follows (Tab T-4)

	Hours
30 days	8.8
60 days	37.8
90 days	48.2

e. Mishap Boom Operator (MBO)

The MBO is a qualified KC-46A Boom Operator with 548 hours in the KC-46A (Tab T-7). The MBO was initially qualified as a KC-46A boom operator on 9 December 2022 and was current for air refueling operations with fighter aircraft on the day of the mishap (Tab G-266 to G-267).

The MBO's recent flight time is as follows (Tab G-296)

	Hours
30 days	14.4
60 days	60.0
90 days	90.8

9. MEDICAL

a. Qualifications

At the time of the mishap, all members of the MC had current flight physical examinations and were medically qualified for worldwide flight duty without restrictions (Tab X-3 to Tab X-6).

b. Health

A medical records review of all MC members showed no relevant medical conditions or illnesses that contributed to the mishap (Tab X-5 to Tab X-10).

c. Pathology

Toxicology screening for all aircrew was performed by the Armed Forces Medical Examiner System (AFMES) and initial samples were collected on 21 August 2024. Results of the aircrew testing did not show any abnormal findings (Tab X-5 to X-8).

d. Lifestyle

(1) Crew Rest and Crew Duty Time

Prior to performing flight duties, aircrew members must have proper crew rest, defined as a minimum of a 12-hour, non-duty period before the designated flight duty period begins (Tab BB-95). Crew rest is defined as "free time and includes time for meals, transportation and the opportunity for at least eight hours of uninterrupted sleep" (Tab BB-95). Review of the post-mishap statements of the MC revealed that the MBO had the opportunity but was unable to sleep more than 5 hours prior to the MS, and only slept a combined 7 hours over the 48 hours prior to the MS (Tab R-55). However, neither MP1 nor MP2 noted anything unusual in the MBO's performance on the day of the MS or the day prior (Tab V-3.13). The MBO's lack of adequate crew rest was appropriately documented by the MP1 on their operational risk management (ORM) worksheet (Tab AA-42). All other aircrew were able to get appropriate amounts of sleep prior to the MS (Tab AA-42).

(2) Other Considerations

The MBO reported recent financial and relationship stress within the last three months and stated this was not abnormal but a "baseline stress level" (Tab V-9.5, Tab R-61). However, neither MP1 nor MP2 noted anything unusual in the MBO's performance on the day of the MS or the day prior (Tab V-3.13, Tab V-4.7). Only minor health and stress was noted on the ORM (Tab AA-42).

10. OPERATIONS AND SUPERVISION

a. Operations

The operations tempo at the 905th Air Refueling Squadron (ARS) was described as low by squadron leadership (Tab V-13.1). The 905 ARS leadership described a significant lack of training opportunities due to deployment preparation, fully mission capable jets being tasked and unavailable, as well as only partially mission capable jets being left to utilize for training (Tab V-13.4). Partially mission capable aircraft can be capable of flying and accomplishing training but are defined as able to perform at least one, but not all, of its assigned missions (Tab V-13.4). Leadership also described a drastic reduction in flying hours within the last three to six months (Tab V-13.4).

The MC conducted a routine air refueling mission on the way from McConnell AFB to Travis AFB on the day prior to the mishap without incident (Tab AA-41, Tab- V-9.3). Due to the change in time zone and early alert time, lack of sleep was discussed by the MC as a potential ORM concern (Tab V-3.14, Tab V-4.6, Tab V-9.5). The MC noted an elevated Health and Stress Score on the ORM worksheet but were approved for flight by the 618th Air Operations Center (AOC) as the mission's approval authority (Tab AA-42). MA2 departed from and returned to its home station and no ORM concerns requiring an elevated approval authority were noted (Tab AA-47 to Tab AA-50).

b. Supervision

The 905 ARS ensured all flight crew members were appropriately qualified for the mission and no supervision issues were noted (Tab AA-56).

