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14. ABSTRACT

The emergence and proliferation of anti-access / area-denial (A2/AD) capabilities in the INDOPACOM AOR led some in the US naval force to question the effectiveness of the force's current capabilities and concepts to counter the threat in this region. The US Navy and Marine Corps recently developed several nested doctrines to mitigate the A2/AD threat, namely distributed maritime operations (DMO), littoral operations in a contested environment (LOCE), and expeditionary advanced base operations (EABO). EABO maintains that an inside force, composed of small units armed with sensors and a strike capability, will enable a friendly outside force's maneuverability and enhance the naval fleet's overall sea denial capability. By necessity, the inside force must be small, distributed, capable, mobile, resilient, and persistent. The forces currently positioned in the pacific region are capable, but they are concentrated on large bases and platforms, reliant on efficient but static infrastructure, and easily targetable by current A2/AD threats. EABO aims to break away from these large platforms, bases, and stations. Although countries in the INDOPACOM region do not hold a monopoly on A2/AD capabilities, this paper will focus on that specific region to narrow the discussion to capabilities relevant to EABO in a sub-tropic/tropical climate. This paper explores the US Marine Corps' current utilities capabilities, discusses alternatives, and makes suggestions on future procurement of capabilities to offset the risk associated with long logistics chains. This paper will also explore options already proposed by scientists and other experts in the field and discuss whether the answer lies in capabilities such as unmanned stealth delivery vehicles or if production at the site of use is feasible and preferred.

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United States Marine Corps
Command and Staff College
Marine Corps University
2076 South Street
Marine Corps Combat Development Command
Quantico, Virginia 22134-5068

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TITLE:

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AUTHOR:

Maj Stafford A. Buchanan (USMC)

AY 2020-21

Mentor and Oral Defense Committee Member: Matthew R. Slater, PhD

Approved: *Matthew R. Slater*

Date: 13 APR 21

Oral Defense Committee Member: LTCOL CRAIG A. GRANT, DM

Approved: *C. A. Grant*

Date: 13 APR 2021

*United States Marine Corps
Command and Staff College
Marine Corps University
2076 South Street
Marine Corps Combat Development Command
Quantico, Virginia 22134-5068*

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Table of Contents

DISCLAIMER	i
LIST OF ILLUSTRATIONS AND TABLES	ii
EXECUTIVE SUMMARY	iii
PREFACE	iv
ACKNOWLEDGMENTS	v
INTRODUCTION	1
THE CHANGING BATTLEFIELD	3
CURRENT UTILITIES CAPABILITIES	8
EMERGING CONCEPTS AND CAPABILITIES: CONNECTORS.....	19
DIFFERENT VERSUS BETTER.....	20
NEXT STEPS	22
CONCLUSION.....	30
ENDNOTES	31
BIBLIOGRAPHY	35

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LIST OF ILLUSTRATIONS AND TABLES

Illustrations

	Page
Figure 1. China's A2/AD capability in the South and East China Sea	4
Figure 2. Detailed summary of equipment used for NSWC and E2O study	9
Figure 3. Electronic emission signature of a battalion-sized element	11
Figure 4. Ground renewable expeditionary energy network system (GREENS)	13
Figure 5. Solar portable alternative communication energy system (SPACES)	13
Figure 6. Tactical water purification system (TWPS)	16
Figure 7. Lightweight water purification system (LWPS)	16
Figure 8. Individual water purification system (IWPS) Block II	17
Figure 9. Platoon water purification system (PWPS)	18
Figure 10. Small unit water purification system (SUWPS)	18
Figure 11. Squad water purification system (SWPS)	18
Figure 12. Ultra-lightweight expeditionary power system (U-LEPS)	22
Figure 13. Required solar array to produce 10kW	24
Figure 14. Average wind conditions in the Indian and Pacific oceans	25
Figure 15. Average monthly rainfall in the Pacific Ocean and China Seas	26

Tables

	Page
Table 1: Family of Diesel Generators Currently in the Marine Corps Inventory	10
Table 2: Water Requirements for Tropical Zones	15
Table 3: Comparison of Water Systems	28

EXECUTIVE SUMMARY

Title: Self-Sustaining Warriors in EABO

Author: Maj Stafford A. Buchanan, United States Marine Corps

Thesis: To increase the US naval force's capacity to conduct Expeditionary Advance Base Operations in the INDOPACOM area of responsibility, the U.S. Marine Corps must reduce its reliance on long logistics chains for sustainment. Specifically, the U.S. Marine Corps must enable Marines at the lowest levels to self-sustain in power and water production by pursuing promising emerging technologies that are scalable and rely on renewable energy.

Discussion: The emergence and proliferation of anti-access / area-denial (A2/AD) capabilities in the INDOPACOM AOR led some in the US naval force to question the effectiveness of the force's current capabilities and concepts to counter the threat in this region. The US Navy and Marine Corps recently developed several nested doctrines to mitigate the A2/AD threat, namely distributed maritime operations (DMO), littoral operations in a contested environment (LOCE), and expeditionary advanced base operations (EABO). EABO maintains that an *inside force*, composed of small units armed with sensors and a strike capability, will enable a friendly *outside force's* maneuverability and enhance the naval fleet's overall sea denial capability. By necessity, the *inside force* must be small, distributed, capable, mobile, resilient, and persistent. The forces currently positioned in the pacific region are capable, but they are concentrated on large bases and platforms, reliant on efficient but static infrastructure, and easily targetable by current A2/AD threats. EABO aims to break away from these large platforms, bases, and stations. Although countries in the INDOPACOM region do not hold a monopoly on A2/AD capabilities, this paper will focus on that specific region to narrow the discussion to capabilities relevant to EABO in a sub-tropic/tropical climate. This paper explores the US Marine Corps' current utilities capabilities, discusses alternatives, and makes suggestions to pre-stage "dual-purpose" supplies and capabilities forward pre-conflict; this paper focuses on future procurement of capabilities to offset the risk associated with long logistics chains. This paper will also explore options already proposed by scientists and other experts in the field and discuss whether the answer lies in capabilities such as unmanned stealth delivery vehicles or if production at the site of use is feasible and preferred.

Conclusion: Success on the future battlefield will rely on winning the *hider/finder* competition. By developing self-sustainment technologies in power and water production and fielding them at the individual, squad, platoon, and company level, future US Marines engaging in EABO will be harder to find and target by enemy kill-chains. By reducing the need for long logistic resupply missions, utilities support to EABO will provide greater flexibility to the warfighter.

PREFACE

From June 2017 to July 2019, the Marine Corps gave me the great privilege of serving as the Utilities Instruction Company Commander for Marine Corps Engineer School in Camp Lejeune, North Carolina. While there, I worked alongside many forward-thinking and highly capable experts in the utilities community. Chief Warrant Officer 5 Micah S. Butler and Master Gunnery Sergeant Richard J. VanEyck, in particular, are two of the finest utilities Marines whom I have ever met. They both took the time to mentor me in a way few had in the past. Their passion for making better Marines and making better utilities Marines, fortunately for me, extended to making me a better Combat Engineer Officer as well. I am grateful for their mentorship. Their enthusiasm for teaching and developing more capable utilities Marines is genuinely inspirational.

I undertook this project because A2/AD has made sustaining long logistics chains extremely hazardous. I wanted to explore the future of utilities support to forces conducting EABO and provide some alternatives to the current plan. The goal of this Master's dissertation is to extend the discussion into areas of utilities and EABO not yet fully explored and propose possible next steps. My hope is that the reader comes away with a better understanding of the problem and that through this dissertation, readers may recommend more capable tools or develop better doctrine for providing utilities support to the warfighter conducting EABO.

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I would like to personally thank both Dr. Matthew R. Slater and LtCol Craig A. Grant for their mentorship and guidance throughout my time at Marine Corps Command and Staff College. They were both tremendously helpful and supportive as I progressed through this Master's program.

To my family, thank you for your support these past ten months. To my wife Kaye, thank you for your love, your understanding, and your patience during this entire process. I could not complete this work without you. You are truly an amazing wife and mother. Mahal kita! Walang iba!

INTRODUCTION

In his opus *On War*, Carl von Clausewitz wrote that the nature of war remains the same, but it is the ever-changing character of war that determines how one fights it.¹ Simply put, war is, and always will be, a struggle of wills. Due to the improvement in technology, conflicts will continue to unfold in novel and unpredictable ways. Militaries try to anticipate the changing character of war, identify the emerging technologies and concepts that will define the future battlespace, and evolve to maintain the competitive advantage.

