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MV-22B LOGISTICS FLIGHTS SUSTAINING THE AVIATION COMBAT ELEMENT IN THE INDO-PACIFIC

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MV-22B LOGISTICS FLIGHTS SUSTAINING THE AVIATION COMBAT ELEMENT IN THE INDO-PACIFIC

December 2022

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Two hypothetical scenarios are presented as frameworks to aid in the understanding of MV-22B utilization for logistics. Real-world high-priority aircraft part demand and sortie data, provided by the operating forces, were collected, analyzed, and inserted into the scenarios. The resulting outputs provide new insight on aircraft employment and risks associated with sorties in the engagement zone. Recommendations are given for improving sustainment capabilities while operating in a Marine expeditionary unit construct.

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LIST OF ACRONYMS AND ABBREVIATIONS

ACE	Aviation Combat Element
AH-1Z	Light Attack Helicopter
AIMD	Aviation Intermediate Maintenance Department
AO	Area of Operations
AOR	Area of Responsibility
ARG	Amphibious Ready Group
AVLOG	Aviation Logistics
CLF	Navy Combat Logistics Force
CRAF	Civil Reserve Air Fleet
CSB	Commercial Service Branch
DAO	Distributed Aviation Operations
DOD	Department of Defense
GAO	Government Accountability Office
GHS	Global Heavyweight Service
HMX-1	Marine Helicopter Squadron 1
LHA	Amphibious Assault Ship, General
LHD	Amphibious Assault Ship, Multipurpose
LPD	Amphibious Transport Dock
MAG	Marine Aircraft Group
MAW	Marine Aircraft Wing
MCAS	Marine Corps Air Station
MEU	Marine Expeditionary Unit
PMC	Passenger/Mail/Cargo
RAS	Replenishment at Sea
TMS	Type/Model/Series
UDP	Unit Deployment Program
UH-1	Light Attack Helicopter
UNREP	Underway Replenishment
U.S.	United States
USINDOPACOM	United States Indo-Pacific Command

USMC	United States Marine Corps
USTRANSCOM	United States Transportation Command
VMM	Marine Medium Tiltrotor
WEZ	Weapon Engagement Zone

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—Nellie

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—David

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I. BACKGROUND

With the introduction of *Force Design 2030* in March 2020, the commandant of the Marine Corps, General David H. Berger, established new priorities for the service given the direction of the *2018 National Defense Strategy*. The paradigm shift directs the Corps' focus of efforts to the Indo-Pacific where conflict presents a myriad logistical constraints and concerns. In the 2020 document, General Berger explains, "I am not confident that we have identified the additional structure required to provide the tactical maneuver and logistical sustainment needed to execute DMO [distributed maritime operations], LOCE [littoral operations in a contested environment], and EABO [expeditionary advance base operations] in contested littoral environments against our pacing threat" (Office of the Commandant of the Marine Corps [CMC], 2020, p. 10). Recognizing that there are severe limitations in our knowledge related to our capabilities and that logistics is the "pacing function" in future conflict, it is imperative that the Marine Corps identifies threats to its ability to supply the ACE [aviation combat element] of the Marine Air Ground Task Force (CMC, 2022, p. 11). This research evaluates the supportability of the ACE as it conducts distributed aviation operations (DAO) inside and on the periphery of the weapon engagement zone (WEZ) in the Pacific area of operations (AO). Specifically, we analyze the Marine Corps' organic MV-22B aircraft's ability to close the supply chain gap left between the civil fleet and the end-user.

Marine Corps and Department of Defense (DOD) leadership have identified constraints with supporting logistical operations in the Indo-Pacific AO, justifying the need for further inquiry. Two Government Accountability Office (GAO) reports and one DOD report provide evidence of this strategic need. First, in a June 2011 report, *Military Buildup on Guam: Costs and Challenges in Meeting Construction Timelines,* GAO focused on the U.S.–Japan security alliance by directing the framework for future U.S. force structure in Japan. Additionally, it calls for implementing a new strategic approach in the Pacific as part of a worldwide Basing Strategy (Government Accountability Office [GAO], 2011). Headquarters Marine Corps' Deputy Commandant for Aviation echoes the GAO's emphasis on strategic basing in their *Marine Corps Aviation Plan* (2022) which provides the most recent Marine Corps Aviation planning guidance. The publication identifies Guam's strategic location in logistically supporting the ACE.

Providing further evidence of the supportability concerns is a 2022 GAO report, *Challenges Facing DOD in Strategic Competition with China*, which stated that the "DOD needs to take steps to assess and mitigate risks associated with key supply chain-related challenges, including the F-35's central logistics system, and to determine the F-35's ability to effectively support operations in the Pacific" (p. 2). This report emphasizes a gap in logistically supporting the DOD's most advanced weapon system, the F-35, in operations against Western Pacific adversaries. This further amplifies the deficiency of a clear and executable logistics plan in support of the Indo-Pacific theater.

Headquarter Marine Corps' Department of Aviation's 2021–2026 Aviation Supply Campaign Plan identifies the need for "frequent, reliable, intra-theater distribution of assets between supply nodes" (p. 6). This recognition of unidentified assets and capabilities further demonstrates the operational gap between commercial shipping and military resources. Several government-sponsored aerial shipping platforms exist to transport cargo and troops. These include commercial carriers such as FedEx and DHL, as well as contracted support governed by United States Transportation Command (USTRANSCOM). One of USTRANSCOM's missions is to "globally integrate mobility operations" (United States Transportation Command [USTRANSCOM], n.d., main page). They will "enable theater rotary-wing and fixed-wing contract airlift support where there is a demand and security conditions permit" (United States European command, 2021, p. 9). The limits of such airlift, to include capacity and level of demand have yet to be determined in a contested environment. The Marine Corps' ACE readiness depends on the effectiveness of the connected supply chain network which includes "redundant nodes through which support assets can flow" (Headquarters Marine Corps, 2021, p. 6). A clear supportability framework must exist in theater to support aviation operations.

This research has the potential to educate and inform the critical decisions faced by leaders in the aviation logistics community. In assessing the shortfalls and risks associated with contested logistics in the Indo-Pacific, we gain a better understanding of strategic opportunities that will provide sustainment capabilities with an enduring supply chain. As the commandant has said, “Our aviation combat element remains central to all we do, both as a Stand-in Force and in response to crisis” (CMC, 2022, p. 10). We therefore must answer how we will best sustain the ACE in the great power competition. While much will remain unknown about the operating environment during conflict, this research will reduce the uncertainties associated with the utilization organic aviation assets operating from a strategic sea base.

A. PURPOSE

The purpose of this research is to use historical requisition demand and MV-22B sortie data to determine the capacity use of the MV-22B for logistics sorties. Supporting the ACE during conflict is critical and ensuring repairable parts are readily available maintains operational tempo. This research looks at the current and historic Marine expeditionary unit (MEU) makeup and focuses on how aviation logistics can sustain maintenance practices during conflict. We seek to answer these three main questions:

(1) Can the ACE of the 31st MEU conduct logistics flights to sustain itself with organic assets while maintaining and achieving primary flight operations?

(2) Can the ACE of the 31st MEU support the last tactical mile by bridging the gap between nodes ashore and the amphibious assault ship, multipurpose (LHD) or amphibious assault ship, general purpose (LHA)?

(3) How do passenger/mail/cargo (PMC) sorties impact the ACE’s readiness?

We seek to gain a better understanding of expeditionary logistics as it applies to the Marine Corps’ aviation community. An analysis of our results will provide a basis for our recommendations and suggestions for future research.

B. SCOPE

While numerous topics relating to expeditionary logistics in the Pacific area of operations could be studied related to MV-22B usage, the scope of this research is more narrowly focused on PMC sorties from the LHD/A of the ARG in a contested environment. We do not assess the dangers or capabilities of Chinese weapon systems. Instead, we acknowledge their ranges in order to establish their engagement zones to identify two distribution nodes inside and two on the periphery. The purpose of identifying distribution nodes inside the WEZ is to compound a decision point when determining which node to route cargo to as well as to identify the risk associated with PMC flights, in terms of probability of demand and sorties flown.

The MV-22B provides a wide range of capabilities. Its versatility is important to the ACE and MEU commanders. This research, however, does not consider any mission-sets or tasking aside from PMC sorties. For the purposes of our scope, it was not necessary to identify tasks in order to illustrate sortie rates and demand. We do not identify operational tempo in terms of aircraft tasking, instead we use PMC sorties as a surrogate to measure the impact to primary flight operations and readiness.

II. LITERATURE REVIEW

A. ALLIES TO THE UNITED STATES IN THE PACIFIC

In Marine Corps doctrine, Aviation Operations (2018), emphasis is placed on the importance of multinational operations, "U.S. military operations are often conducted in cooperation with the armed forces of other nations in pursuit of common objectives. Multinational operations, both those that include combat and those that do not, are conducted within the structure of either an alliance or a coalition" (p. 7–3).

The United States Indo-Pacific Command (USINDOPACOM) is a geographic Combatant Command whose mission is to protect and defend "the territory of the United States, its people, and its interests" (United States Indo-Pacific Command [USINDOPACOM], 2022, par. 4). The U.S. is allied with Australia, Japan, Republic of Korea, Philippines, and Thailand through defense treaties to promote the security and stability of the Asia-Pacific region (USINDOPACOM, 2022). In the 2022 *Indo-Pacific Strategy of the United States*, the National Security Council has identified additional regional partners as "India, Indonesia, Malaysia, Mongolia, New Zealand, Singapore, Taiwan, Vietnam, and the Pacific Islands" (p. 9). The strategic partnerships in the area of responsibility (AOR) broaden the U.S.'s logistical capabilities. The U.S. will require access to defended and well-positioned seaports and airports in order to sustain operations.

