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Since September 11, 2001, the United States Marine Corps has grown increasingly dependent on assortments of technological advances aimed at capitalizing on the vast technology gap between its current and potential adversaries. Nation states such as China, North Korea, Russia, and Iran have capitalized on this opportunity by closing the technological gap with the United States, developing strategy and capabilities to contest the information environment. A generation of Marines learned how to fight with very little consideration for a contested information environment, resulting in a new critical vulnerability. Peer-competitor nation states have closed the technological gap by developing and adjusting their strategies and acquiring the means capable of exploiting the Marine Corps' critical vulnerabilities. The Marine Corps finds itself ill-postured to fight an enemy without the asymmetric advantage on the battlefield provided by superior technology. To dominate the EMS, a peer-competitor would employ an integrated approach to target vulnerabilities integral to space-based capabilities, denying or degrading the Marine Corps' ability to maneuver within the information environment. Marine leaders must learn to manage their electronic signature, operate as a far more dispersed force, and use new technologies to obfuscate enemy sensors.

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TITLE: Maneuver Warfare Within a Contested Information Environment: The Marine Corps' Next Fight

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PREFACE

This paper touches on several individual technologies, concepts, and capabilities of which researchers and academics devote entire writings. My intent for this writing is to focus on the information environment holistically by identifying emerging threats, analyzing how the Marine Corps is vulnerable within it, examining how the Marine Corps is addressing these vulnerabilities, providing additional solutions, and presenting a combined approach to posture the Marine Corps for its next fight.

I am not an expert in most of the technologies, concepts, and capabilities contained in this writing. It is for this reason that I chose this topic, as my intended audience is current and future MAGTF commanders that likely are also not technical experts in these areas. My intent for writing on this topic is to expose those commanders with little experience on the threat to the information environment, ensure the contested information environment problem set remains a trending topic among senior Marine leaders, and hopefully push this ball a little further down the field. By exposing current and future commanders to this very real threat to the future of Marine Corps operations, the next evolution in warfare is more likely to emerge from a great mind or two from within the Corps' ranks. Much like Major Earl "Pete" Ellis' contributions to the Marine Corps' island-hopping campaign in WWII, an evolution in warfare is upon us and by keeping this threat at the forefront of our focus, the next great mind will emerge.

My interest in this subject comes from my previous assignment at Marine Corps Forces Cyberspace Command (MARFORCYBER) as the Deputy Current Operations Officer and Deputy Special Technical Operations Chief, and grew through my experiences as Communications Company Commander at Marine Corps Forces Special Operations Command (MARSOC). I am one of many who believe that the single greatest threat to Marines on the next

battlefield is the contested information network. I am a product of 16 years of fighting an enemy incapable of contesting the information environment, and I have firsthand planning and operational experience within it. My experiences at MARFORCYBER and MARSOC exposed me to the evolving character of warfare and the threats posed to a new Marine Corps critical vulnerability: operating in a contested information environment. A mindset and culture change must begin to take shape for the Marine Corps to be ready for its next fight.

Executive Summary

Title: Maneuver Warfare Within a Contested Information Environment: The Marine Corps' Next Fight**.**

Author: Major Adam Harrington, United States Marine Corps

Thesis: While the Marine Corps remains battle-hardened through more than a decade of fighting, the advantages experienced fighting in an uncontested information environment has ill-postured it against a peer-competitor nation state capable of relentlessly contesting the information environment.

Discussion: Since September 11, 2001, the United States Marine Corps has grown increasingly dependent on assortments of technological advances aimed at capitalizing on the vast technology gap between its current and potential adversaries. Nation states such as China, North Korea, Russia, and Iran have capitalized on this opportunity by closing the technological gap with the United States, developing strategy and capabilities to contest the information environment. All Marine Corps warfighting functions are enabled by capabilities that rely on access to, and freedom of maneuver within the electromagnetic spectrum (EMS). A generation of Marines learned how to fight with very little consideration for a contested information environment, resulting in a new critical vulnerability. Peer-competitor nation states have closed the technological gap by developing and adjusting their strategies and acquiring the means capable of exploiting the Marine Corps' critical vulnerabilities. The Marine Corps finds itself ill-postured to fight an enemy without the asymmetric advantage on the battlefield provided by superior technology. Contesting the information environment through technological advances not only creates challenges for the Marine Corps' use of it, but also creates maneuver space for an adversary to exploit. China and Russia's systems of complex integrated sensors exploit the EMS and create an information environment that would make it very difficult for Marine forces to avoid detection on the battlefield. To dominate the EMS, a peer-competitor would employ an integrated approach to target vulnerabilities integral to space-based capabilities, denying or degrading the Marine Corps' ability to maneuver within the information environment. A visual representation of the information environment, specifically the EMS, and the ability to integrate IE Ops across the range of military operations are vital to MAGTF commanders' decision-making process. Marine leaders must learn to manage their electronic signature, operate as a far more dispersed force, and use new technologies to obfuscate enemy sensors. New communications tactics must be employed, as well as possibly reverting to some Cold War techniques to undermine enemy efforts to deny the EMS to Marine forces.

