UNITED STATES AIR FORCE AIRCRAFT ACCIDENT INVESTIGATION BOARD REPORT

RQ-4B, T/N 09-2041

348th Reconnaissance Squadron
9th Reconnaissance Wing
Grand Forks Air Force Base, North Dakota

LOCATION: NEAR THE COAST OF ROTA, SPAIN

DATE OF ACCIDENT: 26 JUNE 2018

BOARD PRESIDENT: COLONEL ROBERT K. CLEMENT

Abbreviated Accident Investigation, conducted pursuant to Chapter 12 of Air Force Instruction 51-307

EXECUTIVE SUMMARY
UNITED STATES AIR FORCE
AIRCRAFT ACCIDENT INVESTIGATION

RQ-4B, T/N 09-2041
NEAR THE COAST OF ROTA, SPAIN
26 JUNE 2018

On 26 June 2018, at approximately 0919 local (L) time,* a RQ-4B Global Hawk, tail number (T/N) 09-2041, made impact with the ocean off the coast of Rota, Spain, approximately 13 hours and 24 minutes after takeoff from Grand Forks Air Force Base (GFAFB), North Dakota (ND), for a ferry flight to a downrange operational location. The mishap remotely piloted aircraft (MRPA) was assigned to the 9th Reconnaissance Wing, Beale Air Force Base, California but located at one of its Geographically Separated Units, the 69th Reconnaissance Group, 348th Reconnaissance Squadron (348 RS), GFAFB, ND. The mishap crew were all assigned to 348 RS at GFAFB, and they were all active duty members of the mishap unit. The mishap did not result in any injuries or damage to private property. The MRPA along with its payload sensor system, together valued at $98.83 million, were destroyed.

On 25 June 2018, between 0730L to 1840L, maintenance and aircrew personnel conducted pre-flight inspections at GFAFB and the MRPA took off at 1956L. On 26 June 2018, after approximately 11 hours and 49 minutes, at 0745L, the MRPA received initial engine fault codes indicating low oil quantity and low oil pressure. At 0811L (26 minutes after the first indication), the MRPA's engine experienced an uncommanded inflight shutdown, based on system faults ranging from low oil quantity to oil pressure to engine vibration, consistent with an oil leak rapidly emptying the oil tank followed by oil starvation and eventual mechanical failure. At 0812L, the mishap pilot (MP) made the decision to divert the MRPA to an emergency route. In accordance with training and the approved mission plan, at 0908L, the MP made the decision to crash/ditch the MRPA in the ocean. The MRPA continued to glide for 11 minutes, where at 0919L, the MRPA crashed into the ocean off the coast of Naval Station Rota, Spain, avoiding loss of human life and infrastructure damage.

I find, by a preponderance of evidence, that the cause of the mishap was an oil leak from a cracked oil line, which caused an engine uncommanded inflight shutdown. Furthermore, I find, by a preponderance of evidence, that the unit's approved mission plan for the mishap sortie did not provide the MP with sufficient emergency divert airfields for unpowered aircraft recovery, substantially contributing to the mishap.

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.

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* All times referenced herein, to include the time of the overseas mishap, are expressed in local time for the stateside Air Force base operating the aircraft and tracking the overall sequence of events.

SUMMARY OF FACTS AND STATEMENT OF OPINION
RQ-4B, T/N 09-2041
NEAR THE COAST OF ROTA, SPAIN
26 JUNE 2018

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ACRONYMS AND ABBREVIATIONS

AAIB	Abbreviated Accident Investigation Board
AC(#)	Aircraft Route
ACC	Air Combat Command
ACCEL	Accelerometer Temperature
ADI	Attitude Director Indicator
AF	Air Force
AFB	Air Force Base
AFI	Air Force Instruction
AFMAN	Air Force Manual
AFMC	Air Force Material Command
AFTO	Air Force Technical Order
AFPD	Air Force Policy Directive
AFSC	Air Force Specialty Code
AGB	Accessory Gearbox
AIB	Accident Investigation Board
AMU	Aircraft Maintenance Unit
AMXS	Aircraft Maintenance Squadron
ASM	Airspace Manager
ATC	Air Traffic Control
ATS	Air Turbine Starter
BPO	Basic Post Flight
C	Celsius
C2	Command and Control
CA	California
CC	Commander
CCM	Crew Chief
CENTCOM	Central Command
CFR	Code of Federal Regulations
CO	Commanding Officer
DC	Deputy Commander
DO	Director of Operations
DoD	Department of Defense
ERT	Extended Range Transfer
F	Fahrenheit
FADEC	Full Authority Digital Engine Control
FCIF	Flight Crew Information File
GFAFB	Grand Forks Air Force Base
GHOC	Global Hawk Operations Center
GHOCP	Global Hawk Operations Center Pilot
H(#)	Hawkeye
HQ	Headquarters
Hz	Hertz
IAW	In Accordance With
IFE	In Flight Emergency
IMDS	Integrated Maintenance Data System
IMINT	Imagery Intelligence
IMMC	Integrated Mission Management Center
ips	Inch Per Second
ISR	Intelligence, Surveillance, Reconnaissance
L	Local Time
LRE	Launch Recovery Element
MAJCOM	Major Command
MC	Mishap Crew
MCE(#)	Mission Control Element
MP	Mishap Pilot
MRPA	Mishap Remotely Piloted Aircraft
MTBF	Mean-Time Between Failure
MTI	Moving Target Indicator
NDI	Non-Destructive Inspection
NG	Northrup Grumman
nm	Nautical Mile
NOTAM	Notice to Airmen
OCONUS	Outside Contiguous United States
OG	Operations Group
OS	Operations Supervisor
PIC	Pilot in Command
PR	Pre-Flight
psig	Pounds Per Square Inch Gauge
RG	Reconnaissance Group
RPA	Remotely Piloted Aircraft
RRC	Rolls-Royce Corporation
RS	Reconnaissance Squadron
RW	Reconnaissance Wing
SME	Subject Matter Expert
SMU	Sensor Management Unit
SQDO	Squadron Director of Operations
TCTO	Time Compliance Technical Order
T/N	Tail Number

T.O.	Technical Order	USAF	United States Air Force
UIFSD	Uncommanded Inflight Shutdown	USAFE	United States Air Forces Europe
U.S.	United States	WAI	Walk-Around Inspection

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 15 August 2019, the Air Combat Command (ACC) Deputy Commander, appointed Colonel Robert K. Clement to conduct a legal investigation into the 26 June 2018 crash of an RQ-4B Global Hawk aircraft, tail number (T/N) 09-2041, occurring off the coast of Rota, Spain (Tabs R-16, Y-3 to Y-4, and CC-6). This investigation was conducted by an abbreviated accident investigation board (AAIB), pursuant to Chapter 12 of Air Force Instruction (AFI) 51-307, *Aerospace and Ground Accident Investigations* (Tab Y-3). The investigation was conducted at Grand Forks Air Force Base (GFAFB), North Dakota (ND), from 20 August 2019 to 20 September 2019, and a Legal Advisor (Captain) and Recorder (Staff Sergeant) were also appointed as board members (Tab Y-3 to Y-4). Additionally, a RQ-4 Mission Commander (Captain) and an engineering expert (civilian) were appointed as subject matter experts to assist the AAIB (Tab Y-5 to Y-6).

b. Purpose

In accordance with (IAW) AFI 51-307, this AAIB conducted a "legal investigation to inquire into all the facts and circumstances surrounding [this] Air Force aerospace accident, to prepare a publicly releasable report, and to obtain and preserve all available evidence for use in litigation, claims, disciplinary action, and adverse administrative action" (Tab BB-8).

2. ACCIDENT SUMMARY

The mishap remotely piloted aircraft (MRPA) was a RQ-4B, T/N 09-2041, assigned to the 9th Reconnaissance Wing (9 RW), Beale Air Force Base (AFB), CA (Tab K-2). The MRPA was physically located at the 348th Reconnaissance Squadron (348 RS), GFAFB, ND, one of the wing's Geographically Separated Units under the 69th Reconnaissance Group (69 RG) (Tabs K-2 and CC-15). On 25 June 2018, the MRPA took off at 1956 local (L),[2] on a ferry flight to be relocated from GFAFB to a downrange operational location (Tabs K-2, V-2.6, V-8.9, and EE-18). During the same flight, at approximately 0745L on 26 June 2018, the MRPA began receiving various engine fault codes ranging from low oil quantity to low oil pressure, leading to engine vibration and engine shutdown (Tabs J-51 to J-52, R-14 to R-16, and V-1.14). The MRPA continued to lose oil quantity and oil pressure until the engine experienced an uncommanded inflight shutdown (UIFSD) at 0811L (Tabs J-51 to J-52, J-82, R-16, and V-1.15). For nearly an hour, the mishap pilot (MP) glided on auxiliary battery power (without engine propulsion) towards an emergency divert airfield at Naval Station Rota, Spain, but the MP ultimately calculated that the MRPA could not safely make the distance to the airfield (Tabs R-19 to R-21, and V-1.25). On 26 June at 0908L, the MP made the decision to crash/ditch the MRPA into the ocean off the coast of Rota, Spain where it impacted at 0919L (Tab R-16 to R-17). The MRPA along with its payload sensor system,

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together valued at $98.83 million, were destroyed (Tab FF-153).

3. BACKGROUND

a. Air Combat Command (ACC)

ACC's primary mission is to support global implementation of national security strategy; ACC operates fighter, bomber, reconnaissance, battle-management and electronic-combat aircraft (Tab CC-2 to CC-5). It also provides command, control, communications and intelligence systems, and conducts global information operations (Tab CC-2 to CC-5).

