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CREWING THE HAV AIRLANDER 10:
A FINANCIAL ANALYSIS OF ALTERNATIVES

by

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December 2023

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ABSTRACT

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LIST OF ACRONYMS AND ABBREVIATIONS

2P	Patrol Plane Pilot
3P/PM	Patrol Plane Co-Pilot / Pilot Monitoring
AFM	Aircraft Flight Manual
AIM	Aeronautical Information Manual
ANA	American Nurses Association
AoA	Analysis of Alternatives
AOL	Aircraft Operating Limitations
ASuW	Anti-Surface Warfare
ASW	Anti-submarine Warfare
AWO	Acoustic Warfare Operator
CNAF	Commander, Naval Air Forces
CNO	Chief of Naval Operations
CO	Commanding Officer
COTAC	Co-tactical Coordinator
DOD	Department of Defense
DoDI	Department of Defense Issuances
DON	Department of the Navy
EASA	European Aviation Safety Agency
EO/IR	Electro-optical/Infrared
ESM	Electronic Support Measures
EWO	Electronic Warfare Operator
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FDP	Flight Duty Period
HADR	Humanitarian Assistance Disaster Relief
HAV	Hybrid Air Vehicle
HS	Homeland Security

IAW	In Accordance With
ICAO	International Civil Aviation Organization
IFF	Identification Friend or Foe
IFR	Instrument Flight Rules
ISR	Intelligence, Surveillance, Reconnaissance
LEMV	Long Endurance Multi-Intelligence Vehicle
LTA	Lighter than Air
NATOPS	Naval Air Training Operating Procedures Standardization
NFO	Naval Flight Officer
NIOSH	National Institute for Occupational Safety and Health
NPS	Naval Postgraduate School
OMB	Office of Management and Budget
PPC	Patrol Plane Commander
SAR	Search and Rescue
SIC	Second in Command
TACCO	Tactical Coordinator
USN	United States Navy
WOCL	Window of Circadian Low

EXECUTIVE SUMMARY

The CNO has tasked the Navy to identify economically viable and environmentally friendly vehicles as it continues to advance its technology. The Airlander 10 could potentially address this call, but before proceeding, specific considerations needed to be addressed. These included determining crewing requirements, defining potential missions, and evaluating the financial feasibility of Airlander 10. This study investigated the crewing of Airlander 10 by analyzing existing regulations and insights from Crew Endurance studies. It detailed and strategized potential real-world applications for Airlander 10, collected financial data, all while maintaining comparisons with the Navy's P-8A Poseidon.

The recent naval collisions in 2017 highlighted the devastating consequences of fatigue-related incidents, underscoring the critical need for well-rested crewmembers in ensuring safety, performance, and overall well-being. In aviation, the preservation of crew rest is paramount. As a result, stringent regulations are in place to safeguard the safety and performance amongst pilots and aircrew. As Airlander 10 is capable of long-haul flights (greater than 21 hours) it presented a unique problem in manning the aircraft. The suggested crewing approach for Airlander 10 is meticulously designed, considering variables like operational tempo, environmental conditions, risk factors, and flight hours, all while adhering to current relevant civil and military aviation regulations. For flights lasting 72–120 hours, the recommended configuration involves three crews onboard, totaling 18 crew members, with a minimum of three required. In contrast, for flights under 18 hours, two crews onboard Airlander 10 would comprise 12 mission crew members and two pilots. This proposal promotes a flexible approach that considers both single-piloted and multi-piloted operations during different phases of operation, while continuing to adhere to established regulations. Drawing from the Navy's proven success, circadian-based watch schedules have been incorporated into Airlander 10. These schedules not only bolster overall safety measures but also prioritize the health, safety, and efficiency of crew members, thereby significantly contributing to mission success.

In light of the U.S. Navy's commitment to upgrading its fleet with more energy-efficient vessels and platforms, Airlander 10 must be considered. The Navy's current mainstay, the P-8A Poseidon, has demonstrated superior efficiency compared to its predecessor the Orion. Airlander 10 offers an opportunity to transform maritime aviation. As an energy efficient vehicle, the Airlander 10 would reduce fuel consumption and operating costs, while increasing range and endurance for the fleet. A comparison of the Airlander 10 and P-8A was conducted, highlighting aspects such as crewing, outfitting, arming, missions, and the associated costs for each platform.

Two mission scenarios, Anti-Submarine Warfare and Intelligence, Surveillance, and Reconnaissance, underwent a comprehensive examination. The findings indicated that the P-8A performs exceptionally well in missions requiring swift responsiveness and adaptability to changing circumstances. In contrast, the Airlander 10 demonstrates excellence in missions demanding extended endurance or characterized by less dynamic changes. Notably, the Airlander 10's slower repositioning capabilities make it better suited for missions like ISR as opposed to ASW, and as such, it should be deployed accordingly.

If policymakers and the Department of Defense choose to move forward with the acquisition of Airlander 10, a financial assessment and comparison would be essential. This study conducted an analysis of alternatives between Airlander 10 and P-8A. The analysis employed a Discounted Cash Flow method to account for the time value of money throughout the lifespan of the assets. The results unequivocally demonstrated that Airlander 10 offered significant cost savings compared to P-8A, particularly in terms of fuel and airframe expenses.

While Airlander 10 offers considerable advantages for future naval applications, the optimal strategy to capitalize on these benefits involves deploying a combination of Airlander 10s and P-8As. Employing the Airlander 10 for extended missions requiring extensive coverage would release P-8A crews for versatile and dynamic tasks such as ASW. By introducing the Airlander 10, the Navy can take a substantial step towards shaping a military force that prioritizes adaptability, resource efficiency, and environmental responsibility. This strategic move aligns with the broader goal of crafting a more versatile and eco-conscious defense system. The Airlander 10 distinguishes itself

from the P-8A with its exceptional green energy efficiency, resulting in significantly reduced fuel consumption. This remarkable capability, combined with its economic advantages, strongly underscores the Airlander 10 as an aircraft deserving further research and in-depth analysis.

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We want to express our heartfelt gratitude to the individuals and organizations who have played a pivotal role in the successful execution of this study.

First and foremost, we extend our sincere appreciation to Dr. Nick Dew for his invaluable guidance, unwavering support, and candid feedback throughout the entire research process. His mentorship, direction, and patience have played a pivotal role in this undertaking.

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I. INTRODUCTION

A. PURPOSE

In a world of constrained budgets, the U.S. Navy (USN) must pivot toward cost-effective technology solutions to maintain a competitive advantage against adversaries, while achieving overall strategic goals. The former Chief of Naval Operations (CNO) emphasized the Navy must phase out legacy platforms that have become economically unsustainable and obsolete while maintaining its status as a maritime force (Gilday, 2022). Coupled with the Department of Defense's (DOD's) "Department of Defense Climate Adaption Plan" published in 2021, the emphasis on developing an adaptable force that is efficient, effective, and energy conscious has become self-evident (Department of Defense, 2021b).

In response to these challenges, the Navy must shift focus and proactively invest in the development of more affordable alternatives. For example, the P-8A Poseidon, the USN's newest maritime naval aircraft, is one candidate for closer evaluation of cost, capability, and energy efficiency. The P-8A has a track record for dependability as a critical asset for naval surveillance and anti-submarine warfare, yet still comes with substantial operating costs in terms of overall acquisition cost, fuel consumption, and required maintenance. The development of any viable alternatives must incorporate the Navy's goals to minimize environmental impact, reduce fuel consumption, and enhance mission endurance while maintaining effectiveness.

One option deserving of the Navy's consideration is the Hybrid Air Vehicle (HAV) Airlander 10. This aircraft could harmonize the overarching objective of achieving cost-effectiveness while minimizing carbon emissions that align with the DOD Climate Action initiatives. The HAV Airlander 10 may allow for substantial cost savings when compared to traditional fixed-wing aircraft. Its innovative design facilitates extended endurance and reduced fuel consumption, potentially yielding a considerable reduction in long-term operational expenses. Moreover, the Airlander 10's capability to maintain prolonged flight

missions may be attractive, as it enables the U.S. Navy to leverage a single platform with the versatility to meet a range of operational roles.

B. RESEARCH QUESTIONS

The purpose of this study is to determine crew composition for an Airlander undertaking naval operations and conduct an overall financial Analysis of Alternatives (AoA) to understand the missions in which the Airlander might be competitive with existing platforms. The thesis examined the following research questions:

- What is crew rest and what role does Circadian Rhythm play in civil and military operations?
- How would Airlander 10 be piloted and crewed for multi-day missions?
- How would Airlander 10 perform in comparison to the P-8A in real-world scenarios?
- What costs are associated with acquiring and operating the Airlander 10 and P-8A over a 25-year lifespan?

This research examines two mission scenarios Anti-submarine Warfare and Intelligence, Surveillance, and Reconnaissance (ASW and ISR) comparing the Airlander 10 to the USN P-8A Poseidon (the USN's current multirole maritime air asset).

C. METHODOLOGY

1. Analysis of Crew Rest and Crew Rest Regulations

In 2017, after over a decade of research, Dr. Nita Shattuck, and the Naval Postgraduate School (NPS) Crew Endurance Team concluded and presented their extensive circadian rhythm sleep study. Their study caught the attention of then Commander, Naval Surface Forces and transformed the way the surface fleet now builds its duty section watchbills. Using this study, factors such as sufficient rest and circadian rhythm will be principal in determining what watch-bill works best on Airlander 10, which can stay airborne for up to five days. This sleep study partnered with current civil aviation

regulations such as the Federal Aviation Regulation (FAR) Parts 61 and 91 and naval aviation regulations found in Commander Naval Air Forces (CNAF) 3710, will guide the establishment of how many crew members total will be required to conduct both standard civil flights and military operational flights.

2. Scenario-based Asset Comparison

To accentuate the potential of Airlander 10 as a viable solution in response to the DOD's Climate Adaption Plan, it is critical to cross-examine against successful and capable assets the USN currently uses. The P-8A is an ideal candidate due to its long relative on-station endurance, its multi-purpose maritime use, its mission success rate, and crewing model. Strengths and weaknesses of both the P-8A and Airlander 10 will be highlighted via comparing performance parameters such as max/cruise altitudes, airspeeds, weight capacities, and mission scenarios.

3. Financial Analysis of Alternatives

In accordance with the guidelines outlined in Department of Defense Instruction 5000.84 (DoDI 5000.84) (2020) and Office of Management and Budget (OMB) Circular A94, it is mandatory to carry out a financial Analysis of Alternatives (AoA) before initiating the procurement of any significant program. The AoA for the P-8A and Airlander 10 involved the collection and comparison of expenses associated with the same annual flight hours. After the AoA, a sensitivity analysis was executed to assess the impact of parameter changes on the outcomes.

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II. CREW REST BACKGROUND

A. CREW ENDURANCE

Crew rest is critical for an effective and resilient crew. The importance of crew endurance in operational effectiveness cannot be overstated. When crewmembers are fatigued, performance and safety is placed at risk. This was made evident in 2017 when the Navy suffered two separate and tragic collisions between its guided-missile destroyers, the USS Fitzgerald (DDG 62) and the USS John S. McCain (DDG 56), and merchant ships (Department of the Navy, 2017). In both cases, the Navy's investigations found that one major factor contributing to the collisions was crew fatigue. As a result, the Navy shifted its surface fleet watchbills to better align with principles from the aviation and submarine force. Dr. Nita Shattuck and the NPS Crew Endurance Team performed extensive studies which resulted in the publication of the Crew Endurance Handbook, focused on improving the performance and quality of life for U.S. Navy Sailors (Crew Endurance Handbook, 2023). This Handbook guides leaders with best practices in developing schedules to support the health and effectiveness of their crews and organizations.

B. CIRCADIAN RHYTHM

One key finding from the USS Fitzgerald (DDG 62) and the USS John S. McCain (DDG 56) incidents, and the Crew Endurance Handbook is the importance of circadian rhythm and the establishment of "circadian rhythm watchbills." Circadian rhythms are intricate internal processes that play a crucial role in regulating various aspects of our daily lives. These rhythms serve a vital purpose, orchestrating our bodily functions in alignment with anticipated environmental changes. They dictate the optimal time for activity, rest, and nourishment, making sure that our body is prepared for the demands of the day. The intricacy of these rhythms becomes evident when individuals need to adapt to new sleep schedules due to work or travel. The circadian pacemaker, which tends to operate on a cycle slightly longer than 24 hours, makes it easier to adjust to a later bedtime and wake-up time, but struggles when one must rise earlier (CDC, 2021). This discrepancy is

challenging for shift workers whose schedules often clash with the natural light/dark cycle, resulting in circadian rhythms that promote daytime sleep and nighttime wakefulness.

The circadian-based watchbill is a work and rest schedule designed to adhere to the natural 24-hour day cycle with watches and sleep occurring at the same time each day. The essence of this watchbill lies in its ability to synchronize work, meals, and rest, ensuring that individuals engage in these activities the same time each day. In doing so, it harnesses the innate 24-hour rhythm ingrained in the biological system. The philosophy is simple yet profound: well-rested crewmembers are the bedrock of operational success. Sleep deprivation can compromise crewmembers' cognitive abilities, decision-making skills, and overall physical health. As we navigate the complexities of modern naval operations, the value of a circadian-based watchbill and steadfast adherence to sleep schedules becomes more apparent in achieving mission success and crew resilience. In the ever-evolving landscape of modern-day naval operations, the significance of watch schedules aligned with circadian rhythms is paramount to mission success and the resilience of the crew.

C. WHY IT'S IMPORTANT

As the Navy operates 24/7, with personnel tasked with critical duties and missions, aligning work schedules with circadian rhythms is crucial to ensuring that sailors perform at their highest levels of alertness and capability during vital operational periods. This reduces the threat of errors and accidents in high-risk evolutions such as navigation, combat control, aviation, and maintenance. Safety is of utmost concern in the maritime environment, where fatigue-related incidents can have catastrophic consequences. By synchronizing watchbills along circadian rhythms, the Navy can significantly enhance safety measures, decreasing the likelihood of accidents caused by sleep-deprived or fatigued personnel (Crew Endurance Handbook, 2023). Circadian rhythm watchbills play a pivotal role in mitigating the detrimental effects of shift work, including sleep disturbances and mood disorders, ultimately leading to an enhanced overall well-being among crew members.

Fatigue-induced errors can result in substantial costs, encompassing equipment damage, lost time, and even human lives. The implementation of a circadian rhythm

watchbill aids sailors in adapting swiftly to these changes, minimizing disruptions to their internal clocks and sustaining their operational effectiveness (Crew Endurance Handbook, 2023). The Navy has seen success in implementing the circadian watchbill across its fleet. While there is not one set standard for how a watchbill should be created there are watchbills that are categorized as Good, Bad, and Ugly. Figure 1 is a visual representation of Good, Bad, and Ugly Circadian Watchbills that show how watch teams are divided into sections over a 24-hour span.

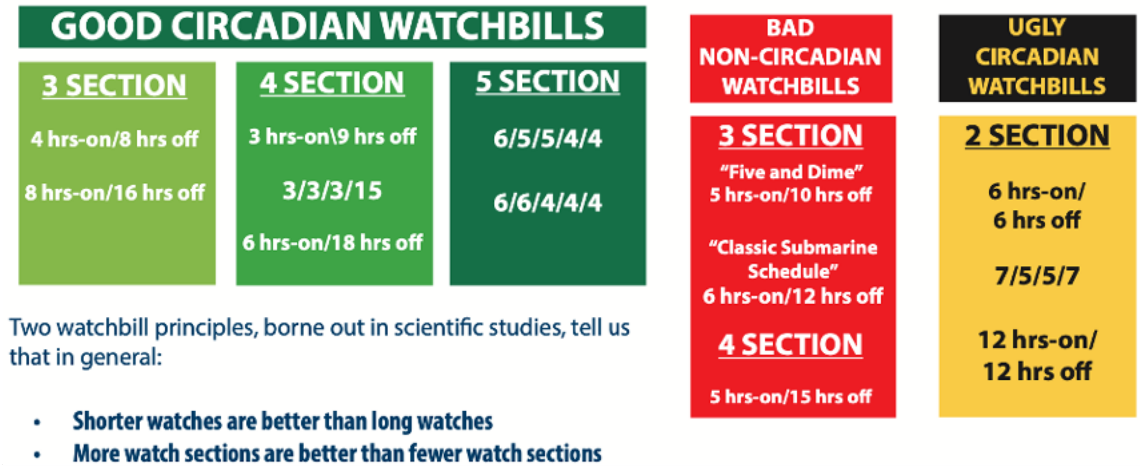

Figure 1. Good, Bad, Ugly Circadian Watchbills. Source: "Crew Endurance Handbook" (2023).