11. HUMAN FACTORS ANALYSIS

a. Introduction

The Department of Defense Human Factors Analysis and Classification System 7.0 (DoD HFACS 7.0) lists potential human factors that can play a role in aircraft mishaps and identifies potential areas of assessment during an accident investigation (Tab BB-123). Six human factors were identified as relevant to the mishap:

b. AE104: Overcontrolled/Undercontrolled Aircraft/Vehicle/System

This is a factor when an individual responds inappropriately to conditions by either over- or under-controlling the aircraft/vehicle/system. The error may be a result of preconditions or a temporary failure of coordination.

c. AE103: Procedure Not Followed Correctly

This is a factor when a procedure is performed incorrectly or accomplished in the wrong sequence.

d. AE201: Inadequate Real-Time Risk Assessment

This is a factor when an individual fails to adequately evaluate the risks associated with a particular course of action and this faulty evaluation leads to inappropriate decision-making and subsequent unsafe situations.

e. PE205: Automated System Creates an Unsafe Situation

This is a factor when the design, function, reliability, symbology, logic or other aspect of automated systems creates an unsafe situation.f. PC504: Misperception of Changing Environment

This is a factor when an individual misperceives or misjudges altitude, separation, speed, closure rate, road/sea conditions, aircraft/vehicle location within the performance envelope or other operational conditions.

g. PP109: Task/Mission Planning/Briefing Inadequate

This is a factor when an individual, crew or team failed to complete all preparatory tasks associated with planning/briefing the task/mission.

12. GOVERNING DIRECTIVES AND PUBLICATIONS

a. Publicly Available Directives and Publications Relevant to the Mishap

(1) AFI 51-307, *Aerospace Accident Investigations*, 18 March 2019
(2) AFI 48-123, *Medical Examinations and Standards*, 8 December 2020
(3) DAFI 21-101, *Aircraft and Equipment Maintenance Management*, 20 December 2023
(4) DAF 91-202, *The Department of the Air Force Mishap Prevention Program*, 20 March 2020, Change: 10 April 2024

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

b. Other Directives and Publications Relevant to the Mishap

(1) 1C-46(K)A-1_FCOM_Rev20.1, *Flight Manual, Flight Crew Operations Manual*, Boeing Revision 20. Air Force Revision 20.1, 17 June 2024
(2) 1C-46(K)A-1CL-1-QRH_Rev20, *Flight Manual, Quick Reference Handbook, Pilot Handheld Checklist*, Boeing Revision 20, Air Force Revision 20, 18 April 2024
(3) TO 1F-15E-1, *Flight Manual, USAF Series F-15E*, 08 April 2024, Change 17: 15 July 2024
(4) ACC FCIF 24-03C, *CAF Fighter and KC-46A Air Refueling Operations,* Update 3
(5) AFTTP 3-3.F-15E, *Combat Fundamentals F-15E*, 25 August 2023
(6) Air Mobility Command, *Pharmacological Fatigue Countermeasures Program Concept of Operations*, 04 September 2024
(7) AMCI 90-903, *Aviation Operational Risk Management (AVORM) Program*, 15 March 2023
(8) ATP-3.3.4.2. NATO Standard Air to Air Refueling, Edition D Version 1, April 2019
(9) ATP-3.3.4.2, US Standards Related Document (SRD), 1 August 2024

c. Known or Suspected Deviations from Directives or Publications

(1) ATP-3.3.4.2, US Standards Related Document (SRD), 1 August 2024 Chap 6-2,6-3,6-4,6-7, Chap 8-10, 8-11, 8-79
(2) 1C-46(K)A-1CL-1-QRH_Rev20, *Flight Manual, Quick Reference Handbook, Pilot Handheld Checklist*, Boeing Revision 20, Air Force Revision 20, 18 April 2024, MAN 1.1

PATTON.DIANE.E. Digitally signed by PATTON.DIANE.E. Date: 2025.06.03 08:12:09 -04'00'