As a force provider and Combat Air Forces lead agent, ACC organizes, trains, equips and maintains combat-ready forces for rapid deployment and employment while ensuring strategic air defense forces are ready to meet the challenges of peacetime air sovereignty and wartime air defense (Tab CC-2 to CC-5). Additionally, ACC develops strategy, doctrine, concepts, tactics, and procedures for air and space-power employment (Tab CC-2 to CC-5). The command provides conventional and information warfare forces to all unified commands to ensure air, space and information superiority for warfighters and national decision-makers (Tab CC-2 to CC-5). The command can also be called upon to assist national agencies with intelligence, surveillance and crisis response capabilities (Tab CC-2 to CC-5). ACC numbered air forces provide the air component to U.S. Central, Southern and Northern Commands, with Headquarters ACC serving as the air component to Joint Forces Commands (Tab CC-2 to CC-5). ACC also augments forces to the United States' European, Pacific, Africa-based and Strategic Commands (Tab CC-2 to CC-5).

b. 9th Reconnaissance Wing (9 RW)

The 9 RW is responsible for providing national and theater command authorities with timely, reliable, high-quality, high-altitude reconnaissance products (Tab CC-8 to CC-10). To accomplish this mission, the wing is equipped with the nation's fleet of U-2 and RQ-4 reconnaissance aircraft and associated support equipment (Tab CC-8 to CC-10). The wing also maintains a high state of readiness in its expeditionary combat support forces for potential deployment in response to theater contingencies (Tab CC-8 to CC-10). The 9 RW is composed of more than 4,500 personnel in four groups at Beale AFB and across multiple stateside and overseas operating locations (Tab CC-8 to CC-10).

c. 348th Reconnaissance Squadron (348 RS)

The 348 RS is located at GFAFB (Tab CC-11 to CC-12). The 348 RS mission is to provide a broad spectrum of intelligence, surveillance, and reconnaissance (ISR) collection capability to support joint combatant forces in worldwide peacetime, contingency and wartime operations (Tab CC-11).

d. 12th Reconnaissance Squadron (12 RS)

The 12 RS is located at Beale AFB (Tab CC-13). The 12 RS mission is to expertly train, deploy and employ Airmen and assets to deliver globally integrated ISR in support of warfighter needs and national objectives (Tab CC-13).

e. 13th Reconnaissance Squadron (13 RS)

The 13 RS is located at Beale AFB (Tab CC-14). The 13 RS is an associate reserve unit that provides theater commanders with near-real-time intelligence, surveillance, reconnaissance and target acquisition data (Tab CC-14). The squadron operates and maintains deployable, long-endurance RQ-4 Global Hawk aircraft and ground control elements to fulfill training and operational requirements generated by the Joint Chiefs of Staff in support of unified commanders and the Secretary of Defense (Tab CC-14).

f. RQ-4B – Global Hawk

The RQ-4 Global Hawk is a high-altitude, long-endurance, remotely piloted aircraft with an integrated sensor suite that provides global all- weather, day or night ISR capability (Tab CC-6 to CC-7). The Global Hawk's mission is to provide a broad spectrum of ISR collection capability to support joint combatant forces in worldwide peacetime, contingency and wartime operations (Tab CC-6 to CC-7). The Global Hawk provides persistent near-real-time coverage using imagery intelligence (IMINT), signals intelligence and moving target indicator (MTI) sensors (Tab CC-6 to CC-7).

4. SEQUENCE OF EVENTS

a. Mission

The MRPA was a RQ-4B, T/N 09-2041, assigned to the 9 RW, Beale AFB, CA (Tabs K-2, K-5, and FF-158). The MRPA was physically located at one of the wing’s Geographically Separated Units, the 69 RG, 348 RS, GFAFB, ND (Tabs K-2, K-5, and FF-158). As of 25 June 2018, the MRPA’s airframe had 208 sorties/landings and 3,772.6 hours (Tab DD-5). The mishap sortie was a scheduled extended range transfer (ERT)/ferry flight, relocating the MRPA from GFAFB to the downrange operational location (Tabs K-2 to K-3, V-8.9 to V-8.10, and EE-18).

The MC were all assigned to 348 RS at GFAFB, and they were all United States Air Force Airmen members of the mishap unit (Tabs K-4 and FF-128). The MC included: a mishap pilot (MP) inside the Mission Control Element (MCE); an Operations Supervisor who oversaw flight operations in the Global Hawk Operation Cell (GHOC); a RQ-4 pilot assigned as a GHOC Pilot, known as a relief pilot (GHOCP); the primary Hawkeye Mission Commander (H1), who conducted the aircrew preflight walk around at GFAFB on 25 June 2018; three RQ-4 Mission Commanders at the MCE

(MCE1, MCE2, and MCE3); and a RQ-4 Mission Commander at the Launch and Recovery Element (LRE1) (Tabs K-4, R-14, V-1.10, V-1.13, V-1.22, V-2.8, V-12.7 to V-12.8, and FF-128). The MCE1, MCE2, MCE3, and LRE1 each flew the aircraft prior to the MP (Tabs K-4, R-5, V-4.2, V-11.2, and V-12.2).

b. Planning

On 26 June 2018, the MP conducted preparation duties and briefed the mishap sortie IAW the mission plan (Tabs R-14, V-6.11, V-14.5, and EE-2 to EE-18). The brief included mission, duties, weather, safety, and risk mitigation (Tab F-2 to F-37). The mission plan was approved by the 348 RS (Tabs FF-106 to FF-107, FF-111, and EE-3). Planning included divert locations and impact points for aircraft not controllable for landing (Tabs V-6.11, V-6.14 to V-6.15, V-10.10 to 10.11, EE-2 to EE-15, FF-106 to FF-107, and FF-111).

c. Preflight

On 25 June 2018, between 0730L to 1630L, 69 RG maintainers, to include the four Crew Chiefs (CCM1 - CCM4), two Avionics Technicians (AV1 and AV2) and the Production Superintendent (PS) prepared the MRPA for flight and towed the aircraft to its launch location (Tabs D-3, R-103 to R-108, V-15.2 to V-15.3, V-18.2, DD-3 to DD-4, and DD-68 to DD-88). Between 1810L and 1840L, H1 accomplished a preflight walk-around of the MRPA and reviewed its maintenance documentation (Tabs D-3, R-103 to R-108, V-5.5 to V-5.9, DD-3 to DD-4, DD-68, and DD-114 to DD-120). Another Hawkeye pilot (H2) observed the walk-around and communicated to the GHOC, LRE1 and MCE1 that the walk-around was complete and the forms were signed (Tabs D-3, V-5.5 to V-5.9, and DD-3 to DD-4). Prior to launch, LRE1 and MCE1 experienced minor software problems uploading the mission plan (Tabs V-11.12, FF-4 to FF-5, and FF-17). Additionally, the MRPA experienced a pre-taxi discrepancy for an ambient temperature warning, known as a "Red Ball" fault (Tab R-105). All pre-taxi issues (software uploading and "Red Ball") were resolved (Tabs R-105, V-11.3, V-15.3, DD-3 to DD-4, and FF-5). LRE1 performed the launch at 1956L, without further incident (Tabs R-105, V-15.3, and FF-5).

d. Summary of Accident

The MRPA took off on a sortie from GFAFB at 1956L on 25 June 2018 (Tabs K-2 to K-3, L-2, and V-15.3). After pre-taxi discrepancies were cleared by both operations and maintenance, the MRPA's taxi, takeoff, climb-out, and cruise to 51,000 feet were uneventful (Tabs V-15.2 to V-15.3, FF-5, FF-17 to FF-18, FF-31, and FF-44). On 26 June 2018 at 0745:23L, 11 hours and 49 minutes into the flight, 15 minutes into the MP's shift, the first engine fault (Yellow 05 – oil level less than 1.5 gallons) appeared (Tabs J-51 to J-52, L-2, and R-14). One minute and forty seconds later, at 0747:03L as the engine oil quantity quickly decreased, there was an additional Engine Yellow 04 fault, indicating the engine oil was less than one gallon (Tabs J-51 to J-52, L-2, and R-15). Two minutes and seven seconds later, at 0749:10L, an Engine Yellow 27 fault was recorded, indicating oil pressure was less than 53 pounds square inch (psi) (Tabs J-52, R-15, and V-1.7). Twenty four seconds later, at 0749:34L, Engine Red 26 fault was recorded, indicating oil pressure was less than 48 psi (Tabs J-52, L-2, and R-15).

At this time, the MP declared an inflight emergency (IFE) (Tabs J-52 and R-18). The MP then descended to 45,000 feet IAW the RQ-4 flight manual emergency procedures (Tabs R-15 to R-16, R-18, V-1.7, and DD-121 to DD-148). Seventeen seconds after the Engine Red 26 fault, at 0749:51, Engine Yellow 02 fault was recorded, indicating oil pressure less than 25 psi (Tabs J-52 and L-2). At 0809:44L, approximately 24 minutes into the IFE, the engine experienced violent vibrations, as indicated by multiple Engine Yellow 13 faults (engine core vibration exceeds 1.1 ips) and Engine Red 12 faults (engine core vibrations exceeds 2.5 ips) (Tabs J-51 to J-52, L-2, and R-16). Then, at 0811:27L, one minute and forty three seconds after the initial engine core vibration fault (Engine Yellow 13), the engine ceased to operate, as indicated by multiple "Engine Out" fault messages (Tabs J-51 to J-52, L-2, R-16, R- 21, and V-1.13 to V-1.14).

Over the next 50 minutes, the MP continued to glide the MRPA, IAW the Mission Plan, coordinating emergency divert procedures with Lisbon, Portugal, and Naval Station Rota, Spain Air Traffic Control (ATC) (Tabs R-15 to R-16, EE-2 to EE-15). The MP also calculated the aircraft's glide ratio, with help from the GHOCP, OS, DO and DC (Tabs R-16, R-20, V-1.13 to V-1.14, and V-1.18). The MP immediately diverted to the nearest emergency route (Tabs R-15 and V-1.13). At 0907:59L, 56 minutes and 32 seconds after the engine's UIFSD, the aircraft batteries began to fail, causing voltage to fall below tolerance preventing continued guidance control, as indicated by Electrical Power Yellow 12 and Electrical Power Yellow 16 faults (Tabs J-51 to J-52, L-2, and R-21). At 0908:05L, at an altitude of approximately 5,700 feet, the pilot issued a heading override to "ditch" the aircraft (Tabs J-51, L-2, and R-16). Command and Control (C2) logs from the MCE 1/5 Hertz (Hz) were used to verify fault codes and timeline (Tab L-2).