Naval watch bills typically consider the total crew size aboard a vessel. For example, on a submarine with approximately 110 personnel, a three-section schedule is often implemented, with crew members working 8 hours on duty followed by 16 hours off duty, as illustrated in Figure 2.

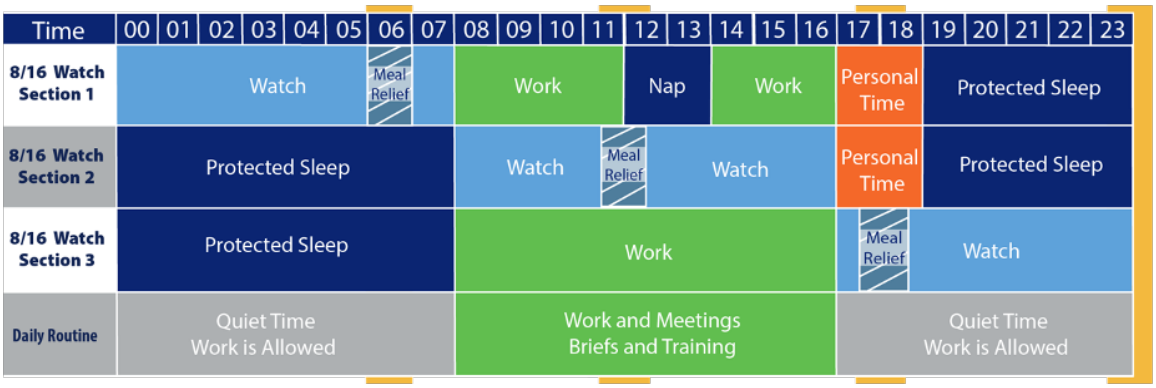

Figure 2. Example of 8/16 Watchbill Source: "Crew Endurance Handbook" (2023).

On larger ships with a greater number of crew members, a watchbill may incorporate four sections, each covering six-hour watches, as depicted in Figure 3. This allows for a work/personnel time as the watches will be shorter.

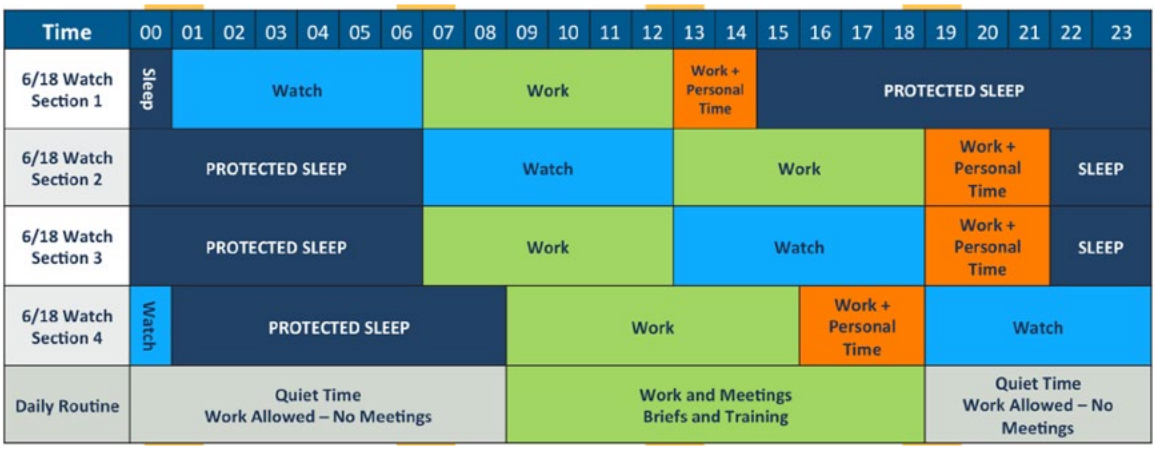

Figure 3. Example of 6/18 Watchbill. Source: "Crew Endurance Handbook" (2023).

D. CIRCADIAN RHYTHM CIVILIAN SECTOR

Modern society has also increasingly relied on continuous operations that necessitate 24/7 coverage. Sectors such as manufacturing, energy production, transportation, healthcare, law enforcement, and pilots all depend on maintaining a workforce around the clock. These sectors have adopted a structured form of shift work,

which typically falls into one of three categories: day shifts, swing shifts, and night shifts. Day shifts conform to the conventional work schedule, spanning from 9:00 AM to 5:00 PM. Swing shifts usually commence around 4:00 PM and extend until midnight, while night shifts occur overnight, typically starting at midnight and concluding around 8:00 AM. These shifts are assigned for a set duration within a rotation period, with the most common rotation lasting one week. However, some argue that longer rotation periods are more effective, allowing for the necessary adjustment of circadian rhythms. The challenge arises when workers revert to a "normal" day/night schedule during their days off, potentially nullifying any adaptation achieved during their work shifts.

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III. CREW REST IN AVIATION AND AIRLANDER

A. FEDERAL AVIATION ADMINISTRATION

Pilots often work in demanding shift schedules that can disrupt their circadian rhythms due to the nature of aviation operations, especially for those involved in long-haul or international flights. Circadian rhythm considerations are crucial for pilots to maintain safety, performance, and overall well-being. As pilots frequently cross multiple time zones during international flights, jet lag occurs as the body's internal circadian clock is out of sync with the local time at the destination. This misalignment can result in fatigue, sleep disturbances, and impaired cognitive function. Airlines typically use rotating shift schedules for their flight crews. Aviation regulatory authorities, such as the Federal Aviation Administration (FAA), impose strict rest regulations for pilots to ensure they have sufficient recovery time and adequate sleep. Its guiding document, the Federal Aviation Regulation/Aeronautical Information Manual (FAR/AIM) Section 91 establishes the following rules and regulations:

- Calendar Quarter and Year Limits: The regulation specifies limits on flight time based on calendar quarters and years. For example, crew members cannot exceed 500 hours in a single calendar quarter, 800 hours in any two consecutive calendar quarters, or 1,400 hours in a calendar year. These limits are in place to prevent crew members from consistently working long hours without adequate rest.

- 24-Hour Flight Time Limit: The regulation sets a maximum limit for flight time during a 24-hour period. Single-pilot crews are limited to eight hours of flight time within a 24-hour window, while two-pilot crews can fly for up to 10 hours during the same period. This ensures that crew members have a reasonable amount of time for rest between duty periods.

FAR 91 continues:

- Crew: No program manager may assign any pilot to an augmented crew, unless the program manager ensures, adequate sleeping facilities are

installed on the aircraft for the pilots. No more than 8 hours of flight deck duty is accrued in any 24 consecutive hours for a three-pilot crew, the crew must consist of at least the following:

- A pilot in command (PIC) who meets the applicable flight crewmember requirements of this subpart and § 61.57 of this chapter.
- A PIC qualified pilot who meets the applicable flight crewmember requirements of this subpart and § 61.57(c)and (d) of this chapter.
- A second in command (SIC) who meets the SIC qualifications of this subpart. For flight under [Instrument Flight Rules] IFR, that person must also meet the recent instrument experience requirements of part 61 of this chapter. (14 CFR 91, 2023)

Figure 4 shows the FAR/AIM time restrictions for Pilots with the maximum extension times allowed.

	Normal duty	Extension of flight time
(1) Minimum Rest Immediately Before Duty	10 Hours	10 Hours.
(2) Duty Period	Up to 14 Hours	Up to 14 Hours.
(3) Flight Time For 1 Pilot	Up to 8 Hours	Exceeding 8 Hours up to 9 Hours.
(4) Flight Time For 2 Pilots	Up to 10 Hours	Exceeding 10 Hours up to 12 Hours.
(5) Minimum After Duty Rest	10 Hours	12 Hours.
(6) Minimum After Duty Rest Period for Multi-Time Zone Flights	14 Hours	18 Hours.

Figure 4. FAR/AIM Duty Day Time Restrictions. Source: 14 CFR 91 (2023).

B. NAVAL AVIATION REGULATION

Like the civilian sector the Navy has rules and regulations it applies to pilots. The CNAF lays out rules and regulations in the Naval Air Training and Operations Procedures Standardization (NATOPS) General Flight and Operating Instructions Manual (CNAF, 2022). CNAF mandates that crew rest:

> Before a duty day, watch, or flight period. Crew rest shall include an opportunity for eight hours of uninterrupted sleep for every 24-hour period… Crew rest does not begin until after termination of official duties and is required prior to reporting for preflight preparations. Flight crew shall not be scheduled for continuous alert and/or flight duty (required awake) in excess of 18 hours. (CNAF, 2022)

Delineation of flight time limitation is varied depending on many conditions, but the following guidelines outlined in CNAF play a role in determination.

- Daily Flight time – Not to exceed three flights or 6.5 hours single piloted, 12 hours multi-piloted (ejection seat aircraft), 12 hours multi-piloted non-pressurized aircraft, or 12 hours multi-piloted pressurized aircraft.

- Weekly Maximum – 30 hours single piloted, 50 hours multi-piloted (ejection seat aircraft), 50 hours multi-piloted non-pressurized aircraft, or 50 hours multi-piloted pressurized aircraft.

- Crew Rotation: When a long flight extends beyond the allowable duty time, CNAF states that personnel shall be cleared by the Commanding Officer (CO) in the form of a "High Time Waiver."

- Performance Efficiency: If awake "time exceeds 16 hrs. performance efficiency begins to drop, after 18 hours. performance rapidly declines to 75% effectiveness or less. This loss is manifested by lapses in attention, slower reaction time, slowed processing speed, and increased error frequency." CNAF Max Flight time for Aircrew is illustrated in Figure 5 (CNAF, 2022).

Figure 5 shows the CNAF maximum flight time allowed for Pilots based on total pilots onboard and period of days.

PERIOD (DAYS)	SINGLE PILOTED AIRCRAFT	MULTI-PILOTED (PRESSURIZED) EJECTION SEAT AIRCRAFT	MULTI-PILOTED NON-PRESSURIZED AIRCRAFT	MULTI-PILOTED PRESSURIZED AIRCRAFT
1	6.5	12	12	12
7	30	50	50	50
30	65	80	100	120
90	165	200	265	320
365	595	720	960	1120

Figure 5. CNAF Max Flight Time. Source: CNAF (2022).

C. SINGLE-PILOTED VS. MULTI-PILOTED

It is essential to understand the distinction between single-pilot and multi-pilot operations, as the determination of flight hours is influenced by each approach. Single-pilot operations are defined as "one pilot in the cockpit, assisted by advanced onboard automation and/or ground operators providing piloting support services" (Matessa, 2017). Whereas multi-piloted operations require two pilots in the cockpit throughout the duration of the flight.

D. LONG DURATION FLIGHTS

When considering the crewing requirements for Airlander 10, a distinct challenge emerges. Given the Airlander 10's capability to remain airborne for a continuous period of five days, the question arises: how should the aircraft and its pilots be crewed? To gain insights into this complex issue, one can examine the longest civilian flight currently in operation—a journey from New York JFK to Singapore, covering 9,530 miles and lasting just over 18 hours. From this comparison, certain conclusions can be drawn. The flight carried two flight crews: two captains, and two first officers (Page, 2020). The second team was the "relief" set of pilots with the plan to return from their rest break approximately an hour before the scheduled landing time, dividing the remaining flight time in two equal segments. For instance, in the case of a 17-hour and 30-minute flight, both rest periods would amount to roughly eight hours each (Page, 2020).

Another illustrative instance comes from Qantas Airlines (Maaz, 2023). In 2017 Qantas announced an initiative known as "Project Sunrise," which entailed plans to operate flights from the East Coast of Australia to destinations in Europe and New York. These extraordinary journeys, specifically from Sydney or Melbourne to London or New York, are projected to span more than 20 hours in flight duration. The main concern with this flight being that it would not align with the current regulations which allow up to only 18 hours of maximum duty for long-haul operations.

The European Aviation Safety Agency (EASA) who oversees regulations related to aviation operations, underlined the impact this trip would have on Flight Duty Period (FDP) for pilots and crew (Maaz, 2023). The FDP begins when a crew member is scheduled

to report for duty, with most airlines expecting pilots to report about one hour and 15 minutes to one hour and 30 minutes before a flight. It concludes when the aircraft comes to a full stop and completes engine shutdown (Maaz, 2023). Figure 6 below illustrates an example of an FDP schedule. It's worth noting that during Project Sunrise trial flights, Qantas engaged a total of four pilots, comprising one captain, one first officer, and two second officers (Maaz, 2023).

Start of FDP at reference time	1–2 Sectors	3 Sectors	4 Sectors	5 Sectors	6 Sectors	7 Sectors	8 Sectors	9 Sectors	10 Sectors
0600–1329	13:00	12:30	12:00	11:30	11:00	10:30	10:00	09:30	09:00
1330–1359	12:45	12:15	11:45	11:15	10:45	10:15	09:45	09:15	09:00
1400–1429	12:30	12:00	11:30	11:00	10:30	10:00	09:30	09:00	09:00
1430–1459	12:15	11:45	11:15	10:45	10:15	09:45	09:15	09:00	09:00
1500–1529	12:00	11:30	11:00	10:30	10:00	09:30	09:00	09:00	09:00
1530–1559	11:45	11:15	10:45	10:15	09:45	09:15	09:00	09:00	09:00
1600–1629	11:30	11:00	10:30	10:00	09:30	09:00	09:00	09:00	09:00
1630–1659	11:15	10:45	10:15	09:45	09:15	09:00	09:00	09:00	09:00
1700–0459	11:00	10:30	10:00	09:30	09:00	09:00	09:00	09:00	09:00
0500–0514	12:00	11:30	11:00	10:30	10:00	09:30	09:00	09:00	09:00
0515–0529	12:15	11:45	11:15	10:45	10:15	09:45	09:15	09:00	09:00
0530–0544	12:30	12:00	11:30	11:00	10:30	10:00	09:30	09:00	09:00
0545–0559	12:45	12:15	11:45	11:15	10:45	10:15	09:45	09:15	09:00

Figure 6. Example of FDP Schedule. Source: Maaz (2023).

EASA recognizes the significance of Circadian Rhythm as well establishing the acronym WOCL Window of Circadian Low. WOCL is the time frame, occurring during a physiological night, is when the average human experiences the greatest sleepiness and normally spans from 02:00 to 05:59 hours. EASA permits the extension of the FDP, contingent upon providing each pilot with proper in-flight rest. In-flight rest facilities are categorized into three classes to meet specific minimum standards. Class 1 facilities include bunks or surfaces that allow for flat or near-flat sleeping positions and are situated separately from both the flight crew compartment and the passenger cabin. They provide isolation from noise and disturbances, and the crew member can control lighting

conditions. Class 2 and Class 3 facilities are similarly structured with variations in seating angles and separation from passengers.

