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14. ABSTRACT
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Table of Contents

Disclaimer

Table of Figures

List of Tables

Executive Summary

Expeditionary Advanced Base Operations (EABO) is a new Marine Corps concept for operating inside an enemy's weapon engagement zone (WEZ), but this study's operations analysis of various employment options for the Marine Corps' F-35 stealth aircraft suggest the Corps will be hard pressed to operate this platform solely as an inside force against a Chinese threat. The F-35's relatively short range, small payload—particularly when operating in stealth mode—and basing vulnerabilities indicate the Marine Corps will need to develop a balanced role for the F-35 operating as both an inside and an outside force. This mixed approach offers the best chance for reducing risk to the F-35 while maximizing the platform's strike capabilities. As an inside force, F-35s operating stealthily from land or ship will improve their odds of survival, but at the cost of reduced offensive capabilities; as an outside force, F-35s configured to maximize payloads and range can bring heavier firepower to bear, but at greater risk of detection and interdiction by the enemy.

This study's operations analysis also strongly suggests the Marine Corps should make significant additional investments in procuring the Small Diameter Bomb—which significantly boosts the F-35's offensive capability over larger 1,000- and 2,000lb bombs; and proceed with experiments that are operating amphibious ships as "light aircraft carriers" vice multipurpose helicopter carriers. The analysis also suggests that further study needs to be given to the basing mix for the F-35—whether ship- or land-based, and for the latter, the actual feasibility of establishing small, austere airfields that can reasonably avoid detection from China's vast and expanding intelligence, surveillance, and reconnaissance (ISR) network. These basing challenges will in turn drive further assessments of the appropriate mix of future Marine procurements of F-35B, short take-off and landing variants, vice F-35Cs, which use traditional,

large airfields ashore like the Air Force or large aircraft carriers like the Navy. This study employs rigorous quantitative and qualitative tools to make significant contributions to the analysis of the F-35's employment as an aircraft, but could not, within the restraints of a short Master's thesis, address in a similarly rigorous manner, the myriad basing issues that will be critical to adapting the F-35 to EABO concepts.

I. Introduction

The United States Marine Corps is exploring Expeditionary Advanced Base Operations (EABO) as an evolving operational concept conducted by dispersed, low-signature naval and joint forces operating within range of enemy weapon engagement zones (WEZ).[1] In today's increasing anti-access/area denial (A2/AD) environment, EABO is a concept that allows for continued United States power projection and freedom of movement in a contested environment.[2] The concept of EABO is future-focused and well matched with the F-35's 5th generation stealth technology, enabling operations inside an enemy WEZ. However, the benefits of stealth—embodied in the F-35 model of aircraft—are offset by several factors. The actual utility of the F-35 in EABO will be heavily dependent on three main issues: first, in peacetime, deciding which models—B or C variants—to procure; second, in wartime, operational decisions made on whether to configure the aircraft to maximize stealth or payload; and third, in planning and in operations, whether to base the aircraft on land or at sea, or in what mix. This study focuses on the utility of the F-35 aircraft as it relates to EABO, specifically, whether the F-35 should be an inside force or an outside force and the costs and benefits associated with these courses of action (COA). This study presents operational analysis of the utility of the F-35 in a notional EABO scenario accounting for weapon loadout, fuel load, and shore versus ship basing.

This study takes a traditional operations analysis approach that provides decision-makers with a quantitative and qualitative basis for making decisions for forces and operations under their control.[3] The systematic approach to operations analysis provides insight and allows decision-makers to analyze COAs to make a rational choice.[4] The systematic methodology is broken down into three parts: identify the problem and the scope, develop an analytical approach, and conclude with findings and recommendations.

II. Problem and Scope

The first step of operational analysis is to identify the operational problem.[5] The Commandant of the Marine Corps made clear that the Corps is not optimized to meet the demands of the National Security Strategy (NSS) for great power competition.[6] The Marine Corps' force design, organization, and capabilities are insufficient for high-intensity, large scale conflicts against well-armed adversaries.[7] EABO is a new concept to satisfy the Commandant's vision of a future Marine Corps suitable for the great power era, but EABO is in its early stages, and has not yet definitively explained how the F-35 will be employed to support the concept. The "EABO Handbook"—an informal working document that, while not official Marine Corps doctrine, is informing current thinking among Marines—does express its heavy reliance on stealth technology, but only broadly identifies the role of F-35s, mentioning the F-35 as an inside force.[8] This study asserts that the F-35 can also provide value as an outside force, and in fact, may be forced to remain an outside force owing to the myriad challenges of operating the platform inside China's WEZ.

The operational problem for determining the F-35's optimum role in support of EABO is threefold: a) defining its role as an inside force or an outside force by optimizing its employment to maximize its stealth; b) deciding on how to maximize its fuel vis-à-vis its time on-station and combat radius; and c) determining its optimal basing modes on land and at sea.

An inside force is defined as a force with a persistent forward presence within an enemy WEZ. When defining the F-35 as an inside or outside force, strategists and tacticians are primarily concerned with ballistic missile WEZs that could strike F-35 bases at sea or on land.[9] The F-35 will not persistently operate inside a surface to air missile (SAM) WEZ, but is considered an inside force if persistently operating inside a ballistic missile WEZ. When faced with a SAM threat, F-35s are expected to penetrate a SAM WEZ, employ weapons, exit the SAM WEZ, then assess the SAM threat.[10] Additionally, the aircraft will be in stealth configuration if the situation warrants and will not operate in "beast" configuration—Marine slang for F-35s loaded with externally-carried munitions that negate the aircraft's stealth characteristics[i]—unless operating in a low threat permissive environment.[11]

An inside force relies heavily on stealth capabilities to maintain a forward and persistent presence. The importance of stealth technology and its substantial financial investment suggests the F-35 will be configured to maximize its stealth attributes. Stealth configured F-35s have a weapon loadout that only utilizes the internal weapon stations, or weapons "bays," that allow the F-35 to carry weapons while maintaining stealth characteristics.[12] The persistent and forward presence inside a known enemy WEZ also underscores the importance of survivability. The EABO Handbook states that the enemy's ability to target multiple dispersed EABs complicates the enemy's targeting solution; however, multiple, dispersed, and maneuvering EABs will further complicate the enemy's ability to target Marine Corps forces. Operational maneuverability, in turn, favors ship-based over shore-based aircraft, which argues for the F-35B model; however, the F-35B has less fuel load than the F-35C model.

Conversely, an outside force, such as large naval surface combatants that are vulnerable to the enemy's missile attacks, typically only enters the inside force's area of operations after the WEZ threat has been reduced. However, in the case of friendly aviation fires or long-range missile fires, an outside force can also augment inside forces with additional strike capabilities.[13] As an outside force, the F-35 can operate intermittently inside an enemy WEZ, but stealth is

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[i] Pentagon F-35 Subject Matter Expert: Headquarters Marine Corps, Aviation, F-35 Requirements, Tactical Air (TACAIR), APW-21: "Beast mode" has been popularized as a term in some Marine and media publications for F-35s that are configured to have a weapon loadout that utilizes both internal and external weapon stations. Due to the external weapon loadout, the F-35 will be able to carry additional weapons at the cost of increasing its radar cross-section. This increased radar cross-section degrades the aircraft's stealth characteristics.

generally not as important as that of an inside force. Therefore, the F-35 can potentially use "beast mode" to maximize aviation fires. Additionally, because outside forces are not persistently inside an enemy WEZ, there is less need to complicate enemy targeting with operational maneuverability, which allows for F-35s to operate from shore-based airfields. Shore-based airfields located outside an enemy WEZ allows for, and may require, longer-range capabilities, such as those held by the conventional F-35Cs over short take-off F-35Bs. Nevertheless, F-35Cs need longer runways that are inherently more vulnerable to enemy detection.

In sum, this study offers insights on the applicability of the F-35 as either an inside force or an outside force, or a mix of both. Additionally, this study provides insight on the risk to mission success associated with air operations from shore or ship bases. The F-35 is a capable aircraft, but there are gaps as they pertain to the EABO concept. For instance, aerial refuelers, airborne command and control platforms, ships, and shore-bases are all vulnerable when operating inside an enemy WEZ. The F-35 is a multi-billion-dollar platform that is capable of multiple mission sets, but represents a huge portion of the Marine Corps' budgetary burden.[14] Like the Marine Corps' legacy fighter and attack aircraft, the F-35 was developed before the EABO concept. The F-35 is being incorporated into a new concept, making it a timely question to assess the extent to which and how the F-35 can best support EABO.

The study recognizes the practical importance of all functions of Marine aviation and F-35 capabilities, but this study will focus on the offensive air support (OAS) function, mainly, close air support (CAS). CAS is the quintessential "Marine" employment of aviation—Marines conducting CAS for Marines on the ground is an oft stated rationale for why Marine aviation is not duplicative of Navy or Air Force aviation.[15] Therefore, this study uses CAS as the litmus test for the suitability of the F-35 in supporting EABO. Last, this study offers a notional scenario—an escalating crisis that requires the employment of a Marine Expeditionary Brigade (MEB)-sized response—as well as several assumptions concerning the scenario and the operations analysis.

A. Courses of Action

The objective of this study is to identify the optimal roles of the F-35 in support of EABO, specifically, whether it is feasible for the F-35, and its bases, to operate as an inside or outside force. To frame this study, two COAs were identified: COA 1, F-35s will operate as an inside force in support of EABO; and COA 2, F-35s will operate as an outside force in support of EABO. With the Marine Corps' decision to purchase the F-35C model,[16] COA 1 was further broken down into subcategories; the feasibility and risk to mission success of sea-based or shore-based F-35s.

B. Analytical Assumptions and Constraints

This study uses unclassified data in an academic setting to establish a basic methodology to aid the evaluation of operational concepts, but remains short of the rigor and detail required to support actual military plans and operations. This study was simplified by using the following constraints and assumptions.

First, this study is constrained to unclassified data. Tactical employment, combat system capabilities, and other factors above the unclassified level will contribute to the decision or feasibility of a COA.

Second, environmental factors effect aviation operations. Weather factors were considered, but are outside the scope of this study and not included.

Third, the resilience and survivability of bases once hit is a critical factor, but is beyond the scope of this study's focus. To simplify the analysis, this study assumes that bases or platforms within the WEZ, if hit, will result in a catastrophic loss, depending on the number of hits, the precision of the hits, and the explosive weight and characteristics of the enemy weapons.[ii]

Last, mathematical models and calculations did not account for every possible variable. In calculating aircraft required, equations prioritize stealth configuration to maximize the F-35's stealth capabilities at various readiness levels. Additionally, CAS involves a dynamic, on-call, fluid environment with an unpredictable number of targets—in contrast to a predictable, static target set developed for a pre-planned air attack. The number of targets calculated in the notional scenario reflects an assumption that the enemy will operate at 80% readiness. This enemy readiness level is held constant by depicting a set number of targets, despite that CAS conducted in a combat situation is unpredictable. In reality, this notional set number of targets are typically targeted in separate or successive phases of a developing battle, with varying number and rate of F-35 sorties. However, again, to support a structured comparison, this assessment simplifies the scenario by summarizing the overall F-35 strike effort against a set number of targets. While striking these targets, the study assumes that one weapon station will provide one weapon to achieve desired effects on one target, therefore, desired weapons effectiveness is not calculated. Last, this study did not include specific dispersion distances of EABO forces throughout the Pacific, in relation to the time frame for CAS to support these dispersed EABs.