In recent years the increased proliferation of effective anti-access / area-denial (A2/AD) technologies caused an identity crisis within the United States (US) Navy and US Marine Corps. Senior leaders began to understand that long-held assumptions about the US military's ability to readily dominate and control sea and airspace anywhere in the world were no longer absolute. Military leaders realized that the US could no longer expect to gain sea, land, and air dominance whenever and wherever it wanted using its current capabilities and doctrine. These A2/AD systems, composed of long-range land-based missiles and capable sensors/radars, require increased standoff for naval forces and make conducting forcible entry operations against such threats extremely hazardous endeavors.

At the beginning of the 21st century, Russia, China, and Iran began developing and refining their A2/AD capabilities, while the US, distracted by two land wars in the Middle East, focused on counterinsurgency and counterterrorism. After nine years at war, the US began to understand that with China's rise, a new era of great power competition was on the horizon. Since the *2010 Quadrennial Defense Review* and President Obama's 2011 "Pivot to the Pacific," US policymakers identified that developing a strategy to counter the A2/AD threat was a national priority.² In response, the US Navy and Marine Corps developed several nested military

concepts. These concepts are distributed maritime operations (DMO), littoral operations in a contested environment (LOCE), and expeditionary advanced base operations (EABO). These concepts required the Marine Corps to create an *inside force* that would operate in small teams in austere environments distributed throughout an enemy's weapons engagement zone (WEZ). Hidden from enemy sensors but able to sense and target enemy platforms, the *inside force* aims to provide the conventional US naval fleet, or *outside force*, greater sea control and maneuver space and deny the adversary the same.

A problem emerges when one thinks about the logistical sustainment of these small teams operating deep within the enemy's WEZ. In comments made to the 2018 USMC Hybrid Logistics Symposium, Lieutenant General Michael G. Dana said, "70 to 80 percent of all military logistics is the transportation of water and fuel."³ Also, recent academic studies indicate that about one service member dies in every twenty convoys.⁴ If this holds true, then the naval force's regular resupply of these small teams deep within the enemy WEZ will increasingly endanger the mission as time goes on. The US Marine Corps' success in future EABOs inside the enemy WEZ will hinge on the force reducing its reliance on long logistics chains for sustainment. The US cannot expect to win the next war using logistics, technology, and doctrine developed to fight the last war. By analyzing the current threat environment and taking stock of the limitations of the current Marine Corps' water and power capabilities, it becomes increasingly evident that change is required. To increase the US naval force's capacity to conduct Expeditionary Advance Base Operations in the INDOPACOM area of responsibility, the U.S. Marine Corps must reduce its reliance on long logistics chains for sustainment. Specifically, the U.S. Marine Corps must enable Marines at the lowest levels to self-sustain in power and water production by pursuing promising emerging technologies that are scalable and rely on renewable energy.

THE CHANGING BATTLEFIELD

As the battlefield changes, so should the military's approach to it. The authors of the DMO, LOCE, and EABO concepts recognized the paradigm shift in naval warfare that the A2/AD threat presented, and they also recognized that it necessitated an equally drastic shift in doctrine and capabilities to meet the threat. These concepts also serve as justification for funding from the US Congress and prioritization by senior military leaders and service secretaries. Fortunately, the concepts developed by senior leaders of our nation's military apparatus gained traction during the first year of General Berger's term as Commandant of the US Marine Corps. As observed in the *38th Commandant's Planning Guidance* (38th CPG) published in 2019 and the resulting *Force Design 2030* published in 2020, the Marine Corps took significant steps toward reshaping itself to better counter the A2/AD threat.⁵ The DMO, LOCE, and EABO concepts led to a vigorous scholarly debate about the current force posture, capabilities, and readiness to fight peer or near-peer adversaries.

The authors of DMO, LOCE, EABO, and the 38th CPG, focused on building a naval force that could operate within a peer or near-peer adversary's WEZ and deny pockets of sea and air space to that adversary. The purpose was to enable the US to exploit these gaps for military advantage using the conventional fleet.⁶ Essentially the inside force denies battlespace to enemy ships and sensors and enables the maneuverability and force protection of the large naval ships in the outside force.⁷ Unfortunately, a majority of the research surrounding these concepts is theoretical and relatively nascent. Despite their newness, these concepts all consistently stress the importance of mobility, survivability, persistence, and the need to develop innovative technologies.⁸ These qualities enable a distributed inside force to persist in an austere environment and gain maneuver space for an outside force. Most researchers focused their

research on the technology required to sense and strike targets from those austere locations; they short shrift the logistics innovations required to make concepts such as EABO successful.

Experts agree that the US naval force must increase its capacity to execute EABO by decreasing the inside forces' reliance on long logistics chains for sustainment; however, those few experts who propose innovations in logistics disagree on how to accomplish this.⁹ Where some suggest better air, surface, and subsurface delivery vehicles, others suggest means to reduce the overreliance on long logistics chains for support.

To scope the problem at hand, this paper will only address expeditionary advanced bases (EAB) within the climate type unique to much of the South and East China Seas. The authors of DMO, LOCE, and EABO agreed that the current US posture in the Pacific theater is vulnerable to an A2/AD threat.¹⁰ The US's adversaries accurately analyzed the Department of Defense's

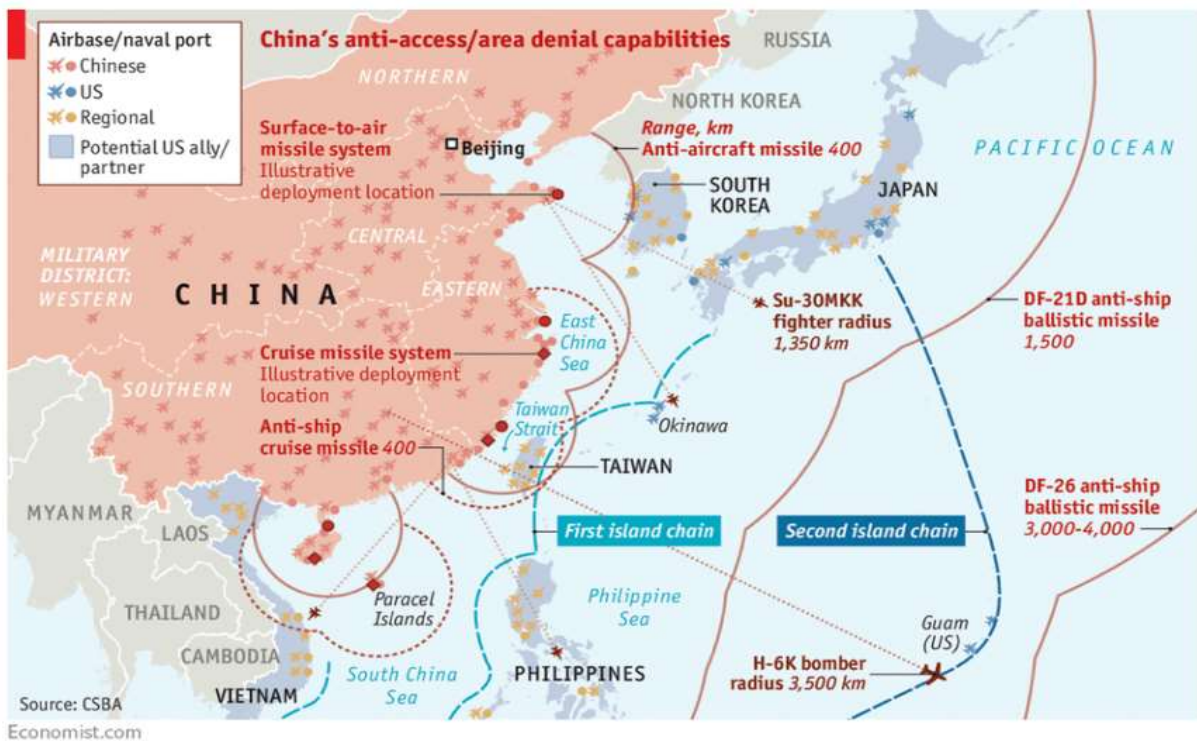


Figure 1. China's A2/AD capability in the South and East China Sea

Source: "The Odds on a Conflict between the Great Powers," *The Economist*, January 25, 2018, <https://www.economist.com/special-report/2018/01/25/the-odds-on-a-conflict-between-the-great-powers>.

capabilities to project power abroad.¹¹ Those same adversaries identified the critical capability as the US's forward bases and stations and developed a defense in depth of integrated weapons and sensors to counter it.¹² As a result, many experts believe that due to the A2/AD threat, the US's large overseas bases and stations are no longer a source of power but vulnerabilities to the joint force.¹³