E. BENEFITS OF AIRLANDER 10

When examining crew rest requirements of long-duration flights, Airlander holds a significant advantage over conventional fixed-wing aircraft in its capability to facilitate crew rest inflight. The combination of its low ambient noise levels, minimal vibrations, and the absence of cabin pressurization creates an environment conducive to sound sleep. With the engines located on the side and stern strategically distant from the cabin, the result is an almost noise-free environment for pilots and crew.

Traditional commercial aircraft cabins, which, according to a study conducted by the National Institute for Occupational Safety and Health (NIOSH), produce 60–65dBA during takeoff, 80–85dBA during flight, and 75–80dBA during landing from systems such as engine noise, equipment cooling and pressurization (CDC, 2023). This is not the case for Airlander 10, which operates below 10,000 feet and does not utilize many of the same systems. This absence of pressurization and other similar system noise contributes to a quieter and more conducive atmosphere for crew rest. Finally, Airlander's slower flying speed compared to conventional aircraft generates significantly less aerodynamic noise. The reduction in noise levels ensures that crew members may experience an environment more conducive to quality rest while onboard (HAV, 2023b).

F. PROPOSED AIRLANDER PILOT MANNING

When assessing piloting requirements for Airlander 10, various factors were considered, such as operational tempo, level of risk, and total flight hours. Pending category approval, Airlander 10 will utilize a hybrid of single-piloted/multi-piloted operations during flight with all "high risk" phases of flight requiring two pilots in the cockpit. The following assumptions were used to determine pilot manning recommendations:

- In Accordance With (IAW) CNAF 3710 – Airlander 10 will operate less than 7 days with each pilot accruing up to 50 hours of flight time.

- IAW CNAF 3710 – "Crew rest does not begin until after termination of official duties and is required prior to reporting for preflight preparations." (CNAF, 2022)
- IAW CNAF 3710 – "Flight crew shall not be scheduled for continuous alert and/or flight duty (required awake) in excess of 18 hours." (CNAF, 2022)

- If single-piloted flight is approved for Airlander 10, CNAF 3710 guidance of 6.5 hours for single-piloted operations would be violated, however FAA guidance of 8 hours would be adhered to.

- All pilots will be given 24-hour (plus) notice before any mission to begin their adjustment to the required circadian rhythm watch bill.

Following a flight simulator demonstration, it was evident that, given Airlander 10's flight characteristics, it is possible for single-piloted operations (pending approval from organizations such as the International Civil Aviation Organization (ICAO), FAA, EASA, and CNAF) except for those phases of flight categorized as "high-risk." These high-risk phases encompass operations such as take-off, landing, adverse weather conditions, and low-level flight. Considering guidance mandated by federal, international, and DOD policy makers, the recommendation for Airlander 10 would be to implement a two- or three-person pilot rotation for missions depending on length. Any flight under 12 hours will only require two pilots aboard Airlander 10, while any flight exceeding 12 hours will require three pilots in rotation.

Assumptions for Airlander 10 watchbills as shown in Figures 7 and 8 are that certification for single-piloted flight operation is approved by Civil Aviation Regulators, no pilots fly over nine hours in a 24-hour period, and one safety observer is present at all times. Figures 7 and 8 illustrate how Airlander 10 watchbills could be organized depending on the flight hours and total pilots on board.

	0000-0800	0800-1600	1600-0000
Pilot 1	Watch	Work / Personal Time	Sleep / Uninterrupted Rest
Pilot 2	Sleep / Uninterrupted Rest	Watch	Work / Personal Time
Pilot 3	Work / Personal Time	Sleep / Uninterrupted Rest	Watch

Figure 7. Three Pilot Airlander 10 Watchbill Multi-Day No Take-Off / Landing

12 Hour Flight	
1.5 Hours Take Off	Multi-Piloted
4.5 Hours Flying	Single-Piloted (Pilot 1)
4.5 Hours Flying	Single-Piloted (Pilot 2)
1.5 Hours Landing	Multi-Piloted

18 Hour Flight	
1.5 Hours Take Off	Multi-Piloted
5 Hours Flying	Single-Piloted (Pilot 1)
5 Hours Flying	Single-Piloted (Pilot 2)
5 Hours Flying	Single-Piloted (Pilot 3)
1.5 Hours Landing	Multi-Piloted

24 Hour Flight	
1.5 Hours Take Off	Multi-Piloted
7 Hours Flying	Single-Piloted (Pilot 1)
7 Hours Flying	Single-Piloted (Pilot 2)
7 Hours Flying	Single-Piloted (Pilot 3)
1.5 Hours Landing	Multi-Piloted

Multi-Day Flight No Take-Off / Landing	
8 Hours Flying	Single-Piloted (Pilot 1)
8 Hours Flying	Single-Piloted (Pilot 2)
8 Hours Flying	Single-Piloted (Pilot 3)

Figure 8. Airlander 10 Pilot Rotation Schedules

G. CHAPTER SUMMARY

The devastating consequences of fatigue-related incidents, as witnessed in the naval collisions of 2017, emphasized the critical need for well-rested crewmembers in ensuring safety, performance, and overall well-being. The integration of circadian-based watch schedules in the Navy has proven to be a successful strategy for mitigating the detrimental effects of shift work and continuous 24/7 duties. These schedules not only enhance safety measures but also reduce the risk of accidents while bolstering the overall resilience and effectiveness of naval crews.

In the civilian sector, particularly in aviation, the preservation of crew rest is equally paramount. Stringent regulations are in place to safeguard safety and maintain the optimal

performance of pilots. When delving into long-haul flights, Airlander 10 emerges as a promising remedy for crew rest. With its unique attributes and tranquil environment, it offers distinct advantages over conventional fixed-wing aircraft, providing a conducive setting for in-flight rest. The proposed pilot manning strategy for Airlander 10 is a product of careful consideration regarding operational pace, risk factors, and total flight hours. The proposal is forward-thinking, considering potential changes while complying with existing regulations for the Airlander 10, a blend of single-piloted and multi-piloted operations during different flight phases is suggested, with a clear emphasis on prioritizing crew rest and safety.

Recognizing the value of circadian rhythms and implementing well-structured watch schedules is vital in both naval and civilian sectors. These measures are essential for safeguarding the health, safety, and efficiency of crew members, ultimately playing a crucial role in achieving mission success.

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IV. ASSET COMPARISON

A. P-8A POSEIDON SUMMARY

Replacing older and more expensive Navy vessels with newer, more energy-efficient ones is a core tenant of the CNO's message to the fleet. The CNO emphasizes that the Navy must chart a sustainable course of action to ensure its status as a maritime force with one of the primary strategies to phase out legacy platforms that have become economically unsustainable and obsolete (Gilday, 2022). One of these platforms is the Navy's P-3C Orion, a multi-role aircraft, has been replaced by the P-8A Poseidon, the newest maritime patrol aircraft for the United States, and several allied and partner nations. After being awarded the developmental contract in June 2004, Boeing conducted the P-8A's first test flight in 2010 and completed its first production aircraft by March of 2012. Jumping forward to 2023, the U.S. Navy has now taken delivery of over 110 P-8As and plans to take delivery of at least 20 more to replace its reserve component squadrons.

As a multi-role aircraft, the P-8A serves as the Navy's quick response asset for multiple mission sets to include ASW, ISR, Anti-Surface Warfare (ASuW), and Search and Rescue (SAR). Equipped with state-of-the-art communication suites, radars, cameras, Electronic Support Measures (ESM) and capable of being armed with five different types of sonobuoys, torpedoes, harpoons, and SAR kits, the P-8A has already proven itself to be a valuable asset for the Navy, despite its short time in service. Involved in highly visible operations such as the missing Malaysian Airlines Flight 370 in 2014, disaster analysis and relief to the Bahamas in 2017, and rescuing three fishermen lost at sea in the Pacific in 2018, the P-8A continues to successfully carry on the legacy the P-3C Orion left behind. Figure 9 shows a P-8A in flight.

Figure 9. P-8A Poseidon Test Squadron Flight Test. Source: Boeing (2023).

B. P-8A PERFORMANCE

By leveraging the 737–800 Series airframe, Boeing successfully converted a well-established platform into a highly proficient military asset. This transformation significantly enhanced flying performance compared to its predecessor, in alignment with specific requirements set forth by Navy officials when the contract was announced. Capable of flying up to 41,000ft, at an average of 300 knots, with a max takeoff weight of 190,000lbs, the P-8A can fly higher, faster, and longer (airborne aerial refueling capable) than the P-3C. With a max fuel capacity of 72,000lbs, the P-8A could stay airborne for more than ten hours, a duration the P-3C could only achieve by doing an "engine loiter shutdown" in which pilots would shut down one to two engines to conserve fuel and extend on station time.

Along with an increase in overall performance, the P-8A got a bump in both the capacity and flexibility of the stores it carries. The newer platform now carries 129 sonobuoys rather than the 84 on the P-3C. Although this difference may appear subtle at first glance, it extends the capacity for longer search missions and the ability to maintain contact for extended periods. In addition to the increased capacity, the P-8A stores its sonobuoys internally vice externally, which permits operators to change sonobuoy settings such as depth, life, and channel to adapt with the ocean environment. These small changes allow operators to track submarines more efficiently, accurately, and for a longer period.

The P-8A is equipped with up to five MK-54 Block II torpedoes, four AGM-84 Block IC harpoons, or two SAR kits (Military.com, 2023).

C. P-8A CREW AND INTERNAL LAYOUT

In the United States, civil aviation standards and guidance are overseen by the FAA through documents like FAR/AIM, Aircraft Operating Limitations (AOL), and Aircraft Flight Manual (AFM). On the international stage, the ICAO and EASA play similar roles in ensuring aviation safety and compliance with regulations. While U.S. military aircraft are required to abide by all guidance and directives by the FAA, ICAO (if operating internationally), the CNAF 3710, and aircraft specific NATOPS provide service specific guidance. Within these documents, regulators have established how many crew members are required to operate an aircraft based on factors such as type of aircraft, complexity, flight duration, and number of passengers onboard. A standard crew in the P-8A consists of nine people, two less than what the P-3C required. The P-8A NATOPS Manual defines standard mission crew roles and recommends three pilots, two Naval Flight Officers (NFOs), two Acoustic Warfare Operators (AWOs), and two Electronic Warfare Operators (EWOs), defining those crew positions even further by seniority. Given the size/type of aircraft and crew/passenger capacity of 21 total, the P-8A requires a minimum of two pilots and one "observer" to fly as per FAR 91.53.

FAR 91.531 states that,

- Except as provided in paragraph (b) of this section, no person may operate the following airplanes without a pilot designated as second in command:
- Any airplane that is type certificated for more than one required pilot.
- Any large airplane.
- Any commuter category airplane. (14 CFR 91, 2023)

FAR 91.533 states that,

- No person may operate an airplane unless at least the following number of flight attendants are on board the airplane:
- For airplanes having more than 19 but less than 51 passengers on board, one flight attendant (safety observer). (14 CFR 91, 2023)

D. P-8A CREW

Below is a list of the nine-person crew, positional titles, and job descriptions for any given mission flight. Multiple individuals within the same title/positional roles are necessary not only for redundancy and preventing single points of failure, but also for upgrading/training. Senior members include: the Patrol Plane Commander (PPC), the Tactical Coordinator (TACCO), the senior acoustic enlisted operator, and the senior electronic warfare enlisted operator (America's Navy, 2019).

- **PPC:** As the senior ranked pilot onboard the PPC is responsible for ensuring flight safety, accurate navigation, and orderly conduct, from mission planning to post-flight tasks. This authority is independent of the presence of senior personnel onboard. The PPC should use judgment in assessing a pilot's capability to control the aircraft safely, especially in adverse weather or emergencies. The PPC also signs for the plane prior to each flight, verifying all maintenance inspections, weight & balance, flight plans, and safety requirements have been completed (Tegler, 2023).

- **Patrol Plane Pilot/Copilot (2P):** The 2P must be qualified to perform all Patrol Plane Copilot roles as defined by the Patrol Plane Copilot/Pilot Monitoring (3P) position. Additionally, 2Ps should hold a NATOPS Pilot qualification and display the capability to lead the flight deck and crew if the PPC is not present. If the PPC becomes incapacitated during flight, the 2P assumes the PPC's authority, duties, and responsibilities (Tegler, 2023).

- **Patrol Plane Copilot/Pilot Monitoring (3P/PM):** The 3P holds a NATOPS Pilot qualification and performs various duties such as, Pilot, Copilot, Pilot Monitoring, and Safety Observer. The 3P carries out tasks as instructed by the PPC or 2P and meets the Third Pilot requirements outlined in CNAF M-3710.7. If the PPC becomes incapacitated during flight, the 2P assumes the PPC's authority, duties, and responsibilities, while the 3P assumes 2P's duties and responsibilities (Tegler, 2023).

- **NFO #1/TACCO:** The TACCO's role is to optimize mission execution. TACCO is responsible for tactically employing the P-8A, creating safe flight paths, coordinating emergency procedures, and managing mission logs. TACCO is responsible for employing search and weapon stores (Tegler, 2023).

- **NFO #2/Co-Tactical Coordinator (COTAC):** The COTAC supports TACCO in various tasks such as external communication and tactical planning. COTAC carries out tasks assigned by TACCO, such as managing sonobuoys and weapon stores, creating tactical flight paths, overseeing track management, handling navigation, and coordinating emergency procedures with crew (Tegler, 2023).

- **AWO x 2:** Acoustic operators are responsible for detecting, classifying, and reporting acoustic data. The off-duty acoustic operator may be tasked with loading sonobuoy launchers as directed by the TACCO (Tegler, 2023).

- **EWO x 2:** EWO's are responsible for employing APY-10 radar, Identification Friend or Foe (IFF), Electronic Warfare Support Measures (ESM), and Electro-Optical/Infrared (EO/IR) systems. Their role is to identify and assess operationally important targets and offer radar intercept and navigation data to the pilots and TACCO (Tegler, 2023).

E. P-8A INTERNAL LAYOUT

Figure 10 illustrates the interior layout of a P-8A. The flight deck has three chairs, with the Pilot and Co-Pilot at the controls, and Pilot Monitoring station for observing. Aft of the cockpit sits two crew rest seats for off-duty crew members followed by five mission crew workstations. From midline aft sits all electronics, communication suites, search/ weapon stores, and employment systems.

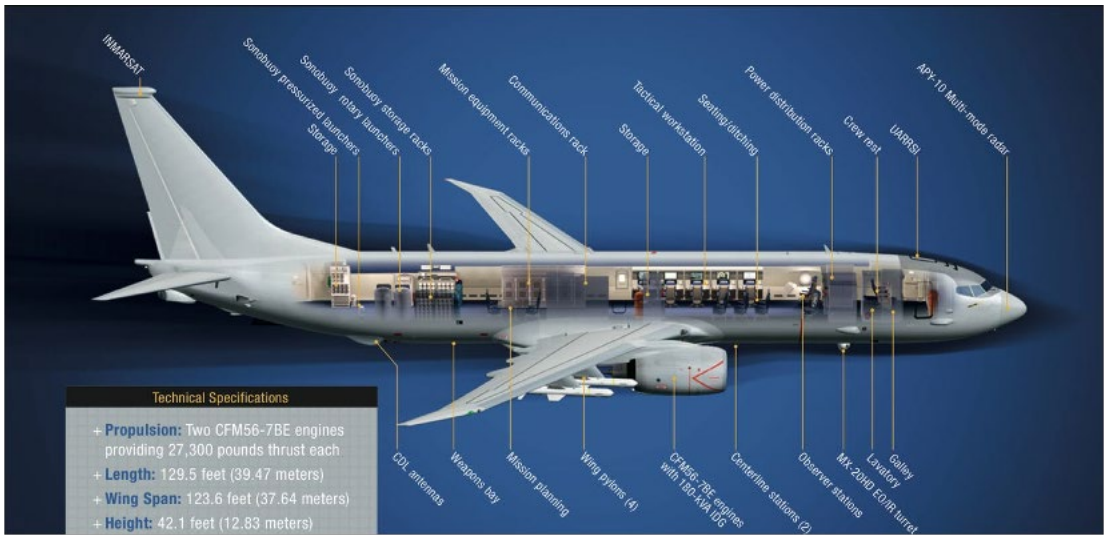

Figure 10. P-8A Interior Layout. Source: Bienaimé (2014).