[ii] Spaeder, Leo. "Get Small or Get Shot: Increasing Survivability for Maritime Operations." Marine Corps Gazette 103:12 December 2019. A variable for resilience will require additional analysis and metrics such as ship construction and survivability, number of hits and weapon types, and circular error probabilities that go beyond the scope of this study. The same type of metrics will have to be analyzed for land-based runways to include runway dimensions and/or repair capabilities and limitations.

C. Scenario and Scenario Assumptions

1. Scenario Assumptions

Overall Scenario. According to the EABO Handbook, inside forces should provide shaping actions, such as supporting friendly naval sea denial efforts, that allow follow-on outside forces to enter the conflict area. EABs are designed to challenge the enemy's ability to locate inside forces, but not all EABs will remain undetected.[17] This study depicts a worst-case scenario that involves EABs that are detected and attacked by a Chinese quick reaction, "counter landing" force operating within active WEZs. This scenario posits a limited clash between People's Liberation Army Navy Marine Corps (PLANMC) forces in the vicinity of the South China Sea and a forward-deployed United States deterrence and reassurance force that was present as a crisis escalated to a medium-level conflict. The fighting is high-intensity, has drawn in outside forces, but remains generally localized in the South China Sea.

Specific Scenario. The scenario involves a battalion-size Marine force conducting EABO that is detected and attacked by a Chinese rapid reaction force composed of a Chinese Marine brigade.[iii] The battalion-sized Marine force, is one of several dispersed units that fall under a MEB containing two F-35B detachments aboard two landing helicopter assault ships (LHA), and two shore-based F-35C squadrons. This scenario includes several other assumptions listed below.

First, this study focuses on a MEB conducting EABO as part of a larger joint force, not a MEB fighting China.[iv] The scenario is not an air tasking order versus China in an air campaign.

[iii] In reality, EABs are likely to be staffed by small units, even down to the squad or platoon-level, with a battalion headquarters controlling potentially several EABs in a designated area of operations. The scenario depicts the United States Marine presence—whether in one or several nearby EABs—as one battalion-sized Marine force conducting EABO. This simplification streamlines the calculations and modeling.

[iv] This study recognizes that a future MEB, and existing Marine Corps force structure will be fundamentally reorganized and reshaped in line with distributed EABO. However, we use the concept of a MEB to denote a higher headquarters commanding disparate subordinate elements in a EABO environment.

The scenario consists of EABO as part of a larger joint and/or combined force with a vast array of capabilities and assets that can contribute to the overall fight.

Second, the scenario follows the Marine Corps' 2019 aviation plan and the new Lightning Carrier deployment concept.[v] According to the aviation plan, the Marine Corps will procure 135 F-35Bs and 23 F-35Cs by the end of fiscal year 19.[18] Additionally, the aviation plan apportions aircraft in support of actual operations with a detachment of six F-35Bs aboard a Marine Expeditionary Unit (MEU) and a mix of 10- to 16-aircraft per squadron that are either shore-based or carrier-based; however, this study assumes shore-based F-35Cs.[19] In comparison to the standard MEU squadron detachments, the Lightning Carrier concept will deploy between 20 to 23 F-35Bs aboard one LHA.[20]

Third, this study compares various employment options that reflect current Marine Corps practice; therefore, the notional scenario will assume a standard MEU detachment compared with the Lightning Carrier concept for analysis. Using a standard MEU detachment of F-35Bs, the study analyzes a MEB with two F-35B detachments aboard two LHAs, and two F-35C shore-based squadrons for a total of 12 F-35Bs aboard LHAs, and 20 shore-based F-35Cs. In comparison, according to the Lightning Carrier concept, the study analyzes 44 F-35Bs aboard two LHAs, and 20 shore-based F-35Cs.

Fourth, the scenario uses LHAs, assuming that new, smaller types of amphibious ships have not yet been developed or employed.

Fifth, the scenario assumes the Joint Force Air Component Commander (JFACC) will achieve local air superiority in the EAB's general region, and the Joint Force Maritime

[v] A MEU-postured aviation detachment is designed to support a range of peacetime and crisis-response missions, ranging from helicopter-intensive and landing-craft-intensive humanitarian relief to non-combatant evacuation operations. A Lightening Carrier-postured aviation detachment is designed primarily to support offensive and defensive fixed-wing air operations.

Component Commander (JFMCC) is tasked to achieve local maritime superiority in the same region. To achieve air and maritime superiority, the JFMCC and JFACC have conducted limited strategic attack during shaping operations. These strategic attacks have significantly degraded, though not eliminated, Chinese long-range precision strike and ballistic missile capabilities such as the DF-26 and the HQ-19.[21]

Sixth, there is a high likelihood of active surface to air threats and radar systems in the area of operation. Early warning radars such as the KJ-2000 and the KJ-500 remain a factor,[22] and long-range SAMs, to include the CSA-9, SA-10, SA-20, SA-21, and HQ-19 remain a threat.[23] The high likelihood that these radar and weapon systems are operational, drives the importance of stealth capability during EABO.

Seventh, the scenario assumes the joint force will continue to roll back the WEZ by hitting Chinese SAM sites and radars. However, the enemy's discovery of EABs is a threat if the enemy, short of missile striking power, attempts to defeat the EABs with a counter-landing force. From the Chinese perspective, its diminishing long-range precision strike forces, and the EABO's ability to conceal its position from Chinese overhead intelligence, surveillance, and reconnaissance (ISR), requires a Chinese amphibious landing to root out the EABs. The scenario depicts EABs that are under attack with F-35s providing CAS. Possible CAS targets include command and control, maneuvering infantry, artillery, anti-aircraft artillery (AAA), and armored vehicles. The scenario assumes artillery, AAA, and armored vehicles are primary targets to meet the ground commander's intent. This simplification reduces the analytic uncertainty and unpredictability of enemy forces.

Eighth, recognizing that United States naval and air forces—and even the EAB's own coastal defense missiles—could well detect and destroy PLAN ships carrying the PLANMC brigade, this study assumes the brigade has successfully avoided detection and landed, allowing us to test the scenario of the United States Marine EAB needing to call on CAS in a ground battle.

Last, the scenario recognizes that an EAB can call on its own organic and other supporting fires—loitering munitions, limited artillery, drone swarms, and naval gunfire, but the Chinese landing force's overwhelming intensity and the EAB's extreme situation and deteriorating tactical situation, requires urgent and sustained CAS.

2. Enemy Force

China's military strength and capabilities will continue to advance and have the potential of becoming a peer competitor with the United States. China strives to develop a "world-class" military that is ready to fight and win by enhancing military readiness and modernization by 2035.[24] China's President Xi Jinping and former president Hu Jintao stressed the importance of maritime power.[25] Hu's report to the 18th party congress in 2012 stated that "We should enhance our capacity for exploiting marine resources, resolutely safeguard China's maritime rights and interests, and build China into a maritime power."[26] This comment reflects China's growing strategic policy to gain power in the disputed South and East China Seas, and enhance its anti-access/area denial (A2/AD) capabilities.[27]

The PLANMC is the PLA's primary long-range force capable of combined arms and amphibious assaults from multiple avenues of approach.[28] The PLANMC falls under the PLAN, and in 2012, the PLAN's South Sea Fleet (SSF) had two operational Marine brigades.[29] Table 1 lists the general equipment, location, and size of the 1st and the 164th Marine brigades.[30] The primary mission of the PLANMC is to conduct offensive and defensive amphibious assaults in the South and East China Seas to include the disputed Paracel, Spratley, and Senkaku Islands.[31]

Most importantly, China designated the PLANMC to be its rapid reaction force capable of conducting expeditionary operations and has continued to grow in PLANMC power and capabilities.[32]

Table 1: Equipment, location, and size of the 1st and 164th Chinese Marine brigades.

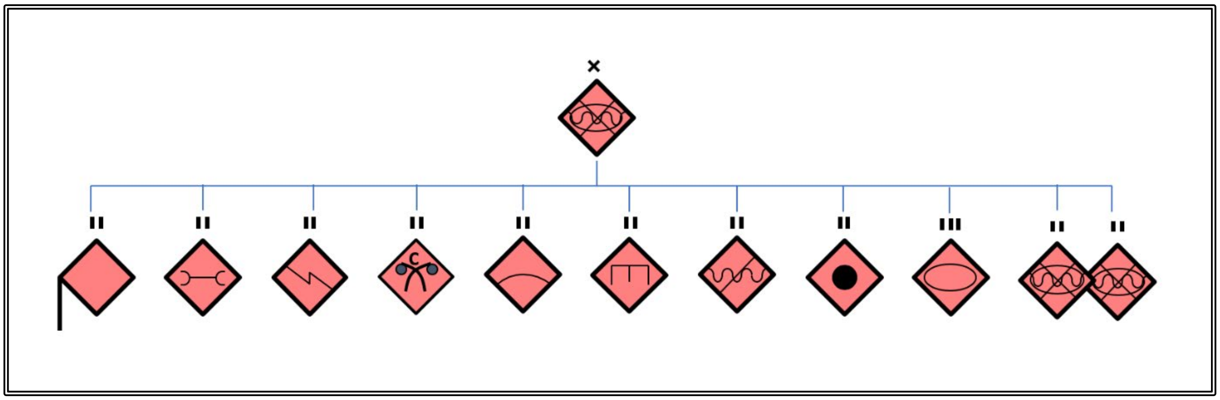
1st Marine Brigade (Zhanjiang)	164th Marine Brigade (Zhanjiang)
• Leaders and departments • 1st, 2nd, and 3rd Marine Battalions • Armor Regiment • Missile, artillery, guard and telecommunications, engineering and chemical defense, and repairs battalions • Amphibious Reconnaissance *Dadui* (两栖侦察大队) (Suixi)	• Leaders and departments • Marine, artillery, missile, guard and telecommunications, engineering and chemical defense, and repairs battalions • Armor Regiment • Amphibious Reconnaissance *Dadui* (Zhanjiang)

Reprinted from, *The PLA as Organization v2.,* Edited by Kevin Pollpeter and Kenneth Allen. Maxwell Airforce Base, AL, July 27, 2018. [33]

3. Enemy Force Organization and Composition

This study created a notional Chinese Marine brigade of 5,000 personnel, using open source information and Annex B of a fictitious operations order used during Exercise Pacific Challenge III at the Marine Corps' Command and Staff College.[34] Figure 1 illustrates the organization of a Chinese Marine brigade and consists of the following: a headquarters battalion, one armor regiment, two infantry battalions, one missile battalion, one artillery battalion, one signals and communications battalion, one engineer battalion, one chemical defense battalion, one maintenance battalion, and one amphibious reconnaissance battalion.[35] The PLANMC does not have organic air or naval assets. The PLANMC receives aviation support from the PLAN as well as naval transport.[36]

Figure 1: Notional PLANMC Force Organization.



Using historical statistics during the Korean War, specifically during the Battle for the Chosin Reservoir, 50% of Chinese forces targeted by the United States were destroyed by CAS aircraft.[37] The total number of potential targets a MEB will expect to face from a Chinese quick reaction force of a PLANMC brigade is 84 CAS targets, illustrated in table 2.