According to Figure 1, a map taken from the 25 January 2018 edition of *The Economist*, US forces in Japan, South Korea, Okinawa, Philippines, and Guam are already within the Chinese WEZ. If the US and China were to go to war, the disparate Chinese weapons systems would be able to target ships and stations already within range and immediately deny US military access to the South and East China Seas.¹⁴ The much-vaunted US Carrier Strike Group (CSG) and Marine Expeditionary Units (MEU) / Amphibious Ready Groups (ARG) are unable to conduct forcible entry operations (FEO) within the region's littorals without suffering catastrophic losses to personnel and ships. Arthur Corbett, the author of the EABO concept, advised us that military leaders must rectify this vulnerability pre-crisis by pre-staging equipment and supplies forward and by "creating more persistently forward postured – but continuously mobile – forces tasked organized to conduct EABO."¹⁵

Some experts suggest that to reduce risk to US forces, diplomats should work with allies and partners in the region to host more mobile and continuously rotated forces to fulfill US security obligations.¹⁶ Other experts counter that vacating large fixed bases in the region for a more dispersed and constantly mobile posture will increase the strain on the logistics required to sustain persistence.¹⁷ Another risk is that China may perceive this new force posture as escalatory. One option to mitigate the logistics strain is to increase contracted logistic support in host countries. However, relying on partners in the region for sustainment will come with

hazards, such as increasing the likelihood of collateral damage and civilian deaths during an enemy attack. Overdependence on partners could also cause strained diplomatic relations between countries if the host nation's support for US troops becomes unreliable. Another option to mitigate the logistics strain and to avoid the perception of escalating tensions would be for the US State Department to negotiate the stockpiling of "dual-purpose" supplies in forward locations. Items such as tents, food, vehicles, heavy construction equipment, water purification capabilities, and other supplies used for humanitarian missions in the region are non-threatening. These items also have a military value during any conflict. The underlying problem is that the naval force must choose between the logistic efficiencies that easily targetable fixed infrastructure provides and the increased logistics requirements of more survivable mobile forces.

The authors of the EABO and LOCE concepts informed us that persistence requires the forces' survivability which hinges on winning the "hider/finder" competition.¹⁸ They also argued that US forces need to become more distributed throughout the theater and reduce reliance on easily targetable infrastructure and sustainment platforms. If we restructure even a portion of the US forces stationed abroad, provide them with new capabilities, and employ a more dispersed posture, the US could get ahead of the A2/AD threat and mitigate the adversary's pre-crisis advantage.¹⁹ Also, most experts agree that physical camouflage is no longer an adequate form of concealment on its own.²⁰ Foreign militaries now have access to sensors that can geolocate military forces based on their electromagnetic (EM) footprint; this ability translates to targeting data for kinetic strikes, jamming, and cyber operations.²¹

As camouflage was necessary for concealment on past battlefields, managing a unit's EM footprint, or saturating the environment with EM decoys, are the two most effective ways to hide

on today's battlefield from a peer adversary.²² Future Marine Corps units conducting EABO missions within an enemy's WEZ will need to conceal their locations from enemy sensors using one of these two techniques. Currently, the US military at large does not efficiently use either one.²³ Based on the nature of the Pacific Ocean's geography, with its vast expanses of open water, saturating the EM spectrum would prove difficult. The EABO mission requires small, lightly equipped, and highly mobile units. Adding EM decoys to their equipment list would increase their load. EABO units would also find it challenging to deploy EM decoys far from their mobile land bases. If commanders use air assets to deploy the EM decoys for EABO units, the decoys would most likely need to be disposable because of the highly mobile nature of the EABO mission. Also, the distances between islands and landmasses in the Pacific Ocean are so great that EM decoys deployed on the ocean might not enable a unit on a small landmass or island to hide its signature amongst the noise. Enemies might easily guess the land-based unit is on the island surrounded by EM noise. In the end, EM saturation might prove too challenging to accomplish in the Pacific when conducting EABO, and it may even prove counterproductive. For these reasons, EM saturation may not be as effective as signature management.

Accomplishing EM signature management will require research, funding, and commitment from the Department of Defense (DOD) because manufacturers of the current capabilities and equipment sets did not always consider EM emissions when designing them.²⁴ The DOD should provide units conducting EABO with new capabilities that maximize utility and produce zero or very low EM signature.²⁵ Large ships and permanent infrastructure are easy targets because they produce large static or slow-moving EM signatures. For this reason, Corbett recommends a more distributed posture. The US has an exquisite Navy, but due to the limited number of ships and each ship's importance to the overall mission, it is a brittle force.²⁶ Experts

agree that an exquisite but brittle force will not be combat-effective on tomorrow's battlefield.²⁷ For this reason, the authors of DMO, LOCE, and EABO recommend an *inside force*, which is difficult to find yet highly capable, to protect and facilitate the maneuver of an *outside force* – composed of vulnerable but highly capable legacy systems and platforms.

CURRENT UTILITIES CAPABILITIES

The authors of DMO, LOCE, and EABO suggest that a capable *inside force*, furnished with equipment that produces low or zero EM emissions, has a better chance of staying hidden within an enemy WEZ and facilitating the maneuver of the conventional naval forces.²⁸ The Marine Corps' current electricity production and distribution equipment does not meet this "low or zero" EM emission requirement. The majority of the Marine Corps' electricity production capability is reliant on diesel-powered generators, and those that are not do not produce enough electricity to meet the needs of a remote command post as currently designed.²⁹

The US military is the best-equipped military in the world, and one could argue that it can overcome the A2/AD dilemma with the current weapons, doctrine, and logistics capabilities; however, this appears optimistic given the emerging capabilities peer and near-peer adversaries now wield. The authors of DMO, LOCE, and EABO rightly concluded that the Marine Corps' doctrine and capabilities currently employed may be inadequate in any future fight in the Pacific.³⁰ Recommended changes to doctrine remain outside of this paper's scope, but the force's reliance on fossil fuels will be a vulnerability in any future fight. The US military's reliance on diesel-electric generators dates back to the anti-aircraft searchlights of World War I.³¹ Even though the current inventory of diesel generators increased in reliability, output, and complexity, the power production concept remains the same.³² The Marine Corps has not conducted a significant overhaul of its diesel generators, exquisitely designed for warfare in Iraq and

Afghanistan, in the last three decades.³³ The changing character of warfare will require this capability to adapt to the new threats, but before designing a new system, it is vital to take inventory of the requirements such a system would need to support.

The Naval Surface Warfare Center (NSWC) and the USMC Expeditionary Energy Office (E2O) conducted a study in October 2011 to profile the electrical energy usage of an average company-sized combat operations center (COC) in Afghanistan.³⁴ Although the Afghanistan climate is different from that confronting an amphibious force in the South and East China Seas, much of the study is relevant to the current topic. The NSWC/E2O study focused on an average

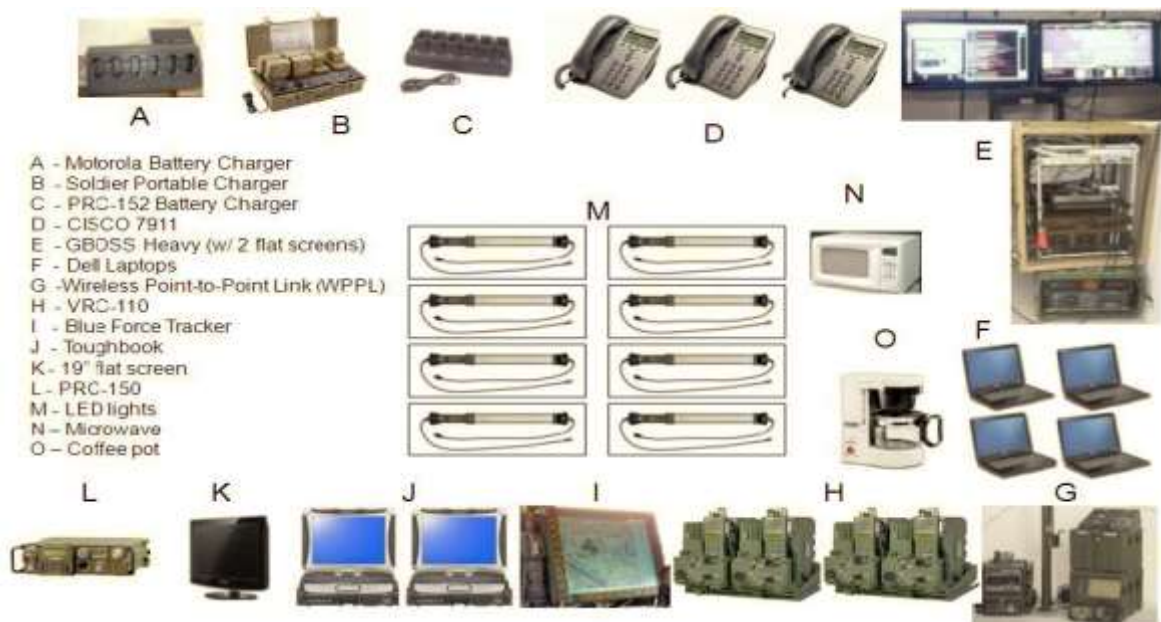


Figure 2. Detailed summary of equipment used for NSWC and E2O study

Source: Newell, Major B H. "USMC Expeditionary Energy Office Report on Expeditionary Energy Data Collection within Regional Command Southwest, Afghanistan," n.d., 43.