B. CHALLENGES IN THE PACIFIC

USINDOPACOM encompasses a vast area comprised of land masses, island chains, waterways, and sprawling ocean space. It creates geographical constraints as conveyance between land masses or ship-to-shore connectors will depend on maritime movements or airlift. Compounding this constraint is the expeditionary advance base concept which purports that forces will expeditiously conduct operations and any sustainment efforts must be adaptive to the warfighter. History shows conflict in the INDOPACOM area of operations will prove challenging, especially against a great power competition.

China’s devotion to modernizing and posturing their military cannot be underestimated. They have prioritized denying access to military vessels and aircraft through stockpiling and improving cruise and armed ballistic missiles. These actions directly challenge U.S. capabilities and assert their regional balance of power. The precision of their long-range missiles presents significant risk to American and allied countries’ bases, ports, and airfields. Townshend et al. (2019) purport that China’s fourth-generation fighter aircraft, modern attack submarines, and advanced electronic warfare equipment make it nearly impossible for U.S. or allied forces to carry out maneuver warfare in any manner.

China is actively seeking to expand their power and influence in the South China Sea by erecting artificial islands in the Spratley Archipelago (Meick, 2014). Since 2014, the Chinese have been dumping rocks, gravel, and sand atop existing reefs to create man-made islands. Claiming sovereignty in the area, they believe their efforts are justified (Pitzl, 2001). Air strips and artillery have been identified on the islands, further raising concern for China’s intentions in the area (Meick, 2014). The strategic location and utilization of the Spratley Islands presents the U.S. with a greater challenge in terms of maneuver and sustainment.

C. GUAM

Marine Corps Base Camp Blaz in Dededo, Guam, has become a strategic location for INDOPACOM operations. Becoming operational in October 2020, Camp Blaz presents the Marine Corps with additional capabilities due to its location in the AO. Marines have operated on Guam dating back to 1898 (U.S. Marines, n.d.-c). The island operated as a staging location during World War II as Marines invaded Iwo Jima and Okinawa. Located 1,415 miles from Okinawa, Guam is accessible via air and sea and will play a critical role in future conflicts, as it did historically. Additionally, Naval base Guam and Anderson Air Force base offer joint force capabilities (U.S. Marines, n.d.-c).

A 2011 statement before the Subcommittee on Readiness, by then Deputy Assistant Security of Defense for Asian and Pacific Security Affairs, East Asia, Michael Schiffer acutely describes the vitality of Guam: “by making better use of Guam’s strategic location and advantages, we will array U.S. forces in Asia more effectively for the evolving security environment…Guam's advantages as a stable, secure, and robust operating base on American soil make it a unique and critically valuable location" (*Long-Term Readiness*, 2011, p. 43).

D. MARINE CORPS AVIATION IN THE PACIFIC

1st Marine Aircraft Wing (MAW) is headquartered in Okinawa, Japan where it has resided since relocating from Iwakuni in 1975 (U.S. Marines, n.d.-a). Its mission in the AO is to provide combat ready forces who conduct all six functions of aviation in order to accomplish engagement, contingency, and other-directed operations. Under the command of 1st MAW are three Marine Aircraft Groups (MAG) which are home to the operational level flying squadrons. Two MAGs are located in Japan; one in Iwakuni and one in Okinawa. 1st MAW's third MAG is located in Kaneohe Bay, Hawaii (U.S. Marines, n.d.-b).

Marine Corps Aviation operates in multiple bases in the Pacific AOR. Marine Corps Air Station (MCAS) Iwakuni, Japan, houses three operational level fixed-wing aircraft squadrons consisting of two F-35B squadrons and one C-130 squadron (U.S. Marines, n.d.-b). A squadron of F/A-18 Hornets deploys to the area, from the U.S., as part of the Unit Deployment Program (UDP), every six months. This program rotates personnel to operate and maintain the F/A-18 aircraft for exercises and contingency operations. MCAS Futenma, in Okinawa, Japan, is home to two permanent Marine Medium Tiltrotor (VMM) MV-22B squadrons and two UDP squadrons made up of AH-1Z, UH-1Y, and CH-53Es. The ACE for the 31st MEU is formed from reinforcing the MV-22B squadrons on Okinawa with a UDP squadron and their aircraft along with an attachment of F-35s from Iwakuni (U.S. Marines, n.d.-b).

E. MARINE CORPS ROTARY WING

In December 1947, the Marine Corps established its first rotary-wing squadron, Marine Helicopter Squadron (HMX) 1 (Thompson, 2012). Marine Corps leadership understood the need to establish conveyance for ship-to-shore movement and recognized the advantages of helicopter utilization. HMX-1 stood up to develop and test tactics and procedures for the movement of troops in amphibious operations. By mid-1950, helicopters entered combat in the Korean War. They provided command and control, reconnaissance, casualty evacuation, and rapid resupply capabilities never before seen. Rotary wing assets were capable of reaching austere, mountainous locations where fixed-wing aircraft could not (Thompson, 2012). Additional type/model/series (T/M/S) were developed and later every model became operational in the Vietnam War (Fails, 1978). With the heavy employment of rotary wing assets, Vietnam was dubbed the "helicopter war" (HQMC, 1986). Between 1965 and 1970, Marine pilots averaged over 60,000 sorties per month as they conducted numerous missions in support of U.S. efforts in the Vietnam War (Shulimson et al., 1997). The successful employment of helicopters during the wars further established the requirement for rotary wing assets.

From the time Marine Corps Landing Force Bulletin Number 17 was published in 1955, great efforts have been made to ensure aviation can support amphibious operations (Rawlins, 1976). Little has changed in the requirement for aviation operations to support ground troop movement while embarked on a Naval ship. Every Marine Corps aircraft platform in its fleet has endured engineering modifications and upgrades to ensure mission accomplishment. Additionally, some T/M/S have faced complete divestment and replacement. The CH-46E and CH-53D medium lift helicopters have been completely replaced by the MV-22B Osprey (U.S. Marines, n.d.-d).

F. MV-22B OSPREY

The Bell Boeing MV-22B Osprey is one of the most heavily relied on multi-mission aircraft used by the Marine Corps in garrison and in combat. Its primary function is to conduct "amphibious assault transport of troops, equipment and supplies from assault ships and land bases" (U.S. Marines, n.d.-d). The application of its uses includes a variety of logistics support operations (Office of the Chief of Naval Operations [CNO], 2020). Since achieving initial operational capability in 2007, the Marine Corps has relied on the Osprey to execute diverse and critical functions (Naval Air Systems Command [NAVAIR], 2020). The aircraft serves in transporting troops, equipment, and gear in various environments. As a tilt-rotor aircraft, it is capable of vertical take-off and landing with airborne movements of a turboprop airplane (Boeing, n.d.). This design makes it ideal for amphibious operations, serving as a connector between Naval ships and the shore.

The Osprey generally operates at a cruise speed of 241 knots (277 miles per hour), capable of a maximum speed of 270 knots (310 mph) at sea level and has a carrying capacity of approximately 20,000 pounds or up to 24 fully loaded combat troops (Boeing, n.d.). Its range is largely variable and dependent on fuel consumption, altitude, wind, and cargo weight, among others. The aircraft's versatility makes it a superior asset for the MEU and ACE commander. Additional capabilities include in-flight-refueling which permits self-deployment to forward positioned bases and external cargo lifts. The MV-22B is capable of slinging up to 12,500 pounds of weapon systems, cargo, or vehicles beneath the aircraft, another significant factor for logistical sustainment (Bell Boeing, n.d.).

When not in flight, the Osprey's rotor blades, or wings, can fold onto itself, as shown in Figure 1, measuring approximately 63 feet by 18 feet by 18 feet, making it compact enough to operate on congested naval vessels (CNO, 2020). Internally, the cargo compartment measures 68 inches clear cabin width and 64.4 inches with troop seats in the stowed position. Its height measures 66.2 inches for clear cabin height and 61.71 at the ramp door opening. The entire cargo area measures 20.8 feet in length (CNO, 2020). This space, as shown in Figure 2, provides ample capacity for carrying various aircraft components.

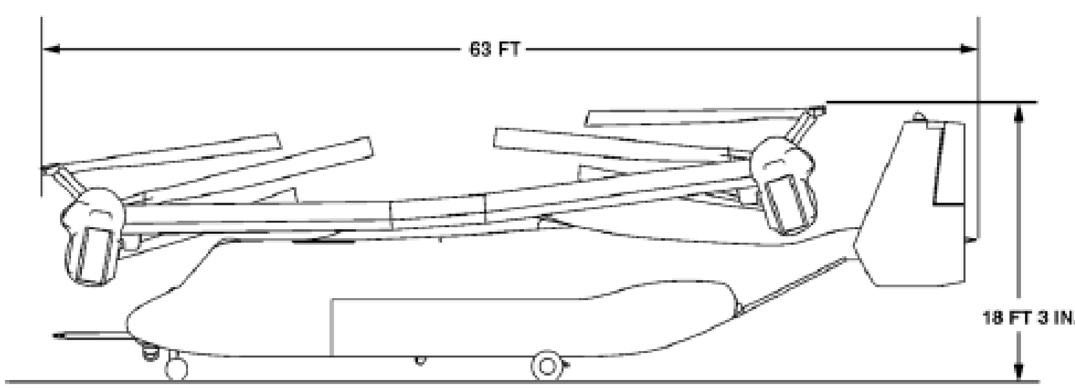

Figure 1. MV-22B with folded blades. Source: CNO (2020).