Conclusion: The Marine Corps is not currently prepared to fight a peer-competitor capable of contesting the information environment. Reorganization and initiatives are underway, but a shift in tactics, culture, and technologies is required to meet a new evolution in the character of warfare. The analysis examined in this writing provides recommendations on where to go from here.

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Introduction

Since September 11, 2001, the United States Marine Corps has grown increasingly dependent on assortments of technological advances aimed at capitalizing on the vast technology gap between its current and potential adversaries. For the past 16 years the Marine Corps has been fighting non-state actors in a virtually uncontested information environment while its peer-competitor nation states enjoy the opportunity to observe how the Marine Corps fights today. Nation states such as China, North Korea, Russia, and Iran have capitalized on this opportunity by closing the technological gap with the United States, developing strategy and capabilities to contest the information environment. Given the Marine Corps' conventional advantages on land and in the air, this could provide China, North Korea, Russia, and Iran an asymmetric advantage if not guarded against. The information environment is the aggregate of individuals, organizations, and systems that collect, process, disseminate, or act on information, and the Marine Corps heavily relies on it for command and control, precision-guided munitions, targeting, intelligence, surveillance, and reconnaissance among many functions.[1] Focusing on the Marine Corps' next fight with a peer-competitor, dependency upon freedom of maneuver within the information environment without ever facing an adversary capable of contesting it, has placed the Marine Corps in a dangerous predicament. While the Marine Corps remains battle-hardened through more than a decade of fighting, the advantages experienced fighting in an uncontested information environment has ill-postured it against a peer-competitor nation state capable of relentlessly contesting the information environment. This writing will analyze how and why technological advantages experienced over the previous 16 years of fighting have placed the Marine Corps in this situation and assess the consequences of a closed technological gap with its peer-competitors. This paper focuses on peer-competitors' current and emerging

technological advancements and strategies affecting the information environment, analyzes how a contested information environment threatens the Marine Corps today, and provides a comprehensive approach to resiliency in a contested information environment.

Defining the Maneuver Space

The information environment is not some new concept derived from technological advancements, as the exchange and processing of information has always been an integral component to warfare. Technological advancements have, however, changed the character of warfare by evolving the exchange of information. According to the Joint Staff, the information environment consists of three interrelated dimensions which constantly interact with individuals, organizations, and systems. These dimensions are physical, informational, and cognitive.[2] This writing focuses on the physical and informational dimensions as they relate to the flow of information through the electromagnetic spectrum (EMS). The physical and informational dimensions consist of command and control systems, supporting infrastructure, where and how information is stored and disseminated. The EMS is a physics-based maneuver space that is essential to control the operational environment during all military operations.[3] It is a highly regulated and congested natural resource that includes the full range of all possible frequencies of electromagnetic radiation such as radio frequencies, infrared, visible light, and ultraviolet.[4] While technological advancements improve how the Marine Corps utilizes this limited resource, emerging technologies also further strengthen its dependence upon freedom of maneuver within the EMS.[5] All Marine Corps warfighting functions including command and control, maneuver, fires, intelligence, logistics, and force protection are enabled by capabilities that rely on access to, and freedom of maneuver within the EMS, these capabilities are known as spectrum-

dependent systems (SDS).[6] Along with enabling the warfighting functions, the EMS also plays a critical role in how the Marine Corps fights in every operational domain: air, land, sea, space, and cyberspace. Figure 1 displays the frequency range of the EMS and depicts its apportionment.