patrol base supporting 45 Marines, in which the COC electrical energy demand per day averaged 30.24 kilowatt-hours (kWh).³⁵ This average represents the sum of all energy used when operating all lighting, one microwave, one coffee pot, and all computers and communications equipment over 24 hours (Figure 2). The peak power requirement, which is the sum of the load at any given moment, never surpassed 4.7kW.

The study then added the ground-based operational surveillance system (G-BOSS) and the environmental control units (ECU), air conditioner/heaters necessary for maintaining climate control for the computers. These requirements increased the power consumption to a total 207kWh and peaked at 30.5kW.³⁶ The ECUs were the most significant power consumers. The study identified the ECUs used by their Table of Authorized Material Control Numbers (TAMCN) as the B0008 and the B0014. The B0008 produces 60,000 British Thermal Units (BTU) per hour and draws 11kW to produce heat and 8.5kW to produce cold air. The B0014 is a smaller variant that produces 36,000 BTU/hr and draws 9.6kW to produce heat and 4.5kW to cool. Both models require a three-phase power source, which the USMC diesel generators

Table 1: Family of Diesel Generators Currently in the Marine Corps inventory

Nomenclature	Kilowatt (kW) produced	Fuel Capacity (in gallons)	Avg. Fuel Consumption (GPH)	Wet Weight in lbs. (Dry + Coolant & POLs)
1MPG	1	.66	.08	31
MEP-501A	2	1.6	.33	138
MEP-531A	2	1.6	.3	152
MEP-831A	3	4	.5	334
MEP-1030	5	3.8	.38 @ 75% load .43 @ 100% load	810
MEP-1040	10	6.3	.61 @ 75% load .75 @ 100% load	1,060
MEP-813A Tactical Quiet Generator (TQG)	10	9	1.07	1,272
MEP-1050	15	8.61	.9 @ 75% load 1.06 @ 100% load	1,610
MEP-1060	30	16.7	1.8 @ 75% load 2.46 @ 100% load	2,330
MEP-1070	60	34.7	3.51 @ 75% load 4.47 @ 100% load	3,205

Source: "TM 11300-15 PRINCIPAL TECHNICAL CHARACTERISTICS OF MARINE CORPS FAMILY OF POWER SYSTEMS AND ENVIRONMENTAL CONTROL EQUIPMENT," November 2020.

provide. There is a single-phase variant called the enhanced environmental control unit (TAMCN B0074 - E2CU). This E2CU produces 9,000 BTU/hr and draws 1.635kW to cool at

95°F and 2.023kW to cool at 125°F outside temperature. This variant could run using batteries and an inverter.

The current family of diesel generators is perfectly suited for carrying the load described in the study. However, diesel generators carry a significant logistical burden and might not be the best option for a unit conducting EABO. The generators currently employed by the Marine Corps range in capability, size, and load capacity. Table 1 above captures the specifics of these generators.

The problems with most diesel generators are that they produce a significant EM footprint, lack fuel efficiency, and are too large to transport unless trailer-mounted. As one US Army unit recently informed us after a regiment-sized training exercise in early 2020, it is hard to hide on today's battlefield (see Figure 3). Army Colonel Scott Woodward, the 11th Armored Cavalry Regiment's commander, posted this photograph on a social media platform along with

comments about how camouflage netting is still valuable, but managing a unit's EM footprint is infinitely more critical on today's battlefield.³⁷ The photograph depicts the EM emissions of a battalion-sized unit as seen from an EM sensor on a satellite. The biggest EM emissions producers are communications equipment and radars while they emit burst transmissions³⁸; however, studies show that diesel

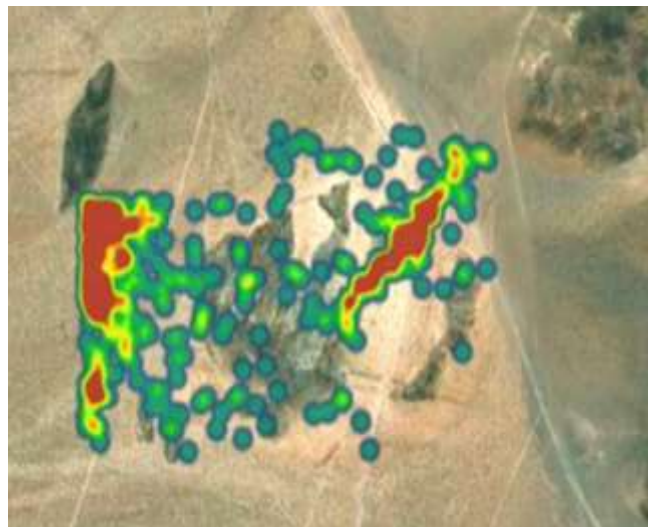


Figure 3. Electronic emission signature of a battalion-sized element

Source: Joseph Trevithick, "This Is What Ground Forces Look Like To Electronic Warfare Systems And Why It's A Big Deal," The Drive, accessed November 10, 2020, <https://www.thedrive.com/the-war-zone/33401/this-is-what-ground-forces-look-like-to-an-electronic-warfare-system-and-why-its-a-big-deal>.

generators and electrical grids also produce significant EM emissions.³⁹ Fortunately, the Marine Corps utilities community can assist units in reducing their EM signatures by finding ways to replace the unit's reliance on diesel generators.

Besides contributing to the unit's EM footprint, diesel generators consume enormous amounts of fuel and are extremely heavy. The generator that powered the COC in the NSWC/E2O study was a MEP-806 60kW (now retired from service).⁴⁰ It powered other sites besides the COC, such as an aid station tent, at the time of the study. If the COC used a 30kW generator instead of a 60kW generator, energy consumption would limit its productivity, but it would save fuel. If a ground combat unit were deployed with a 30kW generator to power the COC instead, the fuel requirement would be different. This is part of an 1141 – Marine Corps Electrician's job: pairing the right capability with the requirement.

During the planning phase of any mission, Marine Corps Electricians calculate the supported unit's power requirements. They use this as a baseline planning factor for pairing it to the most efficient power production and distribution equipment. Doctrinally, generators should run at 80% capacity to maximize fuel efficiency and avoid unnecessary wear and tear on underutilized equipment; this also allows the generator to accommodate unexpected surge requirements.⁴¹ The average 30kW generator (MEP-1060) has a fuel tank capacity of 16.7 gallons.⁴² Under laboratory conditions, running under an 80% load (doctrinal planning factor), consuming two gallons per hour, the generator would need a refill after 8.35 hours.⁴³ It would consume over 48 gallons in 24 hours. The average 60kW generator (MEP-1070, the MEP-806 replacement) has a fuel tank capacity of 34.7 gallons; the generator, while running under an 80% load and consuming a little over 3.5 gallons per hour, would need a refill after about 9.9 hours.⁴⁴ It would consume at least 84 gallons in 24 hours. Additionally, the generators operate in pairs,

and sometimes more depending on power requirements, in order to balance loads and provide uninterrupted electricity in case one fails or there is a sudden surge in the load (redundancy). Taking all of this into account, a company COC would require two generators, each weighing over 2,000 lbs. and each requiring at least 48-84 gallons of diesel fuel per day. Utilities planners must ensure to trailer-mount generators in case the deploying unit has no access to a forklift. This assessment does not account for the lengthy setup time required to establish a power grid using the distribution panels and cables or the time it takes to displace such a grid. Generators are efficient and capable resources, but they have significant drawbacks.