Table 2: Chinese CAS Targets in the Notional Scenario.[38]

Troops and Equipment	Total	80% Equipment Readiness
Artillery (e.g. PHL-03, PLZ-05, Type 59-1, Type 66)	18	14
Anti-Aircraft Artillery (e.g. PGZ-95, 07, 04)	4	3
Armored Infantry Fighting Vehicles (e.g. ZBD-05), Armored Personnel Carriers (e.g. ZBL-09)	189	151
Total Possible Close Air Support Targets	211	168
Targets Based on Historical Statistics (50%)	**84 Targets**	

III. Analytical Approach

A. Performance Measures

Again, the operational problem for determining the F-35's optimum role in support of EABO is threefold: a) defining its role as an inside force or an outside force by optimizing its employment to maximize its stealth; b) maximize its fuel vis-à-vis its time on-station and combat radius; and c) determining its optimal basing modes on land and at sea.

Applying the operational problem, the study uses quantitative and qualitative values to provide insight into the feasibility of each COA and insight into which COA is the best.[39] To provide this insight, the study uses four criteria to develop measures of effectiveness (MOEs):[40] the MOE must be quantitative, measurable, or estimable; an increase or decrease in the MOE value must resemble an improvement or worsening in achieving the objective; and the MOE must incorporate both benefits and cost that effect the COAs. The study's MOE is the ability of F-35s to prosecute all targets in the notional scenario, and attempts to provide an answer on whether the F-35 can operate solely as an inside force or an outside force.

Furthermore, the study uses variables, summarized in table 3, as the study's measures of performance (MOPs) that contribute to the MOE. The operational problem has multiple objectives and multiple attributes related to those objectives. The first objective is to minimize F-35 detection while maximizing the ability to strike a given amount of targets. The attribute to this objective is the MOP between stealth configured and beast configured aircraft. The second objective is to maximize combat radius and time-on station. The attribute for this objective is the MOP between an F-35B's fuel capacity versus an F-35C's fuel capacity. The last objective is to identify the risks to mission success associated with shore- versus sea-based F-35s operating inside an enemy WEZ. The attribute for this objective is to compare the ability of shore and sea bases to gain access to host nations, acquire required logistical support, and survive against adversary weapon systems.

Quantitative and qualitative variables are identified and classified in table 3. By definition, a variable is a value liable to change and is a component of the decision problem.[41] Thus, the value of the variables will affect the decision maker's evaluation of the problem and

COA. The study uses both quantitative and qualitative variables, and include the configuration value, aircraft model, and airbase risk to mission success.

Table 3: List of Variables.

Variables	Explanation
Configuration Value	This variable provides a quantitative value between stealth and beast configured F-35s. The F-35 can strike more targets if carrying more weapons, but at a cost of a greater radar cross-section.
Aircraft Model	This variable provides a quantitative value between F-35B and F-35C models. The F-35C has a greater fuel load, but it has additional runway requirements.
Airbase Risk	This variable provides a qualitative analysis between ship- and shore-based F-35s. Focus is on survivability such as dispersion, maneuverability, and defense, and also touches on logistical and diplomatic considerations.

To specify the elements of these variables, equations are used to illustrates how the configuration value is calculated by using two aircraft configurations. The first configuration is the stealth configuration, where the F-35 is limited to two bombs loaded into its internal weapon stations.[vi] When placing bombs in the internal weapon stations, the aircraft maintains its stealth characteristics, hence the name stealth configuration.[vii] The wings of F-35's have additional weapon stations, but they are external to the aircraft's airframe; using wing stations is referred to as beast configuration.[viii] When loading bombs externally under the wings, the aircraft can carry additional weapons at a cost to its radar cross-section. An increase in radar cross-section will degrade the aircraft's stealth characteristics; therefore, the beast configuration is not ideal when operating inside a WEZ.

[vi] Pentagon F-35 Subject Matter Expert: Headquarters Marine Corps, Aviation, F-35 Requirements, Tactical Air (TACAIR), APW-21: The F-35B is limited to a 1,000lb bomb per internal weapon station while the F-35C can carry 2,000lb bombs per internal weapon station.

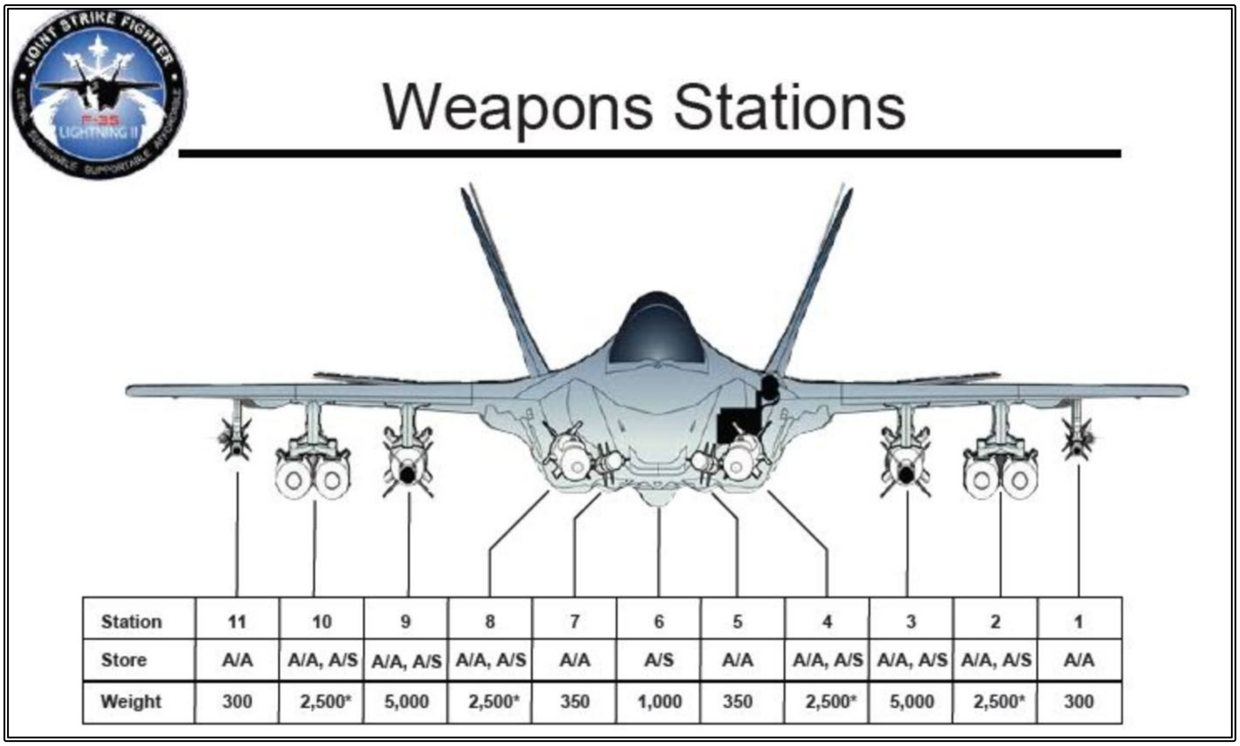
[vii] F-35 Weapon Stations Figure. https://www.thinkdefence.co.uk/2013/01/looking-forward-to-an-f35-future-part-3-the-promise/f35-weapon-stations/: stealth configuration uses stations 4 and 8, which are the internal weapon stations.

[viii] F-35 Weapon Stations Figure. https://www.thinkdefence.co.uk/2013/01/looking-forward-to-an-f35-future-part-3-the-promise/f35-weapon-stations/: beast configuration uses the internal weapon bays and external weapon stations under the wings of the aircraft, which include stations 2, 3, 9, and 10.

When calculating the weapon station value, the study uses two weapon stations for stealth configured aircraft and six weapon stations for beast configured aircraft.[42] Additionally, the F-35 is capable of carrying the GBU-39 Small Diameter Bomb I (SDBs).[43] Therefore, this study also calculates weapon station values when F-35s are loaded with SDBs.[ix] The decreased size of the SDB—250lbs vice the standard 1,000lbs and 2,000lbs bombs, allows the F-35 to carry eight SDBs in stealth configuration compared to only two bombs. Both the F-35B and F-35C models can carry this weapon.[44] For an illustration of the available weapon stations on the F-35, reference figure 2.[45]

[ix] Pentagon F-35 Subject Matter Expert: Headquarters Marine Corps, Aviation, F-35 Requirements, Tactical Air (TACAIR), APW-21: The F-35 is capable of employing the GBU-39 Small Diameter Bomb I (SDB). Currently, external SDBs on the F-35 are not a requirement, and there are no funds available to integrate a new rack system to support externally loaded SDBs.

Figure 2: F-35 Weapon Stations.



Reprinted from F-35 Weapon Stations Figure. https://www.thinkdefence.co.uk/2013/01/looking-forward-to-an-f35-future-part-3-the-promise/f35-weapon-stations/.

The weapon station value is calculated such that:

$$X_1 = Stealth, X_2 = Beast$$

therefore,

$$Weapon\ Station\ Value\ without\ SDBs = 2X_1 + 6X_2$$

$$Weapon\ Station\ Value\ with\ SDBs = 8X_1 + 12X_2$$

The second value calculated is the fuel load value. In calculating the fuel numbers, the study uses subject matter experts who referenced the F-35 pocket checklist (PCL).[46] The PCL provides performance characteristics and emergency procedures for associated platforms. This information is drawn directly from the main F-35 Naval Air Training and Operating Procedures Standardization (NATOPS) flight manual.

This study first calculates usable fuel, for instance, the fuel requirements for flight operations minus the fuel requirements to start engines, taxi, takeoff, and land with reserve fuel. Once airborne, this study uses 30,000 feet mean sea level (MSL) for the cruise altitude.[47] At this altitude, time to level off, distance to level off, optimum cruise airspeeds, and fuel flow is used in the calculations. Ultimately, this study calculates time airborne and distance traveled to compare the F-35B to the F-35C.

The third value is qualitative, analyzes ship- and shore-based F-35s, and analyzes the risk to mission success. To be successful in conducting EABO, the Marine Corps must persistently operate within a WEZ. According to the EABO Handbook, operating within a WEZ will limit the Marine Corps' ability to mass, but does not prevent the Marine Corps from fighting a formidable threat. Operating within a WEZ with the capacity to defeat the enemy requires security, support, and sustainment.[48] With the proper logistical support, EAB forces can disperse, maneuver, and defend against attack, increasing the likelihood for an EAB to survive.[49] It is clear that EABs are not invulnerable, which requires the ship- and shore-based options to be evaluated against the following MOPs; logistics, survivability, and diplomatic access. When referencing survivability, the study focuses on three specific qualitative MOPs:[50] EABs must be widely dispersed, maneuverable, and have defensive capabilities. The probability of each MOP is not amenable to quantification; therefore, this study uses a qualitative analysis of alternatives.

B. Initial Analysis

<u>Configuration Value.</u> The study uses readiness rates from 10% to 100% to demonstrate F-35 capabilities in both the stealth and beast configuration, with or without SDBs. Feasible solutions are revealed at low F-35 readiness levels, but the study does not advocate that low readiness rates are acceptable. Instead, in what follows, citing a low readiness level implies a positive outcome,

for example, that the F-35 can hit the required number of targets even if aircraft availability or readiness fell to as low as, say, 20%.

The study uses the configuration value to determine the feasibility of F-35s operating as an inside force or an outside force. The configuration is directly related to the ability of F-35s to mass firepower. Beast configuration maximizes weapon loadout at the cost of an increased radar cross-section, and stealth configuration maintains stealth characteristics, but at a reduced weapon loadout. Therefore, when operating inside an enemy WEZ, beast configured F-35s are less desirable than stealth configured F-35s.

