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Masters Thesis

Expeditionary Energy in the Arctic Domain

The Impacts of Emerging Technology and Interoperability on Energy Requirements in the High North Environment

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Foreward

First and foremost, a special thank you to my wife Silje, son Aaron, and daughter Evelyn for their patience over the past year and my acknowledging the time this project has taken away from our daily family life. I am also grateful to the multiple Norwegian and Marine Corps entities that assisted with providing feedback, guidance, and support during the development of this project. Finally, thank you to the Norwegian Defense University College for the opportunity to complete this thesis and to my thesis advisor, Professor Tormod Heier, for your guidance throughout this process. All errors within this document are my responsibility and every effort has been made to provide appropriate credit to contributing sources. I hope this paper will provide value as an orientation to the Norwegian High North's operational environment, promote future interoperability and information exchanges between the United States and Norwegian entities, and encourage continued discussion on advancing expeditionary electrical energy solutions in the Norwegian High North. I believe that expeditionary electrical energy solutions developed or refined because of collaborative efforts also have the potential for global application. Finally, my thoughts and opinions reflect my own views and do not necessarily reflect the official positions of the United States Marine Corps or the United States Government unless otherwise stated within official policy statements.

Abstract

Problem Statement: How to improve electrical energy self-sufficiency for tactical-size units conducting distributed operations above the Arctic Circle? What are the challenges? What possible materiel and interoperability solutions can be explored to mitigate these challenges?

Considerations: The discussion will be further framed by limiting the scope to electrical energy logistics, using an examination of any energy consumption empirical data available from USMC training events in Norway (2018 – April 2023) and identification of potential materiel or interoperability solutions.

- Electrical energy technology with Arctic environment applications will be explored.
- Possible interoperability opportunities will be explored.
- Interoperability is limited to Norwegian entities however, identified emerging energy technology solutions could be applied globally.

Desired thesis outcome themes:

- Link electrical energy – Norwegian military and United States Marine Corps operations - Arctic sustainment.
- Further define United States Marine Corps and Norwegian interoperability opportunities related to the further development of increasing electrical energy self-sufficiency in the Arctic.
- Identify emerging energy technology applications or processes that can be used globally for USMC requirements.

Relevance: A significant tenant of the Marine Corps *Force Design 2030* and *Stand in Force Concept* is to leverage Allied interoperability, reducing the logistical footprint required to sustain a smaller, more mobile joint force within the threat zones. The unique challenges presented by the Arctic geography, weather, existing Marine Corps equipment limitations, and finite host nation resources for all to draw upon (including other Allies) are all critical factors for leadership consideration. The Marine Corps University - Norwegian Defense University College Arctic Symposium held at Quantico, Virginia from 4 – 6 November 2021 also discussed energy challenges associated with the Norwegian High North and the need for further research in this area.

Summary

The primary objective of this paper is to explore the current status of electrical energy generation in the Arctic environment and identify possible materiel or interoperability solutions to increase the electrical energy self-sufficiency of tactical-size military units conducting distributed operations in the Norwegian High North. This exploration is undertaken by establishing a knowledge baseline of the Norwegian High North's political, geographical, military, and social considerations. Next, a model of explanation will be introduced using the NATO DOTMILPF-I framework to examine the problem statement. This is followed by examining current Marine Corps electrical energy generation solutions using recent training and exploring emerging technologies that could be used to increase tactical-size unit electrical energy self-sufficiency. The emerging technologies will focus primarily on using hydrogen as an energy carrier; however, other applications will also be considered. The research method and design will be supported by a focused literature review from Marine Corps expeditionary energy solutions sources and content analysis of existing data related to Marine Corps training in Northern Norway from 2018 – April 2023. These methods are augmented by my first-hand observations experienced during this period while supporting Marine Corps training in Norway from 2017 to the present. The Marine Corps emerging doctrinal concepts summarized and linked to the problem statement include *A Concept for Stand-in Forces*, *A Functional Concept for Maritime Reconnaissance and Counter-reconnaissance*, and *Expeditionary Advance Base Operations*. The empirical analysis will be focused by using the NATO DOTMILPF-I framework with the *training, materiel,* and *interoperability* elements selected as the most applicable for exploring this problem statement. Existing interoperability relationships will be explored to identify current relationships and future partnership opportunities between units or research organizations. Finally, key findings will be discussed and recommendations given on addressing this thesis's problem statement. In summary, this paper will provide an understanding of the current Arctic environment and military considerations related to military operations in the Norwegian High North, connect the emerging Marine Corps doctrinal concepts with electrical energy self-sufficiency considerations, and link these considerations to future interoperability between the Norwegian Armed Forces and the United States Marine Corps. Lastly, while the scope of this problem statement will be limited to the Norwegian High North, electrical energy self-sufficiency considerations have the potential for global Marine Corps utilization.

Contents

Chapter 1

The dynamic nature of the current global geopolitical climate, the evolving implications of warming oceans within the Arctic region, and the continuous evolution of technology mandate a close examination of how the Marine Corps can sustain distributed operations abroad within the context of developing doctrinal concepts, and the within the restraints of resources, climate, and geography. This detailed examination of sustainment operations must be taken against an overview of the current resources available within the area of operations.

This paper will seek to answer the problem statement: how to improve electrical energy self-sufficiency for tactical-size units conducting distributed operations above the Arctic Circle. This will be further examined by identifying key challenges and exploring possible materiel and interoperability solutions that can be utilized to mitigate these challenges within the current operational environment.

I hypothesize that emerging technology and increased interoperability with Norwegian entities can provide electrical energy power generation solutions for tactical size unit distributed operational energy requirements in the Arctic environment. These solutions could reduce reliance on the national power grid or petroleum stores in crises and be utilized globally by the Marine Corps.

The main objective of this paper is to contribute to efforts in increasing electrical energy self-sufficiency by linking tactical size unit distributed Arctic environment power generation to Norwegian Armed Forces and United States Marine Corps (Marine Corps) interoperability to emerging technology within a format that has practical applicability for leadership and users alike. The secondary objective is to provide possible interoperability and materiel solutions within the context of both the current physical and political environment of Northern Norway. The primary audience for this paper is individuals associated with the Marine Corps, the Norwegian Armed Forces, the Norwegian Defense Research Institute, and others interested in exploring solutions to the problem statement. The contents of this paper will remain unclassified with acknowledgments to areas that cannot be discussed in greater detail due to information sensitivity to provide the most significant degree of accessibility to this paper.

Why Important?

The importance of the problem statement examined by this paper is reinforced at the United States political level by the *2018 National Military Strategy,* which highlighted the return to Great Power competition with Russia and China (The Joint Staff, n.d., p. 2). The *2018 National Defense Strategy* describes the model for the United States military "dynamic force employment" (The Department of Defense, 2018) and is directly linked to the *38th Commandant's Planning Guidance* (2019) – one of the documents examined in the paper. Finally, the national commitment of the United States government to maintaining a peaceful Arctic is clearly articulated in the *2022 National Security Strategy* (The White House, 2022, pp. 44-45). While not all-inclusive, each of the identified political-level documents, *2018 National Military Strategy, 2018 National Defense Strategy,* and *2022 National Security Strategy,* can be directly linked to the problem statement by establishing how materiel and interoperability solutions can be leveraged to better sustain tactical size units conducting distributed operations within the Arctic environment.

The scope of this paper will be focused by limiting the examination of the problem statement to the geographical area of Northern Norway by focusing on tactical size military operations conducted by the Marine Corps with the Norwegian Armed Forces. Furthermore, only recently developed electrical generation technological capabilities based on emerging technology vice theoretical capabilities will be used for application illustrations using existing Marine Corps requirements. The viability of the proposed electrical power generation and energy storage solution will only focus on periods of low light and extreme cold temperatures. Finally, the term "Norwegian High North" will be defined by this paper as Norway's geographical land and sea territory above the Arctic Circle at 66 degrees and 33 minutes North of the equator. This includes Nordland County and the combined Troms and Finnmark County on the mainland, the approximately 1,500,000 square kilometers of Arctic maritime area, the Svalbard archipelago (to include Bjørnøya or Bear Island), and island of Jan Maye (Hoglund, 2023) (Stange, 2019).

Short Literature Review

Existing research within the energy sustainment sector was extensively explored via literature review as energy sustainment, specifically electrical energy sustainment within the Arctic environment, remains a critical research area with a direct link to the ability of Marine Corps forces to conduct both credible deterrence and combat operations. Furthermore, the Marine Corps and Norwegian entities responsible for expeditionary energy were identified at the organizational level to determine if current research areas related to this paper's focus exist and assess the status of current collaboration relationships.

Defining Key Concepts

The following key definitions, concepts, and organizations will help further frame the focus of this paper. Military activity is categorized by North Atlantic Treaty Organization (NATO) at the tactical, operational, and strategic levels. This paper will focus on tactical size unit electrical energy requirements. NATO defines the tactical level as "the level at which activities, battles and engagements are planned and executed to accomplish military objectives assigned to tactical formations and units" (NATO Standardization Office, 2021). For the purposes of this paper, tactical size units, further defined as a Battalion size or smaller, will be utilized to explore the problem statement by providing a framework with their standing force structure of personnel specialties, equipment, and experience in Arctic operations. Specifically, the Marine Corps 2D Force Reconnaissance standard detachment and Norwegian Military Intelligence Battalion patrol squads will be utilized to share current Arctic electrical energy support practices experienced during the Norwegian-hosted JOINT VIKING 2023 exercise that took place from 6 – 16 March 2023.

Electrical energy is defined as the energy required to power individual or organizational equipment associated with a Marine Corps Battalion or smaller size element. An energy carrier is defined as the method, process, or equipment item used to store excess electrical energy. The traditional Marine Corps method of electrical energy sustainment relies on local access to the national power grid infrastructure or petroleum-based electrical energy generation at the requirement site for more extensive sustainment requirements. Smaller requirements are traditionally supported via battery solutions that may or may not be used more than once. Marine Corps forces utilize these electrical sustainment methods to conduct distributed operations within the Arctic environment.

General Berger, the 38th Commandant of the Marine Corps, describes the concept of *Distributed Operations* as critical to improving the survivability and combat effectiveness of Marine Corps combat power projection within his *38th Commandant's Planning Guidance* (Berger, Commandant's Planning Guidance, 2019). Distributed Operations is defined by the Marine Corps "as small, dispersed land and sea detachments [which] threaten the ability of adversary forces to concentrate from within their anti-access/area denial umbrella. Forces conducting Distributed Operations deny freedom of movement along key sea and air lines of communication" (Headquarters Marine Corps, 2021). The Marine Corps further describes forces that conduct *Distributed Operations* with the capability of full range combined arms as a squad size or larger; smaller than the traditional infantry company historically employed as the smallest organizational unit capable of combined arms operations. The primary objective of distributed forces is to "change the adversary's cost calculus and buy time for flexible deterrence options and assembling a joint task force" (Headquarters Marine Corps, 2021).

Structure of Thesis

The Norwegian Arctic environment and related military concepts will be defined in chapter 2 to provide the reader with a baseline knowledge foundation for the problem statement. Chapter 3 will present the methods and a theoretical model of explanation used to examine the problem statement. The current status of electrical energy generation and possible solutions will be reviewed in chapter 4. The empirical analysis in chapter 5 will be discussed using the *Training, Materiel*, and *Interoperability* elements selected from the NATO DOTMILPF-I framework as the most applicable for exploring this problem statement. Chapter 6 will conclude this paper with key findings and a brief discussion of other research areas. Finally, how can the Norwegian Arctic environment be described, and what related military concepts should be considered?

Chapter 2: Describing the Arctic Environment and Related Military Concepts

The operational environment will be defined by exploring several different considerations. First, I will briefly discuss the critical political-level security considerations and describe Northern Norway's geography, weather, and climate considerations. This will be further expanded to include awareness of the main Norwegian population and civilian centers, electrical energy resources, and key logistical infrastructure on the mainland of the Norwegian High North. Finally, I will introduce several emerging Marine Corps operational concepts linked to this paper, an overview of the Norwegian Armed Forces, and a description of five key relationships related to the defense of the Norwegian High North.

Including these five key relationships is designed to ensure awareness of existing bilateral and multilateral frameworks currently in place and linked to the defense of the Norwegian High North. By understanding the existence of multiple actors, who are both energy requirement users and energy requirement generators, related to various agreements, the complexity of the operational environment is better understood. Specifically, this complexity highlights the importance of increasing electrical energy self-sufficiency for tactical-size units in the context of competition for limited resources between the civilian population, Norwegian Defense Forces, Civilian Authorities, and other Allies in a crisis scenario.

The overall purpose of this chapter is to provide the reader with a baseline operational environment understanding for the forthcoming description in chapter 4 of contemporary electrical energy practices in the Norwegian High North.

The Norwegian Arctic Environment

In 2021, Frank Bakke-Jensen, the Norwegian Defense Minister, described the political balance that Norway seeks to maintain in relation to Russia and other regional actors within the security sector in Northern Norway. "The balance between deterrence and reassurance is our main approach to achieve our security goals for the High North. At the same time, we continue to be prudent and avoid unnecessary provocation" (Bakke-Jensen, 2021). He further describes the importance of the Norwegian relationship with the United States, especially regarding security matters, which remains the cornerstone of the Norwegian Defense policy (Bakke-Jensen, 2021).

> The Russian so-called active defense emphasizes high readiness, agility, mobility and close coordination, as well as the ability to launch massive firepower. Russian

> prioritization of the Arctic has resulted in a large-scale modernization of the armed forces and infrastructure reestablishment in the Russian north. The key task of the Russian capabilities on the Kola Peninsula is global deterrence, making horizontal escalation a lasting concern for Norway. There is no indication that Russia will slow down its engagement in the Arctic — rather, the opposite. (Bakke-Jensen, 2021)

The security situation in Europe changed overnight on 24 February 2022 when Russia invaded Ukraine and launched the largest ground war in Europe since the Second World War. The effects of this war continue to have global implications ranging from the humanitarian impact on the population within the conflict zone to the security environment in Norway. The Norwegian Government has condemned the Russian invasion and provided military and humanitarian assistance to Ukraine (Regjeringen, 2023). The current Norwegian Prime Minister, Jonas Gahr Støre, issued a statement shortly after the invasion condemning the actions of Russia (Regjeringen, 2022).

> Norway condemns Russia's military attack on Ukraine in the strongest possible terms. This attack is a serious violation of international law and will have dramatic consequences for the people of Ukraine. Norway stands together with its Allies and the UN in demanding that Russia immediately ceases its military operations and seeks a peaceful solution. The Russian authorities bear full responsibility for the current situation, which represents a watershed for Europe and a new era in European security.

The new Norwegian security environment was described in a recent article titled *Norway Between the "High North" and the Baltic Sea* by Håkon Lunde Saxi, an Associate Professor at the Norwegian Defence University College, published by National Defense University Press. He describes how the changing security environment in Norway has been marked in some ways by significant policy shifts, including the export of military equipment to Ukraine and participation in economic sanctions against Russia. In other areas, "there has been no radical reconceptualization of Norway's defense priorities, which continue to be focused on deterring Russia in the High North. Norwegian policy is therefore marked more by continuity rather than change since February 2022" (Saxi, 2023). He further elaborates that "Norway has not abandoned its efforts to strike a balance between deterrence and "reassurance" vis-à-vis- Russia, and it continues to seek cooperation in some fields, such as fishery management" (Saxi, 2023).

Several key policies are noteworthy as Norway seeks to maintain this balance between deterrence and reassurance. First is restricting Allied training in the Finnmark region or other areas near the Russian and Norwegian border. Another is the Norwegian Government's policy of not hosting any foreign permanent bases in Norway. This has been the policy of the Norwegian Government since joining NATO in 1949 however, the application of this policy has shifted over time in response to geopolitical changes (Solsvik & Adomaitis, 2021).

The importance of the Arctic to Russia in military terms is often described as the “Bastion Defense,” a term used to describe the multi-layered network designed to protect the Russian naval nuclear second-strike capability based on the Kola Peninsula. These Russian naval bases represent the only current warm water ports free of ice year-round with direct access into the Atlantic Ocean. The Bastion Defense “can be considered as an anti-access network created to protect strategic submarines. It also ensures the Northern Fleet access to the Atlantic and protects the Russian Arctic and the Russian right flank in a major conflict or war” (Hestvik & Bonnar, 2020). Protecting these warm water ports, strategic nuclear naval assets – primarily submarines, and ensuring Russian maritime power protection are key strategic goals of the Russian military.

The strategic role of Norway, given the geographical position of the Norwegian High North in proximity to the Kola Peninsula, can be described with several considerations linked to maintaining consistent awareness of activity in the Arctic. The Norwegian border is located only a short distance from Russian military installations, and in some cases, these are visible from the Norwegian military observation positions (Northam, 2019). The Norwegian military electronic surveillance facility on Vardo Island, partially funded by the United States, also maintains regional awareness of activity in the surrounding Arctic region (Northam, 2019). The Norwegian Air Force has also recently purchased five P-8 Poseidon aircraft from the United States to ensure awareness of the Norwegian High North maritime territory. These aircraft will be based at Evenes Air Force Base with the “main task to ensure maritime surveillance and to build situational awareness and understanding in the northern areas” (Haslestad & Roen, 2022). The consistent awareness of activity within the Norwegian High North ensures timely information to the Norwegian Government and NATO in the event of a NATO Article V scenario.