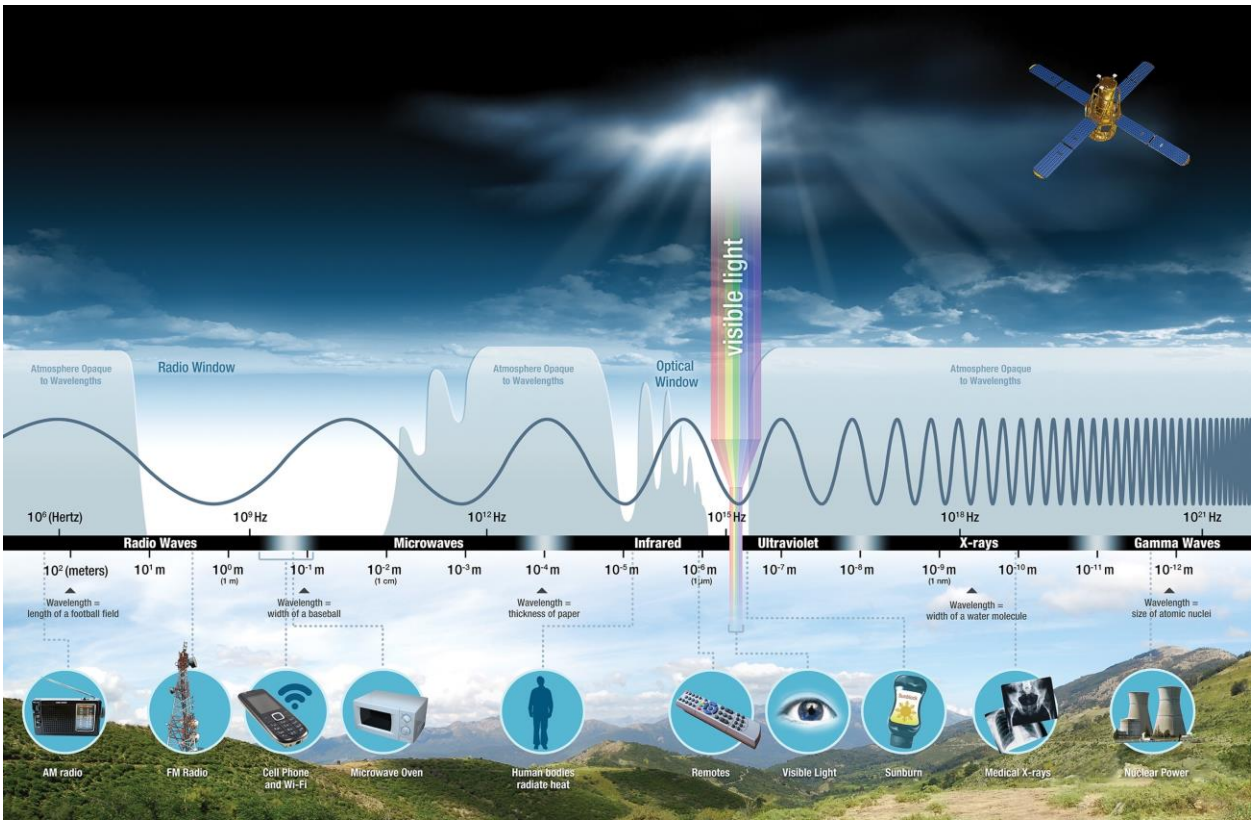

Figure 1. Diagram of the Electromagnetic Spectrum. (Ginger Butcher, Jenny Mottar, Dr. Claire L. Parkinson, Dr. Edward J. Wallack, "Tour of the Electromagnetic Spectrum," National Aeronautics and Space Administration, https://science.nasa.gov, [2016], 2-3).

Within the information environment, the EMS is the maneuver space that the Marine Corps employs its forces to ensure freedom of maneuver and deny the enemy the same. The Marine Corps adopted the Joint Staff's definition of maneuver as, "[T]he employment of forces in the operational area through movement in combination with fires to achieve a position of advantage in respect to enemy order to accomplish the mission."[7] Those forces employed within the information environment to ensure friendly freedom of maneuver and deny the same freedom to

the adversary are known as information-related capabilities (IRCs). IRCs are the techniques, tools, or activities that affect any of the three dimensions of the information environment.[8] As stated above, the information environment is not new, but the Marine Corps' almost complete dependence on it is what is new. Technological advancements have reshaped the information environment landscape and cultivated a Marine Corps dependent on access to it. Later, this writing will frame how more than a decade of fighting an enemy incapable of truly contesting the information environment created a Marine Corps ill-postured to face a peer-competitor more than capable of contesting it.