Initial analysis of the MEU concept revealed an infeasible solution, even at 100% readiness. If all the MEB's F-35s are stealth configured and all aircraft are launched to conduct CAS, there will be 20 CAS targets remaining out of 84 targets, illustrated in table 4. In contrast, if all the MEB's F-35s are beast configured, the initial analysis reveals a feasible solution with as low as 50% mission capable aircraft, also illustrated in table 4. Using SDBs in lieu of traditional bombs reveals feasible solutions in both stealth configured and beast configured aircraft, illustrated in table 4. In fact, F-35s loaded with SDBs can strike all 84 CAS targets at only 40% and 30% readiness for stealth and beast configured aircraft, respectively.

The Marine Corps should prioritize the F-35 stealth configuration to execute effective CAS inside an enemy WEZ to remain undetected during EABO. Since all targets must be prosecuted using stealth configured aircraft, and initial analysis reveals that this is infeasible using the MEU concept without SDBs, an optimization solution is required to determine the number of stealth and beast configured aircraft needed to strike all 84 targets. Using the MEU concept with SDBs also requires an optimization solution to determine the number of stealth and beast configured aircraft needed to strike all 84 targets. This analysis suggests a MEU, at 80%

readiness, will need to deploy 18 F-35s in stealth mode with an additional eight F-35s in beast mode in order to hit all the targets without using SDBs. If SDBs are available, a MEU, at 80% readiness can strike all required targets without needing beast configured F-35s.

Table 4: MEU concept with and without SDBs. Red annotates targets remaining.

Stealth Configuration (MEU Concept) Against 84 CAS Targets										
MC Rate	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
MC Aircraft	3	6	10	13	16	19	22	26	29	32
Targets Destroyed	6	13	19	26	32	38	45	51	58	64
Targets Remaining	78	71	65	58	52	46	39	33	26	20
Beast Configuration (MEU Concept) Against 84 CAS Targets										
MC Rate	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
MC Aircraft	3	6	10	13	16	19	22	26	29	32
Targets Destroyed	19	38	58	77	96	115	134	154	173	192
Targets Remaining	65	46	26	7	12	31	50	70	89	108
Stealth Configuration (MEU Concept Using SDBs) Against 84 CAS Targets										
MC Rate	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
MC Aircraft	3	6	10	13	16	19	22	26	29	32
Targets Destroyed	26	51	77	102	128	154	179	205	230	256
Targets Remaining	58	33	7	18	44	70	95	121	146	172
Beast Configuration (MEU Concept Using SDBs) Against 84 CAS Targets										
MC Rate	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
MC Aircraft	3	6	10	13	16	19	22	26	29	32
Targets Destroyed	38	77	115	154	192	230	269	307	346	384
Targets Remaining	46	7	31	70	108	146	185	223	262	300

Initial analysis of the Lightning Carrier concept reveals a feasible solution for both stealth and beast configured aircraft, illustrated in table 5. If lightning carriers are deployed, F-35s can strike all 84 CAS targets at 70% and 30% mission capable readiness for stealth and beast configuration, respectively. When SDBs are used in lieu of traditional bombs, the study's initial analysis uncovers a feasible solution in both stealth and beast configured aircraft even as low as 10% readiness.

Again, the Marine Corps should prioritize the F-35 stealth configuration to execute effective CAS inside an enemy WEZ to remain undetected during EABO. Since all targets must be prosecuted using stealth configured aircraft, and initial analysis reveals that this is feasible using the Lightning Carrier concept with or without SDBs, an optimization solution is only required if F-35s are experiencing low readiness levels. Low readiness levels will require an optimization solution to determine the number of stealth and beast configured aircraft needed to strike all 84 targets.

Table 5: Lightning Carrier concept with and without SDBs. Red annotates targets remaining.

Stealth Configuration (Lightning Carrier Concept) Against 84 CAS Targets										
MC Rate	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
MC Aircraft	6	13	19	26	32	38	45	51	58	64
Targets Destroyed	13	26	38	51	64	77	90	102	115	128
Targets Remaining	71	58	46	33	20	7	6	18	31	44
Beast Configuration (Lightning Carrier Concept) Against 84 CAS Targets										
MC Rate	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
MC Aircraft	6	13	19	26	32	38	45	51	58	64
Targets Destroyed	38	77	115	154	192	230	269	307	346	384
Targets Remaining	46	7	31	70	108	146	185	223	262	300
Stealth Configuration (Lightning Carrier Concept Using SDBs) Against 84 CAS Targets										
MC Rate	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
MC Aircraft	6	13	19	26	32	38	45	51	58	64
Targets Destroyed	51	102	154	205	256	307	358	410	461	512
Targets Remaining	33	18	70	121	172	223	274	326	377	428
Beast Configuration (Lightning Carrier Concept Using SDBs) Against 84 CAS Targets										
MC Rate	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
MC Aircraft	6	13	19	26	32	38	45	51	58	64
Targets Destroyed	77	154	230	307	384	461	538	614	691	768
Targets Remaining	7	70	146	223	300	377	454	530	607	684

Aircraft Model. Given the F-35C's greater fuel capacity and range, initial analysis reveals that the time and distance problem is significantly greater for the F-35B compared to the F-35C. The F-35C has a greater combat radius and greater on-station time compared to the F-35B making the F-35C more favorable. If EABs need to be mutually supportive and need air support, the combat radius and on-station time of F-35s will restrict the amount of dispersion of EABs and land-bases to the fuel limitations of the F-35C versus the F-35B. Also, when concentrating on risk to the airbase, assuming the F-35C is not carrier-based, the F-35C will require additional runway length compared to the F-35B. Last, the F-35C can carry 2,000lb bombs in its internal weapon bays compared to 1,000lb bombs for the F-35B.[51] This study did not calculate weapon to target match and desired weapons effectiveness, but it is worth noting the F-35B's underperformance in weapons as well as fuel, compared to the F-35C.

Airbase Risk to Mission Success. The last piece to the operational problem is to determine whether F-35s should operate from ship- or shore-based airfields. F-35Cs cannot operate from LHAs; therefore, this study assumes that these aircraft will be shore-based to force analysis of the risks associated with LHAs vice shore-based aircraft.[x] The analysis was conducted for inside airbases; outside airbases are not considered high risk in this study.

C. Modelling

The models in this study are used to quantitatively and qualitatively describe and assess the operation of F-35s in the notional scenario.[52] The goal is to create a realistic model that is amenable to analysis.[53] This study begins with an optimization problem using integer linear programming to calculate the optimum number of aircraft to be configured in stealth and beast configuration. A second model illustrates the fuel load differences between the F-35B and F-35C. Finally, a stop light chart visually illustrates the qualities of sea- and shore-based F-35s, and decision trees illustrate a comparison of alternatives for decision and risk analysis.

1. Integer Linear Programming[54]

The first model involves integer linear programming and illustrates an optimization problem that quantifies the best use of limited Marine Corps resources against a notional Chinese

[x] F-35Cs can also operate from large nuclear-powered aircraft carriers (CVNs), but we exclude this from our analysis in order to keep our focus on comparing F-35C and F-35B in EABO. EABO is a Marine Corps concept that is likely to deploy a MEU using LHAs or the Lightning Carrier concept in rapid response to crisis in a contested and denied environment.

Marine brigade. Specifically, with a MEB of F-35s and 84 CAS targets, the model optimizes the amount of stealth and beast configured F-35s needed to prosecute 84 targets based on various F-35 readiness levels. There are three elements to this optimization problem: decision variables, restraints, and the objective function.[55]

The decision variables represent the quantities of stealth configured F-35s and beast configured F-35s, such that:

$$X_1 = Stealth, X_2 = Beast$$

The model requires four restraints. First, the number of F-35s are less than or equal to the number of MEB F-35s at a given readiness level. This restraint uses both the MEU concept and the Lightning Carrier concept. Second, the number of weapons to targets are greater than or equal to 84. Third, the model is constrained to two air to ground weapon stations for stealth configured F-35s, and six air to ground weapon stations for beast configured F-35s. When incorporating SDBs, the model is constrained to eight air to ground weapon stations for stealth configured F-35s, and 12 air to ground weapon stations for beast configured F-35s. Last, all values for X_1 and X_2 are non-negative integers and are expressed below.

$$X_1 + X_2 \leq Mission\ Capable\ Aircraft$$

$$2X_1 + 6X_2 \geq 84 \text{ or } 8X_1 + 12X_2 \geq 84$$

$$X_1, X_2 \geq 0$$

$$X_1, X_2 \text{ must be integers}$$

The objective function maximizes the X_1 decision variable allowing the model to prioritize stealth over beast configuration. The stealth and beast configuration problem is represented by:

MAX:

$$X_1$$

Subject to:

$$X_1 + X_2 \leq Mission\ Capable\ Aircraft$$

$$2X_1 + 6X_2 \geq 84\ or\ 8X_1 + 12X_2 \geq 84$$

$$X_1, X_2 \geq 0$$

$$X_1, X_2\ must\ be\ integers$$

The second model illustrates the fuel performance comparison between the F-35B and F-35C at a cruising altitude of 30,000'MSL.[56] This model allows for the quantitative analysis of on-station time and combat radius.

2. Stoplight Chart and Decision Trees

It is difficult to quantify variables related to airbase risk to mission success, whether ship or shore-based. The EABO Handbook uses four variables:[57] dispersion, maneuverability, defensive capability, and logistics. This study adds diplomacy as a variable for gaining access to terrain from host nations. This study utilizes a stoplight chart to illustrate the benefits and non-monetary cost of ship versus shore-based aircraft and uses the color red to illustrate the worse choice, and green for the best choice. The stoplight chart and decision trees provide a rough analysis of alternatives.