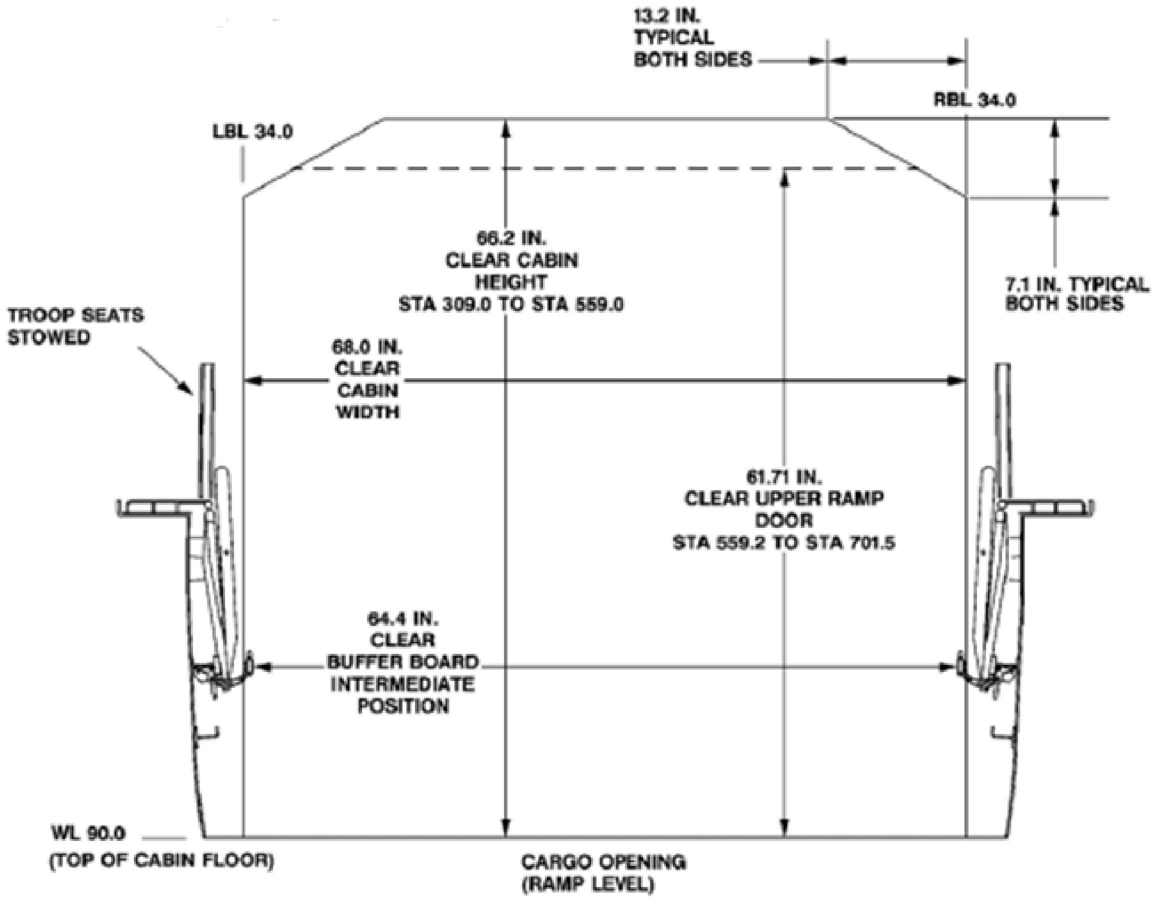

Figure 2. MV-22B internal cargo space. Source: CNO (2020).

To better depict the range of the MV-22B, Figure 3 shows just how much of an asset the aircraft is to the Marine Corps. When considering the distance this cargo aircraft can travel without the need of a runway, it opens logistical sustainment opportunities during conflict. This also makes the Osprey especially important for logistical support while aboard naval vessels.

Figure 3. MV-22B range.

G. NAVY CMV-22B OSPREY

The U.S. Navy employs the CMV-22B, a variant of the Marine Corps' Osprey. This aircraft's primary function is to conduct passenger/mail/cargo (PMC) flights to Navy aircraft carriers while the ship is underway. Its larger fuel cells increase the aircrafts range to approximately 1,150 nautical miles (1,323 miles) (NAVAIR, 2022). Commonly referred to as a "carrier onboard delivery" aircraft, it replaced the fixed wing C-2 Greyhound because of its operational flexibility. Unlike the C-2 Greyhound, the CMV-22B is capable of vertical takeoff and landing and has twice the payload at 20,000 pounds (Chen, 2016). While the Marine Corps' variant of the aircraft provides a plethora of functions, the sole purpose of the CMV-22B Osprey is to travel to and from ships to deliver resources. With the aircraft's singular mission-set, Naval leadership can rely on its logistical functions without detracting from operational tempo.

H. 31ST MARINE EXPEDITIONARY UNIT

The 31st MEU operates in INDOPACOM for crisis and contingency response. It is the only forward assigned of the seven existing MEUs and consists of each element of the Marine Air Ground Task Force: aviation combat element (ACE), ground combat element, and Combat Logistics Battalion (CMC, 2013). The ACE for the 31st MEU consists of both rotary and fixed wing assets which can perform five functions of Marine aviation: control of aircraft and missiles, assault support, offensive air support, anti-aircraft warfare, and aerial reconnaissance (CMC, 2013). The organic ACE rotary wing assets include the MV-22B, UH-1Y, CH-53E, and the AH-1Z. Completing the arsenal is the fixed wing F-35B (CMC, 2013).

MEUs embark on Naval Amphibious Ready Groups (ARG), consisting of amphibious assault ships, multipurpose (LHD) and amphibious assault ships, general purpose (LHA), amphibious transport dock (LPD), and a dock landing ship. Together the ARG/MEU provide Geographic Combatant Commanders and the president with deterrence and various military and humanitarian operational capabilities (CMC, 2013).

With limited space on amphibious ships, aircraft platforms are separated across the ARG. Light attack helicopters (UH-1s and AH-1Zs) are housed on the LPD while the MV-22B, CH-53E, and F-35B reside on the LHD/A. Doctrine calls for 12 MV-22B on the LHD/A, but the MEU commander may alter the plan according to deck space and priorities. For example, since the deployment of F-35B on the 31st MEU in 2018, the number of MV-22B was reduced to 10, in order to leave deck space for the F-35B aircraft (CMC, 2013).

Deployment of the ARG further compounds logistical considerations for the 31st MEU. Light attack helicopters on the LPD are sustained by a parts pack-up which is sourced from the LHD/A. Following a replenishment-at-sea (RAS) or PMC flight, parts must be shuttled from the LHD/A to the LPD. Alternatively, the light attack helicopters can launch from the LPD to the LHD/A to retrieve parts, when operating in the vicinity of each other.

Aircraft maintenance is conducted on the LHD/A and LPD by Marines and Sailors assigned to the Aviation Intermediate Maintenance Department (AIMD). AIMD provides the link between the ACE squadron and aviation supply on board the Naval ships. In a similar fashion, the aviation supply department on board consists of Sailors and a contingent of Marines. Any repair parts that are requisitioned from AIMD are monitored, tracked, and expedited by the supply department. The ship maintains a robust supply and any parts that cannot be filled via ship stores is referred off-ship to be filled by the external supply system, also known as a direct turn over (DTO) document. Resupply then comes via an underway replenishment (UNREP) or RAS.

The Navy conducts UNREPs or RASes as a means of delivering the maximum amount of liquid and solid cargo from Navy Combat Logistics Force (CLF) shuttle ship to combatant ships underway (Department of the Navy [DON], 2001). The ARG ships of the MEU are in receive mode as they are resupplied based off a projected UNREP schedule and daily consumption rate.

Scheduling the CLF begins when combatant ship's operational schedules are published. This provides a generic framework which is then updated daily when underway. Reporting, planning, and scheduling an UNREP is a coordinated effort between multiple logistics coordinators and schedulers (DON, 2001). This structured model is a highly useful and efficient means of replenishing the MEU when resupply can wait for planning and execution. This research examines the replenishment needs of the ACE when awaiting an UNREP or RAS is not feasible in order to maintain flight operations.

Consider the analogy of a bus route versus employing a taxi service for the movement of materiel. USTRANSCOM and the UNREP/RAS construct operates as a bus route, using an existing and sustainable network to flow materiel in and out of theater. This model operates on a pre-determined schedule to deliver to pre-established locations which proves useful for continual sustainment. This research, however, considers the situation which requires deviating from the bus route and employing a quicker and more agile service, similar to a taxi. This taxi service includes two modes of employment: commercial air cargo shipping and organic MV-22B assets. Commercial shipping constitutes the first leg of a taxi trip where repair parts are delivered to an established node or destination. The second, and critical leg, involves a MV-22B launching from the LHD/A to retrieve repair parts ashore. This research narrowly measures the performance of the MV-22B taxi for its logistics mission, in various scenarios.

I. UNITED STATES TRANSPORTATION COMMAND

United State Transportation Command (USTRANSCOM) is a member of the unified Combatant Commands which consist of the following service component commands: Air Force Air Mobility Command, Navy Military Sealift Command and the Army Surface Deployment and Distribution Command (United States Transportation Command [USTRANSCOM], n.d.). USTRANSCOM's main purpose is to provide personnel and cargo movements both domestically and internationally. They maintain partnerships with commercial carriers via their Commercial Services Branch (CSB), to expand their operational reach. Their Global Heavyweight Service (GHS) provides international shipping of cargo over 300 pounds and is advertised to deliver goods according to the "shipper's required delivery date" (USTRANSCOM, n.d.). An important feature of CSB is its services relating to small packages for "less-than-planeload" (USTRANSCOM, n.d.). Often in aviation maintenance, it is a single repairable item that needs expediting via logistical channels to maintain flight operations. Of concern is the capability of the channel or chain to move a single component into theater via the fastest means necessary. When an aircraft is incapable of flying, the squadron must conduct expeditious maintenance and not wait for a carrier to fill its cargo space prior to launching.