Allied training in Northern Norway is limited by self-imposed Norwegian government geographical boundaries to areas away from the shared Norwegian and Russian border but is conducted regularly. JOINT VIKING 2023, hosted by the Norwegian Armed Forces and conducted in the Inner Troms Region of Northern Norway from 6 to 16 March 2023, will be used as a source of information for this paper. This regular training is critical for ensuing the defense of Norway, as described by the Norwegian Armed Forces. “NATO is the foundation of Norway's defense. In order to be able to defend Norway, our allies must exercise on deploying to Norway. They must also know how to operate along with Norwegian forces in a harsh winter climate” (Forsvaret, 2023).

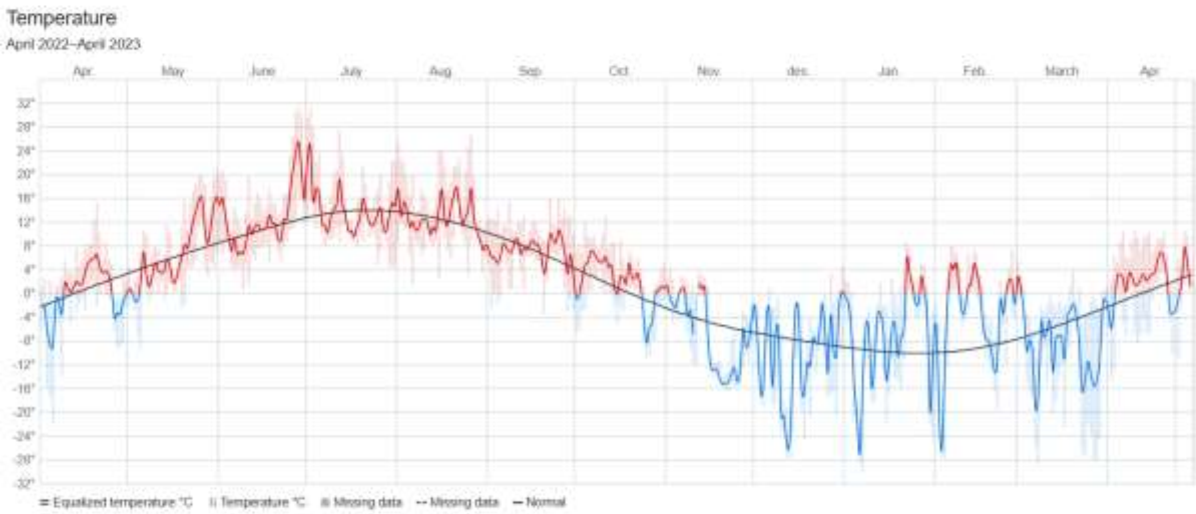
In summary, the Norwegian geographical proximity to the large Russian military presence on the Kola Peninsula allows for Russian military activity and Arctic activity awareness for the Norwegian Government and NATO allies, including the United States. The strategic location of Norway drives the regular allied military training in the Norwegian High North in the context of the NATO alliance and Norwegian defense policy.

In the *2022 National Security Strategy,* the United States government reaffirmed the importance of the Arctic region and the ability of the United States to work with Arctic allies, including Norway, on Arctic security matters. Specifically, the *2022 National Security Strategy* identifies that “Russia has invested significantly in its presence in the Arctic over the last decade, modernizing its military infrastructure and increasing the pace of exercises and training operations. Its aggressive behavior has raised geopolitical tensions in the Arctic,” which has led to an increased risk of conflict, both military confrontation and competition below the threshold of violence (The White House, 2022, p. 44). Russia is not the only Great Power to seek influence within the Arctic region. The *2022 National Security Strategy* also describes the increasing desire by the People’s Republic of China related to Arctic activity. “The [People’s Republic of China] has also sought to increase its influence in the Arctic by rapidly [increasing] its Arctic investments, pursuing new scientific activities, and using these scientific engagements to conduct dual-use research with intelligence or military applications” (The White House, 2022, p. 44). These assessments related to Russia and the People’s Republic of China were further re-enforced within the recently released Norwegian Defense Research Institute *Defense Analysis 2023,* which cited the return to Great Power competition as a risk for increased rivalry within the Norwegian High North (Forsvarets Forskningsinstitutt, 2023).

The combination of understanding the Norwegian Government’s political considerations, the Norwegian Government’s balance between reassurance and deterrence, and the importance placed on the Arctic region by the United States government in the context of Great Power competition with both China and Russia, provide a framework for understanding the importance of increasing electrical energy self-sufficiency in the High North.

The rugged expanses of Northern Norway, which stretch into the Arctic along the current northern flank of NATO, are known for their natural beauty, dynamic mountainous terrain, islands, inlets, and rugged coastlines bisected by deep fjords. Overall, Norway has 239,057 islands and islets and 81,192 rocks and reefs, and when included in the overall coastline measurement, this equates to a coastline that extends over 102,937 kilometers (Ulriksen & Østensen, 2019). “Nearly half of Norway’s land mass is Arctic territory, consisting of the two counties Nordland and the combined county of Troms and Finnmark on the mainland, the Svalbard archipelago and the island of Jan Mayen" (Hoglund, 2023). Additionally, "the country's Arctic maritime area is approximately 1,500,000 square kilometers, corresponding to the combined land area of France, Germany and Spain" (Hoglund, 2023). The Norwegian High North also shares international borders with Russia, Finland, and Sweden. "The municipality of Sør-Varanger lies farthest northeast in Norway and borders both Finland and Russia. The Swedish border runs alongside the length of Nordland County and the southern borderlands of Troms and Finnmark" (Facts About Northern Norway, 2021).[1]

The weather conditions in Northern Norway can be extreme but also moderate along the coastlines, even in winter, with the localized effects of the warm ocean water from the "Norwegian Current (the northeastern extension of the Gulf Stream), which carries four to five million tons of tropical water per second into the surrounding seas. This current usually keeps the fjords from freezing, even in the Arctic Finnmark region" (Christensen, Enander, Joys, Sandvik, & Weibull, 2023). The inland regions and higher elevations experience colder temperatures, and often the temperature differences between the coastal and inland areas can produce high winds. (Northern Norway, n.d.) The harsh conditions notwithstanding, the effects of climate change are also noticeable in the Arctic environment. The Norwegian Defense Research Institute *Defense Analysis 2023* recognized that "climate change will probably lead to ice-free summers in the Arctic by 2030. This could lead to new economic opportunities and increased activity" within the High North (Forsvarets Forskningsinstitutt, 2023). Figures 1 – 6 provide temperature ranges as a reference point from April 2022 to April 2023,



with both coastal, inland, and Svalbard locations represented in figures 1 - 5.

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[1] A map of Northern Norway is enclosed in Appendix A.

Figure 1 (above): Setermoen, Norway; located inland in Troms and Finnmark County, Norway (Yr, 2023).

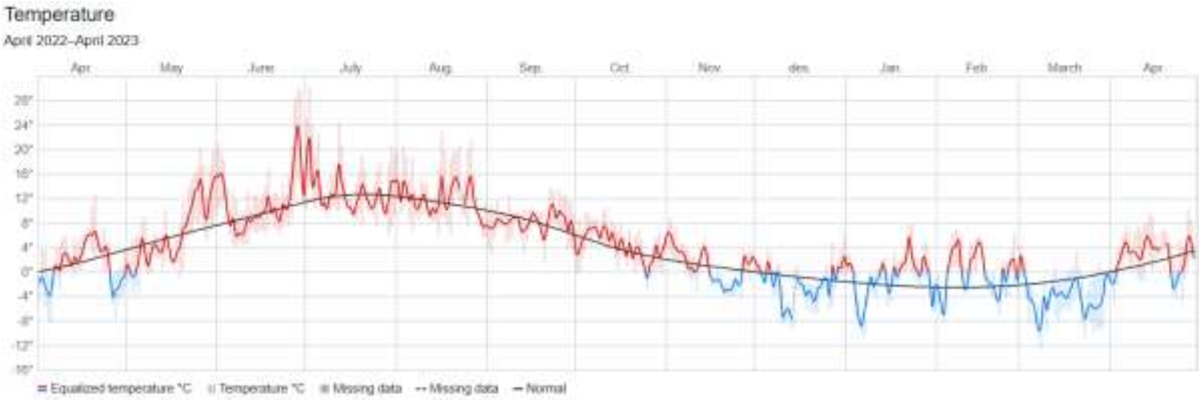

Figure 2 (above): Tromsø, Norway located on the coast in Troms and Finnmark County, Norway (Yr, 2023)

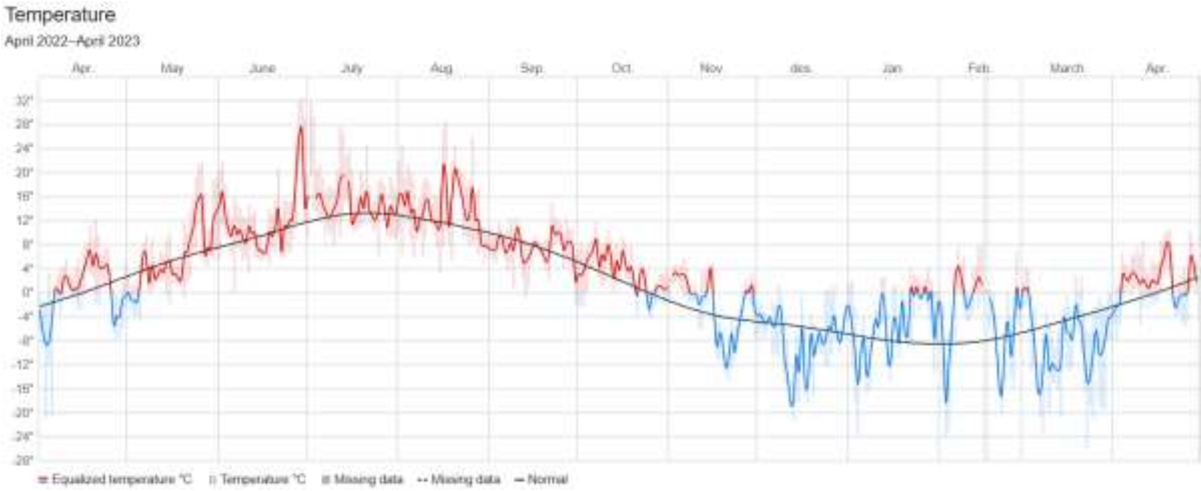

Figure 3 (above): Porsangmoen, Norway located inland in Troms and Finnmark County, Norway (Yr, 2023).

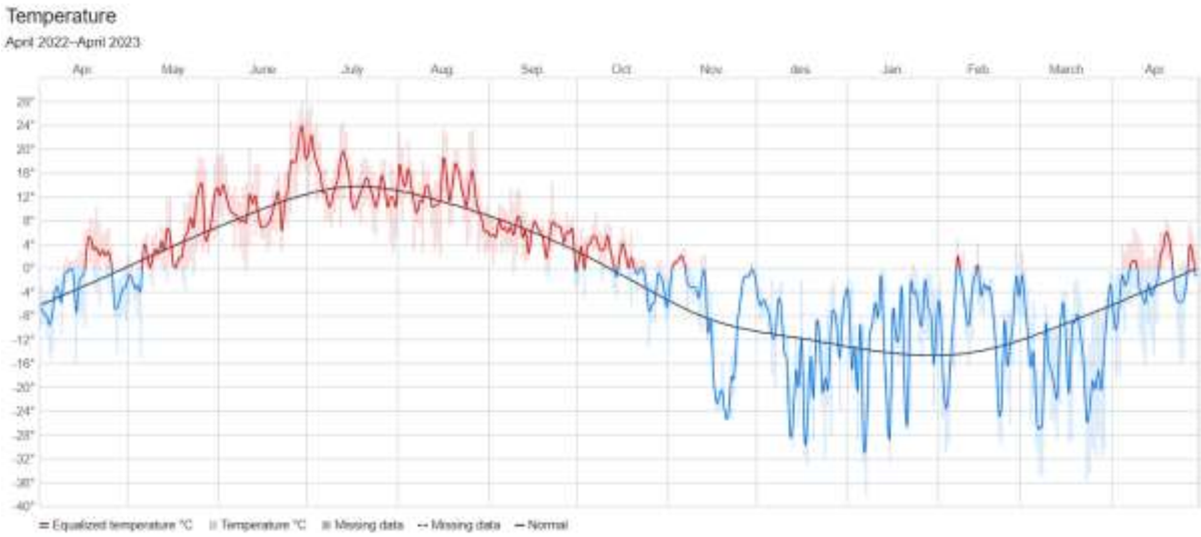

Figure 4 (above): Kautokeino, Norway; located inland in the Troms and Finnmark County, Norway (Yr, 2023).

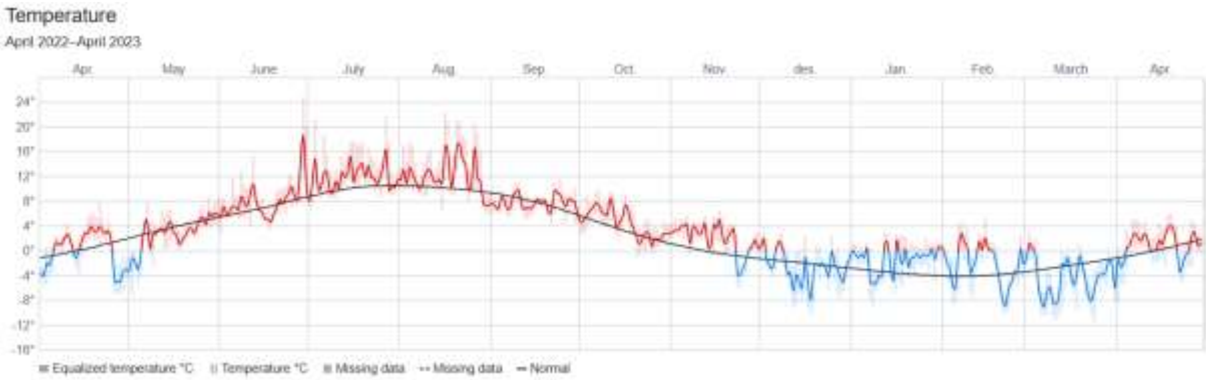

Figure 5 (above): Vardø, Norway; located inland in the Troms and Finnmark County, Norway (Yr, 2023).

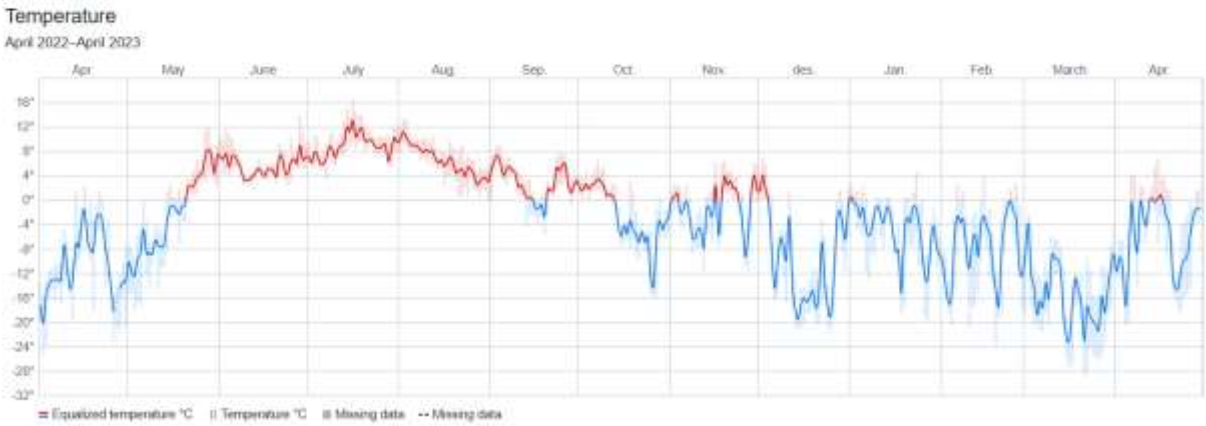

Figure 6 (above): Longyearbyen, Norway; located on the coast in Svalbard County, Norway (Yr, 2023).

The population of Norway was 5,391,369 inhabitants as of 1 January 2021, with a 17:3 ratio of residents per square kilometer (sq. km) living within the overall land area of 323,808 sq. km. The population density of Norway is the lowest in Europe after Iceland; "however more than 80% of the population live in urban areas where the population density is 1,991 residents per sq. km (2020)" (Norwegian Ministry of Transport, 2021). More than 75% of the population live within approximately 16 kilometers or 10 miles of the coastline with over half of the population concentrated in the country's southeastern region near the capital of Oslo (Encyclopedia of the Nations, n.d.). The Norwegian High North is home to approximately one-tenth of the Norwegian population, about 490,000 people (Hoglund, 2023). Most of the Norwegian civilian population is centered in main communities between vast stretches of rural land; the principal cities include Tromsø (41,434 people), Bodø (42,662 people), Narvik (14,035 people), Alta (15,784 people), and Kirkenes (3,384 people) (Statistics Norway, 2022). The areas inclusive of the former Finnmark Country, prior to the merger with Troms County to form the combined Troms and Finnmark County, account for 1.4 percent of the overall Norwegian population (Holm, With Russia on the Border: Is Splitting Troms and Finnmark Madness or Wise?, 2022). Understanding the Norwegian population concentration is essential for military planning, awareness of resource concentration, and likely population movements in a crisis scenario along ground lines of com.

Another critical aspect of understanding the operational environment in the Norwegian High North is the current infrastructure and broad overview of the ground lines of communication (road, rail, seaports), electrical energy generation within the Norwegian High North, the prominent civilian bulk fuel reserve locations, and note the larger airports or seaports. This section aims to provide an overview of civilian resources and infrastructure either present in Northern Norway or used to link Northern Norway to the rest of Norway or neighboring nations within linkages to electrical energy generation.