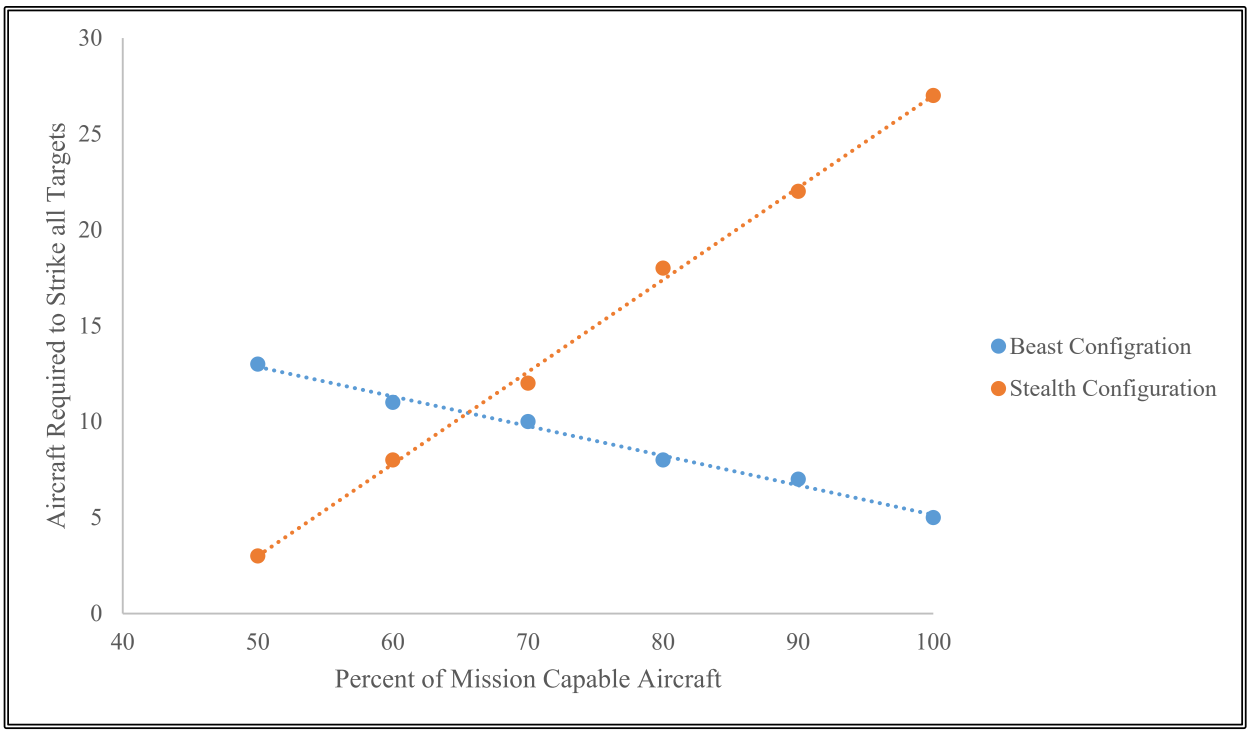
D. Results

The results for optimum stealth and beast configured aircraft using the MEU concept are illustrated in table 6. Using the MEU concept, F-35s need to have at least 50% readiness to strike all required targets. Also, as aircraft readiness levels increase, the requirement for beast configured aircraft decreases, shown in figure 2. This figure illustrates the importance of readiness on the reliance on stealth aircraft providing CAS in support of EABO. Overall, these results show the infeasibility of COA 1; the Marine Corps' inability to strike all 84 targets with stealth configured aircraft, even at 100% readiness.

Table 6: Optimization model for the MEU concept without SDBs.

Optimization Model for Stealth and Beast Configured Aircraft Against 84 CAS Targets using the MEU Concept without SDBs							
Configuration	**10%-40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Beast	Infeasible	13	11	10	8	7	5
Stealth	Infeasible	3	8	12	18	22	27

Figure 3: Mission Capable Aircraft Versus Number of Aircraft Required to Strike 84 CAS Targets.



The results for optimum stealth and beast configured aircraft using the MEU concept with SDBs are illustrated in table 7. The Marine Corps can strike all 84 targets using stealth configured aircraft at only 40% readiness. If, for some reason, the Marine Corps experiences readiness levels below 40%, optimizing beast and stealth configured aircraft is required at 30%

readiness to ensure all 84 targets are prosecuted. However, it is infeasible to strike all 84 targets with readiness levels below 30%, even with all aircraft configured in beast configuration.

Table 7: Optimization model for the MEU concept with SDBs.

Optimization Model for Stealth and Beast Configured Aircraft Against 84 CAS Targets using the MEU Concept with SDBs			
Configuration	**10%-20%**	**30%**	**40%-100%**
Beast	Infeasible	1	Optimization not required. Feasible with all aircraft stealth configured.
Stealth	Infeasible	9	

The results for optimum stealth and beast configured aircraft using the Lightning Carrier concept is illustrated in table 8. Squadrons must have at least 30% readiness to strike all 84 targets using the Lightning Carrier concept. Optimization is required from 30% to 60% readiness with optimized values shown in table 8. Readiness levels must be at least 90% in order to strike all 84 targets with all aircraft in stealth configuration. To put it another way, a Lightening Carrier entering combat with 90% of its F-35s would be able to accomplish the mission—hitting all 84 targets—while operating its aircraft in stealth mode. As readiness falls below 90%, more and more aircraft would need to be configured in beast mode to hit all the targets.

Table 8: Optimization model for the Lightning Carrier concept without SDBs.

Optimization Model for Stealth and Beast Configured Aircraft Against 84 CAS Targets using the Lightning Carrier Concept without SDBs						
Configuration	**10%-20%**	**30%**	**40%**	**50%**	**60%**	**90%-100%**
Beast	Infeasible	12	8	5	2	Optimization not required. Feasible with all aircraft stealth configured.
Stealth	Infeasible	7	18	27	36	

The results for optimum stealth and beast configured aircraft using the Lightning Carrier concept with SDBs are illustrated in table 9. Using the Lightning Carrier concept with SDBs, squadrons can have as low as 20% readiness and are able of striking all 84 targets in stealth mode. In other words, from 20% to 100% readiness, F-35s can strike all 84 targets in the stealth configuration.

Table 9. Optimization model for the Lightning Carrier concept with SDBs.

Optimization Model for Stealth and Beast Configured Aircraft Against 84 CAS Targets using the Lightning Carrier Concept with SDBs		
Configuration	**10%**	**20%-100%**
Beast	Infeasible	Optimization not required. Feasible with all aircraft stealth configured.
Stealth	Infeasible	

All fuel quantities are calculated by subject matter experts referencing the F-35 PCL.[58] The calculations begin by using the full service fuel load for the F-35B and F-35C, which is 13,493lbs and 19,747lbs, respectively. To calculate usable fuel for flight, the PCL assumes 1,400lbs required to start the engine, taxi, and takeoff with a climb at 500 knots, or Mach 0.88, whichever is less. The PCL also assumes landing with a reserve fuel of 1,800lbs; therefore, the usable fuel for the F-35B and F-35C is 10,293lbs and 16,547lbs, respectively.

Once airborne, the study uses 30,000'MSL for the cruise altitude. With a climb and level off at 30,000'MSL, the fuel states for the F-35B and F-35C is 11,200lbs and 17,100lbs, respectively. The distance traveled to level off at 30,000'MSL is 23nm and 34nm for the F-35B and F-35C, respectively. The time to level off is three minutes for the F-35B and four minutes for the F-35C. The differences in these numbers are due to a heavier takeoff weight of the F-35C from its greater fuel capacity.

The fuel flow at optimum cruise speeds at 30,000'MSL is 5.6lbs per hour and 5.8lbs per hour at speeds of Mach 0.84 and Mach 0.815 for the F-35B and F-35C, respectively. The time to reach a fuel state of 6,000lbs for the F-35B and F-35C is 56 minutes and 115 minutes, respectively. These times equate to a distances of 463nm for the F-35B and 921nm for the F-

35C. Ultimately, the fuel capacity for the F-35C is 40% greater than the F-35B allowing for greater range and loiter time.

The results for sea versus shore-based F-35s are illustrated in table 10. These results are not obvious and require further explanation below.

Table 10: Stop Light Chart for Ship vs Shore-Based F-35s.

Shore versus Sea Based F-35s					
	Dispersion	**Maneuverable**	**Defense**	**Diplomacy**	**Logistics**
Shore-Base	Yes	No/Limited	Yes (Passive)[59]	Requires Diplomatic Success	Requires Logistical Footprint
Sea-Base	No/Limited	Yes	Yes (Active)[60]	Not Required	Ship can Sustain

Dispersion. The study defines dispersion as the ability for friendly forces to spread or scatter throughout the area of operation. The notional scenario limits the Marine Corps to two LHAs, and the aircraft on those LHAs cannot scatter or disperse compared to multiple shore-bases. In other words, although the LHAs themselves are mobile, there are more friendly aircraft concentrated on the LHAs compared to dispersed or scattered shore-based F-35s. This is especially true when using the Lightning Carrier concept, which has more F-35s concentrated on a single ship creating a high risk to catastrophic loss if these ships operate inside a WEZ.

It is highly favorable for bases to disperse, especially if they are located inside an enemy WEZ.[61] CAPA Centre for Aviation lists 1,693 airports in 56 countries, operated by 583 different airline companies throughout the Indo-Pacific.[62] These statistics do not include unpublished airfields and non-airline type aircraft. Additionally, at any given time, 62,000 shipping vessels are operating throughout the world's oceans.[63] These vessels do not include smaller civilian craft or cruise ships, only commercial freighters. Assuming Marine aviation EABOs could disperse on even a small portion of those bases, dispersion will allow Marines to blend into the environment, making it difficult for enemy forces to find, target, and engage EABs.[64] Shore-bases are green because they can disperse, and sea-bases are red because their dispersion is limited based on the number of ships available.

Maneuverability. LHAs have greater mobility than shore-bases, and can move at a speed of approximately 20 knots while shore-bases cannot move at all.[65] Additionally, it takes time to build and breakdown a FARP or to construct an expeditionary airfield (EAF). For example, a tactical airfield fuel dispensing system (TAFDS) takes up to 48 hours to establish, and two to three weeks to construct an EAF.[66]

Also important, the F-35B does not operate like the AV-8B Harrier. Though the F-35B can take off and land vertically, there are limitations to that capability. The F-35B's exhaust burns extremely hot and requires high-temperature concrete to land and takeoff vertically.[67] Without high temperature concrete, the Marine Corps should expect the F-35B to conduct slow landings (SL), rolling vertical landings (RVL), and short takeoffs (STO) when operating on asphalt. [68] The STO requires 2,500ft of runway at maximum gross weight, and landing on asphalt is limited to 75 knots, which equates to 1,300ft of landing roll at 38,000lbs gross weight. [69] Conversely, the F-35C requires a runway length of 2,950ft (5,430ft wet) at 40,000lbs gross weight. [70] Last, all landing and takeoff surfaces must be swept clean and free of foreign object damage (FOD) material.[71] The bottom line is that shore-based F-35s are not as mobile as sea-based F-35s; therefore, shore-bases are red and ship-bases are green.

Defense**.** Based on the EABO Handbook, EABs will use passive defense techniques.[72] These defenses include camouflage and concealment, low-observable technology, and stealth technology as a form of defense. Passive defenses will provide a form of protection, but there is always a probability of detection, and if detected, passive defenses are worthless. In the EABO concept, the big assumption is that stealth and low observability will succeed. If a shore base is detected and does not have the rapid mobility of a ship, this can lead to catastrophic losses. In comparison, LHAs have active defenses, but according to the EABO Handbook, ships will be overwhelmed. They will run "Winchester"—meaning, to be completely out of weapons—while operating in an open expanse of water against an aggressive adversary with almost unlimited weapon supplies.[73]

LHAs are armed with the NATO Sea Sparrow Surface Missile System (NSSMS) and the Close-in Weapon System (CIWS),[74] which are short-range anti-aircraft and anti-missile systems designed for use as an active defense method. However, as the EABO Handbook states, the active defense systems will likely be overwhelmed and overmatched by mainland Chinese weapon capabilities, forcing ships to run Winchester. However, if ships are detected and targeted,[75] ships have the mobility to re-establish positions outside a WEZ. Remaining outside the WEZ will increase survivability, but will sacrifice the initiative and access to the area of operations. Even if they disperse, ships are easier to detect because of their large size, [76] but their mobility and kinetic defenses are favorable characteristics.[xi] This redundancy in defensive measures makes ships less risky compared to shore bases. Overall, since both ship- and shore-bases have defensive capabilities, they are both green.