On the MRPA, there are two IMMC flight control computers, IMMC-A and IMMC-B (Tab FF-151 to FF-152). The IMMCs provide the aircraft with flight control, guidance, vehicle management, redundancy management, payload, and communication management (Tab FF-151 to FF-152). IMMC's have installed software to control and monitor all functions of the aircraft (Tab FF-151 to FF-152). The Sensor Management Unit (SMU) acts as a transport mechanism for sending Multi Platform-Radar Technology Improvement Program radar data products to the ground (Tab FF-151 to FF-152). The data products include Synthetic Aperture Radar, IMINT, and Ground MTI data (Tab FF-151 to FF-152). The SMU provides the necessary interfaces and processing resources to manage mission payloads and mission data flow to the ground segments (Tab FF-151 to FF-152). There are two fully authority digitally engine controllers (FADECs) on each aircraft called FADEC A and FADEC B (Tab FF-151 to FF-152). On every engine start, one of the FADECs will be in charge and the other will be the backup (Tab F-151 to FF-152). FADEC A and FADEC B are components of the engine fuel and control system's controlling subsystem to control engine operation, as commanded by the IMMC (Tab FF-151 to FF-152). Since the aircraft was submerged and it experienced prolonged exposure to saltwater, no IMMC, SMU, or FADEC data was used or available (Tab J-54).

e. Impact

The MRPA impacted the ocean on 26 June 2018 at 0919:10L, approximately 23 nautical miles (nm), west-southwest of Rota, Spain (Tabs J-52, L-2, R-17, and R-28). The wreckage was scattered over approximately 11 nm (Tab S-6). Both the wings, and several other flight surfaces, separated at the time of impact and remained on the surface (Tab J-53). The main body of the aircraft, including the fuselage and engine, sank to the bottom of the ocean (Tab J-53).

f. Egress and Aircrew Flight Equipment (AFE)

Not applicable.

g. Search and Rescue (SAR)

Between 26 June 2018 and 8 August 2018, United States Government air and naval assets, as well as contracted naval services, were dedicated to wreckage recovery (Tab S-2 to S-3). On 26 June 2018, initial recovery was performed by the USNS ARCTIC (Tab S-2). The wing sections, right V-tail, a section of aft composite fuselage, forward chin fairing, CDL radome, access panels, SATCOM Antenna and various cored structured fairings were recovered from the surface (Tab J-53). On 8 August 2018, the fuselage, engine and electronic components were recovered by the Phoenix International Recovery Ship (Tab S-3). All salvaged components were shipped to GFAFB (Tabs S-4 and FF-131 to FF-150).

Initial recovery by the USNS ARCTIC (Tab S-2).

Initial recovery by the USNS ARCTIC (Tab S-2).

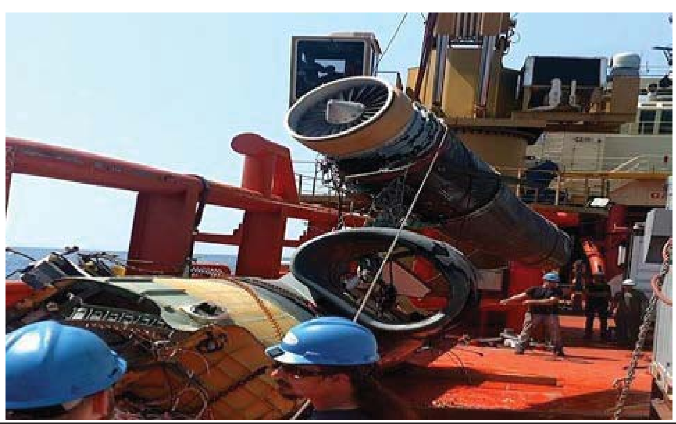
Initial recovery by the USNS ARCTIC (Tab S-2).

Fuselage on ocean floor (Tab S-2).

Fuselage on ocean floor (Tab S-2).

Phoenix International Recovery Ship (Tab S-3).

Phoenix International camera/mapping device (Tab S-3).



Recovery of fuselage and engine (Tab S-3).

Recovery of fuselage and engine (Tab J-53).

Recovery of electronic components (Tab S-3).

Recovery of electronic components (Tab S-3).

Movement of fuselage from ship to land (Tab S-4).

Recovered engine at GFAFB (Tab S-4).

Recovered fuselage at GFAFB (Tab S-4).

Recovered fuselage at GFAFB (Tab S-4).

h. Recovery of Remains

Not applicable.

5. MAINTENANCE

a. Forms Documentation

The Air Force Technical Order (AFTO) 781 series of forms collectively document maintenance actions, inspections, servicing, configurations, status, and flight activities (Tabs D-3 and DD-3 to DD-6). The AFTO 781 forms in conjunction with the Integrated Maintenance Data System (IMDS) provide a comprehensive database used to track and record maintenance actions and flight activity, and to schedule future maintenance (Tab DD-3 to DD-6).

A comprehensive review of the historical AFTO 781 forms and IMDS revealed no discrepancies, overdue inspections, or overdue Time Compliance Technical Orders that would ground the MRPA from flight operations (Tabs D-3 and DD-3 to DD-6). A thorough review of the pulled AFTO 781 forms and IMDS historical records for the 180 days preceding the mishap revealed no recurring maintenance problems (Tab DD-3 to DD-6). Additionally, there was no indication of mechanical, structural, or electrical failure that would have otherwise contributed to the mishap (Tabs R-103 to R-108 and DD-3 to DD-6).

b. Inspections

The Pre-Flight (PR) Inspection and Basic Post-Flight (BPO) Inspection include visually examining the aerospace vehicle and operationally checking certain systems and components to ensure no serious defects or malfunctions exist (Tab DD-3 to DD-6, DD-70 to DD-88, and DD-107 to DD-113). Non-Destructive Inspections (NDI) are a thorough (phase) inspection of the entire aerospace vehicle (Tab DD-3 to DD-4). Walk-Around Inspections (WAI) are an abbreviated PR Inspection and are completed as required prior to launch IAW the applicable Technical Orders (TOs) (Tab DD-3 to DD-6, DD-50 to DD-64, DD-68, and DD-114 to DD-120). The last BPO/PR inspection occurred on 25 June 2018 at 1600L with no discrepancies noted (Tabs R-103 to R-106 and DD-3 to DD-6). A WAI occurred on 25 June 2018 at 0745L with no discrepancies noted (Tabs R-103 to R-106 and DD-3 to DD-4).

Prior to the mishap, the MRPA, and specifically the engine, had no relevant reportable maintenance issues and all inspections were satisfactorily completed (Tab DD-3 and DD-63 to DD-65). There is no evidence that inspections were a factor in the mishap (Tab DD-3 to DD-6 and DD-63 to DD-65).

c. Maintenance Procedures

A review of the MRPA’s historical AFTO 781 series forms and IMDS revealed all maintenance actions complied with standard approved maintenance procedures and TOs (Tab DD-3 to DD-6 and DD-15 to DD-49). There is no evidence that maintenance procedures were a factor in the mishap (Tab DD-3 to DD-6, and DD-15 to DD-64).

d. Maintenance Personnel and Supervision

Personnel assigned to the 69 RG performed all required inspections, documentations, and servicing for the MRPA prior to flight (Tabs R-103 to R-108 and DD-3 to DD-6). A detailed review of maintenance activities and documentation revealed no errors (Tab DD-3 to DD-6). Personnel involved with the MRPA's preparation for flight had proper and adequate training, experience, expertise, and supervision to perform their assigned tasks (Tab DD-3 to DD-6). There is no evidence that maintenance personnel and supervision were factors in this mishap (Tab DD-3 to DD-6).

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

The ocean crash rendered all fluid samples inside the MRPA non-testable (Tab D-3). However, oil samples from the oil servicing cart were shipped to Headquarters (HQ) Air Force Petroleum Office Laboratory at Wright Patterson AFB (Tab FF-129 to FF-131). The Air Force Petroleum Office Laboratory reported the oil sample was consistent with MIL-PRF-23699 Class C/I and analysis showed no detectable contamination (Tab FF-129 and FF-130). A review of the C2 Logs from the MCE 1/5 Hz were used to verify fault codes (Tab L-2). The C2 Logs indicated that navigation and control, as well as the fuel and hydraulic systems, were all operating and responding to the MP's inputs at the time of impact (Tab L-2). There is no evidence that the condition of fuel, hydraulic fluids or oil were a factor in the mishap (Tab L-2).

f. Unscheduled Maintenance

Unscheduled maintenance is any maintenance action taken that is not the result of a scheduled inspection and normally is the result of a pilot-reported discrepancy during flight operations or a condition discovered by ground personnel during ground operations (Tab DD-3 to DD-6). There were no unscheduled maintenance actions since the last scheduled inspection (Tab DD-65 to DD-67). There is no evidence that unscheduled maintenance was a factor in the mishap (Tab DD-16 to DD-17).

6. AIRFRAME, MISSILE, OR SPACE VEHICLE SYSTEMS

a. Structures and Systems

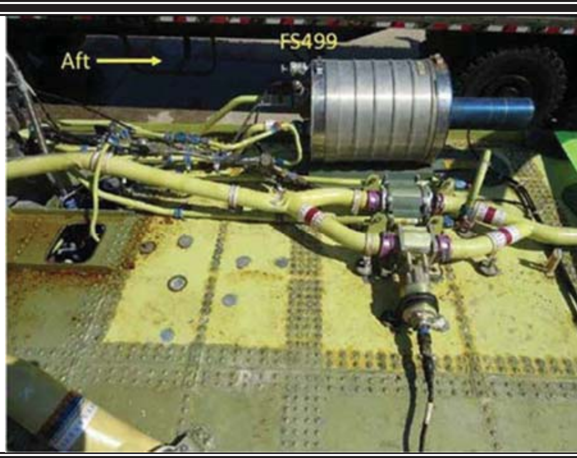
(1) Overall Aircraft Structure

Figure 1: Northrop Grumman Corporation RQ-4 Block 40 Air Vehicle. Flight International Poster, "Northrop Grumman RQ-4 Block 40 Global Hawk", Giuseppe Picarella MRAeS and Tim Bicheno-Brown, San Diego 2010, copyright 2010 Reed Business Information (Tab J-48).

Prior to impact, there was no evidence of in-flight aircraft structural failure (Tab J-53). See Figure 1 for standard RQ-4 Block 40 aircraft configuration (Tab J-48). The engine, fuselage and various airframe sub-components were recovered and delivered to Rolls-Royce Corporation (RRC) and Northrop Grumman (NG) so each company could conduct testing (Tab J-54). The technical team conducted a simulation to model the glide performance and the actual mission (Tab J-65). The MCE's C2 system logs were reviewed for any indication that would suggest structural failure or abnormal aircraft behavior (Tabs J-67 and L-2). The MRPA experienced no flight control issues either before or after the engine fault indications (Tab J-65 and J-67). The MRPA's flight performance was well within the predicted behavior, as modeled by the simulation (Tab J-65 and J-67). All of the aircraft flight parameters were typical of normal flight (Tabs J-67 and L-2). Nothing in the data leading up to and immediately before impact indicated the aircraft experienced either primary or secondary structural failure (Tabs J-67 and L-2).