The Marine Corps recognized the need for alternative energy sources and experimented with solar energy and battery storage in the past. The Ground Renewable Expeditionary ENergy System (GREENS) (Figure 4) and the Solar Portable Alternative Communication Energy System (SPACES) (Figure 5) are two Marine Corps programs of record (POR) items. Both saw service in Operation Enduring Freedom. They are capable



Figure 4. Ground renewable expeditionary energy network system (GREENS)

Source: "TM 11300-15 PRINCIPAL TECHNICAL CHARACTERISTICS OF MARINE CORPS FAMILY OF POWER SYSTEMS AND ENVIRONMENTAL CONTROL EQUIPMENT," November 2020, p. 2-7.



Figure 4. Solar portable alternative communication energy system (SPACES)

Source: "TM 11300-15 PRINCIPAL TECHNICAL CHARACTERISTICS OF MARINE CORPS FAMILY OF POWER SYSTEMS AND ENVIRONMENTAL CONTROL EQUIPMENT," November 2020, p. 2-1.

systems; however, neither could power an entire COC like the one used in the NSWC/E2O study referenced above. SPACES' purpose is to deliver portable power to recharge the batteries of man-packable radios (BB2590/U rechargeable battery) and operate smaller communications equipment.⁴⁵ SPACES receives power from flexible or rigid solar panels, batteries, or NATO vehicles. GREENS, on the other hand, is a bit more capable. It consists of "man transportable components that, when assembled into a system, accepts energy from many different sources, distributes the energy using an intelligent management system, and stores excess energy to provide an average continuous output of 300 Watts (nominal) or 1,000 Watts (peak)."⁴⁶ Its purpose is to support a platoon-sized unit operating far from the main supply routes. Compared to a diesel generator, and in terms of the average company size COC's power requirements, this system is insufficient. Besides its lack of kW production, it does not produce a three-phase output. So, the recommendation to use multiple GREENS packages to meet the need is not a viable option. A single GREENS could not provide enough power to use the smallest (single-phase) E2CU.

Another issue with the GREENS is its size. All the GREENS components together weigh over 960 lbs. Considering that it fills an entire 1,800 lbs. quadruple container (QuadCon), getting it to the battlefield requires a vehicle and heavy equipment for offload.⁴⁷ The current solar energy collection and power storage technology in the Marine Corps inventory is insufficient to power the average company size COC. Either the Marine Corps needs to develop new energy-producing capabilities, or it needs to scale down its power requirements – possibly both. Relying on fossil fuels and the current solar capabilities in a future peer/near-peer conflict will prove extremely hazardous. The Marine Corps must explore other options.

Water is essential for life, and producing and distributing 4.7 to 6.8 gallons per day per Marine (doctrinal planning factor) in a tropical distributed battlespace is a daunting task.⁴⁸ This planning factor, at first glance, appears overly ambitious, but during a military operation, Marines use water for a variety of reasons, but many do not consume it (see Table 2). The military uses for water, other than drinking, include: cooking, heat casualty treatment, laundering, hygiene, medical treatment, CBRN decontamination, engineer construction, vehicle maintenance, and aircraft maintenance.⁴⁹ Using the planning factor of 4.7 to 6.8 gallons per day per Marine may be underestimating the requirement depending on the mission type or length of the mission, and that is why the Marine Corps maintains a robust water purification capability.

Table 2: Water Requirements for Tropical Zones

Company	Daily Gallons-Per-Man Requirements	
	Sustaining	Minimum
Drinking	3.0	3.0
Personal Hygiene	1.7	0.3
Field Feeding	1.3	0.8
Heat Casualty Treatment	0.2	0.2
Subtotal	6.2	4.3
+10% Waste	0.6	0.4
Total	6.8	4.7

Source: Petroleum and Water Logistics Operations. MCWP 4-11.6, 2016, p 10-3

The current inventory of water purification equipment in the Marine Corps is exceptionally designed to provide large quantities of potable drinking water. However, they are cumbersome pieces of equipment that were not designed to support a small, highly mobile force. Marine Corps water purification equipment uses the same reverse-osmosis technology that Marines did in 1979 (Reverse Osmosis Water Purification Unit – ROWPU). Reverse osmosis is still a valuable water purification technology, but recent advances in commercial technology do provide alternatives. The growing need for a highly mobile capability with low or zero EM emissions makes the current systems that rely on diesel generators less desirable for units conducting EABO.

The largest reverse osmosis capability in the Marine Corps inventory is the tactical water purification system (TWPS). It is a 13,000 lbs. unit that can produce 1,500 gallons of potable

water per hour and requires a 60kW generator to provide its power (see Figure 6).⁵⁰ However, the Marine Corps began phasing this system out in 2019.⁵¹ The next size down is the lightweight water purification system (LWPS). The overall weight is about 1,251 lbs., set up takes about 45 minutes, and it can produce around 75 gallons of potable water an hour from a saltwater source or 125 gallons of potable water an hour from a freshwater source (see Figure 7).⁵² The system can purify water in a chemical, biological, radiological, nuclear (CBRN) contaminated environment, though the filters required to do so are costly (~\$2,000 each) and have a shelf life of about two years.⁵³



Figure 5. Tactical water purification system (TWPS)
Source: "B2605 - Tactical Water Purification System" (Marine Corps Systems Command, n.d.), <https://www.marcorssyscom.marines.mil/Portals/105/pdmeps/docs/WATER/B2605.pdf>.



Figure 7. Lightweight Water Purification System (LWPS)
Source: "B0071 - Lightweight Water Purification System." Marine Corps Systems Command, n.d. <https://www.marcorssyscom.marines.mil/Portals/105/pdmeps/docs/WATER/B0071.pdf>.

The LWPS is a self-contained unit that does not require any outside power sources. However, it does require three organic diesel-powered pumps, each with a three-gallon internal tank that consumes .5 GPH per pump.⁵⁴ Therefore, one hour of operation requires 1.5 gallons of diesel to produce up to 125 gallons of potable water, depending on the source. A Marine unit of 45, like the one in the NSWCE2O study, doctrinally would require at least 211.5 gallons of potable water per day. Assuming that the unit must pull from saltwater, this would require 2.82

hours of operation per day to keep up with demand (not producing excess to store for future use) and consume 4.23 gallons of diesel fuel per day. This is a reasonable consumption rate for short-duration EABO missions, but at 1,251 lbs., the unit is not man-portable. If mobility is vital for EABOs to succeed, the LWPS would need to be trailer-mounted and require a vehicle to pull the trailer. If modified as such, it may be a capable and successful solution to short-term missions; however, this increases the capability's physical and EM signature. For more extended-duration missions that still require mobility, the system's diesel fuel requirement and weight may be limiting factors.

The smallest water purification technology that the Marine Corps currently maintains is the individual water purification system (IWPS)

Block II (see Figure 8). The IWPS is an individual use system that Marines can carry in their pack. It can purify water from freshwater sources and act like a straw, or Marines can use it to filter water before filling canteens and Camelbacks.⁵⁵ The IWPS is not a viable option in a CBRN environment, but it



Figure 8. Individual water purification system (IWPS) Block II

Source: Marine Corps Systems Command. Tactical Tuesday: IWPS II, 2017. <https://www.youtube.com/watch?v=58KBM1eFZPA>.

can filter out viruses, bacteria, and cysts.⁵⁶ This capability is limited to purifying fresh water; however, it provides the warfighter another option for personal water purification.

The Fuel and Water Team at Marine Corps Systems Command (MCSC), the unit in charge of all Marine Corps fuel and water systems, recently pursued several other smaller capabilities called the platoon water purification system (PWPS), the small unit water purification system (SUWPS), and the squad water purification system (SWPS). All three systems use reverse osmosis like the TWPS and LWPS. The PWPS and SUWPS can filter from

saltwater or freshwater sources, and the SWPS can filter from brackish or freshwater sources; however, unlike the LWPS, they cannot purify water in a CBRN-contaminated environment.

The benefits of these experimental designs are their smaller size and their ability to run using battery power. The manufacturer intended the PWPS to support a platoon-sized unit.⁵⁷ It comes in one 130 lbs. pelican case and can produce 25 gallons per hour while running using battery power (see Figure 9).⁵⁸ The SUWPS is a

smaller version meant for a squad-sized unit.⁵⁹ The entire system comes in two pelican cases and weighs 96 lbs. It runs using battery power and can produce 15 gallons per hour (see Figure 10).⁶⁰ The third version, the SWPS, comes in one small pelican case the size of a backpack, and it can purify five gallons an hour or

120 gallons per day (see Figure 11).⁶¹ It can run using SPACES, GREENS, a BB2590/U rechargeable battery, vehicle power, or a generator.⁶² None of these three systems require expertise in water purification, and they are all relatively self-contained. At the time of this



Figure 9. Platoon water purification system (PWPS)
Source: Falkowski, Jeff, and Parker Hannifin. "PWPS - H2Opro," n.d., [2.https://www.youtube.com/watch?v=58KBM1eFZPA](https://www.youtube.com/watch?v=58KBM1eFZPA).