J. USTRANSCOM'S CIVIL RESERVE AIR FLEET

USTRANSCOM must engage with and remain in synch with USINDOPACOM, commercial carriers, and coalition partners as it was with U.S. Central Command during the Afghanistan evacuation (USTRANSCOM, 2021). One means by which USTRANSCOM expands its global reach is via its Civil Reserve Air Fleet (CRAF). CRAF consists of contracted aircraft from U.S. airlines that serve to augment the DOD fleet when airlift requirements exceed military capabilities (USTRANSCOM, 2022). The international segment of CRAF is made up of long-range and short-range sections, according to the demand requirement established by the requesting user or "performance characteristics needed" (USTRANSCOM, 2022, p. 1).

The activation and employment of CRAF assets requires approval from the Secretary of Defense via request from the commander, USTRANSCOM (USTRANSCOM, 2022). The decision to activate rests on the amount of augmentation required to meet the DOD's mission. This could include a Stage I activation for humanitarian assistance/disaster relief efforts, Stage II for "major theater war," and Stage

III for mobilization efforts (USTRANSCOM, 2022, p.1). CRAF has never been activated at a Stage III. Only three times in history has a Stage I or II been activated: Operations Desert Shield and Storm, and the Afghanistan Noncombatant Evacuation Operation in 2021 (GAO, 2013; USTRANSCOM, 2021). Additionally, carriers have 24 hours for Stage I, 48 hours for Stage II, and 72 hours for Stage III following an activation order, to have aircraft ready (USTRANSCOM, 2022). These durations demonstrate CRAF's unique ability to almost immediately support Marine Corps aviation logistics operations at a moment's notice. When CRAF is activated, it is important to note the aircraft are no longer operating for profit. Their mission becomes tailored to fit the need that best supports combat operations. This is significant because the amount of cargo is no longer the driving factor for aircraft employment, and they can meet more constricted timelines for mission support.

CRAF's wartime airlift is split into two segments: scheduled service or charter carriers (GAO, 2013). Charter carriers include cargo carriers such as UPS and FedEx, which have the flexibility to provide support according to the DOD's schedules or needs. The DOD, via USTRANSCOM and the Navy, has long contracted with commercial airlift cargo carriers to provide long-reaching logistical support. In October 2020, the Navy signed "firm-fixed price, indefinite-delivery/indefinite-quantity contracts" with multiple domestic and international cargo shipping companies to provide "charter and hire, utilities, force protection, communications and land transportation services to support maritime forces…and other foreign vessels participating in U.S. military or NATO exercises and missions" (Department of Defense, 2022, par. 1). An emphasis is placed on *U.S. military or NATO exercises and missions* as it delineates contractual requirements to provide services during U.S. military missions.

While USTRANSCOM offers significant beneficial capabilities to the DOD and Marine Corps aviation, there are instances where theater operations can hinder its effectiveness with aviation logistics distribution. As identified in Operational Support Airlift (2016), "unpredictable, short notice movements of high priority people and cargo will require an immediate response that is not usually compatible with USTRANSCOM and United States Air Force's airlift missions or commercial route structures" (p. 10).

USTRANSCOM's flexibility during combat operations is limited to route structures and runway availability.

USTRANSCOM will rely on previously established flight routes with redundant destinations, analogous to the bus route. Transporting high priority aircraft parts which fall short of meeting USTRANSCOM's capacity requirements will require the employment of commercial shipping, with follow-on MV-22B logistics runs between the LHD/A and the distribution node ashore. Employing this taxi-like service will support the ACE squadrons faster.

K. EVOLVING LOGISTICS SUPPORT

With the evolving threat in the Indo-Pacific and associated operational and tactical emphasis, comes a paradigm shift in supporting logistical operations. The previously known and understood construct under the umbrella of Global War on Terror saw the "buildup of substantial infrastructure in the combat zone" and "significant inventories of supplies…" (Faulkner, 2014, par. 1). Moving away from urban combat as seen in Operation Enduring Freedom, the longest war in U.S. history, logisticians must critically and strategically think of sustaining operations in the Pacific. Conflict in the Pacific will require more lean and agile logistical operations from a sea base. Lieutenant General William M. Faulkner (USMC) validates the use of MV-22Bs for logistics runs in his 2014 article, *Expeditionary Logistics for the 21st Century*, "aircraft such as the Osprey and CH-53K, as well as unmanned aerial cargo delivery systems, are vital components of our distribution system" (p. 12).

Captains Tod Diffey and Matthew Beck's 2012 master's thesis points to logistical inefficiencies associated with a conflict in USINDOPACOM. A comparison is drawn between shipping via military air (MilAir) and commercial agencies in relation to cost and speed. Cost is not a consideration in our research, but it is noted that shipping an aircraft part via a USMC KC-130J to Thailand, in USINDOPACOM, costs 10 times more than shipping commercially.

It is widely known that logistical constraints present aviation logistics (AVLOG) planners with challenging circumstances in which to plan resupply. Diffey and Beck's

(2012) research highlights the importance of leveraging capabilities that complement military efforts. As they concluded, "it is more efficient and cheaper to ship via commercial" (Diffey & Beck, 2012). Our research seeks to bridge the gap from commercial or MilAir shipping to MV-22B utilization in transporting high priority aircraft parts in the Indo-Pacific. Understanding time savings associated with commercial shipping as delineated by Diffey and Beck (2012), provides AVLOG planners with a knowledge base from which to consider our research. Conducting organic MV-22B flights to retrieve DTOs or requisitions sourced off the ship, becomes a requirement when aircraft are grounded due to supply, otherwise known as non-mission capable supply. Expeditious resupply is a priority for flying squadrons and will be critical during conflict.

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III. METHODOLOGY

The purpose of this research is to develop two hypothetical scenarios based on real-world situations to measure the usage rate of MV-22B conducting logistics flights to understand associated risk and capacity requirements. Real-world data for DTO requisitions is used along with a linear regression technique to forecast the demand for a conflict situation. Additionally, the results of a parametric analysis of risk associated with passenger/mail/cargo (PMC) flights conducted inside and on the periphery of the WEZ will provide the ACE critical information regarding MV-22B sorties.

The nature of this research is open domain and does not draw on classified scenarios. The two which are presented offer real-world implications based on hypotheticals, with the understanding that Marines and Sailors will be operating from the 31st MEU as part of the Navy’s 7th Fleet. This research considers PMC flights inside and on the periphery of the WEZ to identify risk associated with the aircraft completing the mission and the impact on the ACE’s capacity.

A. DEMAND DATA

In order to identify and establish a foundation on which to base projected demand, we analyzed historical data, table located in Appendix A. Using demand output from August 2020 to March 2022 provided by 1st MAW, MV-22B sortie rate was filtered by week and matched to DTO demand. These historical requisitions originated from Marine Medium Tiltrotor Squadrons (VMM) 262 and 265 reinforced operating from the USS America (LHA). Any LPD demand for the light attack helicopters was captured by the aviation supply department of the USS America and therefore was included in the data set analyzed for this research. We assumed any weeks with zero sorties flown was due to the LHD/A being docked and therefore no PMC sorties were conducted.

High priority parts with a 706 and 707 project code, indicating non-mission capable supply or partial mission capable supply that were either not carried or not in stock and requisitioned by AIMD were considered. The assumption was made that any requisitions completed within two to 14 days was due to a PMC flight retrieving the part from ashore.

Inherent in this research is the requirement to maintain high operational tempo by servicing all aircraft as expeditiously as possible, justifying the need to launch MV-22B for high priority parts.

B. SORTIE DATA

The second set of data analyzed included aircraft sortie rates during the same deployment windows between August 2020 and March 2022. Using output from the Aviation Maintenance Supply Readiness Reporting system, the number of MV-22B sorties flown per week from VMM-262 reinforced and VMM-265 reinforced were calculated. While aircraft readiness is not measured in this study, it is important to consider that aircraft readiness and availability equate to mission accomplishment in a contested environment or contingency response.

We established a mean of 8.3 documents per week, from the 1,148 total DTOs (shown in Table 1), to provide a baseline demand for garrison and exercise operational tempo. We assume that conflict increases sortie rate and demand, consequentially. To support these assumptions, we analyzed the linear relationship between sortie rate and demand rate by using the Poisson inverse function to establish levels of demand at various probabilities, as shown in the results section. We found that across the data set, demand for parts increases at a rate of 0.216 for every sortie flown, shown in Figure 4. Note that sortie rate only explains 24 percent of the variance in part demand. While this linear model allows us to predict some of the increased demand associated with increased operational tempo, a better model of part demand is needed, but is beyond the scope of this thesis. These baseline numbers provided us a means for calculating risk associated with demand and sortie rate. To model the increase in sortie and demand rates during combat operations, based on our experience we arbitrarily assumed a 100 percent and 200 percent increase in sorties flown, as shown in the results section. The following sections will explain our model, scenarios, and results.