Problems with a Growing Dependence

The demand for information at the lowest tactical levels up to the strategic level has created an interconnected web of systems entirely dependent on unfettered access to the information environment. While the Marine Corps' acquisitions process struggles to keep pace with commercial technological advancements, these advancements continue to drive operational demands. The pace at which technology has been advancing is staggering. In 1965, Gordon Moore noted that approximately every two years the number of transistors on integrated circuit boards doubles.[9] This trend has resulted in continuously smaller circuit boards, allowing advanced technology to shrink from computers the size of rooms to the world's current smallest computer, the Michigan Micro Mote (M3), which measures in at just less than half a centimeter and can fit on the edge of a nickel (see Figure 2).[10] Additionally, computer processing power also doubles every two years and this trend is expected to continue at least to the year 2020.[11] The rapid advancements related to Moore's Law coupled with ever-increasing processing power

has created an environment rich in technological advancements and innovation, and, at the same time, one that transformed the Marine Corps' interdependence on these advancements. The

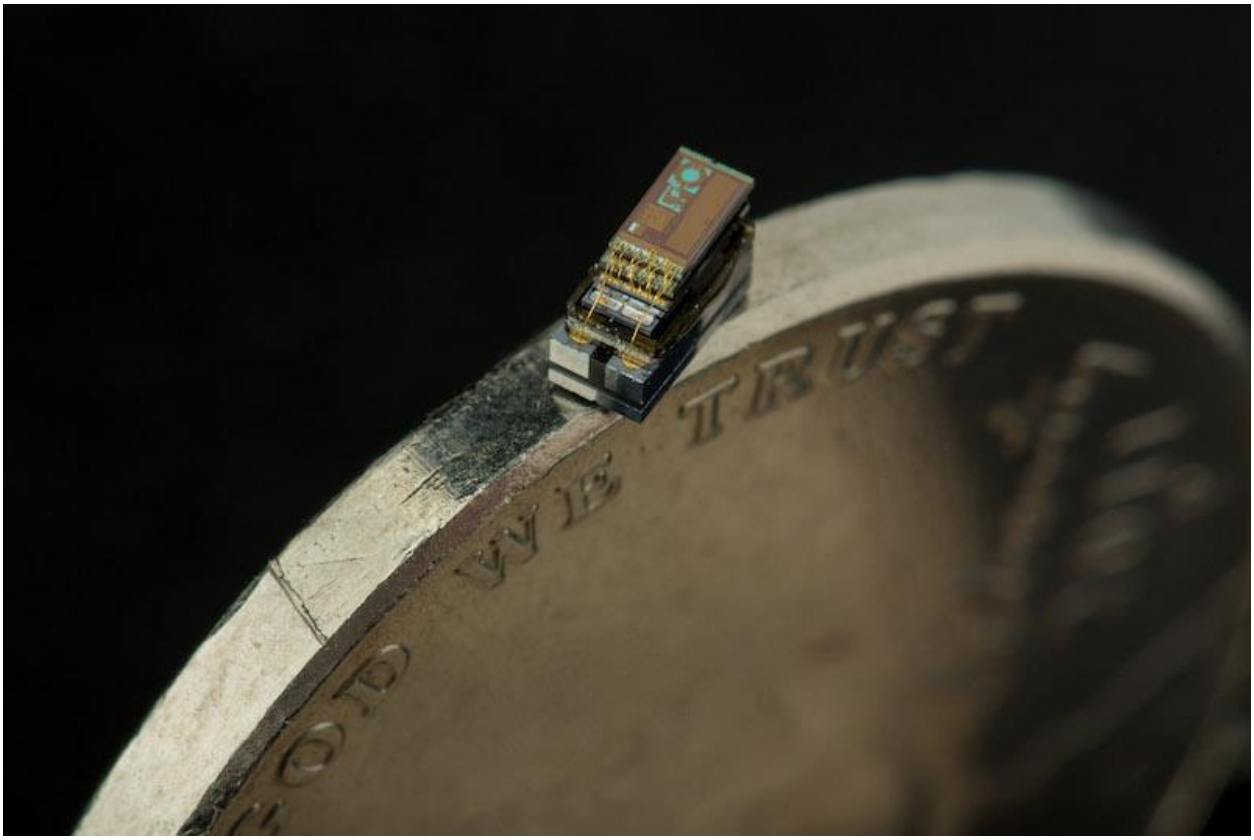

Figure 2. Michigan Micro Mote Computer on the Edge of a Nickel. (Image courtesy of University of Michigan, "Michigan Micro Mote Makes History," https://www.eecs.umich.edu/eecs/about/articles/2015/Worlds-Smallest-Computer-Michigan-Micro-Mote.html. [March 17, 20]).

Department of Defense has invested billions of dollars in developing, maintaining, and employing warfighting capabilities that rely on uncontested access to the EMS.[12] These continually emerging warfighting capabilities improve the Marine Corps' warfighting effectiveness by exploiting the EMS. Capabilities such as Wi-Fi, cellular, advanced weaponry, global positioning system (GPS), drones, radar for landing a plane, finding and detonating improvised explosive devices (IEDs), or just communicating with a dispersed unit require access to and exploitation of the EMS.[13] There is little doubt that the evolved information environment

and technological advancements have increased the effectiveness, precision, and lethality of the Marine Corps today. There are, however, two major concerns that have resulted from 16 years of evolution and advancements that threaten the Marine Corps in its next fight. First, the significant technological gap experienced by an entire generation of Marines in combat. This generation learned how to fight with very little consideration for a contested information environment. They witnessed the