The main ground logistical line of communication from South to North is E-6; a typically narrow road in Northern Norway, often only divided by painted center lines, with limited road shoulders and many tunnels limited by height or narrow bridges limited by weight. Above the Arctic Circle (66” 33’ North) within Norway, E-6 covers over 1,379 kilometers which can take approximately 20 hours to drive at normal speed limits in civilian cars (Google maps). The Norwegian rail network connecting the High North to the rest of the country ends at Bodø. The Norwegian High North's only other rail network is the Ofoten line between Narvik, Norway, and the Swedish border. The Norwegian national rail network consists of over 4,200 kilometers of track, of which 65% is electrified utilizing power from the national power grid (Braekkan, 2020).

Generally, the regional petroleum energy resources are primary located within or near the population centers within the Norwegian High North. It is common to find more extensive bulk fuel petroleum storage in the larger cities along the coast due to the robust commercial maritime industry, and commercial gas stations are commonly located in population centers. It is less common to find commercial gas stations in rural areas between population centers (Iversen, 2022). Hydroelectric power chiefly generates electrical energy with main transmission lines branching from hydroelectric power plants located near population centers (International Energy Agency, 2022). One interesting consideration related to electrical energy in Norway is the profound shift that has been made from petroleum-fueled vehicles to electric cars or hybrid vehicles. During the last year alone, electric cars accounted for 80 percent of new car sales in Norway (Torch, May 8, 2023).

Large-capacity electric transmission lines currently do not connect northern Norway to the rest of the country. There are, however, existing electrical energy connections in the form of high-power transmission lines or shared power generation capabilities between Norway, Sweden, Finland, and Russia in the High North (International Energy Agency, 2022). Of specific interest is the Skogfoss Power Station, located in Northern Norway within Finnmark Country along the Norwegian and Russian border separated by the Pasvik River, which provides 25 percent of the electrical energy required for daily needs in Finnmark. The Norwegian and Russian border is marked in the center of the shared hydroelectric dam. If desired, Russia could limit water flow through the power station turbines on the Norwegian side of the border (Holm, Here, Russia Could Cut Off Eastern Finnmark's Power, 2023). While this has not occurred since the dam opened in 1964, the ability of Russia to quickly impact the national Norwegian electrical grid in Northern Norway is essential for awareness and supports efforts to increase military unit electrical energy self-sufficiency.

In summary, this section has provided an overview of the civilian resources and infrastructure present in the Norwegian High North, which can be linked to either electrical energy generation, transportation capacity to facilitate electrical energy generation or impact the ability of the Norwegian civilian electrical power grid to sustain consumer requirements in peacetime or crisis.

Military Concepts

United States Marine Corps Emerging Doctrinal Concepts

The Marine Corps emerging doctrinal concepts summarized and linked to the problem statement will include the *A Concept for Stand-in Forces*, *A Functional Concept for Maritime Reconnaissance and Counter-reconnaissance*, and *Expeditionary Advance Base Operations*. The following introductions of these concepts and supporting documents will provide the framework to examine further the problem statement in the context of these emerging doctrinal concepts. The intent is not to fully summarize each of these concepts but rather provide an introduction and link relevant components of each to the problem statement examined within the scope of this paper.

Each of these concepts was referenced in *The Commandant's Planning Guidance* published by General Berger, the 38th Commandant of the Marine Corps, on 15 July 2019, expanded on in *Force Design 2030* (March 2020), *Force Design 2030 Annual Update* (April 2021), and *Force Design 2030 Annual Update* (May 2022). *The Commandant's Planning Guidance* provided the framework and justification for the emerging Marine Corps doctrinal concepts introduced in this paper (Berger, Commandant's Planning Guidance, 2019).

> It serves as the authoritative document for Service-level planning and provides a common direction to the Marine Corps Total Force. It also serves as a road map describing where the Marine Corps is going and why; what the Marine Corps force development priorities are and are not; and, in some instances, how and when prescribed actions will be implemented (p. 1).

Force Design 2030, published in March 2020, outlines the transition from a legacy "force design, optimized for large-scale amphibious forcible entry and sustained operations ashore, has persisted unchanged in its essential inspiration since the 1950s (Berger, Force Design 2030, 2020, p. 2). This transition includes the reduction of certain capabilities (tanks, quantity of artillery systems, and personnel) and investment in other capabilities that allow for the Marine Corps to "focus to great power competition and a renewed focus on the Indo-Pacific…needed to support emerging joint, naval, and Marine Corps operating concepts" (Berger, Force Design 2030, 2020, p. 2). As described by General Berger, the Marine Corps' shortfalls included the following capabilities (Berger, Force Design 2030, 2020, p. 2).

> We have shortfalls in expeditionary long-range precision fires; medium- to long-range air defense systems; short-range (point defense) air defense systems; high-endurance, long-range unmanned systems with Intelligence, Surveillance, and Reconnaissance (ISR), Electronic Warfare (EW), and lethal strike capabilities; and disruptive and less-lethal capabilities appropriate for countering malign activity by actors pursuing maritime "gray zone" strategies.

One of the new units introduced in the *Force Design 2030* and subsequent annual updates is the conversion of several legacy infantry regiments into Marine Littoral Regiments (MLR). This unit is task organized to operate in the maritime littorals and "consists of an O-6 Headquarters, a Littoral Combat Team, a tailored Combat Logistics Battalion, and a Littoral Anti-Air Battalion (Berger, Force Design 2030: Annual Update April 2021, 2021, p. 3). The primary purpose of the MLR is to "maneuver and persist inside a contested maritime environment and conduct sea-denial operations as part of the naval expeditionary force to enable fleet operations" (The Marine Corps, 2022, p. 134). Several MLR tasks defined in the *Tentative Manual for Expeditionary Advanced Base Operations* are conducting sustainment operations within the weapons engagement zone, organic sensor capability, and communications capabilities to transmit targeting information to complete kill webs. All of which can be linked to electricity generation sustainment and the scope of this problem statement related to the Norwegian High North. As identified in the May 2022 *Force Design 2030 Annual Update,* "the challenge of providing distribution and sustainment in the context of our emerging concepts makes logistics the pacing function for both modernization and operational planning" (Berger, Force Design 2030: Annual Update May 2022, 2022, p. 11).

The Marine Corps published *A Concept for the Stand in Forces* on 1 December 2021 to define concept objectives and provide an implementation roadmap of this concept concerning Marine Corps operations. The concept's primary goal is to reassure Allies and establish deterrence towards potential military actors "by establishing forces designed to persist forward alongside allies and partners within a contested area, providing the fleet, joint force, interagency, and allies and partners more options for countering an adversary's strategy" (Berger, A Concept for a Stand-in Forces, 2021). Within a *Concept for the Stand-in Forces* (2021), the Stand-in Force (SIF) is defined as follows (Berger, A Concept for a Stand-in Forces, 2021).

> SIF are small but lethal, low signature, mobile, relatively simple to maintain and sustain forces designed to operate across the competition continuum within a contested area as the leading edge of a maritime defense-in-depth in order to intentionally disrupt the plans of a potential or actual adversary. Depending on the situation, stand-in forces are composed of elements from the Marine Corps, Navy, Coast Guard, special operations forces, interagency, and allies and partners. (p. 4)

The SIF concept relies upon the advancement of precision strike fires; specifically, the ability for these fires to be nested and linked into national and allied kill web chains. It is also dependent on the ability of small, mobile, distributed forces operating in the littorals to have the sustainment required to conduct extended operations on behalf of the Joint Force to ensure continued awareness in all domains as a reconnaissance and counter-reconnaissance force. The SIF concept publication and development was directed in General Berger's *Commandant's Planning Guidance* to articulate how the Marine Corps plans to support the Navy's *Distributed Maritime Operations* and compliment the *Expeditionary Advanced Base Operations* (EABO) concept.

A Concept for the Stand-in Forces describes the organization of the small forces conducting SIF operations as a series of layers relying on manned and unmanned sensors to maintain contact with potential advisories, which can provide critical operational awareness information to the joint force. These forces are envisioned to operate within the weapons engagement zone of possible advisories in the littorals and without the traditional larger-scale logistical support framework that Marine Corps entities have become accustomed to using during the land-locked ground wars that have defined the past several decades. The SIF concept depends on maintaining close and presentient relationships with allies to establish effective deterrence below, at, and above the level of conflict to conduct key tasks that include deterring potential opponents, reconnaissance and counter-reconnaissance, establishing control of key littoral terrain, and maintain the ability to effectively complete kill webs to project combat power. In summary, SIF employment within the operational environment defined by this paper will need to be able to conduct sustained operations within the arctic littorals alongside Norwegian Forces with an increased amount of equipment which requires electrical energy sustainment to be successful.

A Functional Concept for Maritime Reconnaissance and Counter-Reconnaissance was published by the Marine Corps in 2022 and describes "how the Marine Corps plans to further develop required capabilities in this area" as an "enduring function for SIF is to help the fleet and joint force win the reconnaissance and counter-reconnaissance battle at every point on the competition continuum (Berger, Force Design 2030: Annual Update May 2022, 2022, p. 2).

The *Tentative Manual for Expeditionary Advanced Base Operations* was published in February 2021 "was developed as part of an iterative process to test, refine, and codify the Concept for Expeditionary Advanced Base Operations signed in March 2019 by the Chief of Naval Operations and Commandant of the Marine Corps" (Headquarters Marine Corps , 2022, p. iii). The described purpose of the document is provide a baseline for further concept development, guide future experimentation efforts, the development of associated force structure in support of the outlined supporting concepts, and inform the development of Naval doctrine (Headquarters Marine Corps , 2022, p. iii). An Expeditionary Advanced Base (EAB) is defined in the *Tentative Manual for Expeditionary Advanced Base Operations* in the following manner (The Marine Corps, 2022, p. 20)

> An EAB is a locality within a potential adversary's WEZ that provides sufficient maneuver room to accomplish assigned missions seaward while also enabling sustainment and defense of friendly forces therein. Its expeditionary nature means it is not permanent and must be able to change location quickly enough to maintain relative advantage.

In an article by Terje Bruøygard, titled *New US Maritime Concept Could be Crucial for Norway* (originally written and published in Norwegian), he outlines how EABO may be misunderstood from a Norwegian perspective without further context (Bruøygard, 2021).

> There may be a danger of misunderstanding the size and scope of this concept. With Norwegian eyes, we can easily be led to imagine small patrols under a tent cloth with binoculars and connections on an island in an archipelago. That's far from reality. It is more likely to think Norwegian small towns with airstrip, port and railway. At the same time, it is essential to understand that the bases should not be permanent.

In summary, an introduction to the Marine Corps emerging doctrinal concepts is essential for exploring the problem statement presented by this paper in the context of the Norwegian High North.

Norwegian Armed Forces

The 2020 Norwegian Government Long Term Defense Plan, published on 17 April 2020, describes the defense of Norway as supported by "three main lines of effort; national defense, the collective defense within the framework of NATO, and bilateral support and reinforcement arrangements with close allies" (Norwegian Ministry of Defense, 2020, p. 4). The national defense capabilities include the *Total Defense Concept* – an important concept that will be discussed separately from existing national defense capabilities. The Norwegian national defense capabilities in Northern Norway will only be described generally to provide the context of their sustainment requirements but not in detail. The selected collective defense agreements and the *Total Defense Concept* will be described in greater detail to provide a better understanding of the agreements in place, the entities associated with these separate agreements, and the impact these forces will have on the limited electrical energy resources in the event of a conflict or national crisis.

The Norwegian Armed Forces consist of a separate Air Force, Army, Navy, Defense Logistics Organization, Defense Materiel Agency, Cyber Defense, Special Forces, and the Home Guard. Facilities and facilities services are provided by the Norwegian Estate Agency – which holds the responsibility for all Norwegian government facilities – inclusive of military installations. While under review for opportunities for increased funding application, the 2020 Norwegian Government Long Term Defense Plan provides baseline capabilities of the Norwegian Armed Forces.

The Norwegian Armed Forces has two critical doctrinal documents related to resources in the High North. The first is the *Concept for Host Base Support* which outlines the method and processes which will be used to provide support to deploying Allied forces (Commander Norwegian Joint Headquarters, 2019). The second is the *Total Defense Concept* which codifies a whole-of-society approach to the defense of Norway and outlines the roles and responsibilities of the military, Government, and civilian society (Norwegian Ministry of Defense, 2020, pp. 16-17).

One unique legal element in place as part of the *Total Defense Concept* is the Requisition Law, which provides the standing legal framework for the Norwegian Government to take immediate ownership of civilian assets or property in times of national crisis with the stipulation of compensation. The Requisition law can also be used in times of peace to facilitate training opportunities throughout

Norway, without limiting training to existing military ranges or bases, withrior coordination and compensation to civilian owners (Forsvaret, 2022).

Five Key Relationships

An understanding of both the international and domestic support agreements which are in place today, linked to the defense of Norway, and applicable to the scope of this paper's focus of the Norwegian High North is equally important. From my perspective, there are five key relationships that are essential to understand in the context of the defense of the Norwegian High North (both as resource consumers and resource requirement generators) and provide the basis for nations to contribute military forces that regularly train in Norway.

United States Marine Corps and Norwegian Armed Forces

The first relationship is between the Marine Corps and the Norwegian Armed Forces, codified in standing bilateral defense plans, inclusive at a higher level of Department of Defense agreements like the Supplementary Defense Cooperation Agreement (United States Department of State, 2021). It is also essential to highlight the Marine Corps Pre-positioning Program – Norway, its associated agreements, and the role this program serves as a tangible example of the Marine Corps' commitment to reinforcing Norway and regional deterrence messaging. The Marine Corps equipment associated with this program is directly linked to the re-enforcement of Norway, available for global Marine Corps requirements, and is located in Norwegian facilities throughout Trøndelag County, Norway. The equipment and program are frequently used to support Marine Corps training exercises in Northern Norway. The program describes itself as the premiere Marine Corps cold weather equipment advocate and storage program and advocate. This is based upon the globally unique and mature program interoperability partnership that has been developed for over 30 years with Marine Corps-trained Norwegian maintenance personnel maintaining Marine Corps equipment and Norwegian logistical personnel advising the Marine Corps on equipment utilization; to include employment in the Norwegian Arctic environment (The United States Marine Corps, 2015, pp. 24-29).

Joint Expeditionary Force

The second key relationship important for operational awareness is the Joint Expeditionary Force (JEF); a political-military agreement led by the United Kingdom which provides the command and control for contributing member nation forces under the deployable Standing Joint Force Headquarters (SJFHQ) based in Northwood, England. There are currently 10 member nations; inclusive of NATO and non-NATO states which makes this framework distinct as there is no requirement for group consensus prior (as in the NATO framework) to initiate collective action against emerging threats. "This flexibility also means the JEF can act against ambiguous hybrid threats that fall under the threshold of NATO's Article 5 or the European Union's Article 42(7) protection guarantees. Given their conventional superiority, hybrid threats are still the most likely form of Russian aggression against NATO members (Monaghan, 2022). The JEF's primary focus is on Northern Europe, including the High North, Baltic, and North Atlantic, and nations can contribute task-organized forces at their discretion. The JEF member nations include Denmark, Estonia, Finland, Iceland, Latvia, Lithuania, the Netherlands, Norway, Sweden, and the United Kingdom. Contributing countries regularly conduct training in Northern Norway. Awareness of this framework is essential to understand within the broader context of organizations operating in the High North.

Nordic Defense Cooperation

Another key framework is the Nordic Defense Cooperation (NORDEFCO). Its main purpose is to "strengthen the participants' national defense, explore common synergies and facilitate efficient common solutions" (The Nordic Defence Cooperation, n.d.); member nations include Denmark, Finland, Iceland, Norway, and Sweden. While this framework does not have a standing force structure, it is designed to facilitate interoperability and cooperation between member states. Non-member nations also can engage in cooperative efforts at the military level for specific areas of activity. This is the primary reason for inclusion in this paper, given the potential for NORDEFCO to serve as a future 'resource gateway' for Arctic-related electrical energy materiel or interoperability solutions (The Nordic Defence Cooperation, n.d.). The current political situation in Europe and the ongoing war in Ukraine will only contribute to increasing the importance and utilization of this framework by member states (Government.no, 2022).

United Kingdom and Norway

The fourth bilateral relationship critical to understanding the allied military force posture in Northern Norway is between the United Kingdom and Norway. United Kingdom miliary forces have a sustained presence in Northern Norway, primarily in the winter months, at Bardufoss Air Force Base and Camp Viking for most of the year. The British Army annually conducts arctic rotary wing aviation training. It annually deploys forces to Bardufoss Air Force Base for five to six months a year to qualify personnel in arctic aviation and operations (Harding & Wills, 2019). The United Kingdom ground forces primarly are located at a recently completed facility named Camp Viking near the Norwegian Army Skjold Camp. Camp Viking is located at Øverbygd, approximately 25 miles east of Bardufoss Air Force Base in the Troms region, and has supported the training of roughly 1,0000 British Commandos during the 2022 – 2023 winter training period (Nilsen, 2023).

Netherlands and Norway

The final bilateral relationship described within this paper is between the Netherlands and Norway. The Dutch Royal Marines conduct their annual winter training in Northern Norway utilizing the former Norwegian Naval base at Olavsvern and other training facilities (Hole & Sterkeby, 2022). During the 2023 JOINT VIKING exercise, 800 Dutch Royal Marines participated in the annual winter training, hosted by the Norwegian Armed Forces and designed to prepare Allies for the harsh conditions of the Arctic (Bye, 2023). The inclusion of this relationship is linked to the requirement for awareness of adjacent Allied military forces conducting regular training in the Norwegian High North.