03 JUNE 2025

DIANE E. PATTON, Colonel, USAF
President, Accident Investigation Board

STATEMENT OF OPINION

KC-46, T/N 17-6028
TRAVIS AIR FORCE BASE, CALIFORNIA
21 AUGUST 2024

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 21 August 2024, at approximately 0927L/1627Z, a United States Air Force KC-46A Pegasus, tail number (T/N)17-6028, Mishap Aircraft 1 (MA1), assigned to the 22nd Air Refueling Wing, McConnell AFB, KS and operated by a primary crew assigned to the 931st Air Refueling Wing, McConnell AFB, KS, departed from Travis Air Force Base (AFB), California, on a mission in support of Operation NOBLE EAGLE to refuel one flight of two F-15Es (Mishap Aircraft 2 (MA2) and its wingman), assigned to the 366th Fighter Wing, Mountain Home AFB, ID. The scheduled flight profile was a single-ship departure from Travis AFB, refueling for approximately two and a half hours with the F-15s, before returning for landing at Travis AFB. During the fourth air refueling attempt of the sortie, MA1 experienced nozzle binding of the boom in MA2's receptacle. Upon release of the nozzle from MA2's receptacle, the boom rapidly flew upwards and struck the bottom aft portion of MA1's fuselage, oscillated left and right for several seconds in increasing frequency, and subsequently a portion of the boom departed the aircraft. There were no fatalities, injuries, or damages to civilian property. The boom striking MA1 and subsequent violent oscillations resulted in a critical failure of the boom shaft structure, portions of which departed the aircraft in flight, and significant damage to the aft fuselage components of MA1. The estimated damages to MA1 are $14,381,303.

I find, by a preponderance of the evidence, that the cause of the mishap was the mishap boom operator's (MBO) control inputs to the air refueling flight control system (FCS), resulting in an excessive fly-up rate of the boom which struck the aircraft and caused a critical failure of the boom shaft structure. Additionally, I find, by a preponderance of the evidence, that four additional factors substantially contributed to the mishap. Specifically, excessive closure rate and instability of MA2, the MBO's attempted contact outside the standard air refueling envelope for the F-15E, a failure to recognize and accomplish immediate breakaway procedures by MP3, and the MBO's lack of knowledge on boom flight control logic were substantially contributing factors that resulted in boom nozzle binding within the air refueling (AR) receptacle of MA2.

2. CAUSE

I find, by a preponderance of the evidence, the cause of the mishap was the MBO's control inputs to the air refueling flight control system, resulting in an excessive fly-up rate of the boom which struck the aircraft and caused a critical failure of the boom shaft structure. The MBO did not heed the caution regarding rapid or abrupt large boom control inputs in the Flight Crew Operations Manual (FCOM) or the instructions in the US Standards Related Document (SRD) which states, "*CAUTION: IF NOZZLE BINDING OCCURS OR IS SUSPECTED, NEUTRALISE BOOM FLIGHT CONTROL INPUTS. AVOID ABRUPT BOOM FLIGHT CONTROL INPUTS.*"

3. SUBSTANTIALLY CONTRIBUTING FACTORS

a. Excessive Closure Rate and Instability of Receiver Aircraft

During the first contact of the first refueling period of the sortie, MP3 required multiple visual and verbal corrections to attain and maintain the correct position within the AR envelope, and the first contact was ended by the receiver reaching the aft disconnect limit. During the first contact of the second refueling period, MP3 misjudged closure rate and angle and did not recognize their location in the boom envelope. MP3 was again given multiple corrections by the MBO and MWSO and proceeded inside the inner limit, again triggering an automatic disconnect.