Figure 10. Small unit water purification system (SUWPS)
Source: "Aquifer 360 Expedition." Accessed January 17, 2021. <https://www.spectrawatermakers.com/us/us/11140-Aquifer+360+Expedition>.[2.https://www.youtube.com/watch?v=58KBM1eFZPA](https://www.youtube.com/watch?v=58KBM1eFZPA).



Figure 11. Squad water purification system (SWPS)
Source: Marines. With the Gear | Squad Water Purification System, 2016. <https://www.youtube.com/watch?v=nEc91lwBU5k>.<https://www.spectrawatermakers.com/us/us/11140-Aquifer+360+Expedition>.[2.https://www.youtube.com/watch?v=58KBM1eFZPA](https://www.youtube.com/watch?v=58KBM1eFZPA).

writing, all three systems were still in the early prototype testing stages. There are trade-offs with all water purification systems currently available and with those in testing. However, for a small and highly mobile force that requires a zero or low EM signature water purification capability, these smaller systems provide a very workable solution.

EMERGING CONCEPTS AND CAPABILITIES: CONNECTORS

There is little doubt that the US Navy could defeat any other nation's navy in the open ocean, and this is why the US's adversaries design their forces around contesting US naval dominance in close and confined seas.⁶³ With the development of A2/AD and long-range precision-guided munitions, logistics operations within this contested zone are incredibly hazardous. Several logisticians suggested that to support EABO, the US Navy and Marine Corps should develop better ways of delivering supplies to those operating within an enemy WEZ.

In May 2019, the *Marine Corps Gazette* published "Logistics in the Contact Layer: Supporting a 'mini-MAGTF'" by Captain Dylan F. Metzler, in which the author made recommendations for a future logistics force. Metzler, a Marine Corps logistics officer, argued that a "future logistics system must be adaptive, anticipatory, responsive, redundant, simple, and cost-effective."⁶⁴ His recommendations align with the Navy's concept, *A Cooperative Strategy for 21st Century Seapower*, which stated that those in the acquisition community must prioritize affordability during the entire acquisition process.⁶⁵ Metzler provided a coherent description of a system that included resupply by smaller, more affordable and agile surface connectors, the use of logistics Unmanned Aerial Vehicles (UAVs), disposable logistics gliders, and procuring more economical vehicles that do not use as much fuel.⁶⁶ Mills, Phillips-Levin, and Fox, in their article "*Cocaine Logistics*" *For the Marine Corps*, recommended the Marine Corps invest in unmanned

logistics platforms. They promote the use of low profile or semi-submersible vessels, like those used by drug smugglers, to deliver logistics requirements to troops conducting EABO.⁶⁷

The problem with a "better delivery vehicle" is that it still has a logistics tether to a hub. If the hub is in California, Hawaii, Guam, or a naval ship allocated to a seabasing mission, the vehicle is still vulnerable en route to its destination. The enemy poses a threat, but so does interception by curious boaters, rogue waves, and the ever-changing underwater topography. Even a bad storm can cause a delay in resupply or even total loss of the payload. The Pacific Ocean, located in the "ring of fire," frequently experiences tsunamis, earthquakes, volcanic eruptions, and typhoons. If the enemy sinks a ship serving as a seabase for logistics resupply, Marines are at risk of being stranded without logistical support for extended periods. This does not mean "better connectors" are a waste of tax dollars. They certainly could prove a valuable redundancy to supplement a more self-reliant force. In EABO, redundancy of capability and resiliency are critical to success.

DIFFERENT VERSUS BETTER

Instead of solely searching for a better delivery system, the naval force must scale down the size of logistic assets and deliver power and water purification production capabilities closer to the point of use. Specifically, the naval force must reduce the need for delivery platforms for fuel and water capabilities. Self-sustainability is far superior to reliance on logistic resupply when conducting EABO. Frequent logistic resupply missions put logistics forces in danger during transport and supported forces in danger of detection during reception. As previously discussed, Lieutenant General Dana informed us that "70 to 80% of all military logistics is the transportation of water and fuel."⁶⁸ This requirement is a heavy burden on the force. Leaders in the Marine Corps must urgently find ways to reduce consumption and the need to resupply these

two commodities. Such a solution would significantly reduce the strain on the supply chain and enhance the warfighter's sustainability. The Marine Corps must also continue to pursue technology that enables self-sufficiency in power and water. Rather than focusing on developing better connectors, the US naval force should capitalize on emerging technologies developed over the last ten years, which make unit self-sufficiency a viable option.

The Marines who landed on Guadalcanal on 7 August 1942 understood the importance of clean water. Two days after the first landings, Japanese pressure on the fleet forced the US Navy to leave the Marines stranded on a Pacific island with insufficient supplies.⁶⁹ The 1st Marine Division relied on chlorine to purify the water that they pulled from the Lunga River.⁷⁰ The lack of proper drinking water led to numerous bouts of dysentery and gastroenteritis during the battle's early days.⁷¹ Such a risk can cripple a fighting force's combat effectiveness. Despite these challenges, this experience serves as an outstanding example of how leaders in the Marine Corps should view self-sustainment in an EABO environment. A future fight with a peer or near-peer competitor will come with the same risks. Resupply will be extremely hazardous, and Marines will have to support themselves. A US Navy ship will want to insert an *inside force* deep within the WEZ quickly, quietly, and without losing any ships in the process. The naval force commander will also not want to risk those *inside forces* or their ships by conducting constant resupply missions. A paradigm shift occurred in recent years, and the US naval force can no longer assume it will gain maritime and air supremacy against a peer or near-peer competitor in the early days of a conflict. The US naval force must change how it plans to sustain the warfighter inside the WEZ without endangering the Marines on the ground and without giving away the troops' locations with regular resupply convoys. Troops who can purify their drinking

water on-site and produce their electricity without using diesel generators will increase the unit's sustainability and reduce the risk to their mission.

NEXT STEPS

Resiliency and persistence require redundancy in capability. Reliance on one source of power or water creates another brittle force. A suite of capabilities that Marines can pick and choose from based on the operating environment and the mission tasked is paramount to mission success. Self-sufficiency in all things is unrealistic, but making smaller tactical units more self-sufficient in their power and water requirements unshackles them from a risky tether for more extended periods. Technology improves rapidly, and there are many commercial off-the-shelf (COTS) technologies already available, which could augment the Marine Corps' current power and water-making capability inventories.

The rest of this section will review COTS technologies organized into several categories: power storage, power production from solar, wind, and hydroelectric sources, and water production. Although emerging technologies carry with them limitations and unknowns, scientists have made significant progress in developing renewable energy sources over the last 50 years, most notably in the solar, wind, and hydroelectric fields. The GREENS and SPACES take advantage of solar power to charge batteries and power small communications equipment. The problem with using these technologies in EABOs is that the GREENS is



Figure 12. Ultra-lightweight expeditionary power system (U-LEPS)

Source: West Coast Solutions. "Expeditionary Power." Accessed January 18, 2021. <https://wecoso.com/technology/expeditionary-power/>. <https://www.youtube.com/watch?v=nEc911wBU5k>. <https://www.spectrawatermakers.com/us/us/11140-Aquifer+360+Expedition.2>. <https://www.youtube.com/watch?v=58KBM1eFZPA>.

extremely heavy and requires a QuadCon for storage and a vehicle to transport.⁷² SPACES is very lightweight and can fit in a backpack, but it provides very little actual power (400 watts).⁷³ The MCSC Power Team recently tested a device, the Ultra-lightweight Expeditionary Power System (U-LEPS), to replace the GREENS. The U-LEPS is 50% smaller than GREENS (see Figure 12).⁷⁴ It is essentially a scalable and reconfigurable system composed of one or more 88 lbs. cases that each contain a high-density lithium-polymer battery core and a power input that can receive energy from NATO vehicles, solar panels, or shore power.⁷⁵ A unit could deploy with one case or link multiple cases to provide additional power storage. It is a battery bank that provides up to 10kW of power and can accept scavenged energy from any source, even unreliable "dirty" sources.⁷⁶ The system does not come with any solar panels or power sources, but it does appear that it could provide the power storage adequate for supporting a 45 Marine unit living in austere conditions. The unit would have to scale down its COC requirements, but this battery bank could power laptops, lights, radios, and an E2CU for climate control.