Norway and NATO

The Kingdom of Norway was one of the original founding member states of NATO in 1949 following the conclusion of the Second World War (Norwegian Ministry of Foreign Affairs, n.d.). NATO membership has been integrated into every aspect of the national defense of Norway; reinforced by regular staff contributions to NATO missions, ensuing compatible weapon systems, training, shared doctrinal standards, and incorporating NATO processes into formal Norwegian military education at the Norwegian Defense University College Staff College (Norwegian Ministry of Defense, 2020).

I believe increased leadership awareness of the Norwegian High North operational environment will allow for more advocacy toward solutions that will provide increased operational flexibility, staying power, and ultimately enable sustained combat power projection. I assume the implementation of emerging Marine Corps doctrinal concepts tied to increased capabilities at the tactical size units will be increasingly linked to the future requirement for these units to conduct longer duration self-sustained distributed operations. This assumption re-enforces the importance of understanding the existence of other entities conducting operations in Northern Norway, both on a regular basis and during times of crisis is critical for leadership and subordinate element to understand as it relates to the availability of local resources. The United States Marine Corps will not be the only entity seeking resources from the local economy or the Norwegian military. While the Norwegian Armed Forces are responsible for de-confliction within Norway and High North, the requirement for de-confliction must be understood and acknowledged in the Marine Corps Planning Process as standing plans are refined.

In summary, the overview of the Norwegian Arctic environment and related military concepts introduced many complexities associated with conducting military operations in the Norwegian High North. It established a baseline understanding of the operational environment for the analytical framework discussed in Chapter 3.

Chapter 3: Theory and Methods

This chapter aims to connect the problem statement of electrical energy self-sufficiency with a useful model of analytical explanation and how to analyze the problem statement of this paper. This will be accomplished by first defining the DOTMILPF-I system, further examining and exploring the *materiel*, *interoperability*, and *training* elements of the DOTMILPF-I system, and lastly summarizing how this theoretical model will be used to scrutinize the electrical energy self-sufficiency problem statement.

A Model of Explanation

The United States Department of Defense (DoD) Joint Capabilities Integration Development System Process is the framework used to design administrative changes and guide acquisition efforts to fill capability shortfalls. This framework identifies the key elements of capability development and can be used to describe any capability. The DoD defines these vital elements as *Doctrine, Organization, Training, Materiel, Leadership, Personnel, and Facilities* – or commonly referred to as DOTMLPF (JP 1-02, Department of Defense Dictionary of Military and Associated Terms, 15 August 2011). The North Atlantic Treaty Organization (NATO) extends the key elements identified within the DoD framework to include the area of *Interoperability* in *DOTMILPF-I* in their definition of a capability. NATO defines capability as, "the ability to create an effect through employment of an integrated set of aspects categorized as doctrine, organization, training, materiel, leadership development, personnel, facilities, and interoperability" (NATO Standardization Office, 2021, p. 45).

This paper will utilize the NATO framework, as defined by AAP-06(2021), to focus on the *materiel* and *interoperability* elements and the additional supporting framework provided through an examination of *training* to examine the problem statement. These three elements were selected as the most relevant to describe and examine the problem statement and possible solutions. Additionally, these three elements, *training, materiel*, and *interoperability* will be discussed together to demonstrate how it is possible to connect these elements to the problem statement and deterrence.

Training

NATO defines *operational training* as "training that develops, maintains or improves the operational readiness of individuals or units" (North Atlantic Treaty Organization, 2016, p. 118). This element of the NATO DOTMILPF-I system will be used to understand and provide another approach to examine how electrical energy self-sufficiency can be explored within the scope of this paper. The *Joint Analysis Handbook* written by NATO's Joint Analysis and Lessons Learned Centre in Lisbon, Portugal provides specific questions linking the assessment of *training* to the DOTMILPF-I framework; these questions from table 4 will be used in the problem statement analysis later in chapter 5 (North Atlantic Treaty Organization, 2016, p. 45).

Training	How are training results being measured and monitored? Is the issue caused by a lack of competency or proficiency on existing systems and equipment? Is the issue caused, at least in part, by inadequate or a complete lack of training? Does training exist which addresses the issue? Is the training being delivered effectively and in a timely manner? Was the issue discovered in an exercise? Do personnel affected by the issue have access to training? Is command/management supporting and/or enforcing the training effort? Is training properly staffed and funded?

Materiel

This is the second element selected to describe the current capabilities being utilized to sustain tactical-size units conducting distributed operations within the Arctic environment. One point of interest identified during the research for this paper is the difference in the definitions for the words *material* and *materiel.* NATO defines *materiel* as "the items used to equip, maintain and support military forces in their activities. note(s): materiel includes software, but excludes real estate, installations, and utilities" (NATO Standardization Office, 2021, p. 105). *Material* is defined as "stuff that you use to do or make something" (Britannica, n.d.). The *Joint Analysis Handbook* written by NATO's Joint Analysis and Lessons Learned Centre provides specific questions linking the assessment of materiel to the DOTMILPF-I framework (North Atlantic Treaty Organization, 2016, p. 45).

Materiel	Is the issue caused, at least in part, by inadequate (outdated) systems or equipment? What current systems are in the Family-of-Systems where the problem is occurring? What functionality would a new system provide that currently does not exist? What increases in operational performance are needed to resolve the issue? Is the issue caused by a lack of competency, proficiency or maintenance on exiting systems and equipment? Can increases in performance be achieved without development of a new system? If so, how? Who would be the primary and secondary users of the proposed systems or equipment?

Chapter 5 will utilize the questions above to analysis the solutions identified within Chapter 4 of this paper and provide the framework for a detailed examination of the proposed solutions.

Interoperability

NATO defines *interoperability* in *AAP-6, NATO Glossary of Terms and Definitions* (2021 Edition, p. 71.) as "the ability to act together coherently, effectively and efficiently to achieve Allied tactical, operational and strategic objectives." NATO further defines *military interoperability* as "the ability of military forces to train, exercise and operate effectively together in the execution of assigned missions and tasks" (NATO Standardization Office, 2021, p. 83). Military interoperability can also be explored within the elements that connect military forces as they train, exercise, and operate together; including technology, communications, processes or procedures, and common professional language (North Atlantic Treaty Organization, 2016). The questions outlined in Table 4 within the *Joint Analysis Handbook* written by NATO's Joint Analysis and Lessons Learned Centre will provide the framework for a detailed examination of proposed *interoperability* solutions in chapter 5 (North Atlantic Treaty Organization, 2016, p. 46).

Interoperability	Is the issue due to problems with interoperability? If so, what type of interoperability? Is the technology interoperable? Are the processes and procedures interoperable? Is it a human interoperability problem?

This paper will seek to answer the problem statement: how to improve electrical energy self-sufficiency for tactical-size units conducting distributed operations above the Arctic Circle. How can the problem statement be improved based on a theoretical model? Figure 6 illustrates the relationship between the three selected NATO DOTMILPF-I capability elements: *training, materiel*, *interoperability,* and electrical energy self-sufficiency.

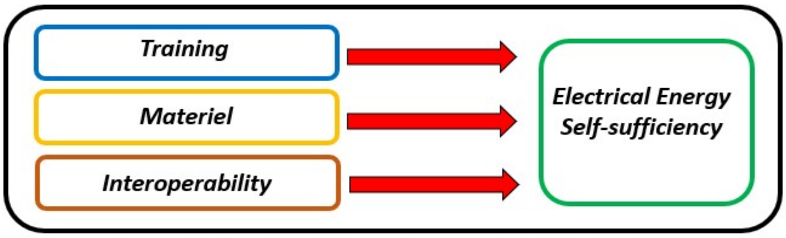

Figure 7: Combined Theoretical Model of Explanation

Based on this model, my hypothesis can describe the effects of how training, materiel solutions, and interoperability can improve electrical energy self-sufficiency. These energy solutions could decrease reliance on the Norwegian national power grid, reduce strain on petroleum stores in crisis situations, and be utilized globally by the Marine Corps in other operational areas.

Evaluating the Collected Data (Reliability)

The problem statement and hypothesis were examined through a contemporary review of training conducted by the Marine Corps in Northern Norway from 2018 to April 2023, a review of current materiel solutions and processes used by Marines to address tactical size unit electrical energy requirements within the Arctic environment, and review of existing interoperability relationships in place between Marine Corps and Norwegian entities related with to this topic.

A literature review was also conducted on materiel related to the identified emerging Marine Corps doctrine concepts using primary sources. The primary sources included *The Commandant's Planning Guidance (2019), A Concept for Stand-in Forces (2021), A Functional Concept for Maritime*

Reconnaissance and Counter-Reconnaissance (2022), *Expeditionary Advance Base Operations (2022)*, *Force Design 2030* (March 2020), *Force Design 2030 Annual Update* (April 2021), *Force Design 2030 Annual Update* (May 2022), and *Headquarters Marine Corps, Prepositioning Handbook 3rd Edition*. The secondary sources included *21st Century Foraging, Powering EABO: Aluminum Fuel for The Future Fight, Reexamining Distributed Operations.* While other sources were studied during the research for this paper, this list includes most materiel reviewed related to the emerging Marine Corps doctrinal concepts.

Numerous documents were reviewed describing the United States and Norwegian Government political level policies and positions related to the Arctic, the development and utilization of emerging technology, hydrogen technology development, and hydrogen technology employment linked to tactical size unit energy application in the Arctic environment. While not inclusive, the United States government political level documents reviewed included the *Supplementary Defense Cooperation Agreement*, *2018 National Military Strategy, 2018 National Defense Strategy, 2022 National Security Strategy,* and *Department of the Navy Climate Action 2030.* The Norwegian government documents included the *Defense Analysis 2023, National Transport Plan 2022–2033, Concept for Host Base Support, the Norwegian Government's hydrogen strategy,* and *Total Defense Concept* documents*.* Hydrogen development and employment documents reviewed included *Making Hydrogen Fuel Anywhere: ONR Tests Prototype to Power Marines in Expeditionary Environments, Army engineers support Marines' expeditionary hydrogen generation demo,* and *Using aluminum and water to make clean hydrogen fuel — when and where it's needed*.

An examination of current military entities either conducting training operations in the Norwegian High North or linked to standing political agreements for the defense of Norway were also examined using open-source information. Significant effort was also taken to review and understand the current United States military, Department of the Navy, and Marine Corps organizational policy documents related to expeditionary energy. Information related to existing relationships between the Marine Corps and Norwegian research entities, specifically the Norwegian Defense Research Institute and the Marine Corps Expeditionary Energy Office, was solicited and received from organizational communications offices via email. Implied organizational bias is acknowledged regarding the data received from the organizational communication's offices. It was also confirmed that specific research initiatives related to hydrogen are in development but were not able to be shared by the Norwegian Defense Research Institute for inclusion in this project due to information-sharing restrictions (A. Melkevik, personal communication, March 17, 2023). Additional Marine Corps related energy initiatives were also identified during the research phase but could not be included in this paper due to United States Government information-sharing restrictions.

Additionally, a significant portion of the data related to the contemporary review of the training conducted by the Marine Corps in Northern Norway from 2018 to April 2023 and interoperability relationships with the Norwegian Armed Forces is based on the on my own observations or notes. I served as the Deputy Officer in Change for Marine Coordination Element - Norway from October 2017 to July 2021 supporting the Marine Rotational Force – Europe rotations and other Marine Corps training activity in Norway. Subsequently I attended the Norwegian Defense University College as the Marine Corps Exchange Officer during the 2021 – 2022 academic year, and then returned in October 2023 to serve as the Marine Coordination Element – Norway Officer in Charge. These assignments provided a unique perspective of Marine Corps training activity and exercise areas of focus as I assisted with the logistical support coordination, supported or observed operational planning of these training events, and facilitated real-world life support for all participating Marine Corps units during this period. This included facilitating payments by the United States Government for Norwegian-supplied petroleum used by the Marine Corps during training throughout Norway. My background as a Marine Corps Supply Officer, with extensive experience in logistical support, knowledge and understanding of both Marine Corps and Norwegian operational and logistical processes, and Marine Corps European Foreign Area Officer accreditation (Billet Military Occupational Specialty 8247) provides the basis for the inclusion of my observations as part of this paper. While organizational bias must be addressed as part of the critical review of my observations and notes, it is also important to note that access to an extended period of training events in one country by a single individual is rare, given the rotational nature of Marine Corps assignment management. Traditionally Marine Corps personnel only remain in the same assignments for an average of two to three years before transitioning to the next role.

One significant challenge related to the development of this paper was the limited existing information-sharing agreements directly linked to research associated with increasing energy self-sufficiency between the Marine Corps and the Norwegian Government. The second challenge identified during the research is the limited information available that can be shared without classification restrictions. This assessment of the over-classification of information was re-enforced recently by General Berger, the 38th Commandant of the Marine Corps comments at the Navy League's Sea-Air-Space panel in National Harbor, Maryland on 3 April 2023. "Sometimes we get in our own way, by over-classifying, over-compartmentalizing," he said. "And yet we say our strategy is underpinned by allies and partners. You can't have it both ways" (Loewenson, 2023). The restriction of information sharing or classification level of data unfortunately limited some of the findings that could not be included in the paper but also contributed to identifying solutions for increasing future interoperability opportunities.

Finally, my own bias must be addressed as a Marine Corps Officer researching a topic directly linked to emerging organizational, doctrinal concepts must be acknowledged while asserting every effort has been made to remain objective in providing critical analysis of the information reviewed during the development of this paper. The analytical framework described in chapter 3 against the background of the Arctic environment overview in chapter 2 will be further explored in chapter 4 to understand the current status Marine Corps arctic energy solutions and initiatives.

Chapter 4: The Quest for Energy Self-Sufficiency

This chapter aims to describe the contemporary status of how electrical energy is currently generated in the arctic environment and future possibilities to set the conditions for an empirical analysis within chapter five. This will be done by exploring how the Marine Corps has generated electrical energy over the past five years within the Arctic environment as part of *Named Exercises* or other training events in Northern Norway. This examination was conducted utilizing three different methods; first, an analysis of exercise objectives related to energy through a review of confirmation briefs available from Marine Forces Europe and Africa to determine if electrical energy is linked in any way to training objectives, secondly from a review of the Marine Corps Center for Lessons Learned (MCCL) After Action Reviews produced by units who participated in training in Northern Norway, and third a review of my own observations taken during this period.

Current Status

The conventional methods for the Marine Corps units to obtain electrical energy within the arctic environment in the Norwegian High North include the usage of national power grid electricity, reliance on petroleum fuel generators to create electrical energy for local requirements, or utilization of traditional batteries; ranging in size from AA batteries for personal equipment to larger car or military radio batteries. The Marines Corp has long recognized the limitations and risks of petroleum-based energy generation. This issue has been the subject of significant research and studies on a wider scale.[2]

The following scenario can help illustrate the current cultural, process, and organizational challenges facing the Marine Corps when addressing electrical energy self-sufficiency for tactical-size units conducting operations in the Arctic. While not attributed to a specific event, similar instances have occurred multiple times during my tenure supporting the Marine Corps training in Northern Norway between 2018 – 2023.

"Good Evening," said the young Marine as he walked into the Marine Coordination Element – Norway office at Setermoen Leir, looking a bit flustered as he entered the office late on a Friday afternoon. "What can we do for you?" asked the Staff Sergeant, who was Marines assigned to coordinate site support for Marines training in Norway. "I am the unit supply representative and

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[2] United States Department of Defense. (2011, May). *Energy for the Warfighter: Operational Energy Strategy.* Retrieved from United States Department of Defense: https://www.acq.osd.mil/eie/Downloads/OE/Operational%20Energy%20Strategy,%20Jun%2011.pdf

have been tasked to buy working replacement AA batteries for our equipment as we are going to the field tonight," the young Marine said. He elaborates further, "the batteries we brought with us from the United States don't work anymore." "What do you mean they don't work anymore?" asked the Staff Sergeant. "Well, Staff Sergeant, they have been staged in our unit supply quadcon (shipping container) since we completed embarkation for winter training five weeks ago," said the young Marine as he warmed his hands. "The same quadcon that has been sitting outside in the snow since you arrived a week ago with – 24 degree Celsius temperatures?" asked the Staff Sergeant. "Didn't it also travel via ship to Norway and sit in the port for several days before getting delivered here to Setermoen Leir?" "Yes," replied the young Marine; "we didn't know this would be a problem. Is there anywhere we can buy new batteries nearby? I have to get enough for all our Marines…we have 85 here to do winter training." The Staff Sergeant thought for a moment and replied, " the closest large electronic store that is open is likely about 2 hours away in Tromsø, but you may not make it before closing…the best idea for you to do is to visit the three area gas stations and buy what you can. Hopefully, that will be enough to support your training before you can drive up to Tromsø tomorrow morning." The young Marine nodded, "thank you, Staff Sergeant – we will see what we can find. I will ensure that any extra batteries are stored inside once we buy them, but it likely will not be enough for what I have been told to procure."