The technical report found no data suggesting structural failure prior to the MRPA's impact (Tabs J-67 and L-2). NG's visual assessment of the main fuselage showed no evidence of missing doors or panels, as seen in Figure 2 below (Tab J-68 and J-71). There was no evidence of large scale damage within the engine inlet (Tab J-68). Engine fan blades were not damaged, as seen in Figure 5 and Figure 6 (Tab J-68 and J-70). There was no evidence of engine foreign object debris ingestion (Tab J-68 and J-70). The NG team noted the engine deck was intact and had no signs of damage or heat discoloration (J-68). There was no obvious puncture, cracking or signs of heat damage, as seen in Figure 3 and Figure 4 (Tab J-68 and J-72). NG also reported that the structure around the bulkheads showed no signs of discoloration, damage, failure or deformation, as seen in Figure 7 and Figure 8 (Tab J-74 to J-75). There was no evidence of an inflight engine fire (Tab J-68). According to NG, the structural damage seen in the Figures 2-8 can be attributed to the aircraft's impact with the ocean and not causal from either a primary or secondary control surface, panel or door departure ingested into the engine (Tab J-68). Based upon the MRPA's expected performance prior to and after engine failure, NG technical representatives asserted that the root cause was not related to aircraft structure or guidance and control systems (Tab J-65).

Figure 2: Fuselage (Tab J-71).



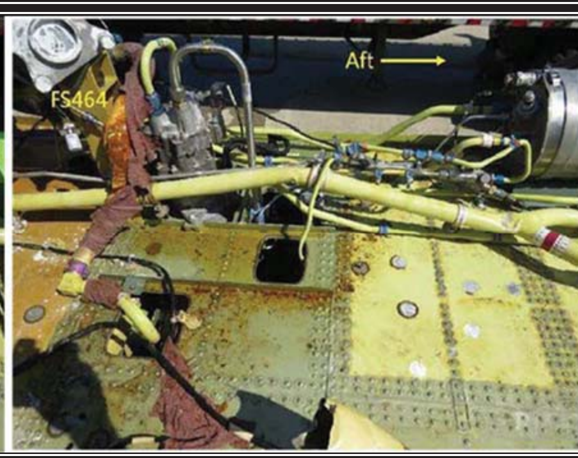


Figure 3: Engine Deck (Tab J-72).

Figure 4: Engine Deck (Tab J-72).

Figure 5: Engine Fan Blades (Tab J-70).

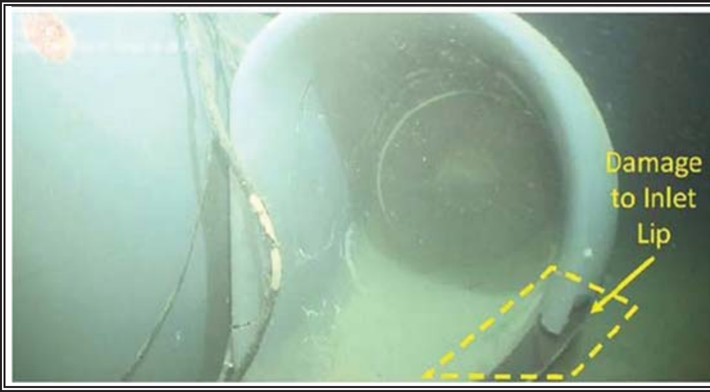


Figure 6: Inside Forward Nacelle (Tab J-70).

Figure 7: Bulkhead (Tab J-74)

Figure 8: Bulkhead (Tab J-75).

(2) Engine System

The RQ-4 engine is a Rolls-Royce AE3007H engine, which is a derivative of the commercial AE3007A and AE3007C engines (Tab J-76). It is similar to United States Air Force (USAF) airframes such as the V-22 and C-130 (Tab J-76). This engine is also known as F137-RR-100 turbo fan engine (Tab DD-5). This engine can be found installed in various Global Hawk derivative airframes (Tab J-76). The engine is controlled by a redundant FADECs (Tab J-76). The engine is installed above the aircraft's main fuselage, towards the back of the aircraft at Figure 1 above (Tab J-79). See Figure 9 for the AE3007H engine model (Tab J-48).

On 28 November 2012, the MRPA engine was originally received and installed on a different Global Hawk Aircraft (Tab DD-3 to DD-4). Routine scheduled maintenance was performed on the engine until it was uninstalled and sent for depot maintenance on 9 June 2014 (Tab DD-3). On 3 December 2014, the engine was sent to a deployed location and regular scheduled maintenance was performed (Tab DD-3). The engine was uninstalled on 3 June 2017, after 5,471.0 flight hours, for depot detailed inspection in accordance with technical data (Tab DD-3). On 13 December 2017, following depot overhaul, the engine was returned to Beale AFB for a scheduled acceptance inspection (Tab DD-3). On 26 January 2018, the engine was sent to GFAFB as a spare engine (Tab DD-3). The engine was installed on the MRPA at GFAFB, on 20 March 2018, with a history of 5,471.0 flight hours (Tabs J-49 and DD-5). The engine operated locally at GFAFB for 65.4 flight hours bringing the cumulative total of engine operating time to 5,536.4 hours prior to the mishap sortie on 25 June 2018 (Tabs K-2, DD-5, and EE-16 to EE-18).

On 18 August 2018, the engine, the Accessory Gearbox (AGB) and both FADECs were recovered from the ocean depths (Tab J-102 to J-103). These components were shipped to RRC, Indianapolis, for examination (Tab J-104). The engine was torn down to investigate the engine failure (Tab J-104). During disassembly, the engineers discovered all engine oil lines were intact, holding the proper torque values (Tab J-105). Oil lines were further inspected for material failure (Tab J-105). The AGB oil line showed evidence of fatigue and can be seen at Figures 10 through 13 (Tab J-105 to J-106). This oil line provides pressurized oil from the oil coolers to the AGB for lubrication and heat management (Tab J-105 to J-106). This AGB oil line can be seen at Figure 12 and Figure 13 (Tab J-105 to J-106). Examination of the AGB line showed the circumferential crack began on the outer surface and propagated inward to a length of 0.66 inch (Tab J-106). The fracture was near, but did not reach, the weld between the extruded tube and elbow fitting (Tab J-106). The fracture also did not reach the adjacent heat affected zone (Tab J-106).

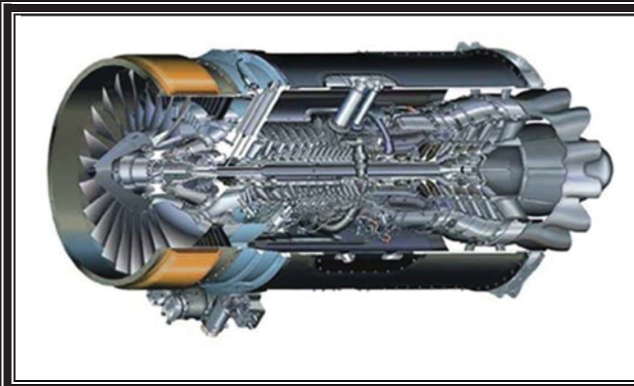


Figure 9: Rolls-Royce AE 3007H engine (Tab J-76).

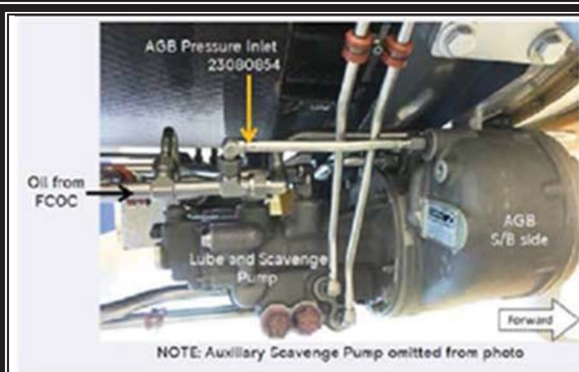


Figure 10: Installed oil line 230808 (Tab J-105).

Figure 11: Salvaged MRPA AGB and oil line (Tab J-103).

(3) Mission Control Element (MCE)

The MCE is a portable shelter from which a flight crew remotely controls an RQ-4's ground functions, takeoff, in flight, and landing operations (Tab DD-5 to DD-6). The MCE is equipped with pilot, sensor operator, quality control and communication workstations that are manned by personnel who control and/or monitor RQ-4 operations (Tab DD-5 to DD-6).

b. Evaluation and Analysis

Until the first fault message occurred on 26 June 2018, 11 hours and 49 minutes into the mission, there was no indication of any issue with the engine or MRPA (Tabs L-2 and R-14). In order to ascertain the performance and health of the engine during the failure event, 1/5 Hz MCE data was compared to predicted engine performance modeling (Tabs J-82 and L-2). In a period of 27 minutes, the engine's oil level, pressure, and temperature, as well as fan and core engine vibrations, fell out of normal operating tolerances (Tabs J-82, L-2, R-14 to R-16, and V-2.13). Specifically, the oil reservoir rapidly drained within six minutes (Tabs J-82, J-115, R-22, and V-9.100). At 0746:01L, at an altitude of 51,046 feet, the engine's oil level decreased from 2.74 gallons to 1.44 gallons (Tab J-82). At 0747:21L, the engine's oil level decreased from 1.44 gallons to 0.89 gallons (Tab J-82). At 0748:57L, the engine's oil level decreased from 1.44 gallons to 0.70 gallons (Tab J-82). The oil level remained at 0.70 gallons through the last engine indication at 0813:11L (Tab J-82). At 0747:21L, the oil pressure was steady and normal at 64.01 pounds per square inch gauge (psig) (Tab J-82). At 0748:57L, the engine's oil pressure decreased from 64.01 psig to 48.50 psig (Tab J-82). At 0749:32L, the oil pressure was down to 30.75 psig (Tab J-82). At 0749:41L oil pressure was down to 27.24 psig (Tab J-82). At 0750:54L, the oil pressure was down to 15.48 psig (Tab J-82). At 0751:39L, the oil pressure was down to 11.44 psig (Tab J-82). At 0755:10L, the oil pressure was down to 6.03 psig (Tab J-82). Between 0755:10L and 0813:11L, the oil pressure continued to decrease to 0.90 psig (Tab J-82).

As the engine oil level and oil pressure dropped, oil temperature correspondingly dropped from a normal operating temperature of 193 degrees Fahrenheit to 47.29 degrees Fahrenheit at 0813:11L (Tab J-82). Evidence revealed that engine fan and core vibrations increased after the engine operated on low oil (Tab J-82). Velocity of vibration is measured in peak units such as inches per second (ips) or millimeters per second (Tab FF-161). The ips is a measure of the instantaneous velocity (speed) at any moment in time; the higher the velocity, the stronger the vibration where another way of looking at velocity is distance per time or how much is the machine moving every second in three important directions at main bearing points (Axial, Vertical, Horizontal) (Tab FF-161). Velocity measurements and monitoring of vibration is the most common unit to identify various problems or acceptability such as: unbalance, misalignment, looseness (machinery structural, foundations, or bearings), harmonics, and many other issues in the machinery frequency range (Tab FF-161). At 0808:55L, engine fan vibrations jumped from a normal operating range of 0.175 ips to 0.423 ips (Tabs J-82 and DD-5). At 0810:09L, engine fan vibrations dangerously spiked to 0.950 ips (Tabs J-82 and DD-5). At 0813:11L, engine fan vibration held at 0.946 ips before the Thrust Lever Angle reading decreased from 66 to 0, indicating the engine chopped to idle/shutdown in flight (Tabs J-82 and DD-5). At 0809:51L, engine core vibrations spiked from 0.269 to 1.570 ips (Tabs J-82 and DD-5). At 0810:09L, engine core vibrations dangerously spiked to 3.242 ips (Tabs J-82 and DD-5). At 0813:11L, engine core vibrations dropped to 1.365 ips, as

MRPA altitude dropped from 45,000 feet to 42,322 feet, further indicating an engine shutdown (Tab J-82).