During the mishap contact sequence, MP3 proceeded from the astern position at a normal rate of closure but MP3 and MWSO did not perceive the continued closure rate towards MA1 and failed to arrest forward motion upon attempted contact. Already towards the lower elevation limit of the boom, the receiver aircraft continued to fly forward, further increasing the low boom pitch profile, compressing the telescope, and contributing to the nozzle binding condition.

b. Attempted Contact Outside the Air Refueling Envelope

Upon approach to contact, the MBO attempted receptacle engagement outside the refueling envelope at 41.9 degrees pitch and 10.2 feet telescope length. The lowest boom envelope limit is 40 degrees pitch. To achieve contact with the receptacle, the MBO was utilizing approximately full fly down input to the flight control stick. The MBO commanded contact; however, the boom status immediately switched to disconnect mode due to the boom being outside of the disconnect envelope at ~42 degrees boom pitch.

c. Receiver Failure to Recognize and Accomplish Breakaway Procedures

The MBO keyed the breakaway switch and attempted to make a breakaway call over the radio when noticing the continued closure of the receiver aircraft. A portion of the call went out, but the call was only partially procedurally correct and was further interrupted by the AR master warning tone when the ALAS ELEVATION fault annunciated. MA1 pilots applied immediate actions in accordance with the Quick Reference Handbook (QRH) and SRD. However, MP3 did not hear the breakaway call and failed to recognize the flashing Pilot Director Lights (PDL) and lower strobe lights in accordance with the SRD, delaying the emergency separation of the two aircraft. MP3 reduced thrust on both engines to initiate receiver breakaway approximately 10 seconds after the disconnect.

d. Lack of Knowledge on Boom Flight Control Logic

There are multiple boom flight control logic modes that are active when the system is powered on. These logic modes toggled as the axial and radial forces on the boom nozzle varied during the attempted contact sequence. The MBO's flight control stick inputs were out of sync with the physical flight controls, and the conflicting inputs caused the automatic flight control system to induce a large elevator mis-trim condition. Upon the boom nozzle becoming freed from the receiver receptacle, this mis-trim drove the boom upwards at a high rate of speed. Half a second was not enough time for the MBO to react and zero out the flight control system's efforts to return the boom to its "home" envelope or fair the flight control surfaces and bleed down residual system pressure.

There is minimal discussion, if any, of the boom logic functions in the Flight Crew Operating Manual, the KC-46 Boom academics, or the AFTTP 3-3.b KC-46. The only reference to fault detection out-of-range limit rates, "return to home" function, and boom envelope soft limits were found in manufacturer proprietary and independent technical evaluation data specifically analyzed as a result of this mishap. There is currently a deficiency in the depth of boom system logic and boom flight control systems knowledge in KC-46 baseline manuals and academics. Additionally, many initial cadre flight instructors for the KC-46 were prior boom operators on the KC-135, which did not have any automated boom flight control systems. The tactics, techniques, and procedures for alleviating nozzle binding and "flying the boom" in the KC-135 are contraindicated for the KC-46 automated systems and may have contributed to outdated techniques being taught during training. Lastly, the ARMS system does not provide adequate real-time indication or feedback to the ARO on control forces or sensor loads when in contact or during nozzle binding. Unlike the KC-10, the KC-46A is not equipped with a boom FCS stick-shaker or other tactile feedback mechanism.

Further contributing to the misperceptions on boom logic and recovery actions during nozzle binding is that the KC-46 simulator models do not accurately represent the boom flight dynamics and the warnings and cautions received in the aircraft that were seen in this scenario. The boom operator trainer (BOT) cannot recreate nozzle binding, especially in earlier variants of the software fielded, preventing aircrew from being able to replicate real-world situations.

4. CONCLUSION

I find, by a preponderance of the evidence, that the cause of the mishap was the MBO's control inputs to the air refueling flight control system, resulting in an excessive fly-up rate of the boom, which struck the aircraft empennage and caused a critical failure of the boom shaft structure. I further find by a preponderance of the evidence that the following factors substantially contributed to the mishap:

- Excessive closure rate and instability of MA2
- The MBO's attempted contact outside the standard AR envelope for MA2
- MP3's failure to recognize and initiate immediate breakaway procedures which further delayed positive separation from MA1; and
- The MBO's lack of knowledge on boom flight control logic and its effects on the boom flight control surfaces prevented the MBO from recognizing the influence of FCS inputs and programmed boom limit functions during operations, especially during nozzle binding situations.

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03 JUNE 2025

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President, Accident Investigation Board

INDEX OF TABS