While perhaps a humorous illustration that may seem easily avoidable it is worth understanding several different background processes that the Marine Corps use related to purchasing and moving batteries from an organizational perspective. The first item to understand is that the Marine Corps purchases items like batteries in bulk, normally from the General Services Administration or other designated sources of supply. The batteries are then usually packed in metal shipping containers and shipped, typically via surface vessel or less often, flown to the deployment training location. In either transportation scenario, the metal shipping container will likely remain outside in the elements, which can be quite cold during winter months within the Arctic Circle. Finally, it is critical to understand from an organizational perspective the junior Marines normally responsible for loading and staging containers upon arrival may not know to store the batteries in a climate-controlled environment – which can lead to scenarios similar to the illustration. Thus while significant in the illustration for the Marines attempting to participate in the cold weather training in Northern Norway, if increased in scope and connected to a real-world requirement for the re-enforcement of Norway – this would have a significant effect on the combat readiness of the Marines due to the limitation of their equipment. The current Marine Corps use of batteries for tactical size unit employment is further explored through the experience of 2D Reconnaissance Battalion Marines who supported JOINT VIKING 2023 in March of 2023 later in this chapter.

The subject of expeditionary sustainment is a trending topic within Marine Corps professional forums as solutions for sustainment linked to the challenges of the Stand-In Force are presented and debated. *Marines need Regenerative Logistics* written by Major Dustin Nicholson (USMC) received the first prize of the U.S. Naval Institute Proceedings 2022 Marine Corps essay contest. The article advocates for a logistical revolution to provide the Stand in Force (SIF), described in chapter 2, more autonomous freedom of maneuver that is not constrained by traditional sustainment methods like "push – pull" which are described in current Marine Corps Logistical doctrine (MCWP 4-1).[3] He advocates for the Marine Corps to "embrace regenerative logistics technologies…to fundamentally transform sustainment resiliency" (Major Dustin Nicholson, 2022). Most importantly from my perspective, he asks a fundamental question: "staying power has always come either from the rear or from local foraging…what if the sustenance for SIF could be created at the point of need instead of having to be pushed or pulled from an external source of supply" (Major Dustin Nicholson, 2022)? I believe that "regenerative logistics" is key for sustaining tactical size forces conducting distributed operations within the arctic region; primarily related to electrical energy generation and storage. Major Nicholson defines *regenerative logistics* as a closed system of sustainment in which SIF produce, consume, reproduce, and consume organically with limited outside support (Major Dustin Nicholson, 2022)" His article briefly highlights efforts related to Marine Corps electrical energy self-sufficiency by primary focusing on advances in both solar and regenerative braking technologies. From my perspective, while these are critical components of a diverse energy generation solution, the Marine Corps needs to ensure that the power generation technologies incorporated into future portfolios also include components that can operate in extreme cold weather conditions or for extended periods of limited to no light conditions.

Electrical energy generation in the Arctic continues to rely primarily on petroleum-based power generation solutions or battery-based electrical energy sources for tactical-size units from a Marine Corps organizational perspective despite advocacy for increased use of alternative energy sources. With a specific focus to the Norwegian High North, as outlined within the scope of this paper, a

[3] Marine Corps Warfighting Publication (MCWP) 4-1, *Logistics Operations* was replaced by MCWP 3-40, *Logistic Operations* on 2 May 2016. This publication was replaced by Headquarters United States Marine Corps on 21 March 2023 with the publication of Marine Corps Doctrinal Publication 4, *Logistics.* The most current publication can be found at mcdp-4_logistics-21M https://www.marines.mil/Portals/1/Publications/MCDP%204.pdf?ver=B_yc-7HbsNYVAprJJouImQ%3d%3d ar2023r.pdf (marines.mil).

review of Marine Corps of cold weather training confirmation briefs or associated exercise documentation available from Marine Forces Europe and Africa or MCCL did not identify any specific lines of effort to electrical energy power generation from 2018 – April 2023. This review also identified that there has not been a particular focus of effort or intent of capturing best practices related to increasing electrical energy self-sufficiency during this period associated with Marine Corps training objectives. Additionally, while localized information has been captured by individual units conducting training, no established venue for this information to be jointly examined in a systematic manner between the Marine Corps and the Norwegian Armed Forces was identified. This finding was reinforced by the Marine Forces Europe and Africa G-35 (Current Operations) Nordics Desk Officer who was not aware of any related Marine Corps lines of effort associated with *Named Exercises* or other Marine Corps training in Norway (M. Janiga, personal communication, March 14, 2023).

Photo: The Marine Rotational Force Europe 23.1 Mobile Command Center was powered by a traditional petroleum-based generator during JOINT VIKING 2023 in Northern Norway. Photo credit: Mathew Vaughn March 2023

Interoperability between the Marine Corps and Norwegian entitles will be examined on two different levels for the purposes of this paper; one within the NATO definition of tactical size units conducting training in Northern Norway and one organizational level. It is important to note that these examples are not all-inclusive of existing relationships but have been selected to highlight the current forums of cold weather training in the Norwegian High North to explore further opportunities combining training, materiel, and interoperability linked together toward a common goal of increasing electrical energy self-sufficiency within the Arctic environment by military units to generate the effect of deterrence.

The Norwegian Army Military Intelligence Battalion, a subordination unit within the Brigade North Force Structure, at Setermoen Leir has established exchange relationships with the Air Naval Gunfire (2D ANGLICO) and the 2D Force Reconnaissance (2D RECON) Battalions. Both of these units are subordinate units under the II Marine Expeditionary Force and regularly conduct annual cold-weather winter training. The training occurs yearly, often in conjunction with the JOINT VIKING or NORDIC RESPONSE (formally COLD RESPONSE) exercise series. Annually both large-scale exercises take place in Northern Norway within the Inner-Troms region and focus on developing lines of effort associated with the re-enforcement of Norway or regional allies; including command and control, long-range precision fires, intelligence, interoperability, and tactical unit cold weather operational proficiency. Common throughout is the preparation of cold weather training that the Norwegian Military Intelligence Battalion provides for 2D RECON and 2D ANGLICO Marines.

JOINT VIKING 2023 was the large-scale exercise conducted in Northern Norway between 6 – 16 March 2023. This training venue provided an opportunity to understand the current approach Marine Corps tactical-size units are utilizing to sustain their electrical energy requirements. The information was provided to me by 2D RECON Marines participating in the exercise during an after-action review. Specific names have been withheld due to security considerations. Still, the individuals are known to me based on personal interaction as part of his Marine Coordination Element - Norway assignment.[4]

During their initial JOINT VIKING 2023 After Action Review discussions, the 2D RECON team identified that their electrical energy sustainment was provided by standard commercially available batteries consisting of AA, AAA, and 123 single-use commercial lithium and alkaline batteries. The Marine Corps also primarily uses two different types of lithium batteries for organizational electrical equipment or "green gear" known as a "2590" or "5590" battery. The 5590 batteries are non-re-chargeable, and while some are still in use, most are currently being phased out, with the "2590" rechargeable batteries being used as a replacement capability. During the eight-day field exercise associated with JOINT VIKING 23, each team member on a standard 6 – 8 person team carried approximately (20) – (40) AA batteries and (14) – (21) AAA batteries for their standard issue personal electronic equipment. One designed team member was also required to carry (11) 123 type batteries and an additional (14) 2590 batteries were distributed throughout the team. There was not any type of expeditionary energy capability used by the Marines in the field to recharge their batteries while conducting the eight-day field training exercise.

As a general range, the temperatures experienced ranged from – 10 F below zero to 20 F above during their field operation during JOINT VIKING 23 execution window 6 – 16 March 2023. The 2D RECON team shared that their (14) 2590 battery performance varied greatly; primarily due to the temperatures based on the location or geographical elevation of the Marines conducting the exercise. Their alkaline AA or AAA batteries last about 15 minutes in a cold weather conditions

[4] Data from observations from JOINT VIKING 23 After Action Review participation on 15 March 2023.

normally encountered during their training in Northern Norway. As a general observation, the Force Reconnaissance Marines also observed that the lithium batteries perform better in any environment than the Alkaline batteries – not explicitly tied to cold weather.

During this past exercise, some Marines maintained their personal batteries in a plastic bag against their body, some used a fanny pack against their body, and the third option was a commercial thermal pouch commonly used for cameras or cell phones. The thermal pouches were commercially obtained from an outdoor hiking store to test methods of increasing battery life. Initial results from this non-scientific experiment showed that the batteries stored further away from body did not sustain their charge. In contrast, the lithium batteries stored in plastic bags against the body performed second best. The batteries stored in the commercial thermal pouch performed the best as a general rule based on the experience of the Marines. The alkaline batteries generally did not hold their charge in the cold weather experienced by the Marines, regardless of the storage method. The background of this experimentation of extending battery life was driven primarily by the unit's desire to explore strategies that extend their operational capabilities without adding additional weight. This experimentation was not directed by either unit leadership or assigned as a formal task as a part of either the exercise objections or a larger research effort.

Another observation observed in the field by the Marines was that the 2590 batteries were able to maintain change in the cold weather environment however they need to be pre-warmed before use either against the body or in a sleeping bag. The approximate time for warming required before use during JOINT VIKING 23 was 20 minutes. Interestingly, the batteries occasionally appeared to have lost their charge (based on their internal sensor) until after warming, when the battery would present with a full charge. It was not identified in the initial After Action Report comments which type of 2590 battery was utilized by the Marines during their training deployment. Further research has determined several different 2590 battery types; with at least one 2590 battery designed to be utilized at lower temperatures than more widely used versions (Bren-Tronics, n.d.). It was also shared that the 2590 batteries were used to change open purchased electrical equipment essential to the core mission tasks and power optical equipment, computers, and phones as a best practice to extend the operational usage in the field environment.

Integrating the 2D RECON Marines with the Norwegian Military Intelligence Battalion allowed for the localized transfer to knowledge and best practices related to extending current batteries within the Arctic weather environment between personnel. It also allowed for awareness of the Norwegian

Military Intelligence Battalion's efforts to conduct their own research and record best practices regarding processes and methods to extend the battery life of mission essential equipment. While awareness of this data set was given to me, it could not be included in this report due to information restriction limitations. It does, however highlight the potential opportunities that exist at the tactical level which could be leveraged more formally with the appropriate information-sharing agreements linked to existing training events to more widely share existing data associated with electrical energy requirements for small-size units conducting independent and dispersed tactical operations in the High North environment. One way to explore a more formal method of information sharing is to examine the current organizational research entities within the Norwegian Government and Marine Corps that are exploring expeditionary energy challenges and solutions.

Figure 8: Marine Corps Expeditionary Energy Office Emblem. (D. O. Diaz, personal communication, April 28, 2023).

The Marine Corps Expeditionary Energy Office is the office with the responsibility of developing and advocating the United States Marine Corps' energy strategy. It is located aboard Marine Corps Base Quantico in Quantico, Virginia. "The Marine Corps Expeditionary Energy Office's (E2O) role is to advise the Marine Requirements Oversight Council (MROC) on all energy and resource related requirements, acquisitions, and programmatic decisions" (D. O. Diaz, personal communication, April 28, 2023). This role is accomplished by a small staff who "analyze, develop, and direct the Marine Corps' energy strategy in order to optimize expeditionary capabilities across all warfighting functions" (D. O. Diaz, personal communication, April 28, 2023).

The EO2 Office confirmed there is no existing relationships with the Norwegian Government or research institutes; nor are there any coordinated activities currently in place to use *Named Exercises* as experimentation venues for existing research projections in Norway. There is a willingness for future collaboration between EO2 and Norwegian military or research entities pending approval from the appropriated United States authorities. EO2 did confirm that there are existing research projects that leverage the use of hydrogen and an energy carrier however details could not be released for this research project due to information-sharing restrictions. (D. O. Diaz, personal communication, April 28, 2023)

The Norwegian Defense Research Institute (FFI) is the premier institution responsible for all defense-related research and development in Norway. It is a Norwegian government entity that conducts contract research, publishes scientific articles, and provides detailed academic analysis on a wide range of topics – both for the Norwegian defense sector and the Norwegian government. The organization has also researched electrical energy power generation specific to Arctic operations. This research has included sponsoring the collaboration forum titled "the Arctic Warrior Experiment," ICE worx, and other research initiatives.

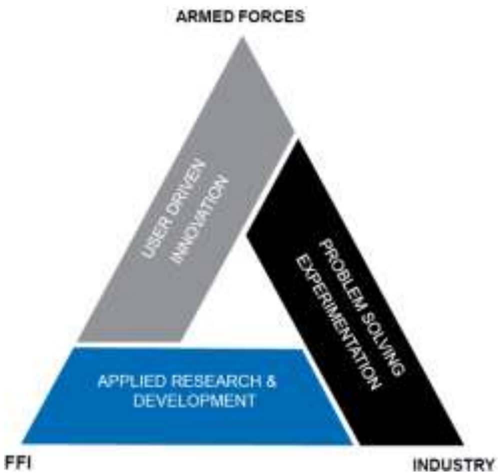

Figure 9: ICE worx relationships *(Norwegian Defense Research Institute, 2023)*

Figure 10: Arctic Warrior Experiment Emblem. (Norwegian Defence Research Establishment, n.d.)

The Arctic Warrior Experiment is a "technical experiment (TE) modeled after the United States Special Operations Command TE with the main purpose of challenging industry and research community to develop new concepts and military equipment that increase the winter warfighters' capabilities in an Arctic environment" (Norwegian Defence Research Establishment, n.d.). The forum enables Special Operations Forces representing Norway, the United States, the United Kingdom, Canada, Australia, New Zealand, Sweden, Denmark, and Finland to engage with leading industry experts "to share experiences, discuss concepts and participate in experiments and demonstrations of new arctic capabilities" associated with Arctic operations at the tactical unit level (Norwegian Defence Research Establishment, n.d.). The event is hosted every two years by the Norwegian Special Operations Command and the Special Operations Research and Development project at the Norwegian Defense Research Institute (Norwegian Defence Research Establishment, n.d.).

The last conference, held 23 – 27 January 2023 at Rena, Norway, focused on the "Remote Effects Delivery adapted to the Arctic environment" and included the following areas of interest: loitering munitions, UXV-platforms (Air, Ground, Sea)[5], GNSS-denied operation and navigation[6], link systems

[5] UxV is a term used to reference unmanned or robotic vehicles in the air, ground, maritime surface and subsurface domains. From "*Pentagon Gets $7.5 Billion for Unmanned Systems,"* J. *Harper, 2021 (*[Pentagon Gets $7.5 Billion for Unmanned Systems (nationaldefensemagazin https://www.nationaldefensemagazine.org/articles/2021/5/27/pentagon-gets-$7-5-billion-for-unmanned-systems e.org)]())

[6] Global navigation satellite system (GNSS) is a general term describing any satellite constellation that provides positioning, navigation, and timing (PNT) services on a global or regional basis. From "*Other Global Navigation*

for use in a contested environment, sensors and effectors, remote safety systems for arming an firing of effectors, and battery and power supply (Norwegian Defence Research Establishment, n.d.). The ability of the Marine Corps to leverage this Technical Experiment and biennial forum through a relationship with the Norwegian Defense Research Establishment represents a unique, while little-known venue to capture current and emerging solutions to arctic operation electrical energy challenges.

Another Norwegian Defense Research Institute program of interest is called ICE worx and functions as "a center for innovation, concept development, and experimentation in an arctic environment" (Norwegian Defense Research Institute, 2023). ICE worx was established in 2020 and is establishing or expanding its offices at five locations throughout Norway, including at Horten, Rygge, Rena, and one in Northern Norway. The specific ICE worx focus for the Arctic environment includes but is not limited to "solutions for communication and navigation in a GPS-denied area, autonomous systems, sensors and Artificial Intelligence to improve reconnaissance, and situation awareness and decision support" (Norwegian Defense Research Institute, 2023). The organization has four distinct components, organized by their organizational structure (personnel and resources), arrangements ('tech talks" "outreach," or assessments" and problem-solving competitions), portfolio (projects categorized as approved, preparation, finished, or stopped), and sites and infrastructure (opened sites or sites under development).

I would describe ICE worx as an accelerator for concepts and materiel solutions designed to mitigate the defense sector's unique challenges. An accelerator in business terms is defined by Susan Cohen of the University of Richmond and Yael Hochberg of Rice University in an article written by Ian Hathaway in the Harvard Business Review as having "four distinct factors that make accelerators unique: they are fixed-term, cohort-based, and mentorship-driven, and they culminate in a graduation or "demo day" (Hathaway, 2016). This description ideally fits the framework provided by ICE worx; with their focus on Iterative processes, cooperation, 360-degree perspectives, and modular systems approach to facilitate faster transitions from experimentation to the fielding of new solutions" (Norwegian Defense Research Institute, 2023). The Norwegian Defense Research Institute is also able to leverage their decades of experience with a focus on "scientific research, cooperation with industry, and experimentation venues available through the Norwegian Armed Forces to develop within a 12 to 36 month period the rapid fielding of proven modules based on user-centric experimentation and accessible technology" (Norwegian Defense Research Institute, 2023). Figure 7

Satellite Systems (GNSS)," U.S. Space Force, 2021 ([GPS.gov: Other Global Navigation Satellite Systems (GNSS)]())

below illustrates the activities encompassed by ICE worx (Norwegian Defense Research Institute, 2023):

Figure 11: IEC worx activities (Norwegian Defense Research Institute, 2023)

The Norwegian Defense Research Institute ICE worx program management confirmed there is currently no existing relationship with the Marine Corps tied connected to either *Named Exercises* or electrical energy self-sufficiency (S. Gundersrud, personal communication, March 30, 2023). There is, however a willingness for future collaboration and information sharing between the Norwegian Defense Research Institute if the appropriate data exchange agreements are implemented (A. Melkevik, personal communication, March 21, 2023).