F. AIRLANDER 10 SUMMARY

In response to a call for research by the DOD in 2007, the Long Endurance Multi-Intelligence Vehicle (LEMV) quickly emerged as a promising project (SAIC, 2016). This hybrid air vehicle was designed to be an unmanned, long-endurance, ISR platform for use in the Middle East by Northrup Grumman and their subcontractor partner HAV. The LEMV was eventually defunded due to budget cuts in February 2013 (Cohen, B. T., Schmaltz, 2022). However, after retaining the intellectual property rights and purchasing the de-militarized aircraft from the U.S. Army, HAV was able to continue its investment, research, and development of the technology via grant-supported funding (HAV, 2023b). In August of 2016, a modified Airlander 10 successfully completed its second flight in Bedfordshire, UK, as part of a long-term development program by HAV. Figure 11 shows the demonstration flight for Airlander 10.

Figure 11. Airlander 10 2016 Demonstration Flight. HAV (2023a).

Since 2020 the DOD and Department of the Navy (DON) have developed new policy to reduce its greenhouse gas emissions stating: "The DON will invest in areas such as transformational, low-carbon technologies and advanced energy storage and power generation solutions to support national security, warfighting advantage, and climate benefits" (Department of the Navy, 2022). As a result, NPS has partnered with HAV to research the potential military uses of the HAV Airlander 10 which could be used in mission sets such as logistics delivery, Humanitarian Assistance Disaster Relief (HADR), Homeland Security (HS), ISR, SAR, and ASW.

G. AIRLANDER 10'S PERFORMANCE

Despite Airlander 10's resemblance to Zeppelins made famous during World War II, modern-day engineering has enabled designers to take the same lighter-than-air (LTA) technology and transform it. Rather than using a semi-rigid design (stiff trusses supporting canvas inflated with hydrogen), Airlander 10 uses a non-rigid aerodynamic inflatable hull, made from composite flexible structural materials, with helium as its lifting gas. The use of helium combined with a non-rigid aerodynamic hull, increases lift, allows for easier ballasting, and lowers maintenance costs without sacrificing structural integrity or safety. Airlander 10 uses a combination of both fixed (aft) and vectored (forward) thrust, which increases efficiency, maneuverability, and capability compared to predecessors and competition. Figure 12 represents Airlander 10's unique hull capabilities.

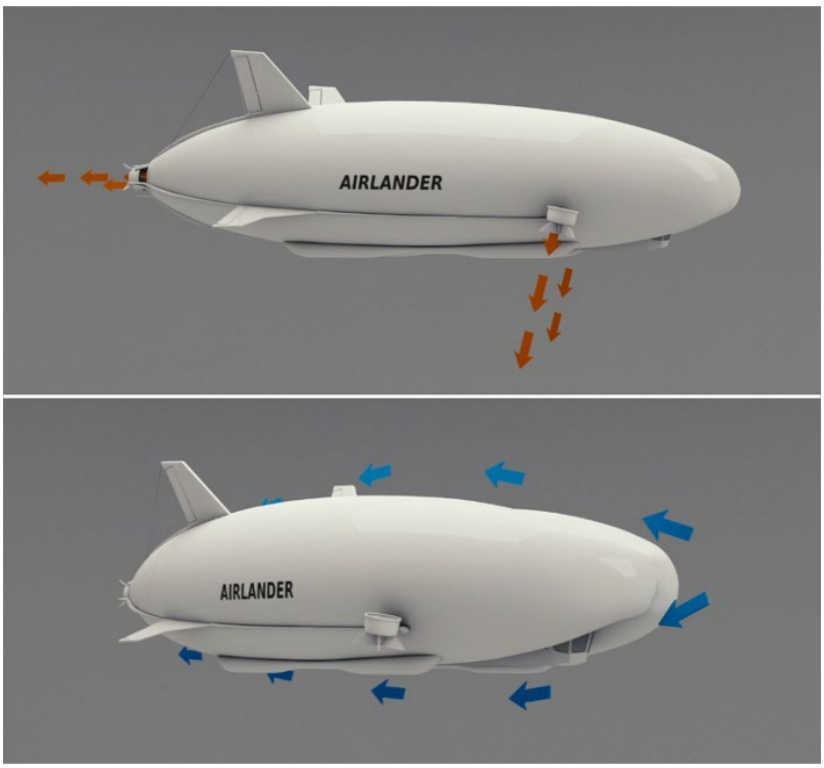

Figure 12. Airlander 10 Hull Design and Thrust Technology Source: HAV (2023b).

These advancements in LTA design and technology give Airlander 10 the ability to fly up to 20, 000ft, at an average speed of around 40 knots, with a max payload of up to 20,000lbs. With a standard fuel capacity of 13,000lbs and the ability to add 7,000lbs when longer flights are required, the Airlander 10 has the capability of staying airborne for up to five days and cover 4,000 nautical miles without refueling. Due to Airlander 10's modular design, customers have the ability to easily change cabin layouts and loadouts (HAV, 2023a). While weapon store capacity is still unknown, it is safe to assume that given a usable cabin space of 60ft x 15ft x 11ft (short cabin model), and a lack of need for a pressurized hull, the Airlander 10 has ample capacity to carry all stores and equipment necessary to complete any mission.

H. PROPOSED AIRLANDER 10 CREW AND CABIN LAYOUT

1. Pilots

Airlander 10 pilot requirements present a unique challenge for policymakers within the aviation industry. Given its description and design, the Airlander 10 would still be categorized as both a LTA and an "airship" under current FAA regulations, and therefore, required to abide by FAR Part 91.

FAR Part 91 states that,

- Except as provided in paragraph (b) of this section, no person may operate the following airplanes without a pilot designated as second in command:
- Any airplane that is type certificated for more than one required pilot.
- Any large airplane.
- Any commuter category airplane. (14 CFR 91, 2023)

FAR Part 91 paragraph (b) states that,

- A person may operate the following airplanes without a pilot designated as second in command:
- Any airplane certificated for operation with one pilot.
- A large airplane or turbojet-powered multiengine airplane that holds a special airworthiness certificate, if:
- The airplane was originally designed with only one pilot station; or
- The airplane was originally designed with more than one pilot station, but single pilot operations were permitted by the airplane flight manual or were otherwise permitted by a branch of the United States Armed Forces or the armed forces of a foreign contracting State to the Convention on International Civil Aviation. (14 CFR 91, 2023)

Given its design and flight characteristics, Airlander 10 should be a hybrid of a single-pilot/multi-piloted air vehicle. Based on this assumption Chapter 2 subsection J discusses a detailed piloting schedule for the Airlander 10.

2. Mission Crew

Given the nature of the USN maritime domain, the mission crew for Airlander 10 would not alter from the P-8A, and therefore still consist of two NFOs, two AWOs, and two EWOs. This provides redundancy for system analysis and troubleshooting and allows

unqualified operators to upgrade and learn from senior qualified members. Since Airlander 10 can stay airborne and on station for days at a time, more crew members would be required to complete multi-day missions. For example, in missions exceeding 12 hours but less than 72 hours, two crews would be required. While one crew executed their 12-hour mission watch, the off-duty crew would get the necessary rest prior to turning over with the on-duty crew. This would not only be in compliance with CNAF 3710 crew rest requirements but would maximize efficiency and workload capacity while maintaining internal circadian rhythm as described in Chapter II. A 12–72-hour mission crew watchbill would resemble Figure 13.

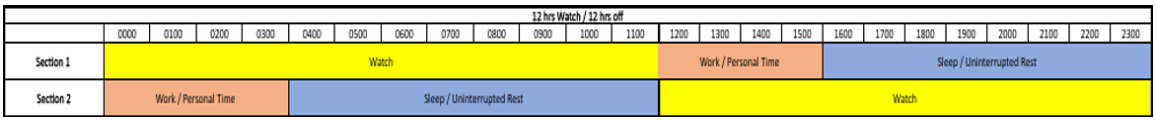

Figure 13. Airlander 10 12-72 Hour Watchbill

Two crews onboard Airlander 10 would therefore consist of 12 mission crew members and two pilots for flights under 18 hours totaling 14 personnel, one additional pilot for flights exceeding 18 hours totaling 15 personnel.

Mission durations exceeding 72 hours would require a three crew watchbill. This would minimize fatigue and allow crew members to establish a sustained circadian watchbill. An applicable analogy that further justifies the shift to a three crew watchbill after a 72-hour period is the medical industry. According to a study by the American Nurses Association (ANA), the recommended schedule for medical professionals is limited to three 12-hour shifts, four 10-hour shifts, or five 8-hour shifts per week. Reasons for doing so are to prevent job fatigue, limit recuperation time, and to ward off weak performance and increased errors by employees (ANA, 2023). Given this information, a three crew watchbill for missions greater than 72 hours would resemble. Figure 14 shows how Airlander crewing would take place 72–120 hours.

8 hrs Watch / 8 hrs Work / 8 hrs Sleep																								
	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300
Section 1	Watch								Work / Personal Time								Sleep / Uninterrupted Rest							
Section 2	Sleep / Uninterrupted Rest								Watch								Work / Personal Time							
Section 3	Work / Personal Time								Sleep / Uninterrupted Rest								Watch							

Figure 14. Airlander 10 72-120 Hour Watchbill

Three crews onboard Airlander 10 would consist of 18 crew members and a minimum of three pilots totaling 21 personnel. Reference Figure 8 for Airlander Pilot Rotation.

3. Proposed Airlander 10 Internal Layout

While the Airlander 10 interior cabin design is still in process, it is evident based on crewing requirements several things must be present in order to accommodate the military air vehicle:

- Nine bunks with sufficient room for off-duty crew
- Lockers for personal gear
- Cooking/refrigeration utilities capable of housing up to five days' worth of food for onboard crew members and
- Restroom with shower. HAV's current interior rendering for a military use Airlander 10 is shown in Figures 15 and 16.

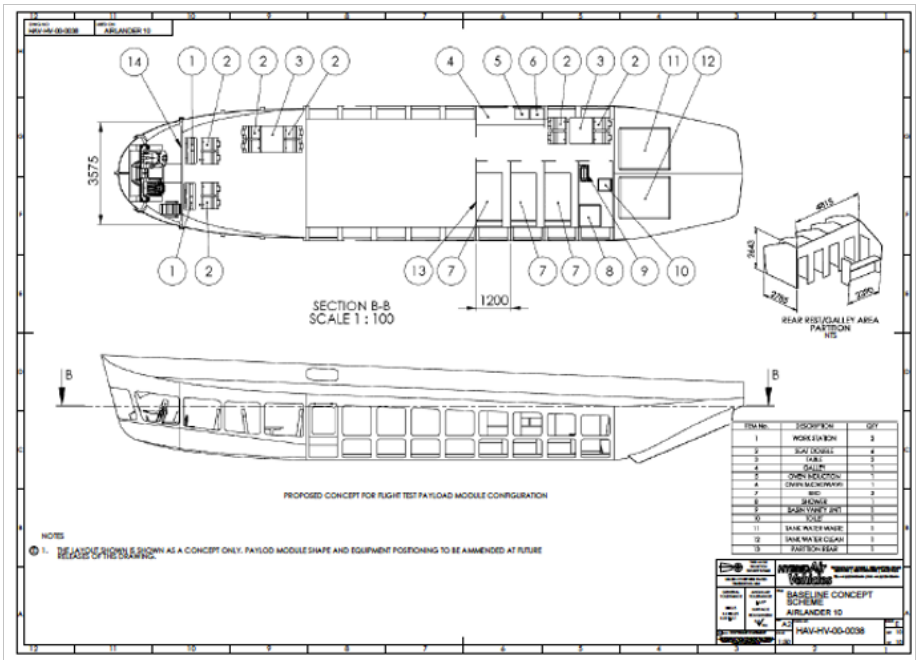

Figure 15. Airlander 10 Interior Layout #1. Source: HAV (2023a).

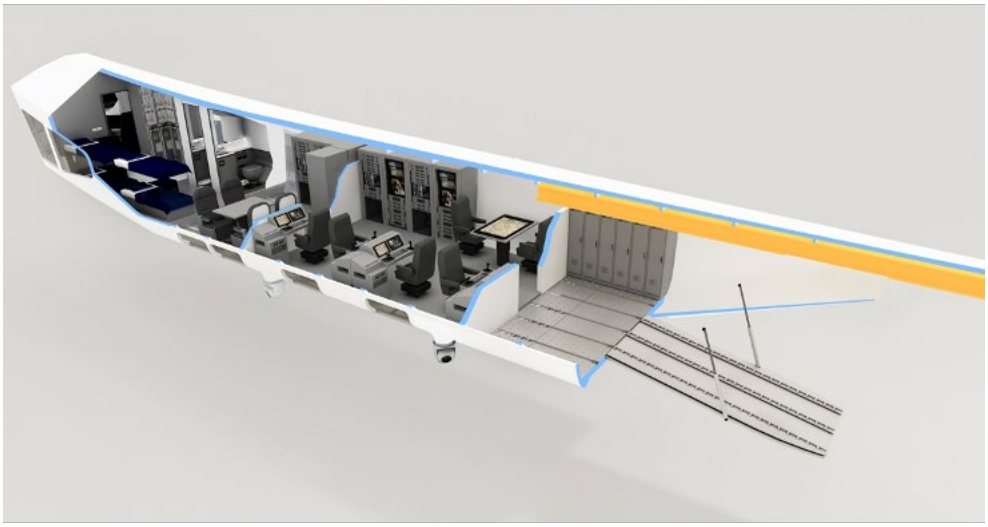

Figure 16. Airlander 10 Proposed ISR Interior Layout #2. Source: HAV (2023a).

I. CHAPTER SUMMARY

The USN is committed to modernizing its fleet with more energy-efficient vessels and platforms. While the P-8A is more efficient than its predecessor, highly capable, and

has proven its value, the Airlander 10 presents an opportunity to transform maritime aviation. By investing in more energy-efficient vessels and platforms, the Navy would reduce its fuel consumption and operating costs, while also increasing range and endurance. This in turn increases agility and responsiveness and will allow the Navy to operate more effectively in a variety of environments. By equipping, arming, and manning the Airlander 10 similarly to the P-8A, the U.S. Navy may be able to acquire an aircraft capability that significantly increases mission coverage time for mission sets like ISR, ASW, and HADR. The following chapters further analyze this possibility.

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V. SCENARIO-BASED COMPARISON

A. PURPOSE

U.S. Code Title 10 states that, "A major defense acquisition program or subprogram may not receive approval or otherwise be initiated until the milestone decision authority determines that an analysis of alternatives has been performed consistent with study guidance developed by the Director of Cost Assessment and Program Evaluation." (10 USC 4251, 2023) While this study is not in preparation for a major acquisition, real-world comparisons are necessary to test the viability of proposed assets. This test will involve a comparison between Airlander 10 and P-8A in the context of maritime ISR and ASW, two missions the P-8A routinely conducts worldwide. The advantages and disadvantages of both airframes will be highlighted through factors like flight endurance, reaction time, and mission execution/coverage. Elements such as weather, climbs/descents, tactical execution, and precise flight profiles cannot be discussed due to scope and classification level. This study will focus solely on publicly available data.