Table 1. Demand and sortie data

Total Observations	706/707 DTOs	Mean Demand Per Week	Total Sorties	Mean Sortie Rate Per Week
9,060	1,148	8.3	660	17.07

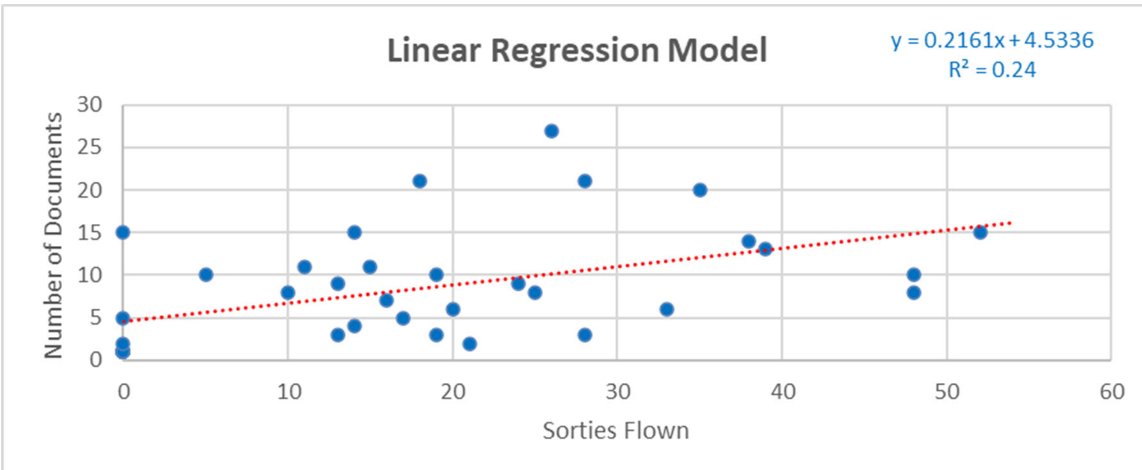

Figure 4. Linear regression model from demand and sortie data.

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IV. MODEL

In this section we will identify distribution nodes and LHD/A locations for two scenarios. Additionally, we will determine risk associated with MV-22B sorties using a complex formula that takes into consideration distance from the supply node, probability of demand, and average daily sortie and demand rate. The data table can be found in Appendix A. When a MV-22B conducts a passenger/mail/cargo (PMC) flight it is no longer available for operational tasking. The amount of time the aircraft is reassigned for a PMC flight depends on the number of trips it takes based on the demand rate and time off station to retrieve the demand. For the purposes of this research, we assume the speed of the Osprey to be 205 knots (236 mph) with a range of 901 nautical miles (~1,000 miles). We assume that the weight of the demand item is inconsequential. The MV-22B's range was determined using detailed calculations which can be found in Appendix B.

In order to establish distribution nodes for our model, we first researched disparate locations which are serviced by both USTRANSCOM via military airlift and commercial air cargo shipping, such as FedEx. The source from which materiel was fulfilled is not a consideration for this research. Regardless of the parts origin, it must transit the theater and be delivered to the LHD/A via organic assets. The below nodes were chosen in consideration of allied nation relationships, accessible aerial ports of debarkation, their strategic location and associated risk.

(1) Da Nang, Vietnam

(2) Okinawa, Japan

(3) Mactan Cebu, Philippines

(4) Guam

Two locations for the LHD/A were chosen to model the risk associated with launching MV-22B to retrieve aircraft parts from ashore. Placing the LHD/A inside and on the periphery of the WEZ inserts it into hypothetical yet plausible situations, operating in support of the ARG/31stMEU. We assume the ship maneuvers in the AO to best position itself according to engagement and tasking. As previously mentioned, this research does not draw on classified information and therefore, the actual ARG route will not be identified. We will now look at these four distribution locations in each of the two scenarios in detail.

A. SCENARIOS

1. Scenario 1

The first scenario involves the LHD/A operating in the South China Sea, in the vicinity of Northern Philippines, inside the WEZ. The center of Figure 5 identifies the location of the LHD/A in this scenario. The outer ring shows the range of the MV-22B, approximately 1,000 miles. The distances from the LHD/A to the four supply nodes are listed in Table 2. Table 3 shows the distribution node distances from the LHD/A along with MV-22B data as it relates to hours required per trip.

Table 2. Shore-based distribution nodes and distances from LHD/A for Scenario 1.

Location	Miles from LHD/A
1. Da Nang, Vietnam	596
2. Okinawa, Japan	973.2
3. Mactan Cebu, Philippines	751.6
4. Guam	1972.9

Table 3. Shore-based distribution nodes and distances from LHD/A with MV-22B data.

Location	1. Da Nang, Vietnam	2. Okinawa, Japan	3. Mactan Cebu, Philippines	4. Guam
Miles from LHD/A (miles)	596	973.2	751.6	1972.9
MV-22B Range	1000	1000	1000	1000
Cruise speed (MPH)	235.91	235.91	235.91	235.91
Hours/Trip	5.1	8.3	6.4	16.7

The three colors used in Figure 5 indicate range capabilities of different Chinese weapons. As previously mentioned, this research identifies the engagement zones, but does not provide an analysis of missile threats. Yellow in the figure indicates the short-range ballistic missile reach of 300 - 1,000 kilometers (km) (Center for Strategic and International Studies [CSIS], 2021). Peach represents the medium-range ballistic missile zone of 1,000 -3,000 km, and the pink depicts the intermediate-range ballistic missile reach of 3,000 - 5,000 km (CSIS, 2021).

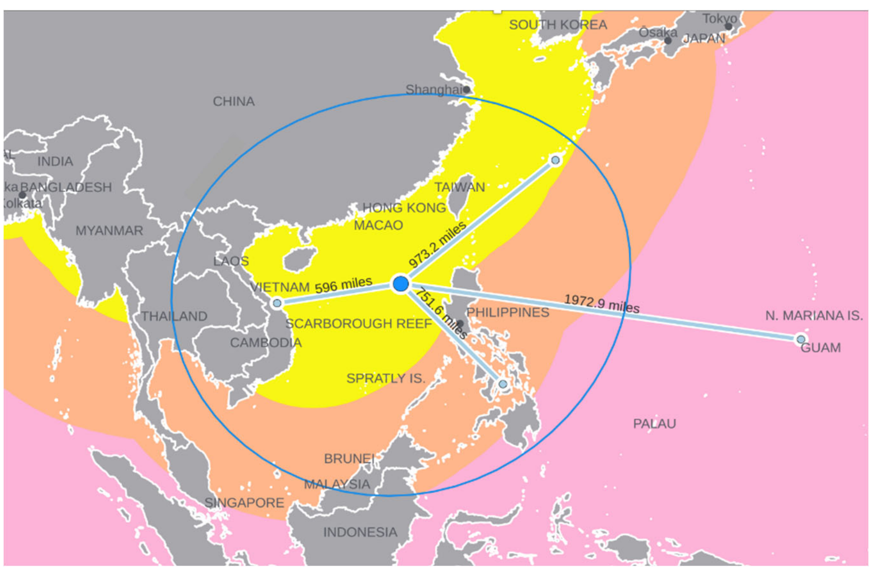

Figure 5. Location of LHD/A and shore-based distribution nodes in Scenario 1.

2. Scenario 2

The second scenario involves the LHD/A operating in the Philippine Sea, east of Northern Philippines, on the periphery of the WEZ, as depicted in Figure 6. The distances from the LHD/A to the supply nodes are listed in Table 4. Table 5 shows the distribution node distances from the LHD/A along with MV-22B data as it relates to hours required per trip.

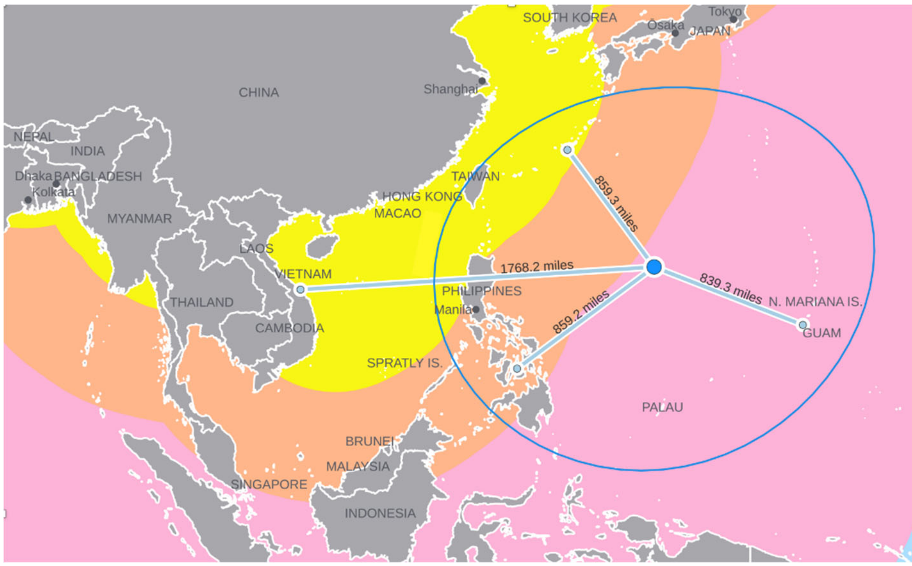

Figure 6. Location of LHD/A and shore-based distribution nodes in Scenario 2.

Table 4. Shore-based distribution nodes and distances from LHD/A.

Location	Miles from LHD/A
1. Da Nang, Vietnam	1768.2
2. Okinawa, Japan	859.3
3. Mactan Cebu, Philippines	859.2
4. Guam	839.2

Table 5. Scenario 2 shore-based distribution nodes and distances from LHD/A with MV-22B data

Location	1. Da Nang, Vietnam	2. Okinawa, Japan	3. Mactan Cebu, Philippines	4. Guam
Miles from LHD/A (miles)	1768.2	859.3	859.2	839.2
MV-22B Range	1000	1000	1000	1000
Cruise speed (MPH)	235.91	235.91	235.91	235.91
Hours/Trip	15.0	7.3	7.3	7.1

B. RESULTS

1. Scenario 1, Base

Figure 7 displays the outputs of our calculations. The Poisson inverse function was used to determine average demand based on probability. We multiplied the hours per trip (from Table 3) by demand probability then divided this number by 24 hours. The resulting outcome, listed under each node, denotes the number of PMC sorties, otherwise referred to as "Osprey Days." The average number of Osprey Days can also be obtained for each location. For example, based on the distance of the LHD/A from Da Nang, Vietnam (596 mi) and the demand probability, two additional Osprey Days, on average, would be required to retrieve parts from this node.