Future Possibilities

One recent technological advancement with significant implications for generating energy in the Arctic environment that has moved past the emerging technology phase and into prototype experimentation is using aluminum as fuel to generate hydrogen. The use of aluminum as a fuel source to generate hydrogen by combining it with both water and specific alloys was discovered by Massachusetts Institute of Technology (MIT) researchers. Further studies by MIT researchers have developed functional guidelines for using scrap aluminum to generate hydrogen with water at room temperature and explore the implications of both the size of aluminum pieces as well as the implications of including different metal alloys (Stauffer, 2021). “Fundamentally, aluminum becomes a mechanism for storing hydrogen — and a very effective one,” says Douglas P. Hart, professor of mechanical engineering at MIT. “Using aluminum as our source, we can ‘store’ hydrogen at a density that’s 10 times greater than if we just store it as a compressed gas” (Stauffer, 2021). This process and the associated advancements with building functional systems that can generate hydrogen represent a critical component to both addressing the issues of sustainment and holds significant potential for

Arctic energy solutions.

This advancement and possible implications for the Marine Corps were described in an article titled *Powering EABO: Aluminum Fuel for The Future Fight* written by Captain Walker Mills, Major Jacob Clayton, and Erik Limpaecher. The article received the first prize essay contest in the August 2022 *Marine Corps Gazette* and is another example of how electrical energy self-sufficiency importance is growing in cultural significance within the Marine Corps. Their article sagely captures both the challenges and the opportunity the Marine Corps has to use the recently developed MIT process to generate hydrogen from aluminum. The authors advocate that this discovery could address the energy sustainment challenges posed by EABO and SIF distributed operations and reduce the risk of sustainment operations to Marines conducting operations within weapons engagement zones. I agree with the authors' assessment describing the importance of logistics within the context of the developing Marine Corps doctrinal concepts (Mills, Clayton, & Limpaecher, 2022).

> Logistics, specifically expeditionary logistics, will be critical in the success or failure of the Marine Corps' new concept Expeditionary Advanced Base Operations, and hydrogen can help overcome the logistics challenges inherent to EABO and future operations to power the Marine Corps.

I also strongly with their assessment that "too little attending has been paid to the promise of petroleum alternatives for powering EABO" (Mills, Clayton, & Limpaecher, 2022, p. 82). I believe petroleum alternatives must be actively explored and tested in any available venue to address this critical limitation. What are some possible alternative solutions?

The prototype Hydrogen Tactical Refueling Point (H-TaRP). (Photo: USMC/Lance Cpl Cheyenne Stillion) (The Shephard News Team, 2022)

One initiative exploring possible solutions to Marine Corps expeditionary energy requirements was sponsored by the Office of Naval Research Global TechSolutions program, which can generally transition emerging concepts into initial prototypes within 12 months. The Office of Naval Research funded research conducted by the Massachusetts Institute of Technology (MIT) Lincoln Laboratory to operationalize the previously described process, discovered at MIT, to convert aluminum into hydrogen fuel in support of Marine Corps expeditionary energy requirements. "The technology used for the hydrogen production requires mixing activated aluminum pellets with water to produce high-pressure hydrogen within 30 minutes and dispense it into a hydrogen fuel tank 20 times per day" (Aliotta, 2021). The initiative prototype, named the hydrogen tactical refueling point or "H-TaRP" system includes "an aluminum dispenser, reactor vessel, water cooling system and a control system manifold to fill an H2 tank" (Hochenberg, 2022). "This technology has the potential to create an expeditionary system for the generation and delivery of hydrogen needed to power operations in support of the Expeditionary Advanced Base Operations / Distributed Maritime Operations tactical construct," said Jason Payne, TechSolutions director at the Office of Naval Research Global" (Aliotta, 2021).

The H-TaRP prototype is demonstrated at Camp Lejeune, N.C. H-Tarp is designed to provide power to forces in expeditionary environments by combining water with aluminum to create hydrogen fuel. (U.S. Navy photo by David Taylor) (Hochenberg, 2022)

The H-TaRP prototype was compatible with hydrogen fuel cell technology, converted aluminum into hydrogen fuel, and easily assembled by Marines who received minimal instruction during a demonstration at Camp Lejeune, North Carolina in February of 2022. The system can utilize any water source, freshwater, salt water, or urine, to produce hydrogen. Minimal sound is made during production, and the process emits steam as the residual exhaust of the chemical reaction(Hochenberg, 2022). Minimal training was also required to establish and start hydrogen production during the demonstration at Camp Lejeune (Hochenberg, 2022).

> During the field demonstration, junior infantry Marines received a brief tutorial on assembling the H-TaRP system and fire teams of up to four warfighters practiced putting it together a couple of times. After one iteration, they assembled the system in just 13 minutes — showing the H-TaRP device could be deployed quickly with minimal training.[7]

The Marine Corps Office of Expeditionary Energy confirmed in March of 2023 that the while the H-TaRP system demonstrated significant potential for future application more developmental work was required to meet Marine Corps expeditionary energy requirements.

Another example of an existing Marine Corps program of record that can generate electricity independent of petroleum is the Ground Renewable Expeditionary Energy Network System (GREENS). GREENS is solar-based electrical energy generation system combined with high energy density batteries for energy storage. Unfortunately, this system is only rated for operations at - 4

[7] US Navy Research. (2022, February 14) *Making Hydrogen Fuel Anywhere: ONR Tests Prototype to Power Marines in Expeditionary Environments* [Video]. Youtube. https://youtu.be/TYRilJU_lo0

degrees Fahrenheit or – 20 degrees Centigrade which could limit the operational effectiveness in arctic weather conditions (Marine Corps System Command, n.d.). However, this stated operational limitation should not preclude the potential use of this system or similar systems within the arctic environment in an experimental setting to confirm operational parameters or explore methods to enable effective operation at lower temperatures.

Other examples of Marine Corps tactical power generation and storage are under development however due to current information restriction guidance, these additional examples could not be included in this paper. However, the confirmation of program development initiatives currently underway within this area of research is important to acknowledge as an opportunity for future joint collaboration at the tactical level for testing or organizational level for research effort partnerships.

The utilization as hydrogen as an energy carrier is not a new concept. Today there are buses, cars, and other equipment that are powered either exclusively by hydrogen or utilize hydrogen as an energy fuel source as part of a hybrid fuel solution (Mills, Clayton, & Limpaecher, 2022). However, this technology has yet to be introduced into the mainstream solutions associated with military energy sources despite the existing technology and possible benefits. This portion of the paper will introduce current hydrogen research related to defense applications and provide a basic understanding of how hydrogen can be used as a fuel or energy carrier. It will set the informational conditions to explore further the potential opportunities to leverage hydrogen as an energy carrier, specific to arctic operations, within chapter 5.

Norway has an advanced hydrogen commercial and industrial sector compared to other nations supported by the Norwegian Government, as the utilization of hydrogen is one method the Norwegian government is pursuing to address climate change emission targets. The Norwegian government published a comprehensive strategy in 2020 titled *The Norwegian Government's National Hydrogen Strategy* outlining government-sponsored application initiatives, providing a baseline understanding of the current hydrogen generation and utilization technologies, and commercial or government (including military) applications (Norwegian Ministry of Petroleum and Energy and Norwegian Ministry of Climate and Environment, 2020).

Hydrogen generation is Norway is primarily reliant on "two main technologies [which are] currently commercially available on the market: Alkaline electrolysis and polymer electrolyte membrane (PEM) electrolysis" (Norwegian Ministry of Petroleum and Energy and Norwegian Ministry of Climate and

Environment, 2020, p. 13). The *Norwegian Government's National Hydrogen Strategy*, published in 2020, notes that both technological processes are relatively developed but not beyond the threshold of further innovation. Figure 12 provides a graphical depiction of the process to generate hydrogen (Norwegian Ministry of Petroleum and Energy and Norwegian Ministry of Climate and Environment, 2020, p. 14).

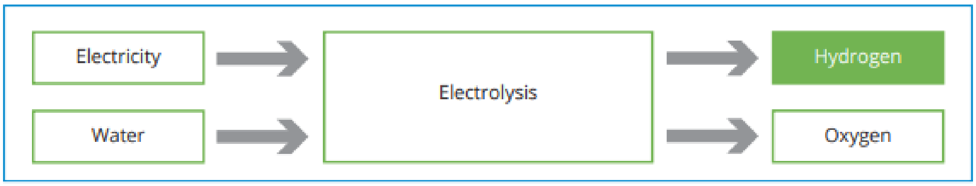

Figure 12 shows electrolysis – using electricity to separate water into hydrogen and oxygen.

"Since hydrogen has a low energy density per unit of volume under normal pressure compared with other energy carriers…its energy density must be increased in order to improve the efficiency of its storage, transport and use" (Norwegian Ministry of Petroleum and Energy and Norwegian Ministry of Climate and Environment, 2020, p. 16). This can be achieved by compressing the hydrogen gas, liquefying at -253 degrees centigrade, or converting it into other hydrogen-rich substances like ammonia for industry use or safer transportation (Norwegian Ministry of Petroleum and Energy and Norwegian Ministry of Climate and Environment, 2020).

Hydrogen as a fuel source can be converted into electricity, with steam and oxygen as the only emissions, which makes its utilization as a fuel source or energy carrier an attractive consideration for military applications. In terms of application within the Norwegian High North, heat (via steam) could easily be utilized to help sustain military personnel conducting operations in the harsh climate. As an energy carrier, hydrogen, hydrogen does not lose its energy potential in extremely cold weather. "According to the U.S. Department of Energy, hydrogen fuel cells paired with electric motors are two to three times more efficient than an internal combustion engine running on gasoline, further—hydrogen gas has nearly three times the energy density of gasoline" (Mills, Clayton, & Limpaecher, 2022, p. 83). However, it also has a major challenge with military application, which is the safe transportation of the hydrogen to the point of application. I believe this has been the largest barrier to introducing this technology into military use applications despite the available technology for using hydrogen across many different applications. The safety consideration specific to bulk transportation could be addressed by the recent MIT discovery of how to use aluminum, as demonstrated by the H-TaRP prototype, to generate hydrogen at the point of need. Clearly, more consideration must be given to developing safety processes and procedures related to the employment of hydrogen as a fuel source or energy carrier in a military environment. The handling of dangerous goods (like fuel or explosives) is commonplace within the military environment, which supports the case that potential safety issues are not insurmountable. The *Norwegian Government's National Hydrogen Strategy* describes in detail the safety considerations for hydrogen employment; this knowledge, combined with the increasing commercial industry usage of hydrogen in Norway, makes partnerships with Norwegian research entities ideal to further Marine Corps military application research.

As described, the Norwegian Government's Ministry of Petroleum and Energy and Norwegian Ministry of Climate and Environment comprehensive hydrogen strategy outlines their initiatives to leverage hydrogen as part of a national strategy for increased energy self-sufficiency and mitigate conventional fuel environmental impacts. Specifically, as related to military application, the strategy emphasized how "new power supply systems with hydrogen as the energy carrier can reduce the probability of unwanted detection of…military units, and also reduce fuel expenses and the negative environmental impact of the Armed Forces' activities" (Norwegian Ministry of Petroleum and Energy and Norwegian Ministry of Climate and Environment, 2020, p. 29). More importantly, the strategy underscored how hydrogen can be used to "to generate electricity in the field, where other power sources are less practical or available" (Norwegian Ministry of Petroleum and Energy and Norwegian Ministry of Climate and Environment, 2020). From my perspective, these statements represent a strong endorsement from the Norwegian Government's political level to enable the Norwegian Armed Forces to engage in experimentation. This is an opportunity for the Marine Corps to leverage this willingness for experimentation through interoperability and more rapidly develop solutions for the identified problem statement.

In summary, this chapter provided a contemporary overview of how electrical energy has been generated or utilized in the Norwegian Arctic environment by Marine Corps tactical size units conducting training from 2018 – March 2023 and identified existing interoperability relationships between Norwegian Army and Marine Corps units linked to existing training events. Existing Marine Corps and Norwegian entities or initiatives were recognized at the organizational level with the identification of future possibilities related to identifying emerging technological methods for energy generation and utilization of hydrogen as an "energy carrier" in the Arctic environment. The information shared within this chapter set the conditions for empirical analysis of the problem statement in chapter five by combining the Norwegian Arctic environment information shared in chapter two and the analytical framework presented in chapter three.

Chapter 5: Empirical Analysis

This chapter aims to explore how to improve electrical energy sustainment in the Arctic environment. Electrical energy sustainment will become increasingly important as the reliance on integrated electronic sensors and the necessity to convey digital information across an extensive network rapidly becomes synonymous with the ability of modern military forces to project combat power. The current war in Ukraine and the effects of technology integration within the conflict support the importance of examining how this electrical energy sustainment.[8]

The empirical analysis of this paper's problem statement will be conducted by the structure and data presented in chapter 4 in accordance with the combined theoretical model of explanation (figure 6). This discussion and examination will be conducted to understand better how electrical energy generation and sustainment challenges within the arctic environment can be mitigated to ensure that Marine Corps and Norwegian military forces can sustain themselves in the best manner possible. Thus creating conditions for combined increased combat power projection that can be linked to increased deterrence in the Norwegian High North.

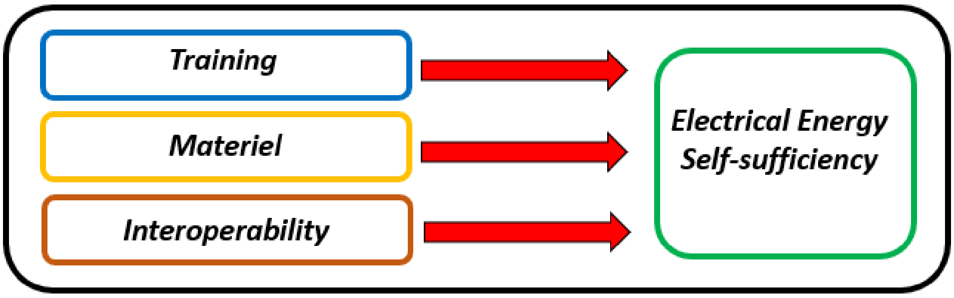

Figure 7: Combined Theoretical Model of Explanation

Training

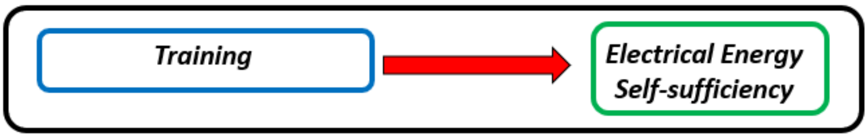

Figure 13: Training Theoretical Model of Explanation

The Marine Corps and the Norwegian Armed Forces conduct regular annual training exercises focused on the mission rehearsal of the Marine Corps re-enforcement to Norway in accordance with existing defense agreements. A majority of this training occurs during winter months between November and May each calendar year, with the main exercise either event either a NORDIC

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[8] Hambling, D. (2023, March 1). *Ukraine's Next-Generation Drone Fleet Is Packed With Upgrades.* Retrieved from Forbes: https://www.forbes.com/sites/davidhambling/2023/03/01/ukraines-next-generation-drone-fleet-enhances-capabilities/?sh=5d00596c2b45

CNN. (2022, May 13) *See how Gamers are Outwitting and Helping to Kill Russian Soldiers* [Video]. Youtube. https://youtu.be/TYRilJU_lo0

RESPONSE exercise series during even calendar years or JOINT VIKING exercise series during odd calendar years. Other regular training events, including the NATO Cold Weather Winter Instructor Course, the Norwegian Military Intelligence Battalion hosted Long Range Winter Patrol Course, and other *Named Exercise* events occur each year in the Norwegian High North.

The NATO Joint Analysis Handbook outlines nine questions associated with the NATO assessments framework connected to the DOTMILPF-I framework element of *training*. These nine questions will be used to guide the examination of the data gathered as part of the research conducted for this paper and examine the status of electrical energy challenges and possible solutions (North Atlantic Treaty Organization, 2016).

1. How are training results being measured and monitored?
2. Is the issue caused by a lack of competency or proficiency on existing systems and equipment?
3. Is the issue caused, at least in part, by inadequate or a complete lack of training?
4. Does training exist which addresses the issue?
5. Is the training being delivered effectively and in a timely manner?
6. Was the issue discovered in an exercise?
7. Do personnel affected by the issue have access to training?
8. Is command/management supporting and/or enforcing the training effort?
9. Is training properly staffed and funded?

The first challenge associated with this problem statement is that a review of the *Named Exercise* events from 2018 to April 2023 revealed that electrical energy generation has not been considered an area of exercise objective for Marine Corps. This assessment is based on a review of *Named Exercise* After Action Reviews (AARs) and my observations while supporting training events in Norway during this period. Specifically, my role in assisting Marine Forces Europe and Africa G-4 (logistics) and G-35 (current operations) with the exercise life cycle logistical planning for these events provided awareness of exercise objectives linked to sustainment. Thus without specific electrical energy generation or sustainment training objectives linked to *Named Exercise* events, the training conducted, particular to this paper's problem statement, was not examined as a direct focus of any training result survey or data collection plan. Instead, the re-occurring theme within the Marine Corps exercise AARs linked to Marine Corps or *Named Exercises* cited the issues with using standard issue Marine Corps equipment batteries or commercial batteries in cold environments. These findings were re-reinforced by the Marine Forces Europe and Africa G-5 (plans) assessment branch (B. Hudson, personal communication. March 15, 2023).