1. What is ISR?

For centuries ISR has been a deciding factor in the success of military operations. It provides policymakers, military leaders, and warfighters with the information necessary to make sound decisions during peacetime and war. Surveillance and reconnaissance are both information-gathering activities but differ in their duration and purpose. Surveillance is prolonged and deliberate, while reconnaissance missions are rapid and targeted to retrieve specific information. After collecting surveillance and reconnaissance data, intelligence experts can analyze and generate reports that serve as crucial information for decision-makers (NATO, 2023). ISR can be conducted through various means, encompassing air, space, land, and maritime domains. The most significant challenge in the maritime context lies in the vast expanse of reconnaissance area that needs to be addressed. Maritime operations encompass coastal regions, oceans, and inland waterways, all of which present a wide area for surveillance. While the execution process varies country to country and service to service, the maritime environment presents a challenge

for all players. ISR assets are asked to monitor a wide range of activities, including ship movements, illegal fishing, drug trafficking, piracy, environmental damage, and maritime terrorism. Maritime ISR is a considerably less dynamic (when compared to missions like ASW and ASuW) mission due to the nature of its requirements, which often involve the surveillance of surface combatants, which are comparatively easier to track, or the observation of stationary enemy assets on land. The central focus of ISR lies in maintaining continuous and uninterrupted surveillance.

2. What is ASW?

The extensive use of submarines during World War I prompted an urgent demand for a countermeasure. This led to the development and deployment of anti-submarine warfare (ASW) tactics and technology. The act of ASW is defined as finding, tracking, reporting, and if necessary, destroying enemy submarines. ASW can be accomplished by utilizing naval vessels, aircraft, submarines, and other classified platforms (ONR, 2022). While ASW tactics vary from country to country and platform to platform, the tools and sensors are generally the same. These sensors include active and passive sonar, magnetic anomaly detectors, and sonar buoys. ASW is an extremely difficult and dynamic mission set that plays a pivotal role in naval warfare. One variable that make ASW dynamic is speed, as faster submarines can be more challenging to track, requiring ASW forces to adapt their strategies to keep up or intercept them. The distance between ASW assets and the target submarine is crucial, with greater distances providing less time for detection and response. Time is of the essence in ASW operations, as the longer it takes to detect and neutralize a submarine threat, the more opportunity the adversary must carry out its mission.

B. AIRCRAFT PARAMETERS

When performing a comparative analysis, it is crucial to clearly establish and evaluate pertinent performance parameters. Figure 17 encompasses all relevant performance data for both P-8A and Airlander 10, sourced from Boeing and HAV. The primary performance factors under scrutiny in this study include *maximum speed, maximum endurance speed, maximum payload capacity, and maximum takeoff fuel*.

QUICK FACTS:			
P-8A POSEIDON		**AIRLANDER 10**	
Manufacturer:	Boeing	**Manufacturer:**	Hybrid Air Vehicles
Engines:	2 x CFM 56-7B engines with 27,300 pounds of thrust each	**Engines:**	350hp with 4 x 6ltr V12 Direct-Injection Diesel Engines, 550hp Each
Length:	129 feet, 7 inches	**Length:**	320 feet, 5 inches
Height:	42 feet, 1 inch	**Height:**	86 feet, 2 inches
Wingspan:	123 feet, 7 inches	**Wingspan:**	162 feet, 6 inches
Approx Interior Cabin Space:	98 feet x 7 feet x 12 feet	**Approx Interior Cabin Space:**	74 feet x 15 feet x 12 feet
Maximum Speed:	490 knots	**Maximum Speed:**	69 knots
Max Endurance Speed:	240 knots	**Max Endurance Speed:**	35 knots
Ceiling:	41,000 feet	**Ceiling:**	20,000 feet
Range:	1,200 NM / 4 hr time on station	**Range:**	2,000 NM / 5 days airborne
Maximum Takeoff Weight:	189,200 pounds	**Maximum Payload:**	20,000 pound payload
Fuel:	JP-5	**Fuel:**	JP-8 / Kerosene
Max Takeoff Fuel:	69,500	**Max Takeoff Fuel:**	13,000 lbs / +7,000
Tactial Mission Crew:	0-12 hours: 9 (5 Officers / 4 Enlisted)	**Tactical Mission Crew:**	0-12 hours: 8 (2 pilots), 12-72 hours: 15 (3 pilots), 72-120 hours: 21 (3 Pilots)
Fleet Inventory:	98	**Fleet Inventory:**	0
Armament:	129 A-size Sonobouys, 4 x Harpoon, 5 x MK-54, 2 x Survival Kit	**Armament:**	Mission dependent / mission duration
Life Span:	25 years	**Life Span:**	30 years
Maintenance Requirements:	Daily, Weekly, Monthly, Yearly	**Maintenance Requirements:**	Daily, Weekly, Monthly, Yearly, 10 Year Re-hull
Missions:	ASW /ASuW / ISR / Search & Rescue / HADR	**Missions:**	ASW / ISR / Search & Rescue / HADR
Customers:	USA / INDIA / AUSTRALIA / UK / NORWAY / NEW ZEALAND	**Customers:**	UK / SPAIN / OTHER EU PARTNERS

Figure 17. P-8A and Airlander 10 Quick Fact Sheet.

C. USEFUL EQUATIONS

Fuel management lies at the heart of aviation operations, serving as a critical factor that affects everything from transit times to the duration of missions. This analysis will explore fundamental principles that emphasize effective fuel management. At its core, this practice revolves around the dynamic relationship between time, distance, and speed, enabling precise estimates of transit times and ranges. Moreover, the concept of usable fuel, is a key consideration that balances the need for operational flexibility with safety margins, ensuring that unforeseen circumstances can be effectively addressed. Understanding the estimated fuel burn rate and endurance plays a pivotal role in mission planning, safeguarding both personnel and assets while optimizing operational efficiency.

1. Time, Distance, and Speed

Any variation of the time, distance, and speed equation can be used to accurately estimate transit times and range. For example, if the distance to an on-station point is 300NM and the P-8A is traveling at 300 knots, the time to get on-station will be one hour.

Distance = Speed x Time

2. Usable Fuel

Usable fuel is calculated by taking the total fuel onboard (or fuel remaining) and subtracting the required fuel reserve. Fuel reserve is the quantity of fuel that must be available on board to account for potential contingencies such as adverse weather, missed approaches, or the need to divert from a planned landing. For example, the P-8A is required to maintain 6,000 pounds of fuel in reserve (around 10% of the total fuel onboard). If 69,500 pounds of fuel is loaded onboard, 6,000 pounds must be subtracted to calculate total usable fuel. This would give the aircraft a total of 63,500 pounds of usable fuel which can later be used to calculate endurance. Since the Airlander 10 is still in development, we will use 10% of the max fuel onboard as the required fuel reserve number (e.g., if 13,000 pounds of fuel is loaded 1,300 pounds of reserve fuel will be required).

Usable Fuel = Total Fuel – Required Fuel Reserve

3. Estimated Fuel Burn Rate

In-flight computer systems are responsible for calculating actual fuel burn rate, however, for this research P-8A and Airlander 10 engineering departments, have provided the following rates. The P-8A will utilize 7,000 pounds per hour for takeoff, transits, and landing and 6,000 pounds per hour for loiter. Airlander 10 will utilize 295 pounds per hour for takeoff, transits, and landing, and 150 pounds per hour for loiter (Aircraft Commerce/ HAV, 2023). The following equation is used to calculate fuel burn rate averages and is useful to cross-check whether the proper amount of fuel is on board.

Estimated Fuel Burn Rate = Usable Fuel / Estimated Flight Time

4. Estimated Endurance

The final, and arguably most important equation that will be used is estimated endurance. It can be calculated by taking the usable fuel and dividing it by estimated fuel burn rates. This equates to an estimated duration an asset can stay airborne.

Estimated Endurance=Usable Fuel / Estimated Fuel Burn Rate

While factors such as altitude, airspeed, air temperature, pressure, and weight greatly affect actual fuel burn rates and in turn affect endurance, specific flight profiles for these mission sets are classified and will not be utilized. Therefore, the fuel burn rate averages discussed will be used to predict estimated endurance.

D. MARITIME ISR

In evaluating mission effectiveness of Airlander 10 vs. P-8A the same type and variant of sensors will be available to both assets. The sensors being utilized are the multi-mission APY-10 radar, ESM, EO/IR camera, and line-of-sight and satellite-capable communication systems. The goal of this mission is to locate all surface contacts via radar, conduct imagery intelligence (IMINT) via EO/IR, collect all electronics intelligence (ELINT) via ESM, and pass vessels of interest (VOIs) through the applicable communication chains. Generic flight profiles, fuel/store capacities, and fuel burn data have all been gathered from publicly available sources. This is solely a hypothetical mission scenario to compare assets and shall not be used in real-world execution.

1. Mission Description

As tensions rise in the Indo-Pacific, it is critical to continuously map and report the maritime picture to intelligence officials and neighboring allied/partnered nations. To do so, the Command Task Force (CTF) has requested 24-hour ISR coverage via air assets stationed on Kadena Air Base in Okinawa. Assets are to locate, identify, track, and report any VOIs within the assigned operating area (AOR), report any unusual activity, and maximize on-station time.

2. Operational Area and Distance from the Airfield

In support of CTF, Japan, and neighboring partners, air assets will depart from Okinawa, and proceed to tasking as described in Mission Description. Given the operational area pictured in Figure 18, transit times will be negligible and will therefore maximize on-station time. The total AOR is 3,150NM and all air assets will adhere to 12NM territorial standoff distances IAW international maritime law. Figure 18 represents the AOR for ISR.

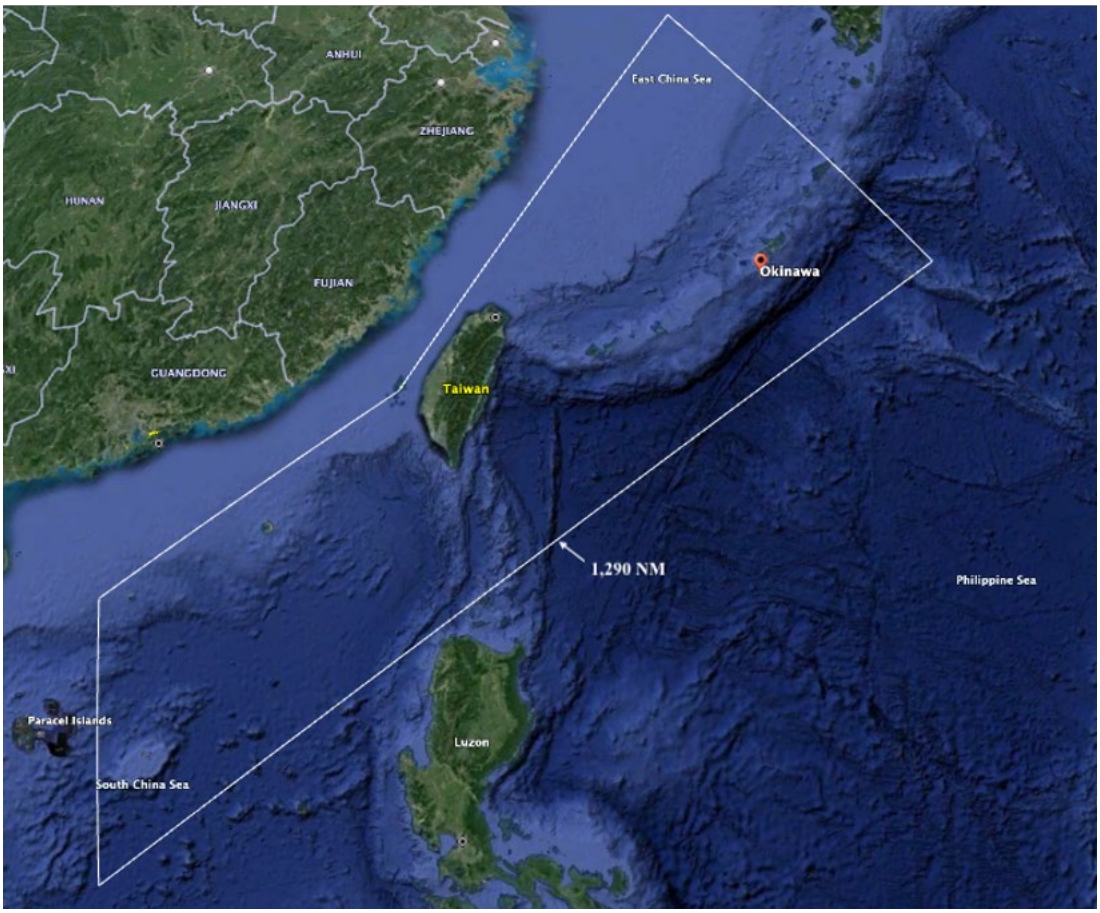

Figure 18. Maritime ISR Mission Scenario Operation Area. Source: Google (2023b).

3. Flight Profile

a. P-8A

All pre-flight/post-flight duties and responsibilities will be conducted IAW NATOPS. After departing Okinawa, Japan the P-8A will immediately climb to 20,000ft at 320 knots, once at altitude, it will proceed to the southwestern portion of the box at max endurance speed of 240 knots. At 20,000 ft / 240 kts the P-8A will conduct a flight pattern authorized at TACCO discretion. Return-to-base (RTB) when BINGO fuel is reached (minimum fuel you must have on board to complete a flight from A to B, then fly to the farthest alternate plus the 6,000 pounds in reserve fuel).

b. AIRLANDER 10

All pre-flight/post-flight duties and responsibilities will be conducted IAW applicable flight publications. After departing Okinawa, Japan the Airlander 10 will immediately climb to 10,000ft at 50 knots, once at altitude, it will proceed to the southwestern portion of the box at the max endurance speed of 35 knots. At 10,000 ft / 35 kts the Airlander 10 will conduct a flight pattern authorized at TACCO discretion. Return-to-base (RTB) when BINGO fuel is reached.

4. Fuel Capacity/Loadout

a. P-8A

CTF is requesting maximum on-station time. As a result, the P-8A will load its maximum takeoff fuel of 69,500 pounds. It will also carry 129 A-Sized sonobuoys, and two SAR kits in the event re-tasking occurs. Weight and balance IAW NATOPS.

b. AIRLANDER 10

CTF is requesting maximum on-station time. As a result, the Airlander 10 will load its main tank with a maximum takeoff fuel of 13,000 pounds and its extra capacity tank with 7,000 pounds. This gives Airlander 10 a total of 20,000 pounds of fuel. Since max endurance is the priority, extra fuel has taken precedence over search stores (sonobuoys). Airlander 10's payload capacity includes all computer systems, sensor systems, personnel,

search stores, and extra fuel. Therefore, the 7,000 pounds of extra fuel comes out of its max payload capacity of 20,000 pounds. This leaves 13,000 pounds for all computer systems, sensor systems, personnel, search stores. The only stores the Airlander 10 will carry for this mission are two SAR kits.

5. Fuel Burn Rate

a. P-8A

For this mission, the P-8A will utilize an estimated fuel burn rate of 7,000 pounds/ hour during takeoff, transits, and landing (first hour and last hour). On-station/endurance legs will only require 6,000 pounds/hour since the P-8A will be flying at its maximum endurance speed.

b. AIRLANDER 10

For this mission, the Airlander 10 will utilize an estimated fuel burn rate of 295 pounds/hour during takeoff, transits, and landing (first hour and last hour). On-station/ endurance legs will only require 150 pounds/hour since the Airlander 10 will be flying at its maximum endurance speed.

6. Endurance

a. P-8A

In determining endurance, the following calculations will be applied in specified order, usable fuel equation and estimated endurance equation. These will calculate how long the P-8A can remain airborne. As a check, the estimated fuel burn rate equation will be used as validation.