By applying a heat map technique which uses a colored gradient, we were able to display a comparative view of the additional Osprey Days required for each location, based on demand probability. The colors provide a visual for displaying Osprey Days. Dark green indicates the least number of days while red depicts the greatest number of days, for the given scenario. The gradients of green, yellow, and orange indicate Osprey Days between the lowest and highest integers.

Scenario 1, Base: RISK Osprey Days / Week

		IN WEZ		WEZ Periphery	
Probability	Demand	Da Nang	Okinawa	Philippines	Guam
0.05	4	1	2	2	3
0.1	5	2	2	2	4
0.2	6	2	3	2	5
0.3	7	2	3	2	5
0.4	7	2	3	2	5
0.5	8	2	3	3	6
0.6	9	2	4	3	7
0.7	10	3	4	3	7
0.8	11	3	4	3	8
0.9	12	3	5	4	9
0.95	13	3	5	4	10
	Mean	2	3	3	6

Figure 7. Scenario 1 heat map showing average Osprey Days.

2. Scenario 1, 100% of Base

To calculate the forecasted demand during conflict, we increased the average weekly sortie rate (17) by 100 percent. We multiplied the rate at which demand increases (0.216), derived from the linear regression, by the average weekly sortie rate of 17. This resulted in an increase in average weekly demand of 3.6 documents. Adding this to the average demand, resulted in 11.97 or 12 documents per week. Using the new average weekly demand (12), we applied the same calculations as the Base Scenario to determine the number of Osprey Days required per node. Retrieving parts from Da Nang, Vietnam now requires three Osprey Days, on average, as shown in Figure 8.

Scenario 1, 100% Base: RISK Osprey Days / Week

		IN WEZ		WEZ Periphery	
Probability	Demand	Da Nang	Okinawa	Philippines	Guam
0.05	7	2	3	2	5
0.1	8	2	3	3	6
0.2	9	2	4	3	7
0.3	10	3	4	3	7
0.4	11	3	4	3	8
0.5	12	3	5	4	9
0.6	13	3	5	4	10
0.7	14	3	5	4	10
0.8	15	4	6	4	11
0.9	17	4	6	5	12
0.95	18	4	7	5	13
	Mean	3	5	4	9

Figure 8. Scenario 1, 100% of Base heat map showing average Osprey Days.

3. Scenario 1, 200% of Base

To further depict the impact of Osprey Days, we increased the tempo, or sorties to 200 percent. Applying the same techniques used in the previous scenario, we multiplied the rate at which demand increases (0.216) by average sortie rate (17) and added this integer to 12. Average weekly demand, therefore, increased to 16 documents per week. Again, we applied the same calculations as the Base Scenario to determine the number of Osprey Days required per location. At a 200 percent increase, Da Nang, Vietnam requires four Osprey Days, on average, as shown in Figure 9.

Scenario 1, 200% Base: RISK Osprey Days / Week

		IN WEZ		WEZ Periphery	
Probability	Demand	Da Nang	Okinawa	Philippines	Guam
0.05	9	2	4	3	7
0.1	11	3	4	3	8
0.2	12	3	5	4	9
0.3	14	3	5	4	10
0.4	15	4	6	4	11
0.5	16	4	6	5	12
0.6	17	4	6	5	12
0.7	18	4	7	5	13
0.8	19	5	7	6	14
0.9	21	5	8	6	15
0.95	22	5	8	6	16
	Mean	4	6	5	12

Figure 9. Scenario 1, 200% of Base heat map showing average Osprey Days.

4. Scenario 2, Base

Figure 10 displays the outputs of our calculations. In the same way that probability of demand was determined in the first Scenario, we again used the Poisson inverse function for Scenario 2. In order to establish a Base, we multiplied the hours per trip (from Table 5) by demand probability then divided this number by 24 hours. The result, listed under each node, denotes the number of Osprey Days required. Additionally, the average number of Osprey Days is also displayed. In this Scenario, Da Nang, Vietnam is now 1,768.2 miles from the LHD/A. Given this distance, it would require six additional Osprey Days, on average, to retrieve parts from this node.

		IN WEZ		WEZ Periphery	
Probability	Demand	Da Nang	Okinawa	Philippines	Guam
0.05	4	3	2	2	2
0.1	5	4	2	2	2
0.2	6	4	2	2	2
0.3	7	5	3	3	3
0.4	7	5	3	3	3
0.5	8	5	3	3	3
0.6	9	6	3	3	3
0.7	10	7	4	4	3
0.8	11	7	4	4	4
0.9	12	8	4	4	4
0.95	13	9	4	4	4
	Mean	6	4	4	3

Scenario 2, Base: RISK Osprey Days / Week

Figure 10. Scenario 2 heat map showing average Osprey Days.

5. Scenario 2, 100% of Base

To forecast an increase in demand, we applied the same approach to Scenario 2 as we did in Scenario 1. We increased the average weekly sortie rate (17) by 100 percent. We multiplied the rate at which demand increases (0.216), derived from the linear regression, by the average weekly sortie rate of 17. This resulted in a total weekly average of 12 documents. Using the new average weekly demand (12), we applied the same calculations as the Base Scenario to determine the number of Osprey Days required per node. At a 100 percent increase in sortie rates, retrieving parts from Da Nang, Vietnam now requires nine Osprey Days, on average, as shown in Figure 11.

Scenario 2, 100% Base: RISK Osprey Days / Week

		IN WEZ		WEZ Periphery	
Probability	Demand	Da Nang	Okinawa	Philippines	Guam
0.05	7	5	3	3	3
0.1	8	5	3	3	3
0.2	9	6	3	3	3
0.3	10	7	4	4	3
0.4	11	7	4	4	4
0.5	12	8	4	4	4
0.6	13	9	4	4	4
0.7	14	9	5	5	5
0.8	15	10	5	5	5
0.9	17	11	6	6	6
0.95	18	12	6	6	6
	Mean	9	5	5	5

Figure 11. Scenario 2, 100% of Base heat map showing average Osprey Days.

6. Scenario 2, 200% of Base

By increasing the average number of sorties flown by 200 percent of the Base Scenario, we obtain the number of additional Osprey Days required per node. We again multiplied the rate at which demand increases (0.216) by average sortie rate (17). Demand, therefore, increased to 16 documents per week, on average. The number of Osprey Days required per location was then determined, as it was in the previous scenarios, using probability of demand and hours flown. At a 200 percent increase, Da Nang, Vietnam requires 11 Osprey Days, on average, as shown in Figure 12.

Scenario 2, 200% Base: RISK Osprey Days / Week

		IN WEZ		WEZ Periphery	
Probability	Demand	Da Nang	Okinawa	Philippines	Guam
0.05	9	6	3	3	3
0.1	11	7	4	4	4
0.2	12	8	4	4	4
0.3	14	9	5	5	5
0.4	15	10	5	5	5
0.5	16	10	5	5	5
0.6	17	11	6	6	6
0.7	18	12	6	6	6
0.8	19	12	6	6	6
0.9	21	14	7	7	7
0.95	22	14	7	7	7
	Mean	11	6	6	6

Figure 12. Scenario 2, 200% of Base heat map showing average Osprey Days.

C. POST-HOC ANALYSIS

Our main analysis quantified the additional Osprey Days required to retrieve aircraft parts from distant distribution locations located inside and outside the WEZ. However, we did not quantify the risk associated with using a closer, yet riskier location inside the WEZ. In this post-hoc analysis we used a parametric analysis to estimate the level of additional risk associated with locations inside the WEZ, that would justify sourcing from a more distant node. We intend to provide an example of how the parametric analysis might be used to compare the risk of alternate source nodes by using Scenario 1. We will not examine the entire network.

The WEZ was used in the same manner as before, in that the different Chinese missile ranges were backdrops to the distribution network depicted. Missile ranges were not used to analyze or assess combat damage for MV-22Bs. We considered risk according to expected losses of Osprey Days, across the distribution of demand. We use the phrase "expected loss" as it relates to an Osprey Day. These losses may be the result of combat damage, but also may be due to a PMC flight launched and the materiel is not at the destination, the aircraft relays a fault and maintenance at the node is required, or there are general maintenance delays as a result of sorties flown.

We do not have access to a combat model and do not claim to calculate the risk in a given combat scenario. However, in this post-hoc analysis, using the derived data, we can identify how much riskier a close node must be before expected losses of Osprey Days would suggest abandoning it and use a distant node instead. By solving for how much risker one location must be before changing destinations, our analysis provides a risk threshold. This threshold determines the level of risk a closer distribution node would need to have before choosing the alternative.

O = Osprey Days needed for transport of parts (a function of distance)

P = Probability of aircraft attrition (combat or other mission loss)

P_iO_i = Expected days lost (a binomial approximation)

When $O_1 < O_2$ then the LHD/A is closer to O_1. Subscripts depict locations, with subscript 1 identifying the closest location.

When $P_1 > P_2$ then P_1 is riskier.

*Note that $O_1 < O_2$ shows O_2 to be farther away from the LHD/A, and therefore safer. Thus, if $O_1 < O_2$, necessarily, $P_1 > P_2$ or P_2 would not be considered an alternative.

O_2 / O_1 = ratio depicting how many times more days are lost because of the additional distance O_2 is from the LHD.

P_1 / P_2 = ratio depicts how many times riskier location 1 must be before it is worth going to location 2.

*Note that when $P_1O_1 = P_2O_2$ the expected loss at each location is the same. That is, the risks are equal when $P_1 / P_2 = O_2 / O_1$

Using the above formulas and data from Scenario 1, we conducted a parametric analysis of Guam and Da Nang, Vietnam. The expected losses were set to equal each other in order to allow the risk percentile to change. By equalizing the expected losses, we were able to seek out the risk percentile which would indicate the risk threshold for using Guam over Vietnam. Our results show that risk at Vietnam would have to increase by 276 percent before choosing Guam (see Table 6).