On 5 September 2018, the engine, AGB and FADECs arrived at RRC for examination (Tab J-104). USAF personnel, RRC and NG engineers were on-site (Tab J-104). During engine teardown, engineers discovered a fatigued AGB pressured oil line (Tab J-83 and J-105 to J-106). This oil line delivers pressurized oil to the engine's AGB (Tab J-83). Further analysis on the oil line was conducted at the RRC Failure Analysis Laboratory (Tab J-83). Engineers discovered evidence of high cycle fatigue (HCF), observed in a crack on the surface of the oil line (Tab J-83 and J-106).

HCF is fatigue that results in failure after a large number of repeated cycles, usually caused by high-frequency vibration. Furthermore, according to the engineer SME, HCF is derivative where the number of cycles between possible inspection(s) is too large to be able to do anything about it in a practical sense (Tab FF-161 to FF-162). The engineer SME further describes HCF to occur at the right end of the S-N curve (conventional stress-life) where the number of cycles is usually too large to be able to obtain sufficient statistically significant data to be able to characterize the material behavior with a very high degree of confidence (Tab FF-162). Using a scanning electronic microscope, RRC Failure Analysis engineers ascertained that the line cracked on the outer surface and propagated inwards (Tab J-106). There was no sign of chaffing on the oil line nor did the line fracture at a weld point, as seen in Figure 12 and Figure 13 (Tab J-106 to J-107). Upon arrival at RRC, the oil line was completely broken (Tab J-106). Inspection of the fractured surfaces revealed that 60 percent of the circumference had failed due to HCF (Tab J-106). The remaining 40 percent failed due to overload, presumably due to the separation of the accessory gearbox from the engine during recovery (Tab J-106).

Further laboratory investigation looked at the engine's Number 4 bearing revealing significant engine vibration that is consistent with oil starvation (Tab J-108). Both the inner and outer bearing races exhibited thermal damage (Tab J-108). Further uninstalled engine tests as well as installed engine tests were conducted to determine the root cause of the HCF and the stresses on oil line 23080854 (Tab J-108). No root cause of failure was determined and there was no evidence that the oil line itself was manufactured incorrectly, damaged by nicks, dented, scratched or suffered from material anomaly (Tab J-110 and J-114). All uninstalled engine and installed engine modeling met and was within RRC design guidelines (Tab J-114). The tested conditions did not exceed material capability of the oil line (Tab J-84 and J-114).

The AE3007H Global Hawk fleet has accumulated 295,000 flight hours with one observed AGB oil feed line failure (Tab J-112). According to RRC engineers, the Global Hawk's engine fleet experienced an oil tube Mean-Time Between Failure (MTBF) is 295,000 hours and the observed failure rate is 1/295,000 hours, where the probability of failure is 3.4 E-06 per flight hour (Tab J-112). When looking across the entire family of AE3007 series (A/C/H) engines, there have been a total of 5 failures of this oil tube over the course of 64 million flight hours (Tab J-85 and J-112). For the fleet of AE3007 engines, the MTBF is 15,950,500 hours and the observed failure rate is 5/15,950,500 hours, where the combined fleet probability of failure is 7.8 E-08 per flight hour (Tab J-115). The failure rate on the commercial AE3007A and AE3007C engines is less than 1.0E-06 (Tab J-85). In this context of the RQ-4, the failure rate on the AE3007H engine is higher at a probability of 3.4 E-06 (Tab J-112). Four failures were on commercial variants and one failure on a RQ-4 Global Hawk variant AE3007H (E0053) (Tab J-85 and J-112). Each of the five oil line failures occurred in flight and each oil line failed in a similar location near the elbow fitting (Tab J-115).

The most significant discovery was that two of the four previous AE3007A/C civilian fleet failures occurred immediately after on-wing maintenance had been performed (Tab J-115). One failure occurred after on-wing maintenance was performed on the Air Turbine Starter (ATS) (Tab J-115). Of note, the engine had its scheduled 1,000 hour ATS oil serviced on 25 June 2018, immediately before the mishap sortie (Tab DD-3 to DD-6). However, there is no clear causal chain as to why ATS maintenance would contribute to HCF (Tab J-115). According to RRC assessments, with respect to the AE3007H fleet, the MTBF failure probability is “Remote” for the Global Hawk engine (Tab J-112). Engineers classified the probability of future failures on the AE3007H risk as a “Medium Risk” level in RCC’s classification system, below “High” and “Serious” (Tab J-113). While the engine’s UIFSD was not immediately catastrophic on 26 June 2018, the event set off a non-recoverable sequence of events that resulted in the MRPA crashing into the ocean, near Naval Station Rota, Spain (Tabs J-112 and L-2).

In summary, according to RRC engineers, the engine subsystem was the primary contributor to the mishap (Tab J-106 and J-114). The failure of the AGB pressured oil line was concluded as the root cause of the incident (Tab J-83). See Figures 12 through 15 (Tab J-106 to J-107). The pressured oil line failed due to HCF that caused a crack allowing pressurized oil to leak out, depleting the oil reservoir in six minutes (Tab J-114 to J-115). The subsequent oil leak, oil quantity faults, oil pressure faults, engine vibration faults, UIFSD, aircraft hull loss, and recovery damage were non-contributory (Tab J-84 and J-114). There was no evidence of any other failed engine component (Tab J-105 and J-114). According to RRC, flight data, hardware in sections, and testing found no evidence that would cause HCF failure such as non-compliant assembly, excessive vibration, or a material anomaly (Tab J-84 and J-114). The cause of HCF was non-attributed and cited to an undeterminable source and combination of higher than normal steady-state and/or vibratory stresses (Tab J-114).

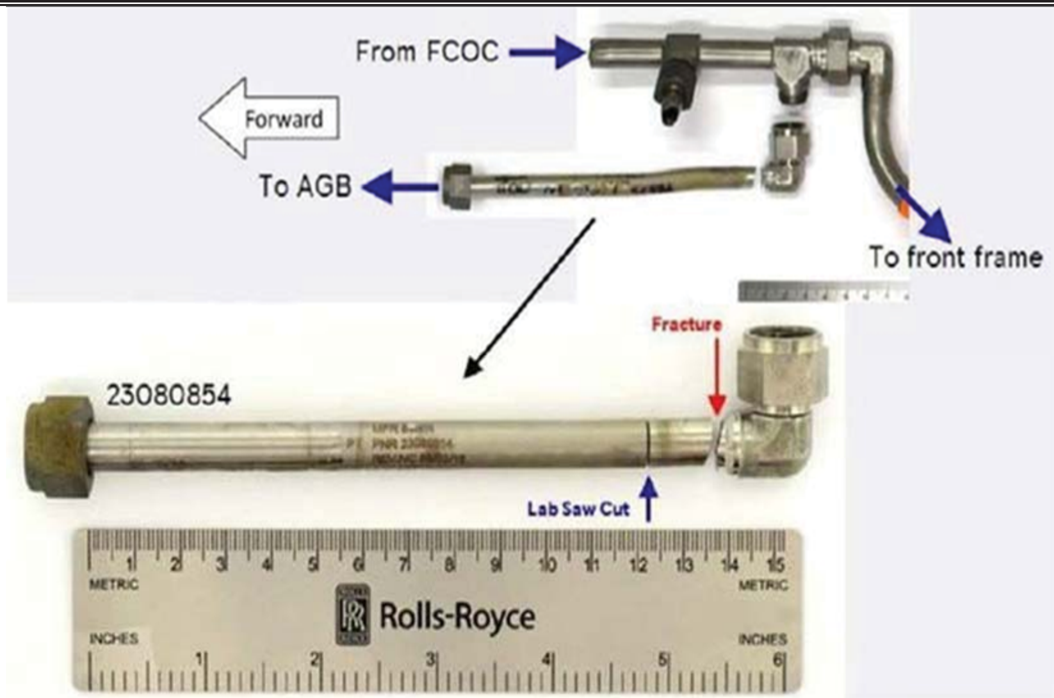


Figure 12: Failed oil line (Tab J-106).

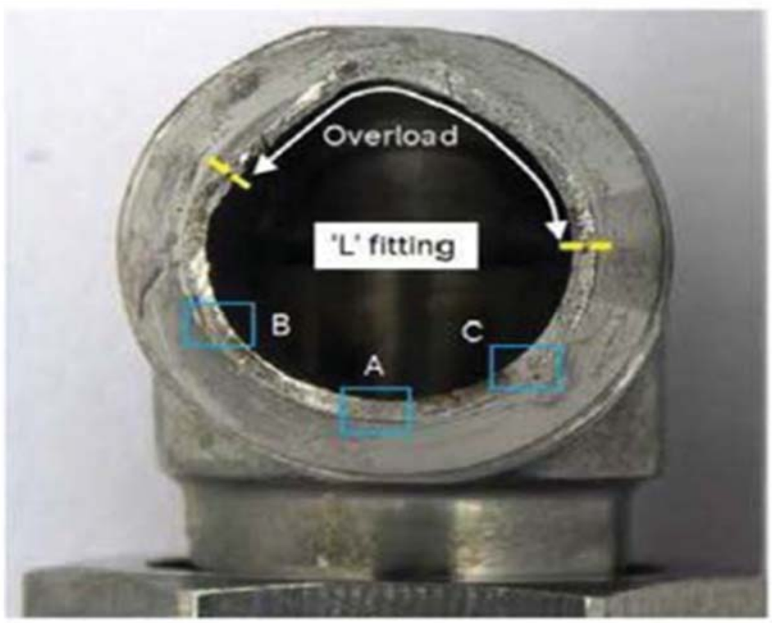


Figure 13: Oil Tube (Tab J-107).