Usable Fuel Equation:

63,500lbs Usable Fuel = 69,500lbs Total Fuel – 6,000lbs Fuel Reserve

After removing the 6,000 pounds of required reserve fuel, the P-8A is left with 63,500 pounds of usable fuel. Usable fuel will be used to calculate estimated endurance. This must be calculated twice based off both fuel burn rates (7,000 and 6,000). The first/

last hour (for takeoff, transits, and landing) will be burned at a rate of 7,000 pounds/hour equaling 14,000 pounds total. These 14,000 pounds will be removed from the 63,500 pounds of usable fuel calculated above leaving a total of 49,500 pounds of usable fuel remaining. This number is used to determine how long the aircraft can stay on-station using the estimated endurance equation given the fuel burn rate at its max endurance speed of 6,000 pounds/hr.

Estimated Endurance Equation:

8.25hrs = (49,500lbs Usable Fuel) / (6,000lbs/hr Fuel Burn Rate at Max Endurance)

After getting an on-station endurance time of 8.25 hours the remaining 2 hours (from takeoff, transits, and landing) must be added back to calculate total estimated endurance. This would give the P-8A a total estimated endurance time of 10.25 hours or 10 hours and 15 minutes. To cross-check the validity of this number the estimated fuel burn rate equation is used to calculate the total average fuel burn rate.

Estimated Fuel Burn Rate Equation:

6,195.12lbs/hr = (63,500lbs Usable Fuel) / (10.25hrs Total Estimated Endurance)

An average of 6,195.12 pounds/hour validates our estimated endurance time because it shows that between 6,000 pounds/hour and 7,000 pounds/hour were utilized for all phases of flight (takeoff, transits, on-station, and landing).

b. AIRLANDER 10

The same controls were used to calculate flight endurance for Airlander 10.

Usable Fuel Equation:

18,000lbs = 20,000lbs – 2000lbs (10% of total fuel onboard)

After removing the 2,000 pounds of required reserve fuel, the Airlander is left with 18,000 pounds of usable fuel. Usable fuel will be used to calculate estimated endurance. This must be calculated twice based off both fuel burn rates (295 and 150). The first/last

hour (for takeoff, transits, and landing) will be burned at a rate of 295 pounds/hour equaling 590 pounds total. These 590 pounds will be removed from the 18,000 pounds of usable fuel calculated above leaving a total of 17,410 pounds of usable fuel remaining. This number is used to determine how long the aircraft can stay on-station using the estimated endurance equation given the fuel burn rate at its max endurance speed of 150 pounds/hr.

Estimated Endurance Equation:

116.1hrs = 17,410lbs / (150lbs/hr)

After getting an on-station endurance time of 116.1 hours the remaining 2 hours (from takeoff, transits, and landing) must be added back to calculate total estimated endurance. This would give the Airlander a total estimated endurance time of 118.1 hours or 4 days and 21 hours. To cross-check the validity of this number the estimated fuel burn rate equation is used to calculate the total average fuel burn rate.

Estimated Fuel Burn Rate Equation:

152.4lbs/hr = 18,000lbs / 118.1hrs

An average of 152.4 pounds/hour validates our estimated endurance time because it shows that between 150 pounds/hour and 295 pounds/hour were utilized for all phases of flight (takeoff, transits, on-station, and landing). While this may seem extreme, the low fuel burn rate and high fuel capacity create an environment for an asset to stay airborne for days at a time.

7. Maximum Range

A range comparison of each asset will be measured by a combination of speed to the AOR, endurance on-station, and sensor coverage.

a. P-8A

Given the P-8A's ability to fly over 300 knots, time to AOR is minimal in this scenario. Based on the assumed one-hour allotment for takeoff, climb, and transit the P-8A

will cover approximately 320NM traveling at 320 knots. Total endurance is 10.25 hours, one hour for the takeoff, transits, and landing provides a total on-station time of 8.25 hours.

Time, Distance, Speed Equation:

1,980NM = 240kts x 8.25hrs

The total estimated endurance range/distance covered would be 1,980NM. Adding back the 2 hours or 640NM covered, in takeoff/transit/landing, the total range for the P-8A mission is 10.25-hour and 2,620NM. This proves that the P-8A is a high-speed lower range asset when compared to Airlander 10.

b. AIRLANDER 10

Given Airlander's slower speed, transit times to the AOR will be significantly longer than the P-8A. Based on the assumed one-hour allotment for takeoff, climb, and transit Airlander will cover approximately 50NM traveling at 50 knots. Total endurance is 118.1 hours, one hour for the takeoff, transits, and landing provides a total on -station time of 116.1 hours.

Time, Distance, Speed Equation:

4,063.5NM = 35kts x 116.1

As shown, the total estimated endurance range/distance covered would be 4,063.5NM. Adding back the 2 hours or 100NM covered, the total range for the 118.1-hour mission would be 4,163.5NM. Despite its slower speed, the distance covered, and therefore, sensor coverage is far greater and longer than that of the P-8A. This proves that the Airlander is a slower-speed longer range asset when compared to P-8A.

8. ISR Conclusion

In the context of ISR, the P-8A's maximum takeoff weight enables the transportation of all critical equipment, facilitating the flexibility for potential mission diversions and executions. This confers a clear advantage over the Airlander, which due to its maximum payload capacity limits the ability to carry extra search stores when loading

additional fuel. The comparison of the P-8A and the Airlander 10 in terms of overall range and capability reveals distinct advantages and trade-offs between these assets based on specific mission requirements. The P-8A's capability is influenced by a combination of factors such as its speed, endurance, payload capacity, and sensor coverage. On the other hand, Airlander 10's slower speed results in longer transit times to on-station points, but due to its longer endurance, it achieves a remarkable range and sensor coverage (4,163NM vs. 2620NM). It excels in terms of distance covered and, consequently, sensor coverage, making it suitable for missions that require extended endurance and expansive coverage such as maritime ISR. The Airlander's on-station time of 118.1 hours vs. P-8A's 10.25 hours showcases its advantages for uninterrupted surveillance. The Airlander's disadvantage is its limited payload capacity, which restricts its ability to carry search stores and execute multiple mission sets while airborne.

E. ASW

The tactical execution of ASW differs depending on asset type and available sensors, in evaluating mission effectiveness of Airlander 10 vs. P-8A the same type and variant of sensors will be available to both assets. Quantities of search stores will vary due to flight endurance and available storage space. The sensors being utilized are passive sonar buoys, active sonar buoys, bathymetry buoys, the multi-mission APY-10 radar, EO/IR camera, and line-of-sight and satellite-capable communication systems. The goal of this mission is to search the assigned AOR, localize, classify, and track any subsurface contacts, and pass VOIs through the applicable communication chains. Generic flight profiles, fuel/ store capacities, and fuel burn data have all been gathered from publicly available sources. This is solely a hypothetical mission scenario to compare assets and shall not be used in real-world execution.

1. Mission Description

As the Arctic Sea Ice Cap continues to melt, strategic transit lanes have presented an opportunity for vessels and submarines of interest to transit from northern naval bases to the North Atlantic via the Greenland-Iceland-UK (GIUK) Gap. Along with submarine advancements and a profound ability to conduct covert operations, unlocated submarines

present a significant threat to North Atlantic Treaty Organization (NATO) allies and partners. These submarines are attempting to collect on, exploit, and intimidate NATO and partnered assets within the region. As a result, sea lanes and sea lines of communication are compromised unless unidentified submarines are located, identified, tracked, and reported. The CTF has requested air assets stationed at Royal Air Force (RAF) Base Lossiemouth to conduct 24-hour ASW operations to find, track, and report any subsurface contact attempting to transit the GIUK Gap.

2. Operational Area and Distance from the Airfield

In support of CTF and NATO, air assets will depart from RAF Lossiemouth, transit 405NM to the AOR and complete tasking as described in the Mission Description. Airborne assets will utilize sonobuoys to survey as much area as possible represented by Figure 19 represents the 700NM x 700NM box of the AOR.

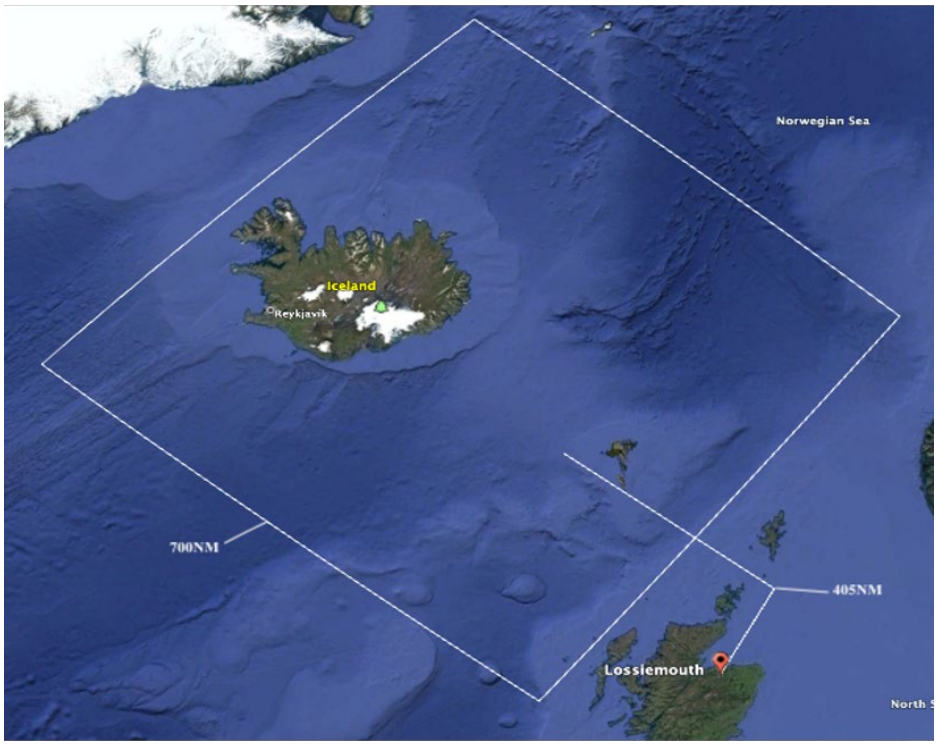

Figure 19. ASW Mission Scenario Operation Area. Source: Google (2023a).

3. Flight Profile

a. P-8A

All pre-flight/post-flight duties and responsibilities will be conducted IAW NATOPS. After departing RAF Lossiemouth, the P-8A will immediately climb to 20,000ft at 320 knots and transit the 405NM to the AOR shown in Figure 19. Once on-station the P-8A will descend, fly maximum endurance speed, and begin search stores deployment. Flight path/tactics patterns that maximize sensor ranges are authorized, at PPC/TACCO. RTB when BINGO fuel is reached.

b. AIRLANDER 10

All pre-flight/post-flight duties and responsibilities will be conducted IAW applicable flight publications. After departing RAF Lossiemouth, the Airlander will immediately climb to 10,000ft at 50 knots and transit the 405NM as shown in Figure 19. Once on-station the Airlander will descend, fly maximum endurance speed, and begin search stores deployment. Flight path/tactics patterns that maximize sensor ranges are authorized, at PPC/TACCO. RTB when BINGO fuel is reached.

4. Fuel Capacity/Loadout

a. P-8A

CTF's priority is locating unknown subsurface combatants by any means necessary. As a result, the P-8A will load its maximum takeoff fuel of 69,500 pounds and carry its maximum buoy loadout of 129 A-Sized sonobuoys allowing for 8 hours of continuous searching and tracking. Weight and balance IAW NATOPS.

b. AIRLANDER 10

CTF's priority is locating unknown subsurface combatants by any means necessary. For Airlander, this means search stores take precedence over fuel. As a result, Airlander 10 will only fill its tank to maximum takeoff fuel of 13,000 pounds. The Airlander touts a 10 ton or 20,000-pound capacity on top of its 13,000-pound fuel capacity. This may seem like a lot, but at an average of 25 pounds (Sparton and Undersea Sensor

Systems, Inc, 2023), sonobuoy weight alone adds up rather quickly. As Airlander 10 is a multi-day asset, the number of buoys needed to execute an ASW mission presents a complex weight problem.

In this mission, key assumptions must be made. First, since the tasked AOR is 405NM away and Airlander can only carry 13,000 pounds of fuel, its total flight endurance will be less than or around 72 hours. This means that, based on the findings of Chapter IV, the number of crew onboard would be 15 (3 pilots, 4 NFOs, 4 AWOs, and 4 EWOs). If we assume that the average person weighs 185 pounds, the total crew weight would be 2,775 pounds. Second, computer equipment, sonobuoy launchers, and other mission equipment weigh around 8,000 pounds. This puts total payload weight at 10,775 pounds. This results in a remaining weight capacity of 9,300 pounds. This will then be used to calculate how many sonobuoys the Airlander can carry. By dividing the remaining 9,300 pounds by the average buoy weight of 25 pounds, it is determined that Airlander 10 can accommodate 372 buoys allowing for 23 hours of continuous searching and tracking. In this configuration an Airlander 10 has the capacity to store three times the number of buoys compared to the P-8A.

5. Fuel Burn Rate

a. P-8A

For this mission, the P-8A will utilize an estimated fuel burn rate of 7,000 pounds/ hour during takeoff, transits, and landing. On-station/endurance legs will only require 6,000 pounds/hour since the P-8A will be flying at its maximum endurance speed.

b. AIRLANDER 10

For this mission, the Airlander 10 will utilize an estimated fuel burn rate of 295 pounds/hour during takeoff, transits, and landing. On-station/endurance legs will only require 150 pounds/hour since the Airlander 10 will be flying at its maximum endurance speed.

6. Endurance

a. P-8A

Since the P-8A is loading the same amount of fuel, usable fuel will remain the same (63,500 pounds). That usable fuel can then be used to calculate estimated endurance. This must be calculated in two different ways. Since fuel will be burned at a rate of 7,000 pounds/hour during takeoff, transits, and landing, transit times must be calculated given transit speed of 320 knots.

Time, Distance, Speed Equation:

1.27hrs Transit Time = 405NM x 320kts

P-8A's transit time is 1.27 hours or 1 hour and 16 minutes. To calculate fuel burned during transit, 1.27 is multiplied by 7,000 pounds/hour. Each transit burns 8,890 pounds, meaning the total fuel burned for both transits equal 17,780 pounds. These 17,780 pounds will be removed from the 63,500 pounds of usable fuel leaving a total of 45,720 pounds of usable fuel remaining. This number is used to determine how long the aircraft can stay on-station using the estimated endurance equation given the fuel burn rate at its max endurance speed of 6,000 pounds/hour.

Estimated Endurance Equation:

7.62hrs = 45,720lbs / (6,000lbs/hr)

After getting an on-station endurance time of 7.62 hours, the remaining 2.54 hours (from takeoff, transits, and landing) must be added back to calculate total estimated endurance. This would give the P-8A a total estimated endurance time of 10.16 hours or 10 hours and 10 minutes. To cross-check the validity of this number the estimated fuel burn rate equation is used to calculate the total average fuel burn rate.

Estimated Fuel Burn Rate Equation:

6,250lbs/hr = 63,500lbs x 10.16hrs

An average of 6,250 pounds/hour validates our estimated endurance time because it shows that between 6,000 pounds/hour and 7,000 pounds/hour were utilized for all phases of flight (takeoff, transits, on-station, and landing).

b. AIRLANDER 10

The same controls were used to calculate flight endurance for Airlander 10.

Usable Fuel Equation:

11,700lbs = 13,000lbs – 1300lbs (10% of total fuel onboard)

After removing the 1,300 pounds of required reserve fuel, the Airlander is left with 11,700 pounds of usable fuel. Usable fuel will be used to calculate estimated endurance. This must be calculated in two different ways. Since fuel will be burned at a rate of 295 pounds/hour during takeoff, transits and landing, transit times must be calculated given transit speed of 50 knots.

Time, Distance, Speed Equation:

8.1hrs Transit Time = 405NM / 50kts

Airlander's transit time is 8.1 hours or 8 hour and 6 minutes. To calculate fuel burned during transit 8.1 is multiplied by 295 pounds/hour. Each transit burns 2,389.5 pounds, meaning the total fuel burned for both transits equal 4,779 pounds. These 4,779 pounds will be removed from the 11,700 pounds of usable fuel leaving a total of 6,921 pounds of usable fuel remaining. This number is used to determine how long the aircraft can stay on-station using the estimated endurance equation given the fuel burn rate at its max endurance speed of 150 pounds/hour.