A review of the contemporary Marine Corps winter training in Norway also identified that electrical generation and storage systems utilized energy generation solutions tied to legacy petroleum-based energy generation or battery systems. Thus, when examining questions 2 – 5, I believe the main issue is not a lack of training but rather a limitation of systems (separate from petroleum or battery-based solutions) that can function in extremely cold weather, designed to support distributed operations and address the logistical supply concerns within a contested environment associated with legacy petroleum systems or batteries. Finally, as the remaining questions 6 – 9 are examined, the most relevant questions that apply to this paper's problem statement are questions 8 and 9. Based on my observations supporting Marine Corps training in Norway during this period, adequate funding is generally not an issue that prevents Marine Corps participation in winter training events. The exercise costs may help determine which units and capabilities are prioritized for training and participation numbers vary year to year based on the *Name Exercise* construct. Still, there has been consistent Marine Corps participation in training events in the Norwegian High North. This training is supported by the staff from the deploying unit, II Marine Expeditionary Force, and Marine Forces Europe and Africa, emphasizing training exercise objectives defined as part of the exercise objectives. However, these training objectives, from the documentation reviewed and my observations during the observation period, have not included electrical energy-specific exercise objectives.

In summary, I believe the failure to date to include electrical energy generation as part of a training exercise scenario and the inclusion of energy sustainment within a contested environment as a consideration is primarily due to historical assumptions developed over time. These assumptions have allowed Marine Corps units to assume access to electrical energy in a "real-world" permissive environment separate from the exercise scenario. This trend has led to this area's failure to be included in the exercise planning life cycle as an exercise objective, planning consideration, and subsequent inclusion in a data collection plan associated with detailed analysis.

Materiel

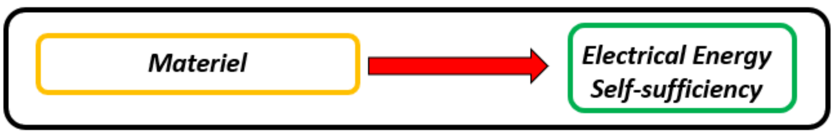

Figure 14: Materiel Theoretical Model of Explanation

The NATO Joint Analysis Handbook outlines seven different questions associated to the NATO assessments framework connected to the DOTMILPF-I framework element of *materiel* as described in chapter 3. The below selected four questions have been determined to be most relevant and will be used to examine the data gathered as part of the research conducted for this paper to explore the status of electrical energy challenges and related possible materiel solutions (North Atlantic Treaty Organization, 2016).

1. Is the issue caused, at least in part, by inadequate (outdated) systems or equipment?
2. What current systems are in the Family-of-Systems where the problem is occurring?
3. What functionality would a new system provide that currently does not exist?
4. Who would be the primary and secondary users of the proposed systems or equipment?

From my perspective, the challenges of electrical energy sustainment, specific to the Norwegian High North, are not necessarily linked to inadequate or outdated systems as petroleum-based electrical energy generation, battery-supported distributed operations, and utilization of national grid electrical resources have been used without issue during the training events conducted during this period. This includes using Norwegian military and commercial gas stations for refueling, locally procured batteries, and fixed infrastructure to recharge battery systems. I believe the largest materiel consideration specific to the current family of systems used for electrical energy generation (questions 1 and 2), is the high level of comfort the Marine Corps as a war-fighting organization has towards expecting sufficient petroleum resources to be available if the environment is no longer permissive but contested in the Norwegian High North. I believe this assumption and possible unintentional assumption of risk associated with expecting sufficient petroleum resources to support and sustain Marine Corps units conducting operations extend to the successful transportation of petroleum to units conducting distributed operations in the Norwegian Arctic. This assessment is based upon observations and logistical planning considerations observed during training conducted during the noted period. The transportation considerations related to electrical energy generation will be elaborated upon further within the discussion section of this chapter.

A new system not directly linked to petroleum-based electrical energy generation would provide a greater degree of self-sufficiency which in turn provides increased combat power projection (in terms of time) compared to historical limitations placed on the availability of either traditional battery or petroleum-based electrical energy generation. Specifically, hydrogen as a fuel source and energy carrier (battery) within the Arctic environment offers several clear advantages. First, the technology to use hydrogen as a fuel source is known and currently commercially available across a wide variety of applications, from powering unmanned aerial vehicles (UAVs), ground vehicles, and aircraft (Mills & Limpaecher, 2021). The H-TaRP prototype development and demonstration described in chapter 4 provides three key developments with specific applications to the scope of this research project, based on the article titled *Making Hydrogen Fuel Anywhere: ONR Tests Prototype to Power Marines in Expeditionary Environments* written by Scott Hochenberg. The first observation is the fielding of a prototype system utilizing the recent discovery of aluminum as a fuel for hydrogen production on a scalable level; utilizing a system small enough in size for tactical unit operational usage. This emerging technology application, specific to utilizing aluminum as a fuel source to generate hydrogen, is no longer limited to development laboratories and has transitioned to the practical application, refinement, and deployment stage. The second observation is the demonstration and development of this system was focused on meeting global Marine Corps expeditionary requirements; without considering the High North applications. This is a key point as the article describes the possible use of the steam, emitted as an exhaust from the chemical reaction, as a source of distilled drinking water but not a sustainable heat source (Hochenberg, 2022). From my perspective, a potential heat source that can also provide energy for immediate usage and storage, safely transported within the battle space (using aluminum fuel stock) by tactical size units, should be evaluated within the Norwegina High North environment.

The primary and secondary users of the proposed systems or equipment are Marines conducting tactical size distributed operations, as described within the emerging doctrinal Marine Corps concepts linked to the *A Concept for a Stand-in Force*, *A functional Concept for Maritime Reconnaissance and Counter-reconnaissance*, or supporting *Expeditionary Advanced Base Operations*. *Force Design 2030* describes "forces that can continue to operate inside an adversary's long-range precision fire weapons engagement zone (WEZ) are more operationally relevant than forces which must rapidly maneuver to positions outside the WEZ in order to remain survivable" (Berger, Force Design 2030, 2020, p. 5). Therefore, the goal is to advocate for electrical energy sustainment systems that will extend these Marines' operational capability and support allied forces like the Norwegian military, government, or civilian actors in the Norwegian High North. These systems, however, must be designed to be operated with minimal training requirements as the legacy luxury of assuming a large enough force for relatively continuous logistical sustainment in a contested environment must no longer be assumed. The ability for the H-TaRP prototype development and demonstration represented described in chapter 4 to be operated by Marines who received minimal training must be extended into further development to ensure that this element of low operator training requirements is maintained as future systems are developed.

The Marine Corps must also work to maintain an understanding of the Norwegian *Total Defense Concept* as the re-enforcement of our Norwegian Allies will not only include simply re-enforcing

Norwegian military forces but an integrated military–civilian force linked to operational concepts that defend the Norwegian society as a whole. I believe this understanding must not stop at the Norwegian *Total Defense Concept* awareness but be actively extended into the existing exercise scenarios so that Marine Corps tactical units become familiar with how to interact with this model in a crisis scenario. The war in Ukraine has demonstrated that Western-based ideals connected the "law of armed conflict" are no longer a defense against civilian infrastructure or populations; Marine Corps planners and leadership alike must also recognize this within the operational environment of the Norwegian High North.[9]

Specifically, Marine Corps organizational or tactical units cannot assume the availability of commercially procured petroleum or electrical energy from commercially procured batteries or national electrical grid access in a contested environment in the Norwegian High North. The concept of Marine Corps "foraging" as a sustainment tool was outlined within the *Tentative Manual for* Expeditionary Advanced Base Operations published by Headquarters Marine Corps in February of 2022 (Headquarters Marine Corps , 2022, p. 102). Peter Thermos and Angel Maldonado gave another definition of this concept in an article titled *21st Century Foraging* published in the March 2021 Marine Corps *Gazette*. They defined "21st century foraging as the local commercial procurement of non-standard logistics, supplies, and services as a means of extending our survivability and mobility to sustain maritime operations" (Thermos & Maldonado, 2021, pp. 50-53). Awareness of this concept linked to the described emerging Marine Corps doctrinal concepts is essential for Norwegian military understanding. It is also crucial for Marine Corps planners and leadership to recognize that other Allied military forces may also be operating in the Norwegian High North as described in chapter 2. The employment of "21st century foraging" by Marine Corps units conducting operations in the Norwegian High North to leverage commercially available resources to sustain electrical energy requirements through direct procurement (using credit cards or Norwegian currency) should not be assumed without detailed coordination with the Norwegian Military as described within the *Concept for Host Base Support*. Marine Corps planners need to understand that within the Norwegian *Total Defense Concept,* all resources are to be used for the defense of the society; thus if Marine Corps units are individually conducting uncoordinated procurement on the local economy, this may have unintended negative consequences within a resource-constrained environment. As materiel

[9] "Law of Armed Conflict" is also known as "International Humanitarian Law" which protects persons who are not or who are no longer participating in hostilities; it also restricts the means and methods of warfare under the Geneva Conventions of 1949 and their additional protocols. From "*Summary of the Geneva Conventions of 1949 and Their Additional Protocols,"* American Red Cross, 2011 (https://www.redcross.org/content/dam/redcross/atg/PDF_s/International_Services/International_Humanitarian_Law/IHL_SummaryGenevaConv.pdf)

solutions are examined and explored to increase electrical energy self-sufficiency, acknowledgment must be made to the operational environment; including the limitation of finite resources linked to legacy electrical energy generation and an understanding of the multiple entities who will be competing for resources within a contest Norwegian High North environment.

In summary, there are materiel solutions commercially available to support the sustainment of Marines and allies conducting distributed operations within the Norwegian High North which could increase the electrical energy self-sufficiency of these forces. Possible solutions for fuel generation, energy storage, and energy employment could employ hydrogen using the technology described in this paper. However, these solutions are not only limited to hydrogen and further research is needed to identify the best solutions; intentional incorporation of possible materiel electrical energy generation solutions into existing training venues linked to a formal assessments program should be pursued as one method to address this problem statement.

Interoperability

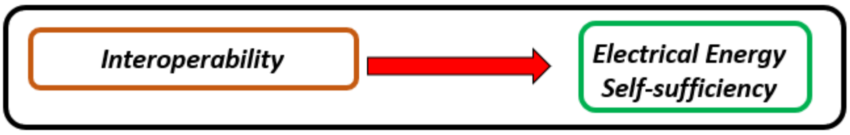

Figure 15: Interoperability Theoretical Model of Explanation

The final DOTMILPF-I framework element of *interoperability* will be used to examine the status of electrical energy challenges and possible interoperability solutions. The NATO Joint Analysis Handbook outlines five different questions associated to the NATO assessments framework connected to the DOTMILPF-I framework element of *interoperability*. These four questions have been selected as the most relevant and will be used to examine the data gathered as part of the research conducted for this paper (North Atlantic Treaty Organization, 2016).

1. Is the issue due to problems with interoperability?
2. If so, what type of interoperability?
3. Is the technology interoperable?
4. Are the processes and procedures interoperable?

I believe the challenge with increasing electrical energy self-sufficiency in the Norwegian High North is not directly linked to a problem of interoperability in the context of the lack of existing relationships between tactical-size units. Rather, based on the research during the development of this paper, the main interoperability issue observed is the lack of employment with the existing Marine Corps and Norwegian military relationships to better utilize these venues for addressing the problem statement. Several different relationships could quickly be established or expanded upon to increase electrical energy self-sufficiency of Marine Corps forces training in Norway. The first recommendation is to utilize existing tactical partnerships, like the exchange relationship between the Norwegian Military Intelligence Battalion and 2D Reconnaissance Battalion, as an experimentation venue for new technology. This relationship represents an ideal platform given the nature of their respective missions, long-range reconnaissance role, and the arctic winter environment used to train Marines in conducting operations. By their very nature, these tactical-size unit missions are linked to the ever-increasing requirement for information by leadership; this information is used to provide key information or complete the kill webs, which enables allied engagement of enemy forces. Critical to this information passage is both electrical energy to develop and transmit this information and to power the sensors required in part to obtain it. Expanding the utilization of this existing relationship also aligns with the understood intent outlined in *Force Design 2030.* General Berger, the Commandant of the Marine Corps, stated, “We will need to conduct full-scale, empirically-based experimentation of the future force in realistic maritime and littoral terrain. Our experimentation must be deliberate and iterative, informed by both threat developments and technology advancements” (Berger, Force Design 2030, 2020, p. 6).

Another type of interoperability is at the organizational level between entities conducting research or advocating for advancing operational energy solutions. Specifically, it was identified that no current collaboration is established between the Marine Corps Expeditionary Energy Office (which sponsored the H-TaRP prototype development) and the Norwegian Defense Research Institute during the research conducted during this paper's development. Both entities confirmed that they are pursuing research related to the use of hydrogen to act as both an energy carrier (battery) and fuel source for tactical-size units during the research for this paper. It would be logical that information-sharing agreements to develop this organizational research relationship are possible based on the numerous other arrangements between the Marine Corps and the Norwegian government. This future partnership could ensure that as both entities are pursuing research initiatives, including the utilization development of hydrogen, future solutions are compatible with shared equipment, and procedures are jointly developed for their utilization within respective military forces.

Combined Theoretical Model Discussion

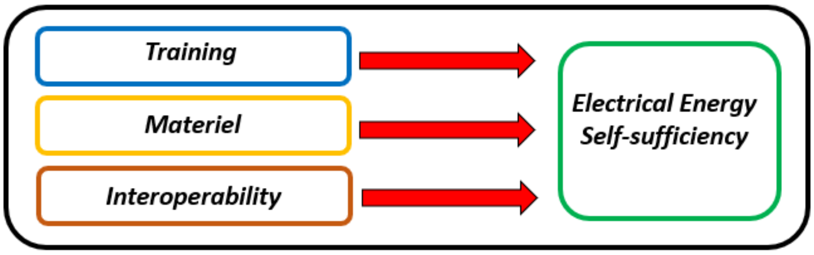

Figure 7: Combined Theoretical Model of Explanation

As the increased proliferation and advancement of technology increases the range of weapons systems, the reaction time for the United States and Allied leadership to make critical decisions in reaction to actions taken by hostile forces along the continuum of conflict will continue to decrease inversely. A review of the emerging doctrinal concepts currently being developed by the Marine Corps emphasizes the importance of the ability of forces conducting operations within the weapons engagement zone to employ sensors and maintain networked connectivity while ensuring a low profile. The increased reliance on technology to increase friendly force reaction time will only continue to increase the requirements for maintaining sustainable electrical energy sources. Given the environmental effects on traditional communications equipment batteries and electrical energy generation, these increasing requirements are challenging for the forces conducting operations within the Arctic environment. The continued reliance on traditional petroleum-based electrical energy generation solutions compounds this challenge.

The United States military establishment acknowledges the challenges associated with reliance on petroleum-based power generation; the contemporary baseline for this challenge was outlined with the United States Department of Defense *Energy for the Warfighter: Operational Energy Strategy* published in May 2011. This report, written during a period of heavy overseas military engagement in both Iraq and Afghanistan, outlined the troubling trend of increased usage of fuel – both at the destination of intended usage – often remote locations – but also the challenges of delivering the fuel and associated costs in time, equipment, energy (fuel), and risk to personnel (United States Department of Defense, 2011). While the United States has ended its military engagement in Afghanistan and significantly reduced the military presence (and associated support requirements) in Iraq, the challenges with extended delivery supply lines through contested engagement areas remain an existing challenge that must be addressed for future conflicts. How does this apply to defined area of Northern Norway in event of a conflict?

I believe my perception of the Marine Corps organizational level of comfort with sufficient petroleum resources should be evaluated by explicitly removing sufficient petroleum resources during existing training scenarios venues (*Named Exercises*) to test the limitations of Marine Corps equipment, sustainment processes and interoperability interactions in the Norwegian High North. Based on first-hand observation of historical training events, incorporating petroleum shortages into existing exercise training scenarios to replicate realistic equipment performance related to the challenges of increasing electrical energy self-sufficiency in the Norwegian High North has not been done. This element of a *Named Exercise* scenario likely would provide both tactical and operational level leadership a sobering opportunity to understand the true limits of both current materiel solutions (equipment) and provide greater motivation for the more rapid incorporation of non-petroleum-based electrical energy power generation solutions. Another aspect of energy sustainment I have observed is the dependence placed by some Marine Corps units during *Named Exercises* on Norwegian host nation contracted movement support vice using organic Marine Corps tactical vehicles for movement. This dependence, primarily based on self-imposed local leadership restrictions linked to safety considerations of Marines conducting tactical vehicle movements on Norwegian roads (often the E-6) in arctic weather, could artificially reduce sustainment risk assumed by the Marines Corps as a result of exercise participation in the Norwegian High North. The additional requirement of increased organic fuel transportation by Marine Corps tactical vehicles to replicate actual actions expected during a crisis response mission should be considered by leadership to better inform operational energy considerations.

Today's technology enables further experimentation and development on standard operating procedures, which can feed inputs into the development and support of both Marine Corps and Norwegian Armed Forces doctrine. From my perspective, the limitation for this technology employment is mainly self-imposed; current frameworks, agreements, and venues exist today that enable the utilization and experimentation of these types of systems in *Named Exercises* or other training opportunities at a lower level.

From the Marine Corps perspective, there are standing directives within existing published guidance from the Commandant of the Marine Corps which direct the further development and expansion of relationships with host nations to further interoperability and enable the execution of concepts outlined within the *Concept of the Stand-in Force*, *Expeditionary Advance Base Operations*, and *Force Design 2023*. Why would the Marine Corps not pursue stronger relationships between existing entities or develop new relationships between organizations that are pursuing similar research objections? Additionally, from the Marine Corps perspective, there has been a significant focus on examining methods, technology, and interoperability solutions to address the challenges of sustaining forces within the weapons engagement zone. The establishment of information exchange relationships between the Marine Corps Expeditionary Office and the Norwegian military research establishment, primarily the Defense Research Institute, is one opportunity that could easily achieve unity of effort towards common research goals. This assessment is based upon information shared and reviewed from both entities that has established common research focuses, especially in the area of hydrogen as an energy carrier or fuel source.