development and fielding of a multitude of SDSs designed to increase effectiveness inundate the theater of combat, and while many of those systems proved to be a force multiplier, they also raised an unwitting generation dependent on those systems. The Marine Corps' enemies in Iraq and Afghanistan did not possess the capabilities to even marginally degrade these systems. A peer-competitor nation state not only has the capability to degrade many of these SDSs, but can effectively render them useless to the Marines within the battlespace. Once denied access to the information environment, a Marine Corps dependent on unconditional freedom of maneuver within it becomes a critical vulnerability. Second, while the Marine Corps has been at war with non-nation states for 16 years, their peer-competitor nation state adversaries enjoyed the opportunity to observe the evolution of the information environment and technological advancements. China, Russia, North Korea, and Iran capitalized on the opportunity to learn how the Marine Corps fights today by developing and adjusting their strategies and acquiring the means capable of exploiting the Marine Corps' critical vulnerabilities. For the past 16 years the United States military has dominated the electromagnetic battlefield, not due to concerted efforts to ensure friendly freedom of maneuver within it, but by default. Today, the United States is neither sufficiently prepared nor adequately armed to dominate the electromagnetic battlefield against a peer-competitor.[14]

Sources of a Critical Vulnerability

There is now a generation of Marines that expect their critical equipment and systems to simply work once powered on. Even in garrison, Marines carry a cell phone in their pockets capable of voice and high-speed data virtually anywhere they need it. Over the 16 years of fighting in Iraq and Afghanistan, dozens of deployment rotations cycled through either preexisting local infrastructure or systems previously established by Marines from years ago. Marine Corps leadership has grown accustomed to forward operating bases where they can capitalize on fixed infrastructure, or they can set up a satellite link that will support their operations for an indefinite amount of time.[15] As a result, secondary and tertiary means of communications seldom factor into mission planning at the tactical level. Marines have enjoyed the luxury of complete freedom of maneuver in the information environment and largely operated with disregard for any semblance of radio frequency emissions control. The enemies in Iraq and Afghanistan possessed very little capability to exploit this lack of emissions control to locate and target Marines on the battlefield. Emissions control was simply never an operational consideration.