[xi] Spaeder, Leo. "Get Small or Get Shot: Increasing Survivability for Maritime Operations." *Marine Corps Gazette 103:12* December 2019. This table is from a Marine Corps Gazette article on the vulnerability of naval ships targeted by anti-ship ballistic missiles. The larger the ship, the higher the probability of a hit. This questions whether the Lightning Carrier concept is feasible for EABO. By adding more F-35s to LHAs, the Marine Corps is concentrating more forces onto fewer ships, the opposite of dispersing forces to increase survivability. The table below illustrates the need for smaller ships, and potentially more ships, to allow for greater dispersion of forces.

Missile Salvo Size to Generate 95% Probability of Hit (PH)				
PH Methodology	CVN-78	LHA-6	LPD-17	San Giorgio
CEP=1/2 CVN-78 Length (169m)	5	8	12	24
CEP=1/2 CVN-78 Flight Deck Beam (39m)	5	26	26	55
CEP CVN-78 Area (92m)	5	14	18	36

Reprinted from Spaeder, Leo. "Get Small or Get Shot: Increasing Survivability for Maritime Operations." *Marine Corps Gazette 103:12* December 2019.

Diplomatic Access. Gaining access to a host nation is vital in the ability to launch aircraft or build and use existing airbases to support EABO. The United States has 2,000 aircraft, 200 ships and submarines, and 370,000 personnel deployed throughout the Indo-Pacific.[77] The United States Indo-Pacific Command (INDOPACOM) Commander, Admiral Davidson, is using military power against China by strengthening alliances and partnerships through joint and multilateral exercises to provide reassurance that the United States is committed to the region.[78] However, there is a competition of power in the Indo-Pacific between China and the United States. As the United States strengthens relations with allies and partners, China is doing the same thing.

China participates in regional institutions and cooperates in multilateral diplomacy to tackle regional problems.[79] Some of these institutions include the East Asia Summit (EAS), the Asian Regional Forum (ARF), and the Association of Southeast Asian Nations (ASEAN).[80] Additionally, China participates in multiple exercises alongside United States allies and partners.[81] The enmeshment of states, such as the ASEAN states, and the competition for power in the Indo-Pacific, illustrates the complex entanglement of interactions and affairs, which will determine whether the United States achieves diplomatic success or failure.[82] For instance, in most recent news, the Philippines have decided to end a significant security pact with the United States, which can have a substantial impact on the United States' ability to conduct military operations in the Philippines.[83] Some host nations may be reluctant to host United States EABs, fearing the Unites States presence will pull their country into a conflict that regional partners may assess the United States will not win. United States EABs can be viewed as "magnets" that draw Chinese strikes and destruction on regional partners, suggesting they may not permit EABs on their territory. Additionally, some believe that United States military presence in the region is elevating Chinese aggression and military presence in places like the South China Sea.

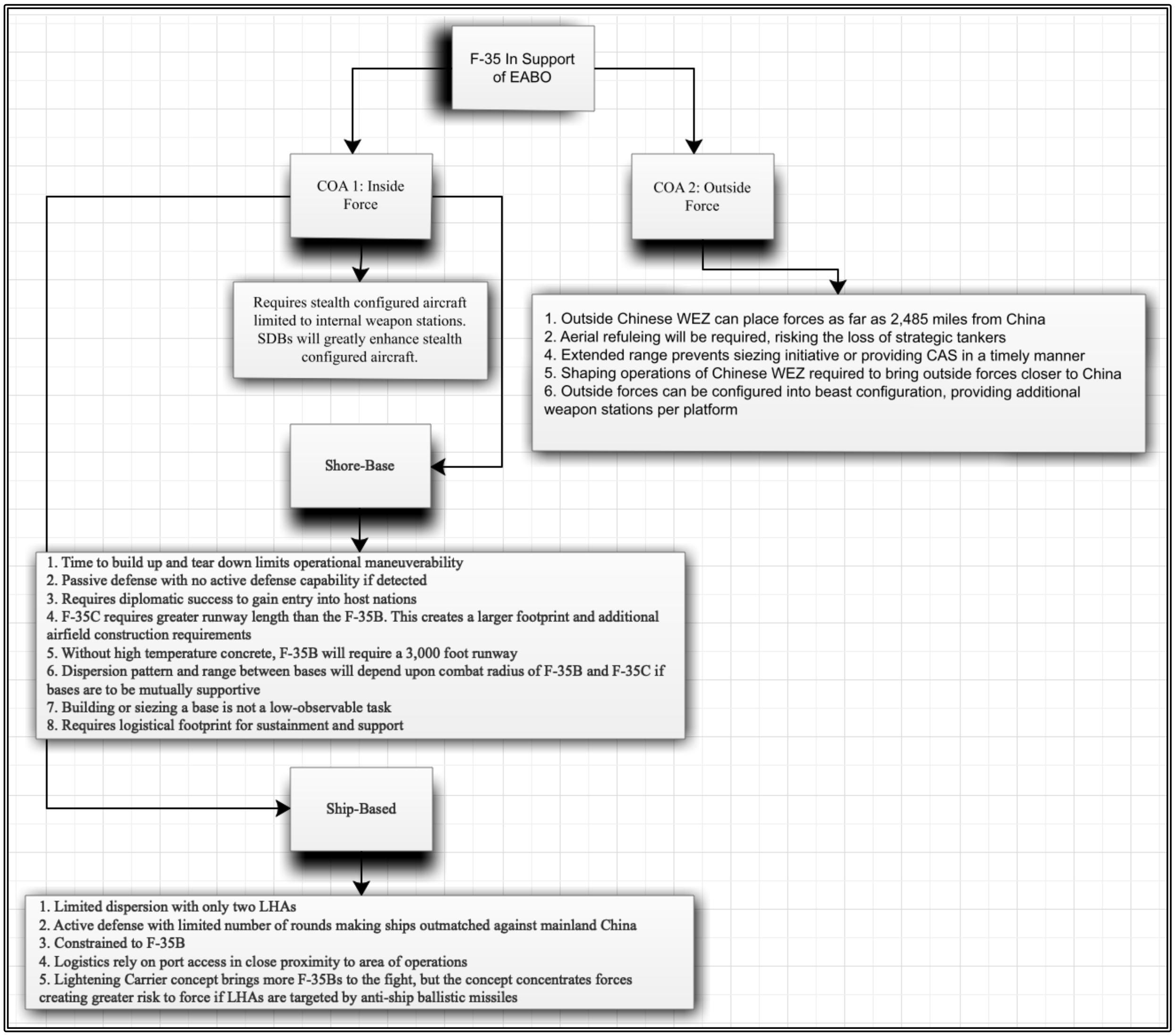
Logistics. Logistical assets need to build, support, and sustain shore bases. Basing F-35s ashore and using FARPs, EABs, or EAFs poses significant logistical problems. Ships need to re-supply too, but if EABs are expected to move and disperse, this requires a tremendous logistical effort. The following list illustrates the requirements and considerations necessary to open and safely operate an airfield; length and composition of the runway, sufficient parking ramps and taxiways, ground vehicles for personnel to support airfield operations, minimum construction and maintenance requirements, constructing hardening structures for passive defenses, sufficient airfield port capacity and capabilities for incoming personnel and logistics, aircraft crash fire rescue, air traffic control radars and communication equipment, certified navigation aids (NAVAID), arresting gear, airfield lighting and markings, and meteorological support equipment.[84] The construction of airfields with bulldozers, or seizing an existing airfield with kinetic fires, is not low-observable. Some of these support requirements are not essential, but the more support assets eliminated, the more rigid and predictable air operations will become. For example, without NAVAIDs, airfield operations will cease during times of inclement weather.

E. Decision and Risk Analysis

Decision and risk analysis is not intended to "solve" the problem.[85] Rather, the purpose of this analysis and the overall study is to provide insight to guide decision-makers toward the feasibility of F-35s supporting EABO from sea- or shore-bases, and to suggest any gaps that need to be identified as the EABO concept continues to develop.[86] This study demonstrates the complexity of the operational problem, and demonstrates that COA 1 or 2 alone cannot achieve all objectives; prosecute all targets in stealth mode with the maximum time on-station and combat radius, operating from ship- or shore-bases. Therefore, decision and risk analysis explores the trade-offs between each COA, and potentially proposes an alternative COA that mixes the best attributes of COA 1 and 2.[87]

All problems involve uncertainty, and uncertainty means risk.[88] In this complex operational problem, the study splits the overall problem into smaller problem sets to aid in the analysis, shown in figure 4.[89] Trade-offs can be easily analyzed with the uncertainties of each COA listed side by side.

Figure 4: COA 1 versus COA 2 Flow Chart.



A decision involving uncertainties and risk are based primarily on attitudes toward risk and uncertainty,[90] with multiple stakeholders to this operational problem likely having many different attitudes toward risk and uncertainty.[91] These stakeholders include: the Commandant of the Marine Corps; MEB or MEU commanders; ground Marines conducting EABO; F-35 pilots, or even Congress and the Executive Branch's "National Command Authority." The two attitudes that this study focuses on are optimism and pessimism. This study is not purporting that any one stakeholder, e.g., the Commandant, is an optimist or pessimist; rather the categories of optimism and pessimism are conceptual extremes that point to contrasting operational emphasis.

Optimism is the tendency of an individual to look on the more positive side or to expect the most desirable outcome of events.[92] From a decision analysis point of view, an optimist will choose the COA with the highest payoff, despite the unknown possibilities of getting its less desirable results.[93] This attitude is a high risk attitude, or a "go-for-broke" approach. The highest payoff comes from COA 1, shore-based F-35Cs operating as an inside force.

There are several uncertainties and aspects involved with this COA that lead to a high payoff. Shore-bases rely on low-observable stealth technology e.g., low electromagnetic spectrum signature, and camouflage and concealment. If EABs succeed in low-observable technologies, the concept is more likely to be successful. In addition, shore-bases cannot maneuver, but, keeping in mind that the F-35B poses greater challenges operating at small, austere bases, than the current AV-8B, if the Marine Corps develops a way to tear down and set up airbases quickly e.g., using AM-2 type matting with portable arresting gear, the concept is more likely to work. Shore-bases lack maneuverability, but their numbers offer greater dispersal options for aircraft. Even so, they are limited to the combat radius of an F-35C or an F-35B if EABs are to be mutually supportive. Next, the Marine Corps must develop a low-observable logistical technique to sustain shore-based operations to make the EABO concept more feasible. On the political side, if the United States government achieves diplomatic success to gain entry to key terrain, the concept has a greater chance for success. Last, in this study's CAS scenario, stealth configured aircraft will not provide sufficient firepower required to strike Chinese PLANMC targets without SDBs or the Lightening Carrier. If ground forces have supplemental firepower capability, such as long-range artillery, the concept is more likely to succeed. These are many uncertainties, but this is an optimistic high-risk approach to achieve the initiative while conducting combat operations inside an enemy WEZ.

Conversely, pessimism is the tendency to see only the shortcomings or to anticipate the most unfortunate outcome.[94] From a decision analysis point of view, a pessimist is tempted to pick the COA with the lowest payoff, despite the unknown possibilities of getting its greater desirable results.[95] This is a low risk, or a conservative approach. The lowest payoff is to choose COA 2, operate F-35s as an outside force.