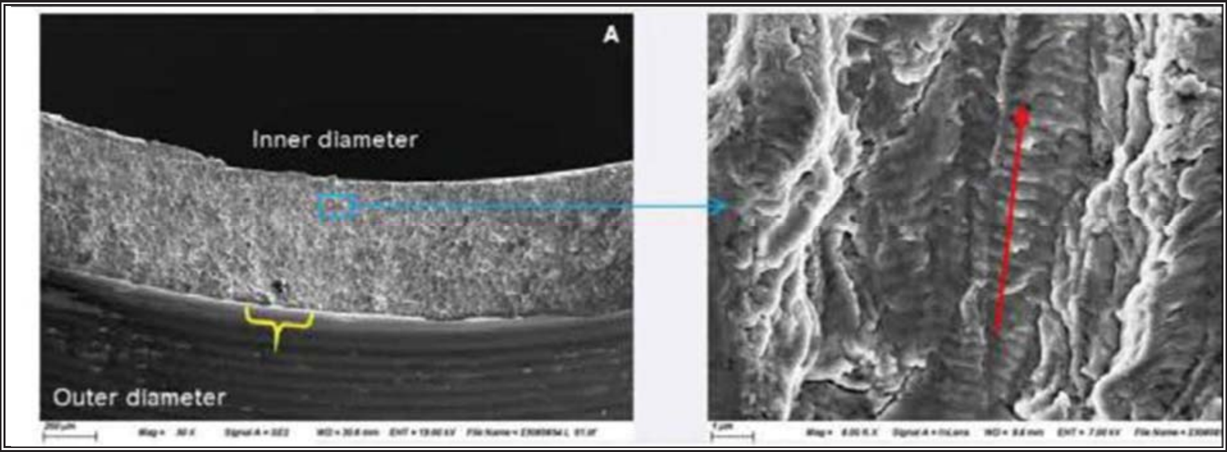


Figure 14: Oil Tube Crack Progression through Tube Wall (Radial Direction) (Tab J-107).

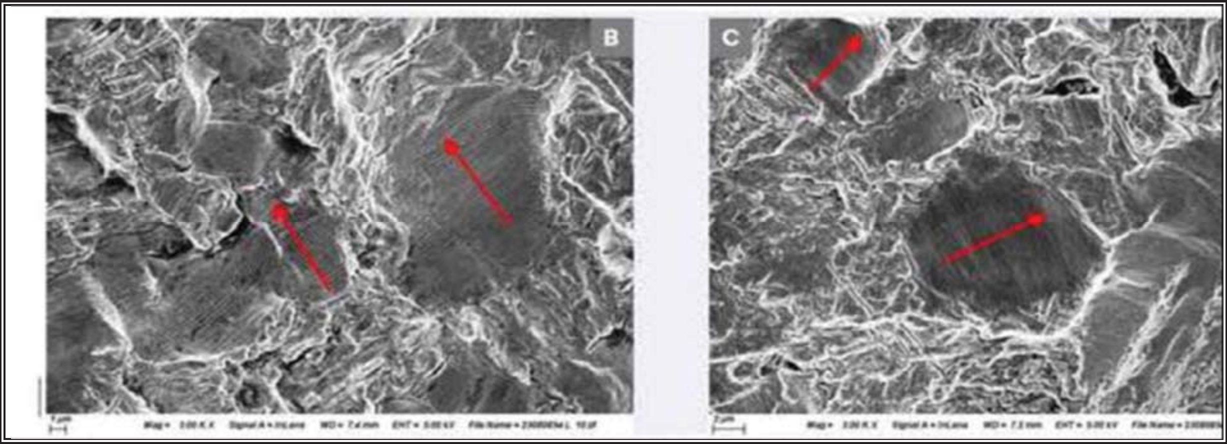


Figure 15: Oil Tube Crack Progression along Tube Wall (Circumferential Direction) (Tab J-107).

7. WEATHER

The temperature on the ground reached as high as 70°F/21°C (Tab F-3). The forecast for the departure airfield was clear with no hazards and no icing issues (Tab F-3). Isolated thunderstorms were forecasted along the planned route with maximum tops of 43,000 feet (Tab F-9). A review of the weather brief revealed that weather was not a factor in this mishap (Tab F-2 to F-13).

8. CREW QUALIFICATIONS

a. Mishap Pilot (MP)

The MP was a current and qualified RQ-4 Block 40 pilot at the time of the mishap (Tab G-2). The MP completed formal training on 14 December 2016, with an RPA Aeronautical Rating on 20 January 2017 (Tab G-9). The MP's total flight time was 234.6 hours, with 47.0 hours in the Simulator and 148.8 hours in the RQ-4 (Tab G-10 to G-13). The MP's flight time in the RQ-4 from 1 March 2018 to 26 June 2018 was as follows (Tab G-6):

	Hours	Sorties
30 Day	9.8	5
60 Day	26.8	9
90 Day	34.3	11

b. Global Hawk Operations Center Pilot (GHOCP)

The GHOCP was a current and qualified pilot at the time of the mishap (Tab T-2 to T-10). The GHOCP completed formal training on 8 July 2016 with an RPA Aeronautical Rating on 5 August 2016 (Tab T-4). The GHOCP's total flight time was 518.8 hours, with 33.8 hours in the Simulator and 362.8 hours in the RQ-4 (Tab T-5 and T-10). The GHOCP's flight time in the RQ-4 from 1 March 2018 to 26 June 2018 was as follows (Tab T-2):

	Hours	Sorties
30 Day	8.1	3
60 Day	57.0	13
90 Day	65.0	16

c. Global Hawk Operations Cell Operations Supervisor (OS)

The OS was a current and qualified pilot at the time of the mishap (Tab T-57 to T-60). The OS completed formal training on 8 April 2016 with an RPA Aeronautical Rating on 6 May 2016 (Tab T-60). The OS's total flight time was 1,650.4 hours, with 13 hours in the Simulator and 42.5 hours in the RQ-4 (Tab T-57 to T-59). The OS's flight time in the RQ-4 from 1 March 2018 to 26 June 2018 was as follows (Tab T-58):

	Hours	Sorties
30 Day	25.1	6
60 Day	36.3	10
90 Day	42.5	13

d. Hawkeye (H1)

The H1 was a current and qualified pilot at the time of the mishap (Tab G-10 to G-19). The H1 completed formal training on 24 February 2017 with an RPA Aeronautical Rating on 24 March 2017 (Tab T-16). The H1's total flight time was 208.1 hours, with 86.6 hours in the Simulator and 122.1 hours in the RQ-4 (Tab T-17 and T-20). The H1's flight time in the RQ-4 from 1 March 2018 to 26 June 2018 was as follows (Tab T-11):

	Hours	Sorties
30 Day	18.1	6
60 Day	47.7	14
90 Day	73.3	20

e. Launch and Recovery Element Pilot (LRE1)

The LRE1 was a current and qualified pilot at the time of the mishap (Tab T-49 to T-56). The LRE1 completed formal training on 21 August 2014 with an RPA Aeronautical Rating on 19 September 2014 (Tab T-52). The LRE1's total flight time as 3903.5 hours, with 94.5 hours in the Simulator and 64.2 hours in the RQ-4 (Tab T-53 and T-56). The LRE1 flight time in the RQ-4 from 1 March 2018 to 26 June 2018 was as follows (Tab T-49):

	Hours	Sorties
30 Day	0.5	1
60 Day	4.8	3
90 Day	6.8	4

f. Mission Control Element Pilot (MCE1)

The MCE1 was a current and qualified pilot at the time of the mishap (Tab T-21 to T-31). The MCE1 completed formal training on 24 August 2016 with an RPA Aeronautical Rating on 23 September 2016 (Tab T-23). The MCE1's total flight time as 840.0 hours, with 35.5 hours in the Simulator and 701.6 hours in the RQ-4 (Tab T-24 and T-31). The MCE1 flight time in the RQ-4 from 1 March 2018 to 26 June 2018 was as follows (Tab T-21):

	Hours	Sorties
30 Day	51.2	11
60 Day	88.8	20
90 Day	151	31

g. Mission Control Element Pilot (MCE2)

The MCE2 was a current and qualified pilot at the time of the mishap (Tab T-32 to T-40). The MCE2 completed formal training on 19 Jan 2017, with an RPA Aeronautical Rating on 17 Feb 2017 (Tab T-35). The MCE2's total flight time as 367.9 hours, with 56.2 hours in the Simulator and 279.3 hours in the RQ-4 (Tab T-36 and T-40). The MCE2 flight time in the RQ-4 from 1 March 2018 to 26 June 2018 was as follows (Tab T-32):

	Hours	Sorties
30 Day	37.7	11
60 Day	84.4	22
90 Day	128.2	31

h. Mission Control Element Pilot (MCE3)

The MCE3 was a current and qualified pilot at the time of the mishap (Tab T-41 to T-48). The MCE3 completed formal training on 4 February 2016, with an RPA Aeronautical Rating on 4 March 2016 (Tab T-42). The MCE3's total flight time as 502.1 hours, with 63.8 hours in the Simulator and 412.4 hours in the RQ-4 (Tab T-43 and T-48). The MCE3 flight time in the RQ-4 from 1 March 2018 to 26 June 2018 was as follows (Tab T-41):

	Hours	Sorties
30 Day	24.2	10
60 Day	50.4	19
90 Day	76.7	25

9. MEDICAL

a. Qualifications

All aircrew were medically qualified (Tabs R-6 to R-13, FF-3 to FF-100, and FF-128). There is no evidence provided to the AAIB that suggested medical qualifications were a factor in the mishap (Tabs R-6 to R-13 and FF-3 to FF-100).

b. Health

A review of the post-accident medical examination records revealed that health was not a factor in this mishap (Tabs R-6 to R-13 and FF-3 to FF-100). Toxicology tests conducted on the aircrew were negative, indicating that neither drugs nor alcohol were a factor in the mishap (Tab FF-169).

c. Lifestyle

A review of the 72-hour and 14-day histories revealed no evidence of personal habits, behavior or stress as factors in the mishap (Tabs R-6 to R-13 and FF-3 to FF-100). There is no evidence that lifestyle was a factor in the mishap (Tabs R-6 to R-13 and FF-3 to FF-100).

d. Crew Rest and Crew Duty Time

For both military and contract aircrews, crew rest is normally a minimum 12-hour non-duty period before the flight duty period begins (Tab BB-14). There is no evidence that crew rest and crew duty time were factors in the mishap (Tabs R-6 to R-13 and FF-3 to FF-100).

10. OPERATIONS AND SUPERVISION

a. Operations

There is no evidence that operations tempo was a factor in this mishap (Tab R-110).

b. Supervision

The three levels of leadership in the Air Force are tactical, operational, and strategic (Tab BB-10 to BB-12). There is no evidence that during the execution of the sortie that tactical or strategic leadership were factors in this mishap (Tabs R-37 to R-112 and FF-128). Operational competence was affected by four human factors (Tab BB-3 to BB-6).