Additionally, even if the enemy could have effectively detected radio frequency emissions, military leadership assumed they would not be capable of locating the source of the signals with quality targeting accuracy or link that information to a long-range precision weapon system.[16] The environment the Marine Corps has been operating in over the past 16 years produced bad habits that will prove to be a critical vulnerability in its next fight without a culture change in an entire generation of warfighters. Recently, Marine Corps leadership began identifying this operational concern. Lieutenant General Robert S. Walsh, Commanding General of Marine Corps Combat Development and Deputy Commandant for Combat Development and

Integration, stated, "While our forces were elsewhere, our potential enemies modernized, reducing the technological advantages American forces once took for granted. In many theaters, we can no longer assume superiority in any domain – sea, air, surface, or the electromagnetic spectrum."[17]

In many ways the Marine Corps has benefited from an asymmetric advantage resulting from superior technology, but current and future adversaries are challenging or negating that advantage. China, North Korea, Russia, and Iran capitalized on the United States' wars in Iraq and Afghanistan by closing the technology gap and studying these bad habits. The operational tempo experienced by the Marine Corps throughout these two wars also aided the closing of the technology gap. A relentless operational tempo, drawn out for more than a decade, has damaged readiness and challenged critical Marine Corps modernization efforts to replace aging equipment. Many of these efforts to expand the technology gap have suffered from drawn-out development timelines, moving and unrealistic requirements, and cost overruns.[18] As a result of these flawed practices and deprived modernization, the Marine Corps finds itself ill-postured to fight an enemy without the asymmetric advantage on the battlefield provided by superior technology.

Enemy Integrated Battlefield Sensors

With the technology gap between the Marine Corps and its future enemies narrowing, emerging threats challenge how Marines have grown accustomed to fighting. Unable to compete with US forces directly, adversaries are leveraging technological advances to create their own asymmetric advantages in countering US military superiority.[19] Contesting the information environment through technological advances not only creates challenges for the Marine Corps'

use of it, but also creates maneuver space for an adversary to exploit. In a conflict, China and Russia would likely first use their widest-area search sensors, such as land-based high frequency (HF) over-the-horizon radars and passive space-based electronic intelligence or signals intelligence receivers to quickly locate and identify an enemy's forces (see Figure 3).[20] These sensors can detect signals such as satellite communications (SATCOM), Global Positioning