Scavenging power is an essential capability for a unit conducting EABO in countries with an underdeveloped power infrastructure. EABO missions will not always require Marines to operate in seclusion. Sometimes an established power infrastructure will be available, and the U-LEPS's ability to scavenge from "dirty" sources will prove an asset. However, if a host nation's power grid were further developed and interoperable with all US equipment, this is preferable. The Department of State and US Agency for International Development could assist developing nations with this in mind. This interoperability would not only help Marines conducting EABO, but it would also serve US forces responding to humanitarian crises.

Using solar energy to produce power for the U-LEPS is an option for units conducting EABO in austere environments away from developed infrastructure. However, the solar array

needed to produce 10kW of electricity would be rather significant (see Figure 13). According to solar retailers, a house with a 10kW solar system installed would require 523.13 square feet of roof space to accommodate 27 solar panels.⁷⁷ Using this as a planning factor, the portable solar arrays required would fill one QuadCon, possibly two, depending on each panel's thickness. This again is problematic for transportation. Researchers in the Special Operations community recently experimented with PowerShade, a 22-foot by 40-foot fabric, pole-supported sunshade with photovoltaic cells woven into its fabric that produced 2kW of power.⁷⁸ It provided shade for operators and power for their equipment. Sunshades or camouflage netting are useful to block the COC from the sun. This allows the COC to stay cooler and require less energy from an ECU during peak daylight hours. If Marine Corps units conducting EABO used PowerShades to camouflage/shade their COCs and billeting areas, they could produce power with something that reduces their energy consumption and their visible signature. Coupled with a few U-LEPs, solar could provide adequate power for a small COC in the right conditions.

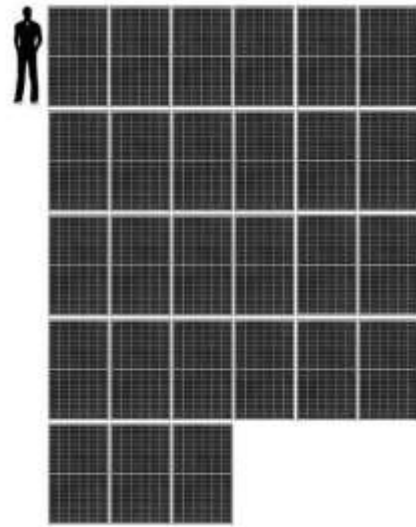


Figure 13. Required solar array to produce 10kW
 Source: SolarQuotes. "10kW Solar System - Solar Power Quotes & Information." Sales. Solar Quotes. Accessed January 18, 2021.
<https://www.solarquotes.com.au/systems/10kw/>.

Wind energy is another exploitable renewable energy source. The MCSC Power Team also looked into developing small wind turbines for forces operating far from main supply lines.⁷⁹ According to a recent study, the South and East China seas have adequate wind averages to make this a viable option (see Figure 14).⁸⁰ The problem with capturing wind energy is that air

currents are generally strongest at 300'-400' above the ground.⁸¹ Reaching those heights requires building on a massive scale like that of commercial wind turbines or by finding an alternative means to reach that height. The company Windlift is one of several manufacturers developing such capabilities. Windlift is in the process of

creating what they call airborne power generators (APG). Their APG design is a system composed of a ground-based, solid framed, tethered glider with propellers that capture passing wind currents and generate electricity from them. It is basically a kite that carries small wind turbines. Windlift designed this capability in several sizes, the smallest of which will weigh about 43 lbs. and produce 700 watts to 1.5kW.⁸² The next size up will weigh

about 113 lbs. and produce up to 4.1kW.⁸³ Due to the flight altitude requirement of 300'-400', they do have a visual signature and are visible up to 1.2 miles away during daylight hours. These "kites" could prove helpful in supplementing solar power at night when the visual signature of the APG is not a concern and solar panels are no longer able to recharge batteries.

Hydroelectric energy is another field of research that provides a renewable energy source; however, it is not as promising as solar and wind. Hydroelectric energy production relies on the same principles of fluid dynamics as wind turbines, except hydroelectric generators capture the energy of passing water instead of wind. The current products on the market are either too large or do not produce enough power to make them a viable option for charging a battery bank like

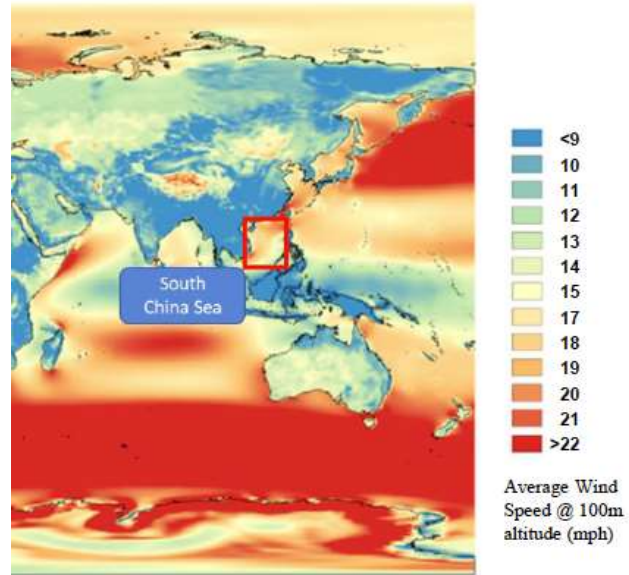


Figure 14. Average wind conditions in the Indian and Pacific Oceans

Source: Stough, Andy, Robert Creighton, Mark Aull, Thomas Burroughs, and Brian Detter. "SBIR Phase III Discussion: Windlift APG System," n.d., 54.

the U-LEPS. One interesting thing to note is that if Marines use an LWPS to produce water during EABO, it is conceivable that the Marines could install a small hydroelectric turbine in the hose system before or after (possibly both) the diesel pumps organic to the LWPS. This would produce power and potable water at the same time and make the most of the diesel fuel consumption.

As for water production, the current inventory of Marine Corps water purification equipment and the PWPS, SUWPS, and SWPS rely on reverse osmosis. While the PWPS, SUWPS, and SWPS all seem very promising, there are other technologies available that can provide redundancy and resiliency to the capability.

Leaders in the Marine Corps must research alternate means of

water production. In the tropical climate of the South and East China seas, with regular and significant year-round rainfall, older technologies like rainwater diverters and collapsible cisterns may be an option for water collection away from water sources (see Figure 15).⁸⁴ Scientists recently experimented with interesting and promising new technologies such as atmospheric water generators (AWG) and metal-organic framework (MOF) water harvesters, which could be options as well.⁸⁵

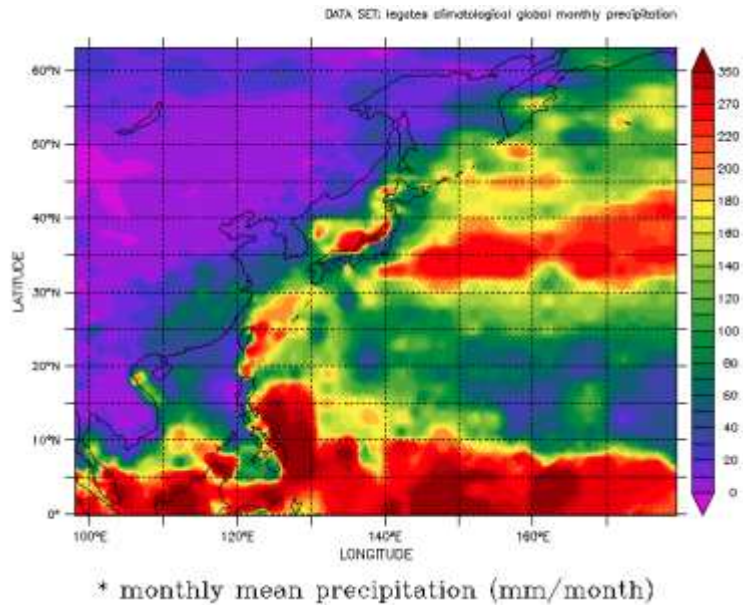


Figure 15. Average monthly rainfall in the Pacific Ocean and China Seas
Source: "APDRC Datadoc | Legates Climatological Global Monthly Precipitation." Accessed March 17, 2021.
<http://apdrc.soest.hawaii.edu/datadoc/legates.php>.