F-35s not operating persistently inside an enemy WEZ significantly reduces the risk of being targeted. This approach is low risk, but it has a meager payoff. Marine Corps EABs could lose the initiative if relying on CAS supported from the outside force. This COA will place F-35s outside ballistic missile WEZs, but at a distance that can make CAS infeasible due to time and distance to transit to the operating area. This increased transit time will require aerial refueling, which will place strategic tankers inside enemy WEZs. These tankers are not stealthy and are sure to be targeted. The DF-26 can place F-35s up to 2,485 miles away from China or Chinese island chains if the DF-26 is employed there. To make this COA feasible, shaping and strategic bombing will be vital in shrinking or shaping the WEZ, which will bring outside forces closer to the fight. This approach is a pessimistic low-risk approach, but it provides a low pay-off. Unless shaping operations are successful, COA 2 is infeasible due to the size and likely resilience of China's WEZ.

<u>Decision Tree.</u> This decision problem is complex with multiple non-monetary costs and benefits. There is an entanglement of interrelated factors that are connected to the problem. This study created a decision tree to provide a structural illustration of the problem, making it easier to determine a course of action and its feasibility.[96] The decision trees below illustrate the variables

used in this study and the gaps associated with the feasibility of F-35 CAS during EABO. Figure 5 depicts a decision tree for COA 1, and figure 6 depicts a decision tree for COA 2.

Figure 5: Decision Tree for COA 1.

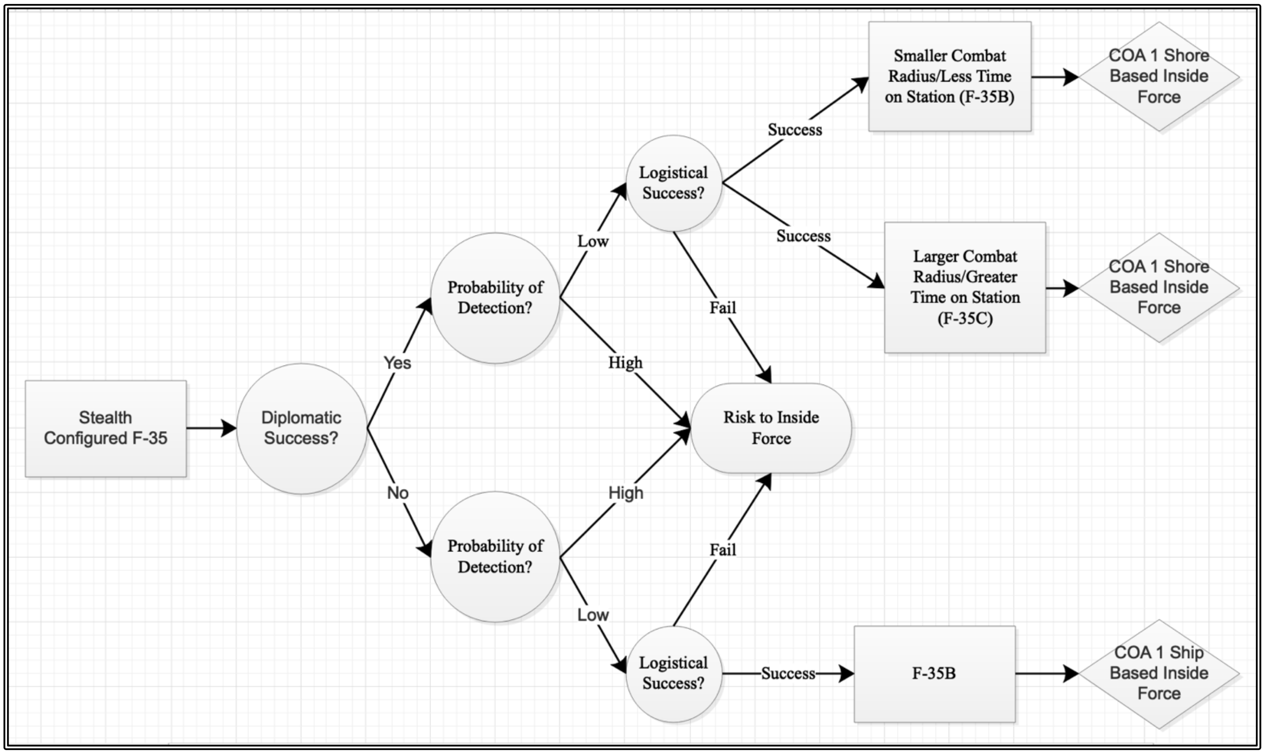
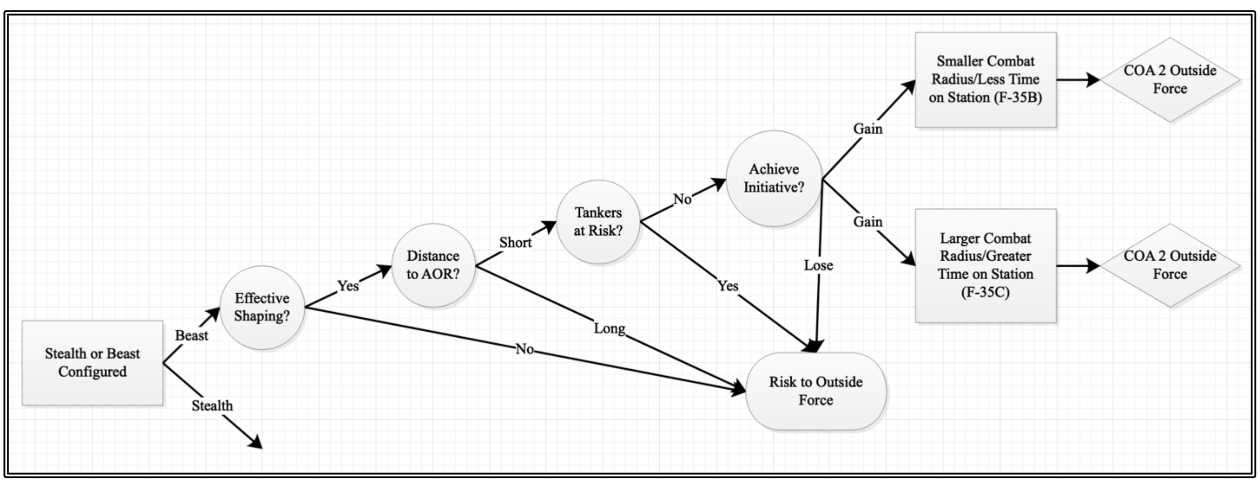
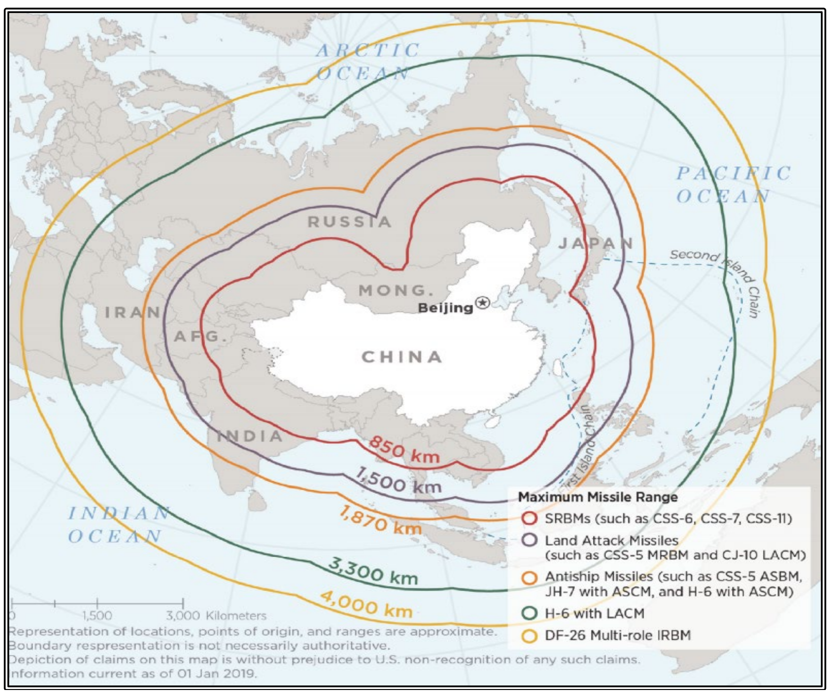


Figure 6: Decision Tree for COA 2.



Additional analysis reveals the various Chinese weapon systems that can strike EABs based on EAB location in the Pacific. Shore- and sea-bases will need to be within the combat radius capabilities of the aircraft to be within striking distance of China's mainland and eastern coastline. This strike distance assumes there are no stealth tankers in operational use. A lack of aerial re-fueling will put sea- and shore-based F-35s inside all WEZs minus China's short-range ballistic surface to surface missiles to include the CSS-6, CSS-7, and CSS-11.[97] Whether F-35s are ship- or shore-based, they will operate inside employment ranges for land-attack missiles, anti-ship missiles, the Xian H-6 equipped with land-attack cruise missiles, and the DF-26 intermediate-range ballistic missile, illustrated in figure 7.[98] In the notional scenario, long-range SAMs are the main threat to F-35s, but the distance of the remaining Chinese WEZ is worth illustrating when comparing the combat radius of an F-35 and the inability for F-35s to tank on stealth tankers.

Figure 7: This figure illustrates the Chinese WEZ.



Reprinted from U.S. Department of Defense. *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2019.* Washington, DC, Office of the Secretary of Defense, 2019. [99]

IV. Conclusion

A. Findings

Configuration Value Findings. Using the MEU concept, the optimization models indicate the need for both stealth and beast configured aircraft. The higher the readiness levels, the more stealth configured aircraft. This information explains the need for F-35s to operate as both an inside force and outside force, but can fluctuate based on readiness levels and expected targets. With the number of F-35s available in the MEU concept, it is infeasible for F-35s to operate exclusively as stealth configured aircraft. The WEZ threat makes the F-35 beast configuration an infeasible option.

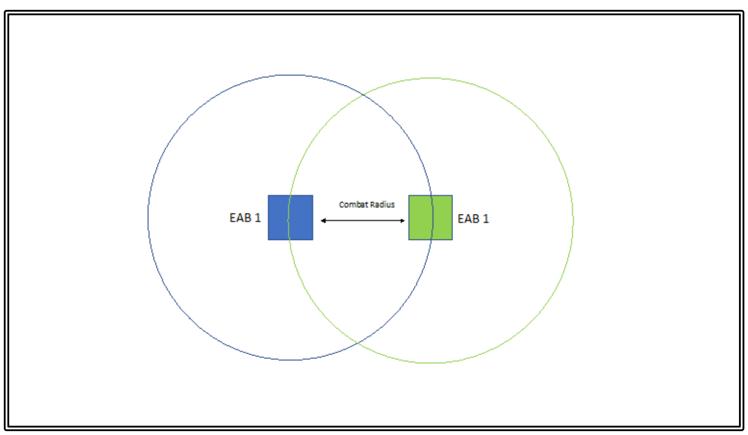
Using the Lightening Carrier concept provides for additional air assets. These additional air assets means that as low as 70% readiness, all aircraft can be stealth configured and strike all required CAS targets. However, at readiness levels below 70%, optimization is required, meaning adding beast-configured F-35s to the CAS mission.

Incorporating SDBs into the MEU and Lightening Carrier concepts dramatically enhances the ability for F-35s to strike all required targets while remaining in stealth configuration. For the MEU concept, readiness levels above 40% can strike all targets with all aircraft configured in the stealth configuration. In the Lightening Carrier concept, anything higher than 20% readiness will achieve the same effects. More notably, using the Lightning Carrier concept with SDBs, readiness levels are not as important compared to the MEU concept without SDBs. However, the study finds that the prevailing trend among all optimization results is that the higher the readiness levels, the lower the requirement for beast configured aircraft.