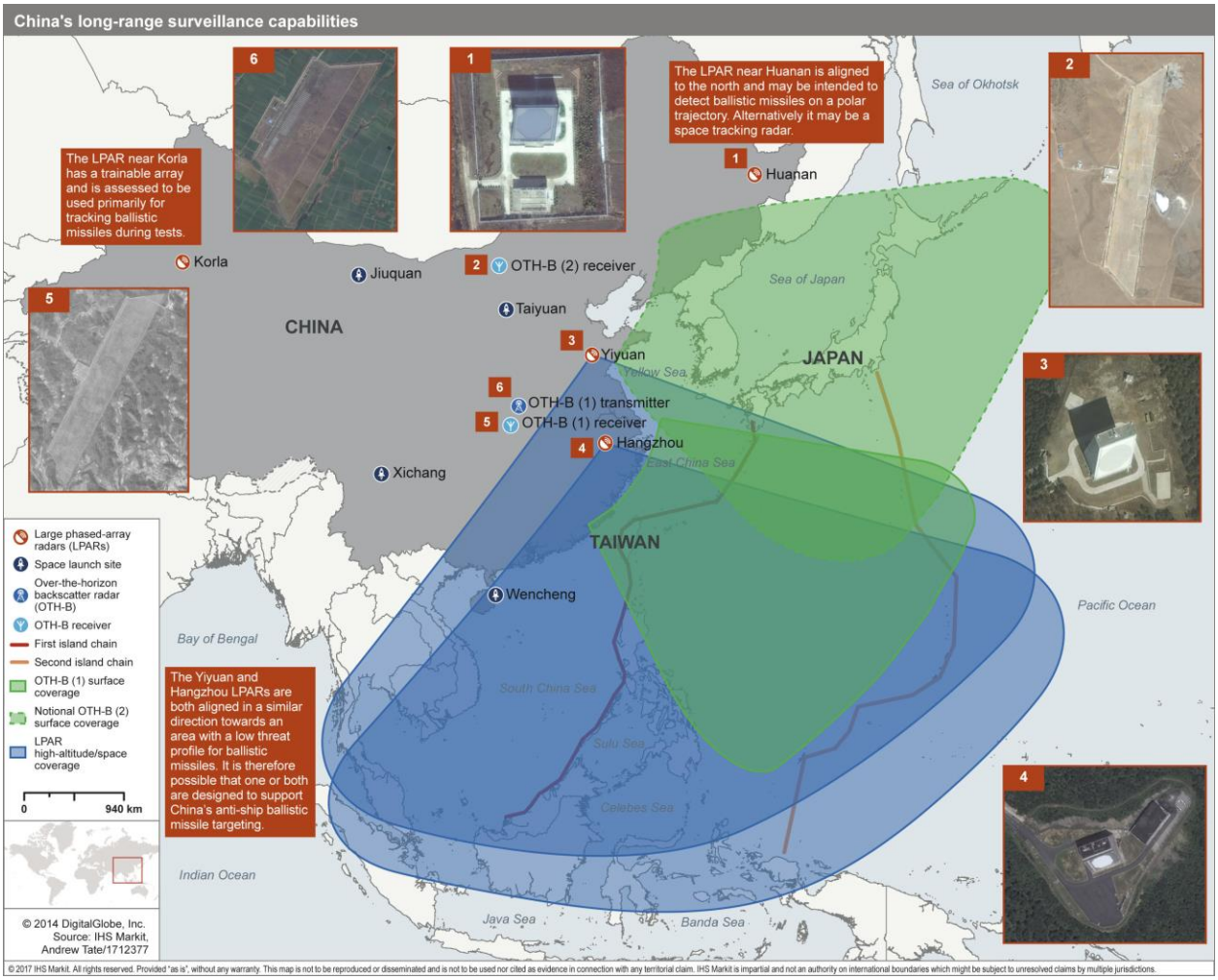

Figure 3. China's long-range surveillance capabilities. (Jane's IHS Markit, [2017]). https://janes-ihs-com.lomc.idm.oclc.org/Janes/Display/FG_673420-JIR.

System (GPS), HF, and cell phone transmissions over the EMS. With the Marine Corps' heavy reliance on the EMS and poor emissions control, these sensors would likely be very effective in

geo-locating Marine forces on the ground. Since these specific sensors are China and Russia's widest-area search sensors, they have very large fields of view that can continuously cover an entire region such as the South China Sea or the Baltics, but typically cannot provide target-quality data across the entire coverage area. As a result, they signal airborne or space-based electro-optical, infrared (IR), or specific radar sensors that can track targets with greater precision.[21] China and Russia's systems of complex integrated sensors exploit the EMS and create an information environment that would make it very difficult for Marine forces to avoid detection on the battlefield without constant movement, which demands logistical strain. This advanced technology coupled with capable strike packages is the type of lethal capability Marines have not previously faced.