11. HUMAN FACTORS ANALYSIS

The Department of Defense Human Factors Analysis and Classification System version 7.0 (DoD HFACS 7.0) lists potential human factors that can play a role in aircraft mishaps (Tab BB-3). Human factors describe how a person's interaction with tools, tasks, working environments, and other people influence human performance (Tab BB-3). The Board considered all human factors as prescribed in the DoD HFACS 7.0 (Tab BB-3 to BB-7).

Four human factors were identified as being relevant to the mishap: (1) Critical Information Not Communicated; (2) Provided Inadequate Procedural Guidance or Unavailable; (3) Organizational Overconfidence or Under-confidence in Equipment; and (4) Automated System Creates an Unsafe Situation (Tab BB-3 to BB-7).

a. PP106 Critical Information Not Communicated

Critical Information Not Communicated is a factor when known critical information was not provided to appropriate individuals in an accurate or timely manner (Tab BB-5).

The ERT/ferry flight mission plan did not incorporate 100% C-3 coverage (Tab V-10.3). C-3 coverage includes waypoints programmed for the MRPA to follow in the event of an emergency (Tab V-12.10). These waypoints can include crash-on-course waypoints or emergency divert waypoints (Tab V-1.4 to V-1.5, V-2.6 to V-2.9, V-6.3 to V-6.6, and V-10.15). During the mishap sortie, there were several airfields in Portugal that were within reach of the MRPA but not available to the MP to choose as a C-3 waypoint because airfield surveys were not completed (Tab V-10.3 and V-10.8 to V-10.12).

Airfields are required to be approved by MAJCOMs, per AFI 11-202, Volume 3, *General Flight Rules,* 10 August 2016 (Tabs V-10.2, V-10.26 to V-10.27, V-16.7 to V-16.8, FF-101 to FF-105, and FF-108 to FF-109). In 2015, the 9 RW CC insisted on 100% C-3 coverage for RQ-4 routes (Tab FF-102). As the request was routed, HQ ACC/A3M (Multi-Role Reconnaissance Operations Division), characterized the 9 RW CC request for 100% C-3 coverage as "not feasible" (Tabs V-6.5 to V-6.6, and FF-102). Additionally, ACC directed the 348 RS to unstitch airfields that were not approved by ACC (Tab FF-101 to FF-105). As a result, the 348 RS DO approved the mission plan with what were deemed acceptable gaps in C-3 coverage (Tabs V-2.4, V-6.11, V-6.14 to V-6.16, V-8.3, V-8.5, V-8.7 to V-8.8, V-9.3 to V-9.5, V-13.2 to V13.3, EE-2 to EE-15, and FF-101 to FF-107).

On 2 February 2015, 69 RG published a Flight Crew Information File (FCIF) directing mission planners to unstitch unapproved airfields (Tab FF-106 to FF-107). Consequently, in 2015, 348 RS unstitched all airfields not approved by ACC (Tabs V-8.3 and FF-101 to FF-107). If the waypoint is stitched, that means waypoints are pre-coded into the mission plan allowing the aircraft to autonomously move to the coded points (Tab V-6.5 to V-6.6). Unstitched waypoints are those points that are available to be selected during flight by the pilot, but they are not built, or stitched, into the direct route of the mission plan (Tab V-6.5 to V-6.6). Aside from the 2015 coordination, there is no evidence indicating the 348 RS or HQ ACC/A3M subsequently communicated to the 9 RW CC that the wing's 100% C-3 coverage requirement for RQ-4 routes was not feasible (Tabs V-3.2, V-8.2, V-8.5, V-13.2 to V-13.3, and FF-101 to FF-105). This mission plan was approved by the DO of the 348 RS in accordance with AFI 11-2RQ-4, Volume 3, *RQ-4/EQ-4, Operations Procedures*, 16 April 2013 and the FCIF (Tabs EE-3 and FF-110). As a result, the MP did not have 100% C-3 coverage for emergency landings to include no approaches into Portugal (Tab V-6.6).

b. OP003 Provided Inadequate Procedural Guidance or Publications

Provided Inadequate Procedural Guidance or Publications is a factor when written direction, checklists, graphic depictions, tables, charts or other published guidance is inadequate, misleading or inappropriate (Tab BB-6).

The Global Hawk, unlike manned platforms, must adhere to the primary constraint that it cannot land at any suitable airfield (albeit military or civil) without scripted airfield approach waypoints (Tab V-2.4 to V-2.5, V-6.6, V-9.5 to V-9.6, V-10.2, and V-13.5). To develop waypoints, an airfield survey must be conducted (Tab V-6.6, V-10.5, and V-10.9). To conduct an airfield survey, the unit must gain access to a given airfield (Tab V-6.6, V-10.3, and V-10.9). Furthermore, OCONUS airfield access near the mishap location was dependent on host-nation clearances negotiated through United States Air Forces in Europe (USAFE) (Tabs V-10.2 to V-10.4, V-10.11, V-13.3, V-13.5, and FF-108 to FF-109). Witnesses indicated that the 348 RS was required to coordinate through ACC to access USAFE airfields (Tabs V-10.2 to V-10.4, V-10.11 to V-10.13, V-13.3, and FF-108 to FF-109). The host nation negotiation process takes time (Tab V-10.3, V-10.8, and V-10.13). In addition to time, due to varying geo-political constraints, the process to secure a host nation agreement for selected airfields is difficult (Tab V-10.3, V-10.8, V-10.13, and V-13.3).

Once host nation agreements for both airspace and airfield have been approved by ACC and USAFE, then the 348 RS can coordinate airfield surveys to develop RQ-4 approach, landing, departure, taxi, and parking waypoints, as well as other logistical/maintenance and base support requirements (Tabs V-6.6, V-10.3 to V-10.4, V-10.19 to V-10.20, V-13.4, FF-108 to FF-109, and FF-112 to FF-119).

Completing an airfield survey can take one to two weeks (Tab V-10.5 and V-13.4). Once the required RQ-4 waypoints are coded into lines of software, unit mission planners incorporate the waypoints into the mission plan (Tab V-2.4 to V-2.6, V-6.6, and V-10.19). This outsourced software coding process can take over one week, dependent upon the airfield complexity (Tab V-8.6 to V-8.7 and V-10.19 to V-10.20). To further complicate the process, neither the 348 RS nor the MAJCOMs have a formal process to communicate and collectively provide a prioritized updated list of divert airfields (Tabs V-6.14 to V-6.15, V-8.7 to V- 8.8, V-10.6 to V-10.8, V-13.4, and FF-109 to FF-110). Airfield status and requests are informally tracked on Excel spreadsheets at the unit or at the ACC SharePoint site; however, evidence presented to the board indicated that there was no centralized management system for the list itself (Tabs V-2.4, V-6.14 to V-6.15, V-8.7 to V-8.8, V-9.6, V-10.7 to V-10.8, FF-109 to FF-110, and FF-112 to FF-119).

During the mishap sortie, there were several airfields in Portugal that were within reach of the MRPA but not available to the MP to choose as a C-3 waypoint because airfield surveys were not conducted. (Tab V-10.3 and V-10.8 to V-10.12). According to the Chief Mission Planning Cell, the airfield approval process for unmanned platforms of the 348 RS is not clear (Tabs V-8.4 to V-8.5, V-8.7 to V-8.9, V-9.4 to V-9.5, V-10.8, V-10.21, V-13.4, V-16.2 to V-16.3, and FF-101 to FF-105). Per AFI 11-202V3, except in cases of emergencies and divert situations, airfields are required to be approved by MAJCOMs (Tabs V-9.4, V-10.2 to V-10.3, V-13.2 to V-13.3, and FF-102). For manned platforms, this guidance is clear (Tab V-1.3 to V-1.4, V-10.18, and V-10.21). According to witnesses, the approval process in the 348 RS for divert situations is problematic (Tab V-8.7 to V-8.8, V-9.4 to V-9.5, V-10.2 to V-10.3, and V-13.4). Mission planning software is inflexible (Tab V-9.4 to V-9.5, V-10.19, and V-13.5). Additionally, IAW AFI 31-101, *Integrated Defense*, 6 July 2017, for Integrated Defense, since the Global Hawk is a PL2/3 asset and is unmanned, landing at an airfield without USAF personnel to secure the aircraft presents additional operational constraints (Tab V-13.5).

Furthermore, evidence revealed that there was no process that automatically pulled current airfield Notice to Airmen (NOTAM) for previously stitched/unstitched airfields in a mission plan (Tabs V-6.16, FF-108 to FF-109, and FF-112 to FF-119). Consequently, the process yielded inadequate guidance, making 100% C-3 coverage unattainable for OCONUS missions (Tab V-10.9 to V-10.12). As a result, the approved mission plan contained known and, according to witnesses, acceptable gaps in C-3 coverage (Tabs V-2.4, V-6.14 to V-6.16, V-8.7 to V-8.8, V-9.3 to V-9.5, EE-2 to EE-15).

c. OC003 Organizational Over-confidence or Under-confidence in Equipment

Organizational Over-confidence or Under-confidence in Equipment is a factor when there is organizational over-confidence or under-confidence in an aircraft, vehicle, device, system or any other equipment (Tab BB-7).

Statistically, the RQ-4 platform is reliable, as recorded in Grand Forks RQ-4 Health of Feet maintenance metrics and testimony (Tabs R-108, V-13.2, and DD-7). The Rolls-Royce AE3007H engine is also reliable, as illustrated by a mean-time between failure rate of 0/295,000 flight hours (Tabs J-112 and R-108). Witnesses believed the RQ-4 had repeatedly proven its reliability (Tab V-9.2 and V-13.2). Thus, witnesses from the unit indicated that, IAW AFI 90-802, *Risk Management*, 11 February 2013 there was no reason to re-evaluate Risk Management (RM) concerning the approved mission plan (Tabs R-108, V-1.4, V-2.6 to V-2.7, V-6.8, V-8.9 to V-8.10, V-9.2, V-9.5 to V-9.6, V-12.8 to V-12.9, and V-13.2). IAW AFI 90-802, the key principles of RM are to refuse risks that are not necessary, to ensure risk decisions are made at the right level in the chain of command, to take calculated risks whenever benefits are considered to be more significant than the costs, and to make use of the RM decision-making process at every stage of planning (Tab FF-163). The 348 RS ferry flights had been backstopped with years of success (Tab V-8.10, V-9.2, and V-13.2). All of the mission commanders interviewed testified that ferry flights were low risk (Tab V-1.5, V-8.10, and V-9.2). Furthermore, the mission planning cell had been conditioned to only request additional airfields when there was no route to accomplish a given mission, as opposed to building a mission plan with routes that have a minimum RM threshold/percentage for acceptable and unacceptable C-3 coverage/divert airfields (Tab V-6.8 to V-6.9, V-8.10, V-9.3, and V-13.3). Because the unit did not contemplate emergency divert situations for all sections of the ferry flight, several airfields in Portugal were not available in the approved June 2018 mission plan (Tabs V-1.4 to V-1.5, V-3.2, V-8.10, V-9.2 to V-9.6, V-10.11, V-12.5 V-12.6, and EE-2 to EE-15).

d. PE205 Automated System Creates an Unsafe Situation

Automated System Creates an Unsafe Situation is a factor when the design, function, reliability, symbology, logic, or other aspect of automated systems creates an unsafe situation (Tab BB-4).