Estimated Endurance Equation:

46.14hrs = 6,921lbs / (150lbs/hr)

After getting an on-station endurance time of 46.14 hours the remaining 16.2 (from takeoff, transits, and landing) must be added back to calculate total estimated endurance.

This would give the Airlander 10 a total estimated endurance time of 62.34 hours or 2 days and 14 hours. To cross-check the validity of this number the estimated fuel burn rate equation is used to calculate the total average fuel burn rate.

Estimated Fuel Burn Rate Equation:

187.68lbs/hr = 11,700lbs / 62.34hrs

An average of 187.68 pounds/hour validates our estimated endurance time because it shows that between 150 pounds/hour and 295 pounds/hour were utilized for all phases of flight (takeoff, transits, on-station, and landing). This showcases that distant on-station points bleed into usable coverage time for Airlander 10. Despite the ability to stay on-station for almost two days, the dynamic ASW environment may prove to be challenging for Airlander.

7. Maximum Range

A range comparison of each asset will be measured by a combination of speed to the AOR, endurance on-station, and sensor coverage.

a. P-8A

Given the P-8A's ability to fly over 300 knots, transit times to and from the AOR are significantly shorter than the Airlander. This was calculated previously in the respective endurance sections 1.27 hours (P-8A) vs. 8.1 hours (Airlander).

Based on 405NM transit legs, the only calculation needed is the distance/range covered during the endurance portion of the flight. The distance/range covered is calculated by multiplying speed by time. Total on-station coverage is 1,828.8NM given a maximum endurance of 7.62 hours of usable fuel at 240kts.

Time, Distance, Speed Equation:

1,828.8NM = 240kts x 7.62hrs

Given a total estimated endurance range of 1,828.8NM and adding back the 810NM covered during takeoff/transit/landing, the total range/distance covered for the P-8A is 10.16-hour and 2,638.8NM.

b. AIRLANDER 10

Given Airlander's slower speed, transit times to on-station points are going to take significantly longer than the P-8A. This was calculated previously in the respective endurance sections 1.27 hours (P-8A) vs. 8.1 hours (Airlander).

Based on 405NM transit legs, the only calculation needed is the distance/range covered during the endurance portion of the flight. The distance/range covered is calculated by multiplying speed by time. Total on station coverage is 1,614.9NM given a maximum endurance of 46.14 hours of usable fuel at 35kts.

Time, Distance, Speed Equation:

1,614.9NM = 35kts x 46.14hrs

Given a total estimated endurance range of 1,614.9NM and adding back the 810NM covered during takeoff/transit/landing, the total range/distance covered for the Airlander is 46 hours and 2,424.9NM.

8. ASW Conclusion

In the dynamic realm of ASW, the P-8A exhibits high flexibility, allowing for swift responses when a contact is identified within the designated AOR. In contrast, the Airlander, with its slower flight speeds, faces limitations in transits, and in continuously tracking subsurface contacts. While Airlander can remain on-station for a greater period, (46 hours) it only holds search stores for continuous of 23 hours. Therefore, search stores are the Airlander's limiting factor. Secondly, if the search area relocates within the AOR, the Airlander 10 may take significantly longer to reposition while the P-8A, capable of flying at speeds greater than 300 knots, has a clear advantage for maneuvering within the AOR. Therefore, for ASW, where speed and distance are critical, the P-8A has advantages over the Airlander.

F. CHAPTER SUMMARY

In summary, the P-8A excels in mission sets requiring speed and flexibility to quickly respond to changing operational conditions. In contrast, the Airlander 10 is better suited for long-endurance missions with a less dynamic operational environment. In particular the Airlander 10 is slower to reposition and therefore less suited to an ASW mission than to an ISR mission. If the Airlander 10 were to become part of the USN's aircraft fleet, its employment should be aligned with its mission strengths.

In principle, the optimal approach to leverage these conclusions would involve deploying a mix of Airlander 10s and P-8As. Utilizing the Airlander 10 for extended missions demanding extensive coverage (ISR, SAR, HADR) would free up P-8A crews to carry out versatile and dynamic tasks such as ASW. For example, if two Airlander's worked in tandem with six P-8As, 24-hour coverage would be provided in both ISR and ASW missions anywhere in the world.

Should policymakers and officials within the DOD decide to proceed with the inclusion of the Airlander 10 in their military inventory, it is essential to conduct a thorough financial assessment and comparison of these assets. The upcoming chapter will provide an in-depth exploration of the financial considerations that underpin this strategic choice. This analysis will delve into the financial aspects associated with integrating the Airlander 10 into the military arsenal and will scrutinize the implications this decision might have on budget allocations and overall fiscal responsibility.

VI. FINANCIAL ANALYSIS

A. INTRODUCTION

While this research is not a preparation for an acquisition project, the subsequent sections in this chapter delve into an Analysis of Alternatives (AoA), which involves a comprehensive analytical assessment comparing the operational effectiveness, suitability, and life-cycle cost of Airlander 10 and the P-8A. The AoA will be executed by conducting a Discounted Cash Flow (DCF) for expenses associated with Airlander 10 and the P-8A over the entire life cycle of each asset.

B. DISCOUNTED CASH FLOW

A DCF analysis is a financial valuation method that is widely used to assess the value of an investment, project, or asset. DCF analysis considers the time value of money and calculates the present value of all expected future cash flows associated with the investment or project. DCF analysis is particularly suitable for assessing long-term investments and projects because it accounts for the time value of money over extended periods.

C. CIRCULAR A-94

The circular A-94 is a document issued by the U.S. Office of Management and Budget (OMB), which provides guidelines for preparing and assessing cost-benefit and cost-effectiveness analyses for federal programs and projects. Circular A-94 includes guidance on various aspects of cost-benefit and cost-effectiveness analysis, including:

- Discount rates: The circular provides discount rates for use in evaluating the time value of money in analyzing federal programs. The discount rates are used to convert future costs and benefits into present values.

- Nominal Discount Rates. "A forecast of nominal or market interest rates for calendar year 2023 based on the economic assumptions for the 2024 Budget is presented below. These nominal rates are to be used for discounting nominal flows, which are often encountered in lease-purchase analysis" (Young, 2023).

- Real Discount Rates. "A forecast of real interest rates from which the inflation premium has been removed and based on the economic assumptions from the 2024 Budget is presented below. These real rates are to be used for discounting constant-dollar flows, as is often required in cost- effectiveness analysis" (Young, 2023). Figure 20 below shows the Real Interest Rates given by the OMB.

Real Interest Rates on Treasury Notes and Bonds of Specified Maturities (in percent)					
3 Years	5 Year	7 Years	10 Years	20 Years	30 Years
1.20%	1.30%	1.40%	1.50%	2.00%	2.00%

Figure 20. Real Interest Rates OMB. Source: Young (2023).

- Sensitivity analysis: Circular A-94 recommends conducting sensitivity analysis to account for uncertainties in the data and assumptions used in cost-benefit analysis. Sensitivity analysis helps assess how changes in key parameters or assumptions can affect the results.

D. COMPARING AIRLANDER 10 AND P-8A

To ensure a comprehensive assessment of the financial aspects involved in the decision between P-8A and Airlander, a DCF analysis will be conducted. This analysis will encompass an examination of various cost elements, ranging from the initial acquisition of these aircraft to ongoing operational expenses. To ensure a fair and equitable comparison, any required costs for the P-8A will be applied to the Airlander, and reasonable assumptions will be made regarding maintenance and fuel expenses. The following factors will be analyzed:

- Initial Acquisition Cost (P-8A / Airlander): The initial acquisition cost to procure a "green" aircraft. A "green" aircraft, being a basic, unmodified, capable of flight airframe.

- Mission System Cost (P-8A / Airlander): Mission System Cost refers to the financial expense associated with the design, installation, and integration of specialized equipment, technology, and systems within the aircraft. Examples of mission systems may include radar, communication

devices, surveillance equipment, and any other technology essential for the aircraft to carry out its intended operations.

- Engine Cost (P-8A): The cost to convert the engines from a Boeing 737–800ERX aircraft to a USN P-8A. The engines are required to support additional onboard electronics onboard.

- Spare Engine Cost (P-8A / Airlander): These spare engines serve as backups in the event of engine failures or the need for replacement. The P-8A requires one spare engine available for each squadron of six aircrafts. The Airlander will require one spare engine.

- Maintenance Costs Scheduled / Unscheduled (P-8A / Airlander): Cover financial expenses related to maintaining and preserving an aircraft or equipment. Scheduled maintenance, being planned and routine maintenance while unscheduled maintenance arises from unexpected repairs, due to wear and tear, malfunctions, or unforeseen issues.

- Re-Hull Costs (Airlander): Re-Hull Costs specifically apply to Airlander and represent the financial expenses associated with the periodic refurbishment or replacement of the airship's hull. The hull, being a critical component of Airlander 10, requires maintenance or replacement every 10 years. In this assessment, the cost of re-hulling will be included in the maintenance cost, as it aligns with the established definition of scheduled maintenance.

- Fuel Costs (P-8A / Airlander): P-8A fuel costs refer to expenses associated with JP-5, while Airlander costs refer to JP-8.

E. BREAKDOWN OF P-8A COSTS

When analyzing life cycle costs of the P-8A, assumptions were made on maintenance and fuel expenses using data from the Naval Visibility and Management of Operating and Support Costs (VAMOSC). P-8A financial data was taken from Department

of Defense Fiscal Year (FY) 2022 Budget Estimates (Department of Defense, 2021a). The following were the results of P-8A costs for its 25 year life cycle.

- Initial Acquisition Cost: The USN buys all P-8A airframes from Boeing with an initial purchase price of $(173,000,000).
- Mission System Cost: In order to upgrade the 737–800ERX from Boeing all radar, communication systems, and missions systems must be outfitted in the aircraft. This costs $(29,000,000).
- Engine Cost: To convert the engine of a 737–800ERX for USN use, the cost for new engines are $(28,000,000).
- Spare Engine Cost: For one P-8A squadron, made up of six aircraft, there is a requirement for one spare engine to be available, this costs $(14,000,000).
- Maintenance Costs Scheduled and Unscheduled: Calculating an average maintenance cost for the P-8A is contingent on the aircraft's wear and tear, which can vary. To determine this average cost, data was pulled from VAMOSC, and is shown in Figure 21. A total maintenance cost of $157,730,403.00 was divided by the total number of P-8A aircraft in the active-duty fleet, 98. This division yielded an average maintenance cost of $(1,609,493.91) for a single P-8A.

P8		
3.4.2.1.1 Contractor Depot Repair - Aircraft Rework	$	35,621,701.00
3.4.2.1.2 Contractor Depot Repair - Aircraft Emergency Repair	$	251,626.00
3.4.2.2.1 Contractor Depot Repair - Engine Rework	$	14,951,293.00
3.5.1.1.1 Contract Maintenance Services - Navy REG	$	10,205,103.00
3.2.1.1.1.1 AVDLR Costs - Navy REG - Cost of Goods	$	78,045,761.00
3.2.1.1.1.2 AVDLR Costs - Navy REG - Cost Recovery	$	3,219,388.00
3.2 Depot Level Repairable (DLRs)	$	15,435,531.00

Figure 21. Data from P-8A VAMSOC

$1,609,493.91 avg cost = $157,730,403 Maint Cost ¸ 98 Active P-8A

- Fuel Costs: Given the variability in flight hours among individual aircraft, an average was used to determine fuel costs for one P-8A over a calendar year. Data from VAMOSC indicated a total of 58,547 flight hours for active-duty P-8A aircraft in 2023. Dividing this figure by the fleet of 98 aircraft resulted in an approximate average of 597 flight hours per aircraft. For the purposes of our analysis, this was rounded to 600 hours. Subsequently, a fuel consumption for the P-8A was based on mission scenarios outlined in the previous chapter. This analysis indicated an average fuel burn rate of 6,150 pounds per hour. To determine the total fuel consumed in a year, this burn rate was multiplied by the 600-hour average flight time resulting in total fuel consumption of 3,690,000 pounds. This was then converted to metric tons and multiplied by the cost of JP-5 fuel per metric ton, $732 (JP-5, 2023). The final calculation showed an average annual fuel expenditure of $(1,225,535.39) for 600 hours of flight, with a burn rate of 6,150 pounds per hour.

597 hours = 58,547 fleet flight hours ¸ 98 Active P-8As

3,690,000 total fuel burnt = 6,150 lbs per hour x 600 hours flight

1,674.23 tons = 3,690,000 lbs fuel ¸ 2204 metric ton

$1,225,535.39 fuel avg price per year = 1,674.23 tons x $732 per ton

In this analysis, the comprehensive cost of a single P-8A for the U.S. Navy at year zero amounts to $(244,000,000). This cost is further broken down into an annual expenditure of $(1,609,493.91) for maintenance and $(1,225,535.39) for fuel, over the aircraft's projected lifespan of 25 years.

F. BREAKDOWN OF AIRLANDER 10 COSTS

When assessing life cycle costs of Airlander in comparison to the P-8A, its ability to fly extended missions presented a considerable advantage. Given that this is a direct comparison to P-8A, Airlander will conduct the same average flying hours for the year, 600. It should be noted that 600 hours is a underutilization of the aircraft as it has the ability to fly for longer durations. To maintain parity with the P-8A, the same mission system cost was applied, and the costs were calculated based on a 25-years to directly compare with the P-8A's lifespan. Nevertheless, HAV has indicated that the estimated lifespan of the Airlander will be 30 years.

- Initial Acquisition Cost: The purchase price from HAV for one Airlander 10 is $(60,000,000).

- Mission System Cost: In order to upgrade the Airlander from a green aircraft all radar, communication systems, and missions systems must be outfitted in the aircraft. This cost will be the same as the P-8A and will be $(29,000,000).

- Spare Engine Cost: In keeping with a direct comparison to the P-8A, Airlander will have one spare engine purchased at year zero. This will cost $(200,000).

- Maintenance Costs Scheduled and Unscheduled: Given that the Airlander 10 is currently not in operation, an assumption regarding its average flight hours was made. In keeping a fair comparison, it was assumed that Airlander 10 would have the yearly flight hours of a single P-8A. The HAV team provided the total estimated maintenance costs for 600 flight hours, $(1,645,394). This yearly cost covered the 10 year re-hulling required for Airlander 10 at years 10 and 20.

- Fuel Costs: 600 flight hours were used to determine fuel costs for one Airlander over a calendar year. Subsequently, a fuel consumption from previous mission scenarios was used for Airlander. This analysis indicated

an average fuel burn rate of 170 pounds per hour. To determine the total fuel consumed in a year, this burn rate was multiplied by the 600-hour yearly flight time resulting in total fuel consumption of 102,000 pounds. This was then converted to metric tons and multiplied by the cost of JP-8 fuel per metric ton, $711 (JP-8, 2023). The final calculation showed an average annual fuel expenditure of $(32,904.72) for 600 hours of flight, with a burn rate of 170 pounds per hour.

102,000 total fuel burnt = 170 lbs per hour x 600 hours flight

46.28 tons = 102,000 lbs fuel ¸ 2204 metric ton

$32,904.72 fuel avg price per year = 46.28 tons x $711 per ton

In this analysis, the comprehensive cost of a single Airlander 10 for the U.S. Navy at year zero amounts to $(89,200,000.00). This cost is further broken down into an annual expenditure of $(1,645,394) for maintenance and $(32,904.72) for fuel, over a 25-year lifespan.