Demand in Scenario 1 results in an average of 2.26 Osprey Days for Vietnam and 6.25 for Guam. It is evident that choosing Guam would require additional Osprey Days and according to the formula ($O_1 < O_2$, $P_1 > P_2$), Guam is farther and less risky. However, according to the ratio of 2.762, it would not be recommended to use Guam unless it is suspected that the probability of a day lost (due to combat damage or other loss variable) is 276 percent greater at Vietnam. Additionally, in choosing Guam, Vietnam would need to be 276 percent risker than the risk of a day lost to anything other than time. Vietnam's proximity provides a great advantage over Guam.

This post-hoc analysis intends to provide an additional level of analysis that will aid in decision making. When comparing nodes, the ratio derived from Osprey Days (O_2 / O_1) provides a risk percentile which explains the level of risk required to abandon a nearby node and choose a more distant one.

Table 6. Risk comparison between Vietnam and Guam.

	Vietnam (1)	**Guam (2)**
Hrs/Trip	5.1	16.72
Loss Probability	0.138	0.05
Osprey Days	2.266	6.258
Expected Loss	0.312	0.312

	Osprey Days (O)	**Loss Probability (P)**
Vietnam (1)	2.266	0.138
Guam (2)	6.258	0.05
Ratio	2.762	2.760

O_2 / O_1	2.762
$P_1O_1 = P_2O_2$	0.313
$P_1 / P_2 = O_2 / O_1$	2.76

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V. ANALYSIS, RECOMMENDATIONS, AND CONCLUSION

This chapter provides an analysis of the results in order to answer the primary research questions posed. Recommendations are also given based on the scenarios which were illustrated in the previous chapter. We provide areas of future research which were found to be out of the scope of this study as well as those which emerged.

We acknowledge the limitations inherent in this research. We provide hypothetical scenarios in order to maintain an unclassified or open-source document. While a great deal of information can be assessed from our given scenarios, using actual ARG locations could provide a more accurate depiction of MV-22B usage (Osprey Days). Given the vastness of the Pacific AO, we chose distribution destinations which were identifiable, accessible, and realistic. Our model and methodology are transferable to other (secret) scenarios which could better assess where to route cargo and what the impact would be to the 31st MEU's mission.

An additional limitation in this research is the assumption that a direct turn-over (DTO) was captured when a document was completed within two to 14 days. PMC sorties were not captured in relation to DTOs. We analyzed all sorties flown to associate them with average weekly demand. While the data analyzed provided a foundation for this research, we were limited by the specific data collection systems and the type of data that resulted in an output.

A. ANALYSIS

The primary purpose of this research was to gain better insight on the employment of MV-22B for logistics sorties in the Pacific area of operations. In this section we will provide an analysis of our results and answer our initial research questions.

(1) Can the ACE of the 31st MEU conduct logistics flights to sustain itself with organic assets while maintaining and achieving primary flight operations?

To first answer this question, we specified "organic assets" to mean MV-22B, specifically. While the ACE embarks with five different type/model/series aircrafts, we chose the MV-22B because of its range and capacity. We therefore looked at the average sortie rate and made assumptions about the tasking of those sorties. Although the ACE's primary flight operations were outside the scope of our analysis, if part-resupply is supported by MV-22B aircraft flights to shore-based inventory points, primary flight operations capacity will be affected. We therefore examined two levels of demand for parts: an estimate of status quo demand based on current data and an increased level of demand. The increased level of demand was meant to give insight into the capacity needed for PMC flights if part demand increases because of increasing operational tempo. We can conclude that this will increase the requirement to conduct logistics flights. Even without analyzing the LHD/A's consolidated shipboard allowance, or inventory, it is certain that aircraft parts will need to be retrieved from locations ashore. The MV-22B's range and capacity ensure it can conduct logistics flights to sustain the ACE's flight operations.

(2) Can the ACE of the 31st MEU support the last tactical mile by bridging the gap between nodes ashore and the amphibious assault ship, multipurpose (LHD) or amphibious assault ship, general purpose (LHA)?

Answering this question requires an understanding of the range limits of the Osprey according to the aircraft's fuel burn rate and contributing factors. Our research assumed optimal flying conditions and negligible impacts of cargo weight. We concluded that with a 1,000-mile range and ample internal cargo space, the MV-22B can indeed support the last tactical mile between the shore and the LHD/A, location-dependent. While the Osprey can travel 1,000 miles, under optimal conditions, it will require refueling prior to its return flight. Additionally, any location beyond the aircraft's maximum range will require in-flight refueling (IFR). Our research did not consider the impacts or feasibility of IFR. We were able to conclude that the MV-22B is a highly capable aircraft that can reach distant locations to retrieve materiel and expeditiously return it to the LHD/A.

(3) How do PMC sorties impact the ACE's readiness?

Aircraft readiness relates to operational availability (A_O). This equation provides a percentage based on the time an aircraft is operational (uptime) and inoperable (downtime). It was not necessary to study A_O to understand that an aircraft being down for maintenance increases its downtime and therefore reduces its readiness or A_O. Although we did not study A_O, we did measure the impact of Osprey Days as required for PMC sorties. We can conclude that increasing sorties results in increasing demand which will require PMC flights (Osprey Days). PMC sorties expedite aircraft part retrieval, thus reducing down time. Instead of waiting for an UNREP or RAS, PMCs close the gap between parts availability and aircraft maintenance. When downtime is reduced, A_O is increased. PMC sorties, therefore, reduce down time by expediting the retrieval process for high priority aircraft parts which results in greater aircraft availability for the ACE.

B. RECOMMENDATIONS

In this section we provide recommendations and support for investigating usage opportunities of the MV-22B and CMV-22B based on our results. We offer suggestions that may improve logistics processes and draw attention to possible solutions to existing needs in sustaining ACE operations. Conflict in the Pacific theater presents logistical challenges, and our research can aid in determining the use of Osprey Days in launching PMC sorties to disparate locations.

1. Use Osprey Days to Aid in Decision Making

Results from the above scenarios provide output data that can aid in decision making. It is recommended that Osprey Days, as determined using sorties and average weekly DTO demand, be used to decide which distribution node to route aircraft parts through and subsequently launch PMC flights to for retrieval. Maintaining control and cognizance over cargo routing is imperative for aviation logisticians. Our results inform the foundation from which aviation logisticians can base a destination decision. We use the results from Scenario 1 at 100 percent of the Base Scenario as an example from which to draw our recommendations. The fundamental lessons in this scenario are transferable across all scenarios, therefore we will not provide redundant recommendations.

In Scenario 1 at 100 percent of the Base Scenario, Da Nang, Vietnam is the closest node (596 miles) to the LHD/A. Our results show an average weekly demand of three Osprey Days for Da Nang and an average weekly demand of four Osprey Days, for nearby Mactan Cebu, Philippines. Although Mactan Cebu is 751.6 miles (155.6 miles farther) from the LHD/A, which resulted in one additional Osprey Day, it is our recommendation that it be used over Da Nang, Vietnam. It may be in the ACE commander's best interest to weigh the criticality of time lost versus potential engagement in the WEZ. Our results show that increasing sortie rates increases average demand and therefore any PMC flights at farther distances will result in increasing demand. This may be an acceptable trade-off when a potential node is located inside the short-range missile WEZ.

2. Support for Providing Dedicated PMC MV-22Bs

As described in Chapter II, MEU logistics is generally a passive process in that the LHD/A receives UNREPs or RASes to replenish supplies and gear. Aside from this in-flow of material onto the ship, MV-22Bs execute PMC flights as needed. While Ospreys are tasked for PMC or logistics flights, they are not their sole purpose. It is our recommendation that the ACE commander consider dedicating a MV-22B aircraft for logistics flights to be executed in the AO. Our research identifies a need for PMC flights to maintain sortie rates. Without the ability to organically support the in-flow of critical repair parts, aircraft readiness will suffer greatly. By establishing the requirement to launch MV-22Bs as needed and maintaining the aircraft for logistics flights, aviation logisticians can better plan resupply efforts. Identifying a PMC Osprey whose sole mission is to not only sustain the maintenance practices of the ACE but provide a steady in-flow of general supplies, allows commanders and the AVLOG community at large to establish readiness metrics separate from MEU mission essential tasks. This separation increases accountability and will result in increased readiness. This concept is recommended for future research, as explained in paragraph C.

3. Support for Acquiring Navy's CMV-22B

We mentioned in Chapter II, the Navy employs the CMV-22B as their carrier onboard delivery system to carry out logistics flights. The extended range of the aircraft and its dedication to PMC usage present the Navy with increased capability. It may be increasingly beneficial for the Marine Corps to consider acquiring this variant or its operating concept. Considering the landscape of the Pacific and the range needed to reach the littorals both inland and out, the CMV-22B is a viable option. This capability exists and its employment by the Marine Corps could result in faster and more reliable sustainment.

4. Utilize Commercial Air Cargo Shipping and Exercise Routing Control

We echo the recommendation of Diffey and Beck (2012) to prioritize commercial shipping of gear. The usage of commercial companies such as DHL or FedEx requires diligence in customs paperwork processing and adequate communication with each location's embassy. Completing host-nation-required documents speeds the processing time and enables the flow of high priority parts into theater faster. While this was not a component of our research, it is critical to identify aspects of cargo routing that will expedite all processes.

With the use of commercial air cargo shipping comes the ability to control the movement of gear. We recommend that the aviation supply department embarked on the LHD/A exercise routing control capabilities in their requisitioning, when appropriate. By coding the destination address according to ship location and MV-22B range, aviation logisticians can effectively have aircraft repair parts delivered quicker, resulting in quicker maintenance and subsequent turn-around-time.