Aircraft Model Findings. Aircraft fuel load is directly related to combat radius and on-station times, with the combat radius of an F-35B being far less than the F-35C.[100] The same is true for on-station times. To maximize combat radius and on-station time, the Marine Corps should prioritize F-35Cs over F-35Bs. However, F-35Cs require greater runway length than F-35Bs.

The study's findings, however, is that fuel load will have a direct impact on how dispersed shore-based F-35s and EABs can be in order for them to disperse while maintaining mutual support. Further analysis also reveals type of dispersed pattern illustrated in figures 8 through 10. These figures illustrate the dispersion limitations of shore-bases, not just due to combat radius, but also due to the requirement for bases to be mutually supportive. These limitations can lead to predictability and EAB detection by China.[xii] Additionally, figure 11 illustrates the vastness of the Pacific Ocean with Chinese WEZs. With EABs located in the Philippines, Ishigaki Island, Japan, and the Mariana Islands, these EABs are dispersed by thousands of miles, and they are exposed to all Chinese WEZs. These shore-base locations will allow the F-35 to be within striking distance of the Spratley, Senkaku, and Paracel Islands.

Figure 8: This figure illustrates the dispersion of two shore-bases.



[xii] The Marine Corps' F-35B V/STOL-capable aircraft operating from small LHAs or from small airfields ashore is a unique capability among the military services. A Marine Corps employing more F-35Cs could risk looking duplicative of Navy and Air Force F-35s, although the Marine's unique and dedicated CAS capabilities and focus remains a powerful justification for Marine aviation.

Figure 9: This figure illustrates the dispersion limitations of three shore-bases.

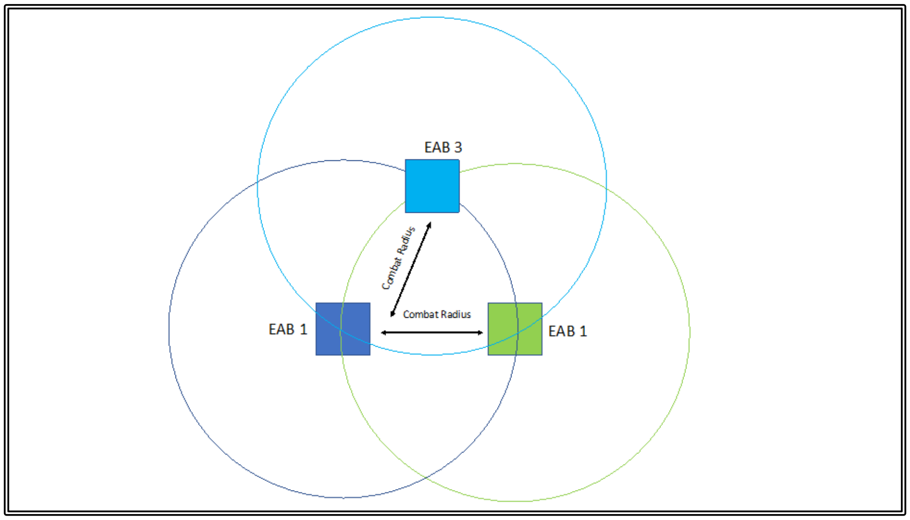


Figure 10: This figure illustrates the dispersion limitation of three shore-bases.

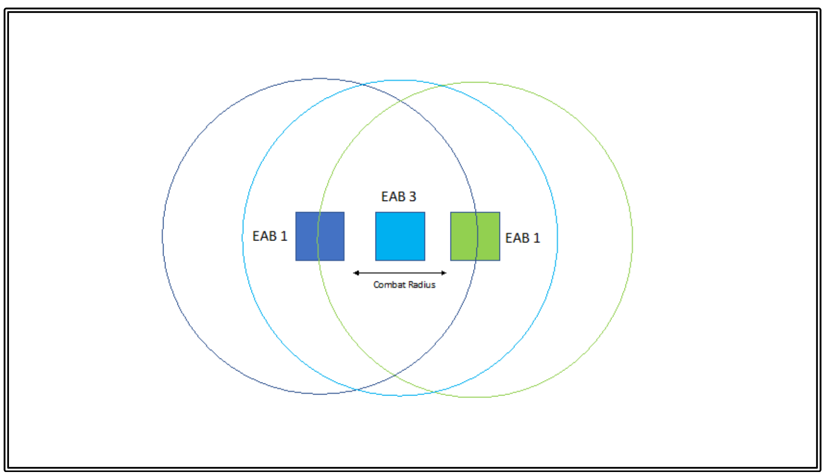
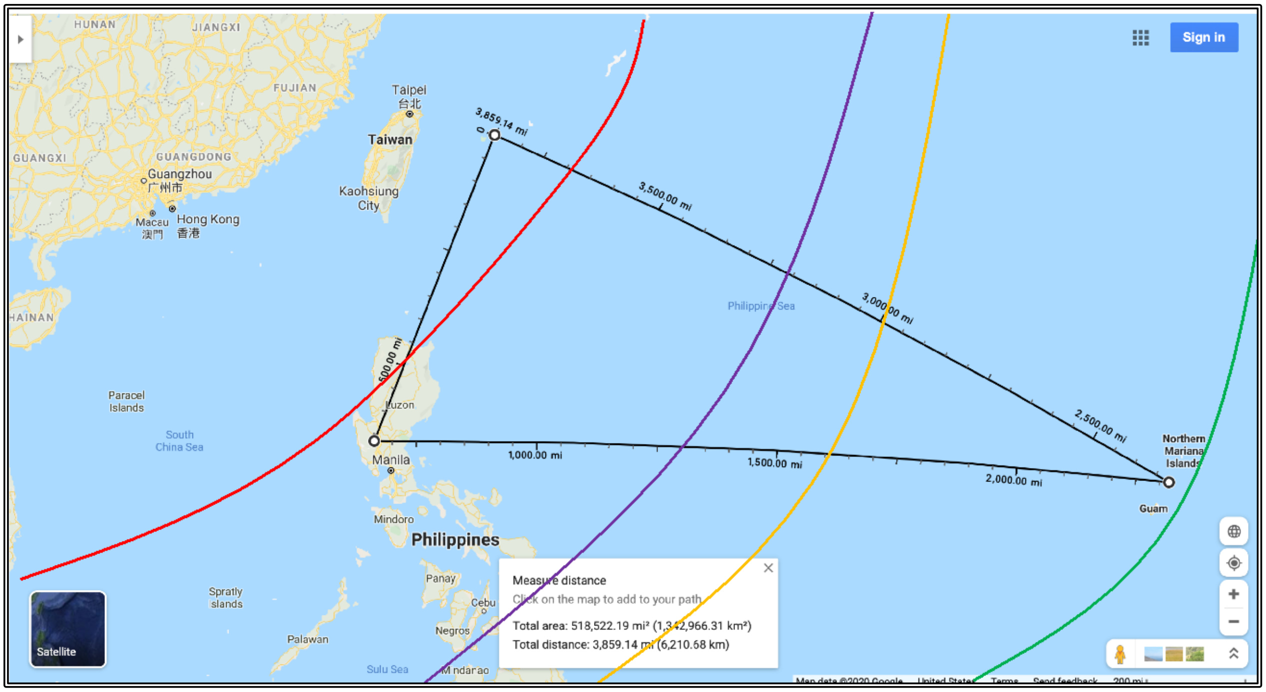


Figure 11: Three Shore-Bases.



Synthesized from U.S. Department of Defense. *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2019.* Washington, DC, Office of the Secretary of Defense, 2019. [101]

Airbase Risk Findings. Shore- versus sea-based analysis is challenging. Shore-bases must rely on diplomatic success, making this option less desirable. Additionally, shore-bases are capable of greater dispersion compared to two LHAs, but they are limited based on the combat radius of F-35s if they are to be mutually supportive of other EABs. Shore-bases cannot maneuverer like a ship, and ships have kinetic defenses while shore-bases rely upon passive defenses, as stated in the EABO Handbook. Chinese strikes on an LHA could result in the catastrophic loss of aircraft—sinking—of the ship or put it out of commission for combat.

Conversely, strikes against an airfield ashore can cause significant damage but not "sink" the airfield. If shore-bases are targeted, there is a potential for repairs of runways, re-supply of fuel and munitions, or to replace destroyed infrastructure. Last, shore-bases will require construction, for both the F-35C and F-35B, and building or seizing a shore-base is vulnerable to detection. Ultimately, ship- and shore-bases provide ideal benefits and gaps that the other can or cannot provide.

B. Recommendations

The inherent stealth characteristics and other capabilities of the F-35 make it a critical component to EABO, but its short range and likely vulnerability of any of its basing modes—ship- or land-based—suggest a mixed inside/outside concept of employment is required to manage risk against a formidable foe's lethal WEZ. After examining the trade-offs between COA 1 and COA 2, and the pessimistic and the optimistic attitudes to the problem, this study recommends combining the trade-offs of both COAs. Combining COAs will essentially create a new COA that has a mix of inside and outside forces that are both based ashore and on ships.

If SDBs are not available for the MEU concept, COA 1's inability to provide sufficient firepower can be augmented by COA 2's beast configured forces, as long as the WEZ has been shaped appropriately. If the WEZ has not been shaped and SDBs are not suitable or available, this study recommends the use of the Lightening Carrier concept. The Lightening Carrier provides more firepower; however, the Marine Corps will concentrate more F-35Bs on fewer LHAs. This study recommends dispersing some of these inside forces to shore airbases due to the possible catastrophic loss of Lightening Carriers operating inside a known anti-ship missile WEZ. Therefore, this study tends to support recent Marine Corps statements calling for the need to shift from a few, large "exquisite" ships to a fleet including greater numbers of smaller ships. More ships and smaller size allows for lower probability of detection, increases survivability, and decreases the risk of catastrophic aircraft loses. For any basing option, Marine Corps procurement of SDBs would allow fewer aircraft to carry more weapons while maintaining stealth characteristics.

Mixing both ship- and shore-bases will utilize the strengths that both options bring to the fight, such as maneuverability, dispersion, defenses, diplomacy, and logistics. Shore-bases cannot maneuver, but ships can. Aircraft on ships cannot disperse, but they can disperse among shore-bases, and filling in the gaps, allowing these bases to disperse with greater distances. Ships also have an active defense that can augment shore-based passive defenses if detected. Airfield construction requirements can decrease if augmented with ship-bases. If diplomacy fails, ships can fill in the gaps. Additionally, F-35Cs provide a significant fuel advantage over the F-35B; however, the F-35C cannot operate from a LHA and, ashore, requires additional runway construction compared to the F-35B requirements.

The uncertainties remain, and therefore, the risk remains; however, combining the strengths of both COAs and ship- and shore-based F-35s, can help mitigate the weaknesses that each COA has. It is not feasible to make F-35s solely an outside force or an inside force. The F-35 must play the role of both types of forces. Additionally, it is infeasible to have only ship-based F-35s or shore-based F-35s. There must be a mix of both, and future developments in ship size, low-observable logistics and construction, diplomatic statecraft, and new weapons systems will make shore- and ship-based F-35s operating as an inside force more feasible and supportable to the EABO concept.

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