G. DCF RESULTS

After determining the year zero costs and and evaluating future costs/cash flows, a DCF analysis can be conducted for both the Airlander 10 and the P-8A, aiming to calculate the NPV over a 25-year life cycle. A 2% real discount rate has been applied, aligning with the guidelines in Circular A-94.

The P-8A, initially priced at $244,000,000 with annual maintenance and fuel costs, resulted in a Net Present Value (NPV) of approximately $(297,621,533.27). This signifies that the cumulative costs and expenditures of the P-8A over the 25-year period are equivalent to having approximately $297.6 million in hand at the commencement of the period.

The Airlander 10, initially priced at $89,200,000 with annual maintenance and fuel costs, resulted in a Net Present Value (NPV) of approximately $(120,943,217.11). This signifies that the cumulative costs and expenditures of the Airlander over the 25-year

period are equivalent to having approximately $120.9 million in hand at the commencement of the period.

Year Zero Costs:

- P-8A: ($244,000,000)
- Airlander: ($89,200,000)

Projected Future Costs:

- P-8A: ($2,835,029.30)
- Airlander: ($1,678,298.72)

NPV:

- P-8A: ($297,621,533.27)
- Airlander: ($120,943,217.11)

H. FINDINGS

For organizations planning to invest in either of these aircraft, the figures emphasize the magnitude of financial commitment required. This information is crucial for budgetary planning, helping organizations allocate resources effectively and understand the potential financial strain associated with these projects. In examining the DCF the following findings were made clear.

- Airframe Cost: The most significant cost component for both aircraft is the airframe expense. In the case of the P-8A, this component represents a substantial 71% of the total expenditure during the initial purchase, while for the Airlander, it constitutes 67% of the overall cost.
- Cost Differential: A noteworthy observation is the substantial cost differential between P-8A and Airlander 10, with P-8A being 2.8 times more expensive.

- Fuel Cost: In the analysis of fuel costs, the year-to-year difference between the P-8A and Airlander 10 is relatively modest, standing at 1.192 million. However, the true significance of this comparison becomes evident over the entire lifespan, resulting in substantial savings over $28 million when choosing to operate the Airlander 10 over the P-8A.

- Initial Year Expenses: The P-8A requires a substantial upfront investment of $244 million, making it a considerably more capital-intensive option compared to the Airlander, which has a significantly lower year zero cost of $89.2 million. Notably, a substantial portion of the NPV costs is concentrated in the initial year, aligning with expectations. What stood out is that the P-8A's initial year costs constituted a significant 82% of the total NPV, in contrast to the Airlander, where these costs accounted for only 74%.

- Crewing: Although the Airlander 10 requires fewer crew members, the savings in this area were considered insufficient to be a factor in the DCF evaluation. However, it's essential to note that while these savings may not drastically impact the overall financial analysis, they play a significant role in job performance and impose limitations on the weight capacity of the Airlander 10.

- Long-Term Planning: Planners should also consider the long-term perspective. The Airlander's lower costs over time, coupled with a projected 30-year life cycle, could provide a significant advantage over the P-8A's 25 year lifespan.

Taken together, these results underscore the economic advantages of choosing the Airlander 10, highlighting its capacity to generate significant cost reductions in both the short-term and long-term scenarios.

I. SENSITIVITY ANALYSIS

A sensitivity analysis is a financial or statistical method used to assess how changes in the input variables or assumptions of a model affect the outcomes, results, or conclusions. It is employed in various fields, including finance, to understand the impact of different variables on a given project, investment, or decision. The goal is to determine how sensitive the model or project is to variations in these input factors. Sensitivity analyses help decision-makers assess the robustness and reliability of their plans and strategies by considering various scenarios and potential risks. For this analysis the following sensitivity analysis were performed on the DCF.

- Real Interest Rate Change: A 2% interest rate served as the baseline point of analysis in compliance with the White House's OMB A-94 guidance. To assess its impact on NPV, variations involving a 2% increase and decrease were considered. Figure 22 shows the sensitivity analysis for the described increase and decrease, as the discount rate (int rate) rises or falls.

Sensitivity Analysis		
AIRCRAFT	Discount Rate	NPV
P-8A	0%	$ (312,040,703.20)
	2%	$ (297,621,533.27)
	4%	$ (287,225,587.24)
A-10	0%	$ (129,479,169.25)
	2%	$ (120,943,217.11)
	4%	$ (114,788,958.70)

Figure 22. Discount Rate % Change

- Fuel Price Change: Fuel prices were sourced from Jet-A1-Fuel as of October 25th, 2023. The standard fuel cost for the P-8A was $732 per metric ton for JP5, (JP-5, 2023) while the Airlander utilized fuel priced at $711 per metric ton for JP8 (JP-8, 2023). Figure 23 shows a twenty dollar per metric ton increase and decrease with the resulting NPV.

Sensitivity Analysis			
AIRCRAFT	Fuel Price	Yearly Fuel Cost	NPV
P-8A	$ 712	$ (1,192,050.82)	$ (296,988,208.53)
	$ 732	$ (1,225,535.39)	$ (297,621,533.27)
	$ 752	$ (1,259,019.96)	$ (298,254,858.00)
A-10	$ 691	$ (31,979.13)	$ (120,925,710.57)
	$ 711	$ (32,904.72)	$ (120,943,217.11)
	$ 731	$ (33,830.31)	$ (120,960,723.64)

Figure 23. Fuel Price Change

The sensitivity analysis delved into potential variations in discount rates and fuel costs but didn't yield substantial shifts in the NPV. It highlights that the P-8A is more reactive to alterations in discount rates, whereas the Airlander project exhibits a more gradual improvement in its financial performance as discount rates rise. In terms of fuel price fluctuations, the P-8A demonstrates higher responsiveness compared to the Airlander. The Yearly Fuel Cost for the P-8A escalates more swiftly with each increase in fuel prices, suggesting the potential for financial volatility in a volatile fuel price environment. Considering these results, substantial increases in discount rates or significant reductions in fuel prices would favor the Airlander, resulting in substantial cost savings.

J. UNCERTAIN CONSIDERATIONS:

This analysis is based on a set of assumptions, and there were certain factors that couldn't be determined or considered when calculating the NPV for Airlander and P-8A. Many aircraft operations break down their costs into a "cost per flying hour" (CPFH) equation to determine the total cost of operating the aircraft. While Airlander provided specific CPFH breakdowns, the USN does not have such a detailed breakdown available.

Another important factor not considered, but with significant financial implications, is the total expenditure related to manpower, both in terms of operating the aircraft and maintaining its onboard systems. It's worth noting that maintenance costs for arrays in the P-8A and Airlander were excluded from the analysis. These costs are assumed

to be managed by the personnel assigned to each aircraft and are not factored into the financial calculations.

K. CHAPTER SUMMARY

In conclusion this chapter looked at the analysis of comparing a P-8A with the Airlander 10 financially. A DCF was used to consider the concept of the time value of money, determining the current worth of projected future cash flows associated with each aircraft. The findings clearly indicate that the Airlander 10 presents noteworthy cost savings in comparison to P-8A, especially in terms of fuel and airframe expenses. Additionally, a sensitivity analysis was conducted to assess how changes in real interest rates and fuel prices impact the NPV of both assets. It's important to acknowledge uncertainties and assumptions within this analysis. Notable, uncertainties include the absence of detailed data on CPFH from the USN and the exclusion of array and sensor maintenance costs for each aircraft. As Airlander is not currently operational the maintenance cost was an estimate given by the engineering team at HAV.

As previously mentioned, the former CNO has emphasized the necessity for the Navy to phase out economically unsustainable platforms (Gilday, 2022) and align with the "DOD Climate Adaption Plan," underscoring the importance of a flexible, efficient, and environmentally conscious military force (Department of Defense, 2021b). In light of these directives, the Navy should prioritize the development of cost-effective and carbon-neutral alternatives such as Airlander. The Airlander 10 truly distinguishes itself from the P-8A through its remarkable green energy efficiency, consuming 36 times less fuel for the same 600 hours of flight. This capability in conjunction with the economic advantages proves that Airlander 10 is an aircraft deserving of further research and study.

VII. CONCLUSION

A. ASSESSMENT

1. Pilot/Crew Manning

Given the Airlander 10's ability to embark on multi-day flights, comprehensive research was undertaken to determine the most effective crewing approach for both pilots and crew members. This thesis utilized findings from the NPS Crew Endurance Team, input from aviation regulations, and research on medical staff shift schedules to develop a circadian rhythm watchbill tailored to Airlander 10. The outcome of this revealed that Airlander crewing would be segmented into three distinct watchbills based on total flight hours required for the mission: 0–12 hours, 12–72 hours, and 72–120 hours. Figure 24 illustrates the corresponding total crew staffing levels aligned with the flight hours.

0 - 12 Hours	12 - 72 Hours	72 - 120 Hours
Pilot 1	Pilot 1	Pilot 1
Pilot 2	Pilot 2	Pilot 2
NFO	Pilot 3	Pilot 3
NFO	NFO (x2)	NFO (x3)
Acoustic Operator	NFO (x2)	NFO (x3)
Acoustic Operator	Acoustic Operator (x2)	Acoustic Operator (x3)
Non-Acoustic	Acoustic Operator (x2)	Acoustic Operator (x3)
Non-Acoustic	Non-Acoustic Operator (x2)	Non-Acoustic Operator (x3)
	Non-Acoustic Operator (x2)	Non-Acoustic Operator (x3)

Figure 24. Circadian Based Watchbill Given Specific Flight Durations

The recommendation is grounded in existing aviation regulations, which currently permit a maximum of 9 hours of single-pilot operation. However, if there is a shift towards a hybrid single-pilot and dual-pilot regulation, adjustments to the crew staffing outlined above could be considered. Apart from pilot-related considerations, the crew staffing is determined by the requirements of military missions, which dictate the necessary personnel to be on board for specific scenarios.

2. Mission

Upon examination of the flight characteristics and capabilities of both the P-8A and Airlander 10, encompassing factors such as maximum speed, endurance speed, fuel/ payload capacity, fuel consumption rate, and flight endurance, a clear distinction emerges. The P-8A demonstrates its superiority in missions that call for agility and speed, making it a suitable choice for scenarios demanding rapid transit to and from specific areas and within AORs. Conversely, the Airlander 10 excels in missions that prioritize endurance and extended time on station. It is particularly well-suited for prolonged missions, especially in less dynamic environments, where it exhibits exceptional performance in scenarios requiring extended loiter capabilities. Mission assignments to ISR, HS, and HADR are ideal for Airlander 10 to demonstrate its strengths.

Based on the mission scenarios outlined in Chapter V, it becomes clear that missions lasting more than 24 hours would necessitate the deployment of three or more P-8As to replicate the coverage that a single Airlander 10 could provide. This result underscores Airlander 10's remarkable capacity for multi-day missions and its potential to excel in long-endurance operations, particularly those demanding continuous coverage and extended loiter times.

3. Financial Cost / Environmental

The cost savings for Airlander 10 are significant both in the short term and long term. As one Airlander 10 is roughly three times cheaper to purchase in year 0 than one P-8A ($89 Million vs. $244 Million) the savings are immediately recognized and can be used in other budgetary concerns. The yearly fuel expenses are also significant over the lifespan of the asset as 27 million would be saved flying the same average P-8A yearly hours. The belief is that Airlander 10 will be able to fly more hours than the average P-8A and this will increase the savings over time.

As the Navy strives to align with the DOD Climate Change policy and reduce its environmental footprint, the Airlander 10 stands out as a unique solution. This innovative platform not only meets mission requirements but also exemplifies the Navy's commitment to environmental responsibility. By incorporating the Airlander 10 into its fleet, the Navy

can set an example for sustainable and eco-friendly operations while also capitalizing on cost savings.

4. 3:1 Ratio

Over the course of this research, a 3:1 ratio has emerged when making direct comparisons to the P-8A. This ratio has been highlighted in terms of total mission duration and financial savings, indicating that the Airlander 10 has the potential to replace three P-8As in terms of flight hours, coverage, crewing, and cost savings for the Navy. This finding shows the possibility for Airlander 10's potentially remarkable value in changing the future of Naval Aviation.

For example, if a mission required 24-hour coverage spanning 72 hours, it would necessitate the deployment of 9 P-8As, each flying 8-hour missions, and a total of 243 personnel. In contrast, a single Airlander 10 with just 21 personnel onboard would be capable of achieving the same mission objectives, highlighting its efficiency and resource optimization.

B. RECOMMENDATION

1. Crewing

Due to Airlander's flight characteristics, it is worthwhile to consider Airlander 10 for single-pilot operations. It is proposed that Airlander 10 is operated as single-pilot for routine flight operations, with the potential for dual-piloting during high-risk phases such as adverse weather conditions, takeoff, and landing. For long haul flights it is recommended that Pilots operate in 8-hour shifts allowing for sufficient rest before flying. Airlander 10 has the potential to effect regulatory advancements by promoting well-rested pilots, as its design permits pilot rest while in-flight, contributing to enhanced safety and operational efficiency.

Although not explicitly addressed in this thesis, one can infer that for long-haul (24 hours or greater) civilian operations, the crew composition would likely include flight attendants and safety observers, in keeping with FAR/AIM Part 93. The suggestion is that staffing would resemble that of commercial flights currently in operation, with the

difference being that Airlander would allow the crew to work in 8-hour circadian rhythm shifts, mirroring the pilots.

2. Mission Application

An advantage of Airlander 10 lies in its ability to remain on-station for greater than 8 hours. In contrast, the P-8A, while faster, is typically constrained to 8-hours on-station, due to fuel capacity and fuel burn. Although the Airlander 10 possesses an extended endurance it may not always have the capacity to continuously support missions requiring specific equipment. For instance, missions like ASW, which necessitate the deployment of hundreds of sonobuoys, rely on high speeds, and frequent shifts of the AOR highlight the flexibility of one P-8A vice one Airlander 10. While Airlander can execute the ASW mission, its potential limitations in speed adjustments, AOR transitions, and storage capacity make it less ideal for such operations. In contrast less dynamic mission sets such as ISR, HS, and HADR which prioritize time on-station and maximum coverage are ideal for Airlander 10's capabilities.

3. Airlander Fleet Integration

While it is possible to substitute a conventional six-aircraft P-8A squadron with just two Airlander 10s, the Navy's current operational fleet of 98 P-8As requires an alternative approach. In light of this, a prospective hybrid squadron takes shape, consisting of four P-8As and two Airlander 10s. Although this deviates from the previously identified 3:1 ratio, current operational demands dictate the need for flexibility in mission execution. With four P-8As and two Airlander 10s, this arrangement ensures that the P-8As are dedicated to dynamic missions, while the Airlander 10 focuses on tasks that align with its capabilities. This well-rounded squadron configuration guarantees versatility and effectiveness in addressing a wide range of operational requirements, while maximizing the potential of each aircraft.

C. FUTURE RESEARCH

This study encompassed an analysis of various aspects related to Airlander 10, including crewing and piloting, mission scenarios, and financial considerations. To

optimize the Airlander 10 for ASW, a comprehensive investigation must be undertaken, within the classified setting, to determine its most effective use in ASW missions. Furthermore, the aircraft's capability of multi-day flights is a critical advantage that sets it apart from other alternatives. Maintaining this ability is essential for maximizing the aircraft's future potential. Further research should be conducted on Airlander 10 fleet size, integration into the U.S. Navy, and comparison to other assets such as ships and submarines.

2024 CRADA topics facilitating additional research include evaluating Airlander Initial Operating Capability (IOC), a ASW focused assessment, the roles of hybrid aircraft in supporting Homeland Security and Border Control operations, and lastly the assessment of Military Certification requirements relevant to the introduction of hybrid aircrafts.

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SUPPLEMENTAL: P-8A VS. AIRLANDER 10 DCF

To access the P-8A vs. Airlander 10 DCF data in spreadsheet format, contact the Dudley Knox Library or visit the thesis pages in the library's Calhoun database.

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