Metzler, in his article, recommended equipping the force with AWGs.⁸⁶ Chief Warrant Officer 4 Sean C. Flores, a Utilities Officer with III Marine Expeditionary Force, also recommended using AWGs to supply forces conducting EABO with ready drinking water.⁸⁷ An AWG is essentially a commercial version of a household dehumidifier. It requires electricity to draw the moisture out of the ambient air. AWGs typically work best in ambient air with temperatures over 45 degrees Fahrenheit and relative humidity of at least 30 percent.⁸⁸ According to the Asia-Pacific Data Research Center, the average relative humidity in the South and East China Seas remains above 65% for most of the year and above 85% during the summer months.⁸⁹ Temperatures in the region are typical of tropical and subtropical climates, with averages ranging from 68 to 87 degrees Fahrenheit.⁹⁰ AWGs, therefore, are ideally suited to the climate found in the Asia-Pacific region.

Metzler and Flores were correct that AWGs can provide alternative means of obtaining drinking water that is not dependent on a water source like the ocean, stream, or lake;⁹¹ however, the AWGs that are capable of providing enough water for a 45 Marine unit use a significant amount of electricity. The GEN-350, an AWG produced by the company Watergen, weighs 1,720 lbs. and can produce 238 gallons of clean water a day, but it requires about 5.6kW per hour and a maximum of 10kW at startup.⁹² A diesel generator could quickly meet this requirement, but this is an unrealistic requirement for a battery bank and renewable energy source. At 1,720 lbs., it is also trailer-mounted and would require a vehicle for mobility. Unfortunately, until AWGs develop more efficient energy usage, they may not be compatible with most EABO mission requirements when facing peer or near-peer adversaries. However, the US could stage "dual-purpose" AWGs in forward locations now, tie them into existing power infrastructure, and maintain them for possible future use in humanitarian missions or to support troops conducting

EABO in less austere locations. For a more concise comparison of the water production systems mentioned above, see Table 3 below.

Table 3: Comparison of Water Systems

Water Production for a 45 Marine Outpost									
System	Weight (lbs.)	Power Source	Purification Rate in gal/hr	Time to Purify 211.5 gal*in hours	Diesel Fuel Req'd. in gallons	Vehicle and Trailer Req'd.	1171 Marine Req'd.	Water Source Capabilities	CBRN Filter
Lightweight Water Purification System (LWPS)	1,251	Three diesel pumps	75 from saltwater 125 from freshwater	2.82 for saltwater 1.69 for freshwater	4.3	YES	YES	Salt, Brackish, and Fresh	YES
Platoon Water Purification System (PWPS)	130	Battery, or any 24 VDC or 120 VAC power source	25	8.5	NONE	NO	NO	Salt, Brackish, and Fresh	NO
Small Unit Water Purification System (SUWPS)	96	Battery, or any 24 VDC or 120 VAC power source	15	14.1	NONE	NO	NO	Brackish and Fresh	NO
Squad Water Purification System (SWPS)	18	Battery, or any 24 VDC or 120 VAC power source	5	42.3	NONE	NO	NO	Brackish and Fresh	NO
Atmospheric Water Generator (AWG) WaterGen's "GEN-350"	1,720	>10kW Generator or shore power	9.9	21.3	~22.8**	YES	NO	Ambient Air	NO
<p>* 45 Marines x 4.7 gal per day per Marine = 211.5 gallons per day per Marine requirement. ** Gallons of diesel fuel required if using the MEP-813A Tactical Quiet Generator (TQG). This is a 10kW generator that consumes 1.07 gal/hr of diesel fuel.</p>									

Sources: "B0071 - Lightweight Water Purification System." Marine Corps Systems Command, n.d. <https://www.marcorsyscom.marines.mil/Portals/105/pdmeps/docs/WATER/B0071.pdf>;
Falkowski, Jeff, and Parker Hannifin. "PWPS - H2Opro," n.d., 2.;
"Cpl. Colby Wallace, Small Unit Water Purification (SUWP)." Accessed January 17, 2021. <https://www.mcwl.marines.mil/Divisions/Experiment/AWE/video/349742/>;
Marines. With the Gear | Squad Water Purification System, 2016. [https://www.youtube.com/watch?v=nEc91lwBU5k](https://www.youtube.com/watch?v=nEc91lwBU5k;);
"GEN-350 Product Sheet." Watergen, n.d. https://adsinc.com/wpcontent/uploads/2019/05/GEN-350_WaterGen.pdf.

A little further into the future, possibly in another ten years, MOF water harvesters might be an incredible option for Marine units conducting EABO in the South and East China seas. MOF water harvesters are a new technology that does not currently exist as a commercial market

product. Researchers at the University of California, Berkeley (UCB), among a few other institutions, recently experimented with a MOF named Zr-MOF-808.⁹³ This particular MOF, one of about 20,000 known variants, can produce 8.66 liters of water per kilogram of MOF per day (about 2.28 gallons of water per 2.205 lbs. of MOF per day).⁹⁴ Researchers mainly tested this material in desert climates, but the research points to greater efficiency in climates with increased relative humidity, like that of the South and East China seas.⁹⁵ The MOF, currently only produced in powder form, requires a minimal electric charge to cause it to cycle from water capture to water release. Researchers at UCB formed Water Harvesting Inc. in the summer of 2018 in order to commercialize the technology. One could only imagine a canteen cap adapter that incorporated MOF and a small battery to keep a Marine's canteen full at all times. The Marine Corps must continue to monitor this promising technology and company.

Over the next few decades, technology will inevitably continue to mature, and scalable, more capable equipment sets will prove necessary on the future battlefield. One change that leaders can make immediately, though, and that will dramatically affect EABO supportability, is to enforce more discipline concerning energy and water conservation. During the wars in Iraq and Afghanistan, Marines took ready and abundant energy and water sources for granted. We must do a better job of conserving water and power. Units need to leave coffee pots, microwaves, and other non-mission essential power requirements at home when tasked to conduct EABOs. While in the field, units will need to ration water and learn to recycle gray water when feasible. The idea to recycle gray water is nothing new. The 1st and 2nd Marine Logistics Groups have already successfully experimented with the Graywater Reuse Filtration System, a prototype add-on filter to the LWPS.⁹⁶ The Marine Corps must continue to experiment

and develop capabilities to reduce the stress on the military logistics chain and the dependence on logistics convoys to support sustainment in austere locations.

This paper merely scratched the surface with COTS technologies and promising emerging technologies. Future researchers and military leaders must continue to push the conversation even further and develop capability sets and doctrine that enables a fully self-sustaining *inside force*. Self-sustainment in all things may be a long way off, but creating technologies and doctrine that chip away at the forces' dependency on logistics hubs will prove beneficial in any future fight.

CONCLUSION

Frequent logistic resupply missions put logistics forces in danger during transport and supported forces in danger of detection during reception; therefore, the US military must continue to pursue technology that enables self-sufficiency. Technology that emerged over the last five years made unit self-sufficiency a better option than experimenting with different connectors. To further reduce the need for long logistics chains, the US Department of Defense must coordinate with the Department of State to negotiate with countries in the INDOPACOM area to pre-stage "dual-purpose" capabilities and supplies. The Department of State and the US Agency for International Development should also seek to develop power infrastructure around the world which is compatible with US equipment. These efforts, benign in nature, will avoid escalating tensions with competitors in the region and further reduce the need to conduct long logistics convoys during a conflict.

Suppose a future Marine unit, tasked with an EABO mission, deployed to an austere location with PowerShades, SPACES, and APGs for power production, U-LEPS for energy storage, and PWPS or SUWPS for water purification. If that unit practiced disciplined water and

power conservation, then it would significantly reduce the requirement for logistics convoys of subsurface or low-profile unmanned connectors. Connectors would only need to provide sporadic and rare resupply of commodities that the unit cannot produce on-site. These steps would not only make *inside forces* harder for the enemy to locate, but it would increase persistence, sustainment, and the flexibility of those *inside forces*. By doing this, a unit conducting EABO would ensure that it was an asset to a Joint Force Maritime Component Commander and not a burden.

Fortunately, EABO, LOCE, and DMO recently gained much traction. The 38th Commandant's Planning Guidance and the ongoing force design efforts in the Marine Corps informed us that leaders at all levels are receptive to new ideas. The US Department of Defense must continue to fund research that enables military forces to survive and thrive in austere environments. Relying on long logistics chains for necessities like fuel and water will only endanger Marines operating within an enemy's WEZ. The development and employment of renewable energy must be a priority. The money and the commitment are there; researchers must continue to develop technologies, and military professionals must continue to experiment with doctrine to lighten the logistician's burden and ensure the survivability of forward-deployed forces.

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