C. FUTURE RESEARCH

We provided recommendations on potential changes and offered a means by which average demand and sortie rate can influence decisions on PMC flights. We also identified the limitations of our research as it relates to our narrow scope. This section will offer recommendations for future research which may further the understanding of expeditionary logistics in a contested environment.

We were able to demonstrate the linear relationship between sortie rate and average demand. The formula used in this research explained the increase in demand with the increase in sorties which resulted in identifying the additional number of aircraft needed for PMC flights (Osprey Days). However, the R^2 only explains 25 percent of the variance. A more sophisticated model could be used for future research to better model the demand data during wartime operations.

This research assumed MV-22B PMC sorties operated at 205 knots with no wind and at 10,000 feet of elevation. These conditions gave the aircraft an optimal performance range of 1,000 miles. Future research can study how elevation, wind, cargo weight, and fuel burn rate impact Osprey Days and aircraft performance metrics. Additionally, in-flight refueling (IFR) is an extremely beneficial capability, especially in the expansive Pacific theater. We recommend future research study the impacts IFR has on Osprey Days, risk, and the associated decision to use locations beyond the MV-22B's range.

In a contested environment, MV-22Bs assigned to the ACE will conduct various missions. We suggest future research to study the outcome of dedicating MV-22B(s) to solely conduct PMC sorties. Conducting a thorough analysis of MV-22B operational tasking will identify how the MEU and ACE commanders are employing the aircraft. This analysis can give greater insight as to the impact of dedicating an Osprey for PMC sorties. Additionally, data relating to aircraft readiness metrics, as it relates to dedicated PMC sorties, can further inform the research.

D. CONCLUSION

This research studied the complexities of contested logistics as it relates to sustaining the ACE of the 31st MEU using organic MV-22B assets. We explored the background of Marine Corps presence and aviation capabilities in INDOPACOM to relate it to expeditionary logistics in the great power competition. Operating in the Pacific will require allied nation support in facilitating the flow of materiel in theater as well as the use of commercial shipping companies. The MV-22B provides the ACE with a versatile capability to transport gear as a connector between the shore and LHD/A.

We analyzed real-world data to determine probability of demand as it relates to sortie rates to better inform decisions regarding PMC sorties and the selection of shore-based distribution nodes. Aviation logisticians understand the criticality of expediting high priority aircraft parts. Components that are not readily available result in decreased readiness as the aircraft will remain inoperable until the item is sourced, expedited, and installed. In our research we used two scenarios, each with various levels of demand, to model the number of Osprey Days required to conduct logistics sorties in expediting parts.

By choosing two locations inside the WEZ and two on the periphery, we compounded the decision-making process. Calculating Osprey Days alone will not necessarily provide answers in choosing nodes. Osprey Days should be used in conjunction with weighing the risk associated with each node, as determined by distance.

As conflict and competition evolve, the Marine Corps must seek all opportunities to ensure the ACE is adequately sustained. With increased aviation tasking in the Pacific AO comes increased sorties and demand. Establishing redundant logistical capabilities will ensure high priority aircraft parts flow into theater and onto the LHD/A via organic Marine Corps assets.

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APPENDIX A. HISTORICAL DATA

Week	Demand/Week	Sorties/Week
29-Aug-20	3	13
4-Sep-20	6	20
10-Sep-20	6	33
19-Sep-20	8	25
26-Sep-20	7	16
3-Oct-20	3	19
10-Oct-20	11	11
23-Jan-21	3	28
30-Jan-21	20	35
5-Feb-21	21	18
13-Feb-21	15	0
16-Feb-21	1	0
15-Mar-21	1	0
24-Mar-21	1	0
22-May-21	1	0
11-Jun-21	0	0
11-Jun-21	2	0
19-Jun-21	10	48
26-Jun-21	13	39
2-Jul-21	10	19
7-Jul-21	4	14
17-Jul-21	9	13
24-Jul-21	8	48
31-Jul-21	27	26
7-Aug-21	11	15
14-Aug-21	5	17
20-Aug-21	8	10
22-Aug-21	1	0
30-Aug-21	1	0
26-Jan-22	2	21
5-Feb-22	14	38
12-Feb-22	15	52
19-Feb-22	21	28
24-Feb-22	15	14
4-Mar-22	10	5
12-Mar-22	9	24
17-Mar-22	5	0
23-Mar-22	1	0

Sortie Avg	17.07894737
Demand Avg	8.324324324
Day Avg	1.189189189
Weekly StDev	6.691844348

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APPENDIX B. MV-22B MAXIMUM RANGE PERFORMANCE

We calculated the Osprey's maximum range using the 2020 MV-22B Naval Air Training and Operating Procedures Standardization Flight Manual. The first step was to determine fuel burn rate. Assuming the aircraft weighs 49,000 pounds and flies at 10,000 feet, we used the Maximum Range Performance chart and calculated fuel burn rate. Beginning by charting the weight (49,000lbs) on the Y axis of both graphs, we intersected this line with the sloping "10" line (10,000 ft). Reading the output on the X axis shows a cruising speed of 205 knots (bottom graph) and a burn rate of 0.085 nm/lb (top graph). We assume the aircraft begins its flight with 11,800 pounds of JP8 fuel, uses 10,600 pounds in-flight, and has 1,200 pounds remaining at landing. Multiplying the 10,600 pounds of available fuel by the burn rate of 0.085 equates to 901 nautical miles (~1,000 miles).

OSPREY MAXIMUM RANGE

Weight (in lbs)	49,000
Altitude (in ft)	10,000
Cruising Speed (in Knots)	205
Fuel (in lbs)	10,600
Burn Rate (in nm/lbs)	0.085

CALCULATION:
Burn Rate * Fuel
0.085 NM/lb * 10,600 lbs 901

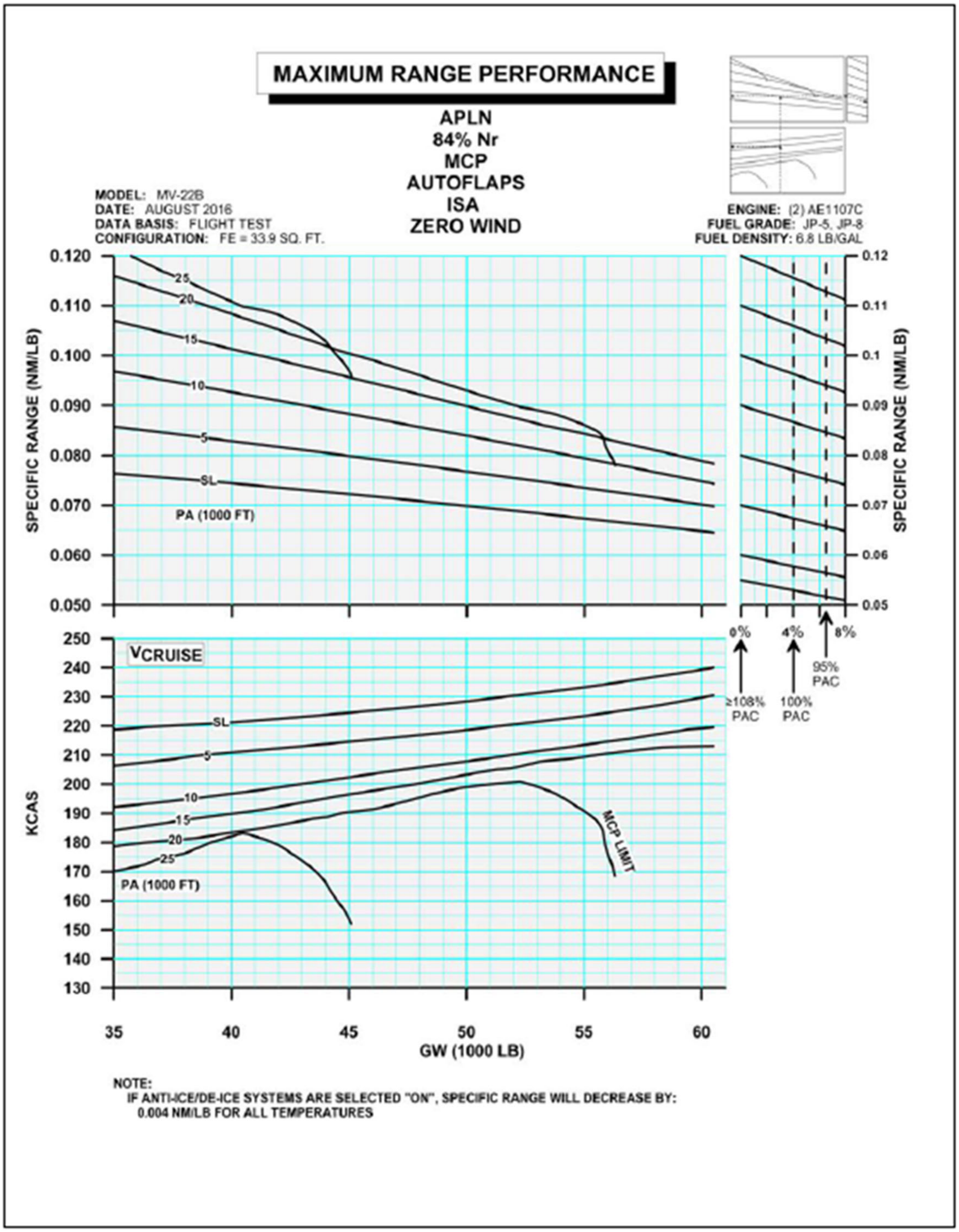

Figure 13. MV-22B maximum range. Source: CNO (2020).

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