Witnesses indicated that the mission planning software was inflexible impacting PIC ability to make real time flight inputs to the mission plan (Tab V-2.4 to V-2.6, V-6.6 to V-6.7, V-14.5, and V-14.8). Only a finite number of airfield waypoints can be stitched or unstitched into the mission plan due to the hard drive constraint of the IMMC (Tab Y-5). If an airfield is not "stitched" or "unstitched," then it was unavailable to the PIC (Tab V-1.17 to V-1.18, V-6.5 to V-6.7, V-9.6, V-10.10, V-10.18 to V-10.19, V-11.10 to V-11.13, and V-12.4 to V-12.5). Pilots were not taught a manual landing (Tab V-1.18 to V-1.19, V-2.6, and V-6.6 to V-6.7). According to the 348 RS/DO, pilots were trained to land at stitched or unstitched airfields (Tab V-1.18 to V-1.19, V-6.6, V-11.10 to V-11.13, and V-12.5). Witnesses testified that, during the mishap event on 26 June 2018, three suitable Portuguese airfields not identified in the mission plan were available but not accessible to the MP since the airfields were neither stitched nor unstitched, thereby precluding landing (Tabs V-2.31, V-6.6 to V-6.7, V-10.12, V-11.13, and FF-103 to FF-107). The constraints of the mission planning software created a situation whereby several airfields in Portugal were not available in the approved June 2018 mission plan (Tabs V-2.30 to V-2.35, V-6.6 to V-6.7, and EE-2 to EE-15).

12. GOVERNING DIRECTIVES AND PUBLICATIONS

a. Publically Available Directives and Publications Relevant to the Mishap

(1) AFI 11-202 Volume 3, *General Flight Rules*, 10 August 2016

(2) AFI 11-2RQ-4 Volume 3, *RQ-4/EQ-4*, *Operations Procedures*, 16 April 2013

(3) AFI 31-101, *Integrated Defense*, 6 July 2017

(4) AFI 48-123, *Medical Examinations & Standards*, 5 Nov 2013; AFMC Supplement, 23 October 2014

(5) AFI 51-307, *Aerospace and Ground Accident Investigations*, 18 March 2019

(6) AFI 90-802, *Risk Management*, 11 February 2013

(7) T.O. 00-20-1 ACC Sup 1, *Aerospace Equipment Maintenance Inspection Documentation, Policies and Procedures*, 9 December 2016

(8) T.O. 00-20-2, *Maintenance Data Documentation*, 15 March 2016

NOTICE: All AFIs listed above are available digitally on the Air Force Departmental

Publishing Office website at: http://www.e-publishing.af.mil. All T.O.s are available on the Tinker AFB website at: http://www.tinker.af.mil/Home/Technical-Orders/. Title 14 of the CFR is available at: https://www.gpo.gov/fdsys/pkg/CFR-2004-title14- vol1/content-detail.html.

b. Other Directives and Publications Relevant to the Mishap

(1) FCIF 15-06B, 69 RG Memorandum for Record on Flight Crew Information File, 2 February 2015
(2) RQ-4 SCG, RQ-4 Security Classification/Declassification Guide, 1 August 2009

c. Known or Suspected Deviations from Directives or Publications

Not applicable.

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12 June 2020

ROBERT K. CLEMENT, Colonel, USAF
President, Abbreviated Accident
Investigation Board

STATEMENT OF OPINION

RQ-4B, T/N 09-2041
NEAR THE COAST OF ROTA, SPAIN
26 JUNE 2018

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 26 June 2018, at approximately 0919 local (L) time,* a RQ-4B Global Hawk, tail number (T/N) 09-2041, made impact with the ocean off the coast of Rota, Spain, approximately 13 hours and 24 minutes after takeoff from Grand Forks Air Force Base (GFAFB), North Dakota (ND), for a ferry flight to a downrange operational location. At the time of the mishap, the mishap remotely piloted aircraft (MRPA) was operated by the 348th Reconnaissance Squadron (348 RS), a geographically separated unit of the 9th Reconnaissance Wing (9 RW), located at GFAFB, ND.

I find, by a preponderance of evidence, that the cause of the mishap was an oil leak from a cracked oil line, which caused an engine uncommanded inflight shutdown (UIFSD). Furthermore, I find, by a preponderance of evidence, that the unit's approved mission plan for the mishap sortie did not provide the mishap pilot (MP) with sufficient emergency divert airfields for unpowered aircraft recovery, substantially contributing to the mishap. I developed my opinion and determined the mishap sequence of events by analyzing factual data from the MRPA. This data included the mission control element data logs, radar information, maintenance records, witness interviews, information provided by technical experts, and Air Force directives and guidance.

2. CAUSE

I find, by a preponderance of evidence, that the cause of the mishap was an oil leak from a cracked oil line, which caused an engine UIFSD. On 26 June 2018, at approximately 0745L, after 11 hours and 49 minutes of uneventful flight, the MRPA began receiving various engine faults as the aircraft's engine quickly leaked oil. After a thorough investigation, there was no evidence of any preflight discrepancy, in-flight aircraft structural, or engine failure. However, evidence revealed the engine subsystem did fail. Specifically, the pressurized oil line that feeds the engine's Accessory Gearbox failed under high cycle fatigue, leading to a substantial oil leak that quickly depleted the oil reservoir, causing a UIFSD. There was no evidence of any other failed engine component. The findings are consistent with expert analysis and the evidence, so I find that an oil leak from a

* All times referenced herein, to include the time of the overseas mishap, are expressed in local time for the stateside Air Force base operating the aircraft and tracking the overall sequence of events.

cracked oil line caused the engine UIFSD and resulting mishap damage.

3. SUBSTANTIALLY CONTRIBUTING FACTOR

I find, by a preponderance of evidence, that the unit's approved mission plan for the mishap sortie did not provide the MP with sufficient emergency divert airfields for unpowered aircraft recovery, substantially contributing to the mishap. For nearly an hour leading up to the 0919L impact, the MP glided the MRPA towards an emergency divert airfield at Naval Station Rota, Spain, but ultimately calculated that the MRPA would not safely make the airfield.

The unit's mission planning for the mishap sortie was adversely impacted by critical information not communicated up and down the chain of command. In 2015, the 9 RW Commander (CC) requested the headquarters (HQ) Air Combat Command (ACC) and the 69 Reconnaissance Group (69 RG) secure 100% C-3 coverage. For various reasons, ranging from internal and external process constraints to the 348 RS Director of Operations (SQDO) and Squadron CC assuming mission risk, the 348 RS mission planners did not adhere to the 9 RW CC's guidance. Furthermore, in 2015, HQ ACC/A3M action officers (Multi-Role Reconnaissance Operations Division) did not clearly communicate back to the 9 RW CC that the wing's C-3 guidance was not feasible. Since 2015, the mishap sortie's mission plan was repeatedly approved by the SQDO and routinely executed with known and acceptable gaps of C-3 coverage. The unit's mission planning was further convoluted by an inflexible process.

First, it is important to understand basic mission planning for any Global Hawk sortie. Mission planning requires waypoints to be coded weeks in advance of mission execution. Waypoints require outsourced software coding for the aircraft to move point to point. Waypoints are required for any aircraft movement, to include parking, taxi, take-off, flying, approach and landing. Therefore, the Global Hawk requires waypoints to, from and at all airfields to be either stitched or unstitched. If the waypoint is stitched, that means waypoints are pre-coded into the mission plan and the waypoints autonomously move the aircraft. Unstitched waypoints are those points that are available to be selected during flight by the pilot, but they are not built into the direct route of mission plan. If an airfield is not "stitched" or "unstitched" into the mission plan, then a manual landing is required. Pilots are not taught a manual landing. This is a critical mission planning constraint.

This constraint underpins the difficulty 348 RS mission-planners face when seeking airspace and airfield access. This is an informal process, requiring communication both up the chain from the 348 RS to HQ ACC, then to HQ USAFE and back down the chain from HQ USAFE to HQ ACC to the 348 RS. However, the primary mission planning constraint of waypoints is always present. Given the constraint in AFI 11-202V3, 348 RS mission planners now must request approval to either stich or unstitch all required and necessary airfields into the mission plan. Specifying overseas divert airfields in cases of emergencies must also be approved because the unit relies on the host nation to grant access to any airfield to collect waypoints. And, 69 RG guidance, codified in a Flight Crew Information File and in accordance with HQ ACC guidance, directed only approved airfields will be mission planned. RQ-4 mission plans may only include C-3 stitching to HQ ACC-approved air fields or ditch points within DoD-owned land or uncongested bodies of water.

On 26 June 2018, during the mishap event, several suitable airfields in Portugal were available to the MP. All of these three airfields were closer than Naval Station Rota, Spain. Any of these airfields could have been utilized by the MP if waypoints had been either stitched or unstitched into the mission plan. Since only Naval Station Rota was coded with waypoints into the mission plan, the MP was limited to either crashing the MRPA into the ocean or try to make the distance to the only divert airfield available.

Lastly, top to bottom organizational overconfidence embraced the 348 RS Global Hawk fleet's near flawless performance over the past 295,000 flight hours, where its persistent performance became the norm. This overconfidence resonated through all aspects of the 69 RG, where the operational pressure to meet combatant command requirements overshadowed the inherent risks of repeatedly flying long endurance sorties. As a result, the 348 RS approved the June 2018 Mission Plan without a risk management model or matrix to identify a minimum threshold of what is and is not acceptable C-3 coverage.

4. CONCLUSION

I find, by a preponderance of evidence, that the cause of the mishap was an oil leak from a cracked oil line, which caused an engine UIFSD. Furthermore, I find, by a preponderance of evidence, that the unit's approved mission plan for the mishap sortie did not provide the MP with sufficient emergency divert airfields for unpowered aircraft recovery, substantially contributing to the mishap.

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12 June 2020

ROBERT K. CLEMENT, Colonel, USAF
President, Abbreviated Accident
Investigation Board

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