The Marine Corps, however, from the information obtained during the research of this paper, has not yet pursued the use of hydrogen as an energy carrier or fuel source specific to the Arctic environment. Analysis during the development of this paper also confirmed a willingness to explore future partnerships between the Norwegian Defense Research Institute and Marine Corps, which could expand mutual resources and capitalize on further integration by utilizing shared research. This can be done using existing relationships and venues, including leveraging the Norwegian Defense Research Institute ICE worx initiative to either test or capture test data that may benefit the Marine Corps.

There is also the unique nature of the Norwegian *Total Defense Concept* which connects both civilian and government entities under a formal framework linked to the defense of Norway using a society as a whole approach. This provides a unique access point for the Marine Corps to leverage a partnership with the Norwegian Defense Research Institute, for example to access key data or information – linked to interoperability and the common defense of Norway – to ideas, processes, experimentation, or technology that could benefit the Marine Corps both in the pursuit of greater energy self-sufficiency in the Norwegian High North but also solutions global application. This relationship could further benefit the Marine Corps with possible access to the Nordic Defense Cooperation initiatives related to improving electrical energy self-sufficiency as all member nations have activity above the Arctic Circle.

The numerous programs and agreements between the Kingdom of Norway and the United States government support my assessment that establishing future partnerships would not be difficult to achieve. The challenge, from my perspective, will be sustaining any future collaboration with resources, specifically funding and dedicated personnel, given the relatively small size of the Marine Corps Expeditionary Office. However, this challenge could be mitigated through the appropriate level of leadership awareness if there is a Marine Crops organizational desire to leverage a research partnership specific towards arctic operational energy.

Another area of observation I have observed during the period identified is the lack of joint assessments conducted during training events specifically tied to issues or initiatives tied to expeditionary energy. This is another area I believe that could be quickly addressed through coordination and assignment of specific personnel at the appropriate level to capture expeditionary energy considerations during the exercise event planning, the actual training event, and the ensuring data is appropriately reviewed with detailed analysis provided back to respective Marine Corps or

Norwegian entities.

In summary, this chapter explored how to improve electrical energy sustainment in the Arctic environment using the elements of *training, materiel,* and *interoperability* from the DOTMILPF-I capability framework, utilizing the NATO assessment questions defined in chapter 3, the implications related to the demonstration of the "H-TaRP" system by tactical size units, and further discussion of related implications.

Chapter 6: Conclusions

The challenges of expeditionary energy in the Arctic domain were explored in this paper using the *training, materiel*, and *interoperability* elements of the DOTMILPF-I framework to explore the current status and understand possible solutions. As described throughout this paper, military operations in the Norwegian High North are uniquely complex, with unforgiving considerations dictated by the arctic weather, geography, infrastructure, and geo-political considerations. The unforgiving nature of military operations in this environment should focus the Marine Corps and Norwegian military leadership at every level on improving our interoperability, increasing our materiel readiness, and conducting realistic training at every opportunity. The importance of understanding ways, ends, and means linked to increasing energy self-sufficiency for tactical-size units conducting distributed operations within the Norwegian High North will only increase as the level of activity increases within the Arctic littoral and maritime domains. The actions demonstrated by Russia and China related to the Arctic environment have shown that while the motivations may differ, their intent only to increase operations within the Arctic domain remains steadfast.

Key Findings

Three key finds have emerged during research conducted for this paper which could be leveraged to address the problem statement. The first is establishing organizational relationships, the second is leveraging the existing venues for experimentation, and the third is fostering joint assessments from these training venues and returning this information into the cycle.

The Marine Corps and the Norwegian Armed Forces have a unique opportunity to increase the combat power projection of distributed forces conducting operations in the Arctic by utilizing existing venues for experimentation and combining parallel research efforts. Increasing collaborative activity between the key entities identified in this paper or others that have not been specifically named is a cost-effective method for the United States Marine Corps to both reassure a key ally in the High North and contribute towards the generation of deterrence messaging towards other regional actors. It also sets conditions for further connectivity with other organizations, like the Nordic Defense Cooperation, as Finland and Sweden increase their participation in NATO activities.

The increased utilization for existing exercise venues for experimentation either solely by the Marine Corps, jointly with Norwegian Armed Forces, or leveraging data collected by Norwegian Defense Research Institute initiatives for testing cold weather energy generation or storage solutions not linked to legacy petroleum or battery sustainment should be prioritized. This prioritization can be achieved by ensuring electrical energy sustainment exercise objectives are included in the planning of existing training events. Likely entities that could be proponents of this prioritization include but are not limited to II Marine Expeditionary Force, Marine Forces Europe and Africa, or the Marine Expeditionary Energy Office. Utilization of the *Named Exercises* as experimentation venues does not have to be limited to units or representatives from these Marine Corps entities. I believe the participation by I Marine Expeditionary Force or III Marine Expeditionary Force units should also be considered by the Marine Corps as the expeditionary energy solutions tested in the Norwegian High North could be applicable on a global scale. This could be specifically applicable to some of the experimentation currently being conducted by the Marine Corps related to the development and employment of the Marine Littoral Regiment construct.

The final key point observed during the development of this paper is the limited existing connectivity between the Norwegian Armed Forces and the Marine Corps related to capturing and sharing of data specific to improving electrical energy self-sufficiency for tactical-size units conducting distributed operations in the Norwegian High North. While some collaboration may exist, I have not found any evidence or observed a formal framework to facilitate this type of information exchange. I believe the formal establishment of such a venue, linked to specific training events would provide an opportunity to capture data otherwise becoming compartmentalized. Additionally, if permissive, the participation by Marine Corps representatives in events like the Arctic Warrior Experiment would facilitate both access to cutting-edge technology solutions and the research behind these developments.

One challenge encountered during the development of this paper was the ability to present more expeditionary energy solutions identified during the research phase currently under development by the Marine Corps. This paper could not include these solutions due to information-sharing restrictions, but they are under development. This challenge could be overcome through information-sharing agreements, but these information-sharing agreements must be endorsed and supported by leadership from all entities at the appropriate level.

Linkage to Deterrence

Deterrence is the stated desired effect and often referenced throughout the emerging Marine Corps doctrinal concepts or supporting documents cited within this paper. These include *A Concept for Stand in Forces*, *Reconnaissance and Counter-Reconnaissance*, *Expeditionary Advance Base Operations*, *The Commandant's Planning Guidance, Force Design 2030,* and subsequent annual updates. Specifically, within *A Concept for Stand-in Forces,* General Berger outlines that this operational concept "is intended to provide options in support of integrated deterrence. Marines acting as stand-in forces will be positioned forward, shoulder-to-shoulder with our allies and partners, leveraging all-domain tools as the eyes and ears of the fleet and joint force" (Berger, A Concept for a Stand-in Forces, 2021, p. 2). I believe the continued relationship between Marine Corps units training with the Norwegian Armed forces in the Norwegian High North will continue to generate the deterrence effect towards potential regional adversaries. This training activity is linked to standing defense agreements and a long history of interoperability. I believe incorporating new energy technology to better sustain operational energy requirements and ensuring shared best practices to increase mutual combat effectiveness by increasing the dwell time of independent distributed operations will only increase this level of deterrence in the future. Further research will be required to validate this belief as the specific examination of deterrence within the Norwegian High North context is beyond this paper's scope.

Critical Reflections on Methodology

The critical reflection of weaknesses within the research design, theoretical framework, and sources selected are an essential aspect of research and presentation of information; this paper is no different. One of the weaknesses I have identified is the use of the NATO DOTMLPF-I theoretical framework used to examine the problem statement. This model is linked to the military establishment and may not consider all approaches to explore the problem statement. Another weakness identified is the potential for bias from the sources of information or my own bias as a Marine Office in reviewing the data. On the other hand, as Marine Officer closely associated with Marine Corps training in Norway, an unparallel observation opportunity was available during the period examined as part of the contemporary review of electrical energy not available to other researchers. This unique observation opportunity was based on firsthand access to Marine Corps training in the Norwegian High North, an extended opportunity to become familiar with the Norwegian High North geography, familiarity with sustainment methods used by Norwegian Armed Forces and Marine Corps units, and both military and political considerations from the Norwegian perspective through my Norwegian Defense University College Command and Staff education. I look forward to learning from others who will explore solutions to the problem statement examined in this paper and other related topics.

Areas For Further Research

The importance of research linked to increasing electrical energy self—sufficiency will only increase in the future as demonstrated by the review of emerging Marine Corps doctrinal concepts against the context of the current war in Ukraine; initiated by Russia, an Arctic nation. I believe several specific areas should be examined among the numerous areas of research that can be pursued within this field. First, increasing mobile electrical energy storage capacity in Arctic weather conditions should continue to be examined. Hydrogen as an energy carrier offers one solution but is not the only solution. Technical advancements in protecting traditional lithium batteries from extreme weather to increase survivability and extend utilization time could be a cost-effective approach. Another area specific to the use of hydrogen as an energy carrier is the employment of a hydrogen-saturated material that could be used to transport hydrogen in a more stable form. Secondly, energy generation solutions not linked to petroleum should also continue to be explored and tested in established training venues to establish both feasibility of utilization and cultural confidence within the military leadership of capability reliability. These energy generation solutions could include small-scale wind, tidal, or hydroelectric solutions. The weather along the Norwegian Arctic coast is an ideal environment for exploring these three applications for the following reasons. First, the combination of geography and temperature differences between the colder inland regions and the warmer coastal areas driven by the mild ocean gulf current almost always produces wind at any given location within a 24-hour period. This same combination of geographical features, combined with the tidal range difference, especially in the inner coastal fjords, provides ideal currents to test tidal applications. Finally, mountainous geography, wind, and adjacency to the long coastline generate constant precipitation levels. This precipitation translates into moving water streams and rivers that feed into lakes or ocean fjords along the coast. One application with significant potential for scalability is identifying key water features that could sustain the employment of portable hydroelectric generation capability. While this application may seem less than practical, several reasons support further research to determine the feasibility of military application in a crisis scenario.

Utilizing water as stored energy or battery is not new; over 90% of Norwegian domestically generated electrical energy is based on hydroelectric power and utilized to sustain the national grid and power exports (International Energy Agency, 2022). There are, however, known weaknesses in the national power system, as previously identified earlier in the paper. One critical venerability of the Norwegian national power grid is the lack of high-power transition lines connecting Northern Norway to Southern Norway (International Energy Agency, 2022). This lack of redundancy and ability to compensate for increased electrical demand or loss of generation capacity must be addressed as a known consideration. Another is that the existing hydroelectric locations are known and should be assumed to be considered targeted sites in the event of a conflict. While not inclusive, I believe these two critical considerations alone warrant a further examination of why portable hydroelectrical generation should be further explored as an electrical power source in the Norwegian High North. The military adaptation of utilizing the unique combination of geography and elevated standing or following water in Northern Norway is an extension of the emerging application of using water in a "closed system" to generate electrical energy. This application is further supported by the following considerations linked to the existing industrial, commercial, and government framework connected to the hydroelectrical sector in Norway. The first is a solid Norwegian civilian technical industrial base supporting the current hydroelectric power generation capability that accounts for 90% of the domestic electrical energy production (International Energy Agency, 2022). This provides both the domestic technical knowledge available in terms of trained personnel and supports the assumption of commercially available hydroelectrical generation equipment. The second is the existence of the *Total Defense Concept,* which could support incorporating this type of electrical power generation capability into standing contingency plans to create a more diversified electrical power grid. The *Total Defense Concept* could also be used as the administrative vehicle to ensure all applicable environmental considerations are lawfully addressed as specific waterway features are identified for the possible emplacement of portable hydroelectrical generation capability. The third is the possibility of combining this mobile electrical energy generation with hydrogen production to store the energy for further utilization by the same family of systems under development that utilize hydrogen as a fuel source. In summary, further research is strongly encouraged to identify key terrain in the Norwegian High North to designate expeditionary energy locations that could sustain hydroelectrical power generation with a military energy application.

Concluding Thoughts

The following observations are offered based on my experiences supporting Marine Corps and Norwegian Armed Forces training during the defined period and a review of current initiatives within the operational energy sector linked to the problem statement of this paper. First, all training events in the Norwegian High North, should be considered as opportunities for increasing electrical energy self-sufficiently regardless of size. This can be accomplished via experimentation, organic electrical energy generation equipment, or reliance on organic tactical equipment to conduct sustainment operations. The absence of this training objective should be recognized explicitly as part of the event After Action Reviews if supplemental electrical energy support is received to ensure awareness of energy sustainment sourcing. Every effort must also be made to ensure deliberate improvements are being made toward increasing tactical size unit electrical energy self-sufficiently for military forces. This increased self-sufficiency will be directly linked to the survivability of future military forces and ensure their extended operational effectiveness in any future conflicts within the Arctic environment. Finally, interoperability cannot remain only a key phrase regarding cooperation on electrical energy sustainment between the United States Marine Corps, Norwegian Armed Forces, or supporting research establishment. Deliberate and concrete actions must reinforce it to ensure effective and efficient collaboration at every level using existing venues to sustain deterrence generation efforts.

In closing, "amateurs talk strategy and professionals talk logistics" is a common military quote often favored by logisticians and attributed to General Omar Bradley, a United States Army General in World War II. Another Norwegian expression often shared during cold weather training is "*Det finnes ikke dårlig vær, bare dårlig klær!"* or "there is no such thing as bad weather, only bad clothing!" Combining these refrains offers an opportunity for reflection; what deliberate actions are being taken to better sustain the Marines and Norwegian Soldiers with electrical energy self-sufficiency in the Norwegian High North? What applications could be developed and tested within this environment that have global utilization for the Marine Corps?

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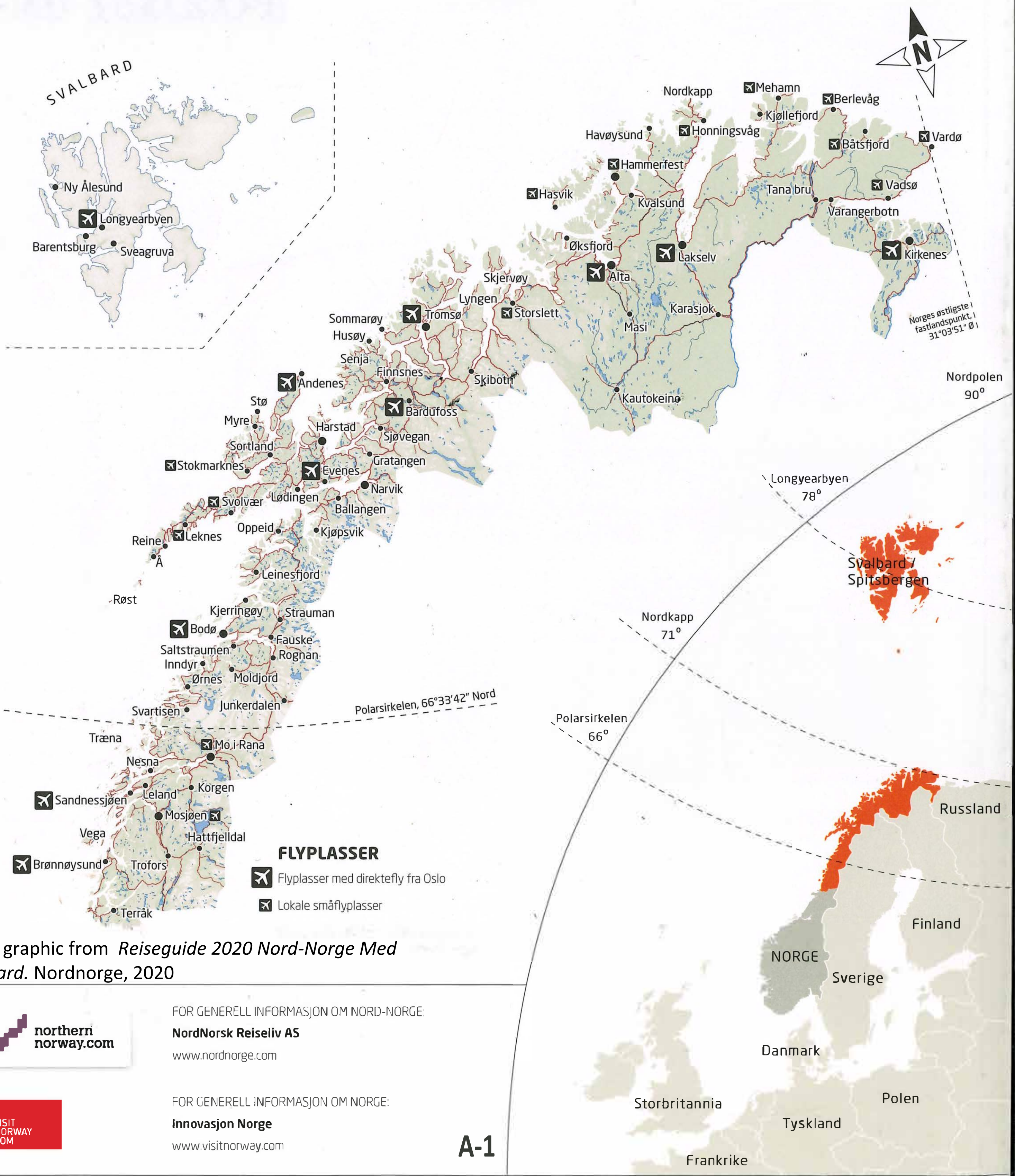

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