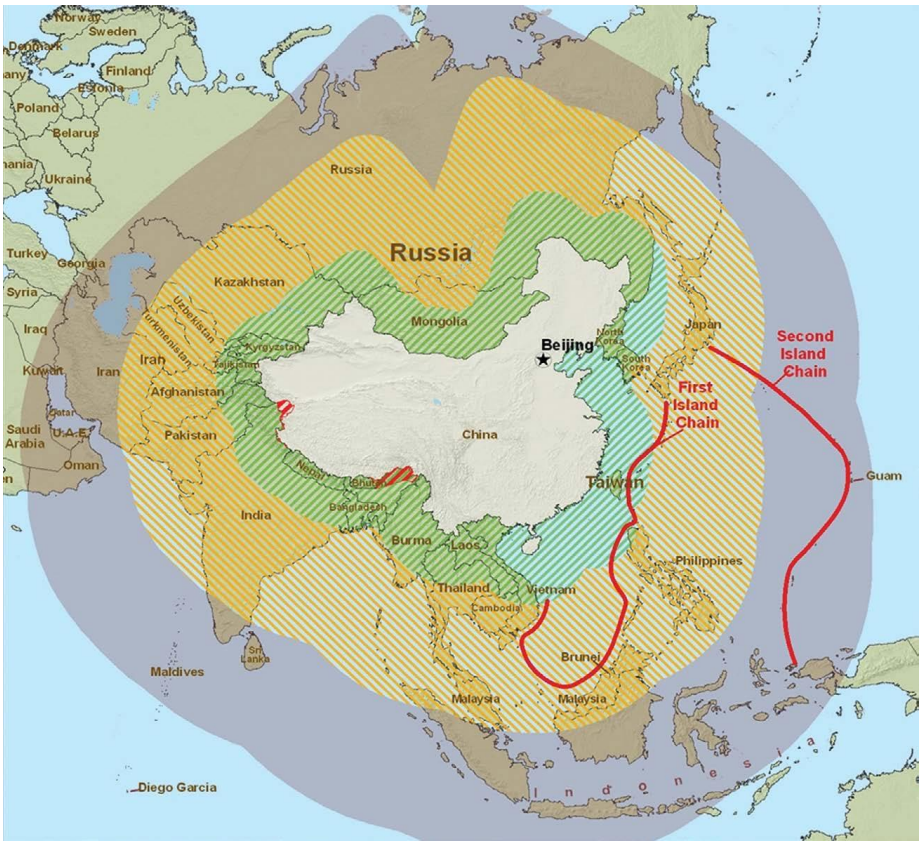

Figure 4. Conventional anti-access missile capabilities of the People's Republic of China. (Reprinted from Department of Defense, Office of the Secretary of Defense, Military Power of

the People's Republic of China: A Report to Congress pursuant to the National Defense Authorization Act, Fiscal Year 2000 [Washington, DC: Department of Defense, Office of the Secretary of Defense, 2009], 23.)

In addition to exploiting the EMS for geo-location purposes, China and Russia have employed integrated sensors to develop strong anti-access/area denial (A2/AD) capabilities. Marine Corps aviation assets designed to suppress enemy air defense radars through electronic warfare (EW) could prove less effective against emerging technology. Chinese and Russian integrated air defense systems (IADS) are becoming increasingly resistant to electronic suppression using passive sensor technologies such as infrared search and track.[22] Exploiting the EMS through technological advances to enhance IADS capabilities provides the enemy additional maneuver space within the information environment and denies the Marine Corps its previously enjoyed asymmetric advantage (see Figure 4). The Marine Corps has never fought an enemy capable of employing such advanced technology and ability to deny and exploit the information environment. Peer-competitors have narrowed the technology gap while observing US forces fight two concurrent wars over the past 16 years. Complex integrated sensors on the battlefield create an information environment never before seen by Marines. Future enemies will contest and exploit the EMS with advanced technology to create their own asymmetric advantages.

A Proposal for Space-based Capabilities

For the Marine Corps to be effective against a peer-competitor such as China, it must prepare for a combination of kinetic and non-kinetic strikes aimed at dominating the EMS. Integrated network electronic warfare is a Chinese strategy combining EW, computer network operations (CNO), and kinetic strikes to disrupt battlefield information systems that support their adversary's warfighting and power-projection capabilities, and stresses that the EMS is a critical

warfighting dimension.[23] Peer-competitors understand the significance of the EMS and have developed strategies to exploit the vulnerabilities inherent in its reliance. The Marine Corps heavily relies on space-based capabilities in support of operations. Many Marine Corps systems are dependent on satellites for GPS, radio and data networks, targeting information, weather, and intelligence. To dominate the EMS, a peer-competitor would employ an integrated approach to target vulnerabilities integral to space-based capabilities, denying or degrading the Marine Corps' ability to maneuver within the information environment. A kinetic strike against the ground stations used to command and control the satellites, jamming or spoofing the data links between the satellite and its intended recipient, and using directed energy to dazzle or partially blind the satellite are all targeting options in an integrated approach.[24] Spoofing the data link between a satellite and its recipient is a process of replacing GPS readings by creating a false signal that leads devices to display incorrect times or locations, could potentially disrupt power grids or hijack systems including weapon platforms and key maneuver systems.[25] With advanced technology and an appreciation for the information environment, peer-competitors will not only pursue efforts to deny and degrade the Marine Corps' maneuver space within it, but also manipulate that information to create an asymmetric advantage.

The Marine Corps' reliance on space-based capabilities presents a critical vulnerability to its peer-competitors, as satellites are susceptible to both kinetic and electromagnetic effects. A declassified intelligence report on Chinese electromagnetic pulse (EMP) and high-powered microwave (HPM) weapons specified that China could detonate a low-yield, low-altitude strategic nuclear warhead to destroy electronic systems while minimizing the effects to Chinese mainland.[26] EMP damages electronic hardware and circuits by producing a surge in electrical current and voltage exceeding their normal functioning capacity. This intelligence is significant

because it sheds light on a peer-competitor using weapons systems to deny multiple warfighting domains simultaneously.[27] The US realized the electromagnetic effects on satellites in 1962 when it conducted a nuclear test called "Starfish Prime" by detonating a 1.4 megaton weapon

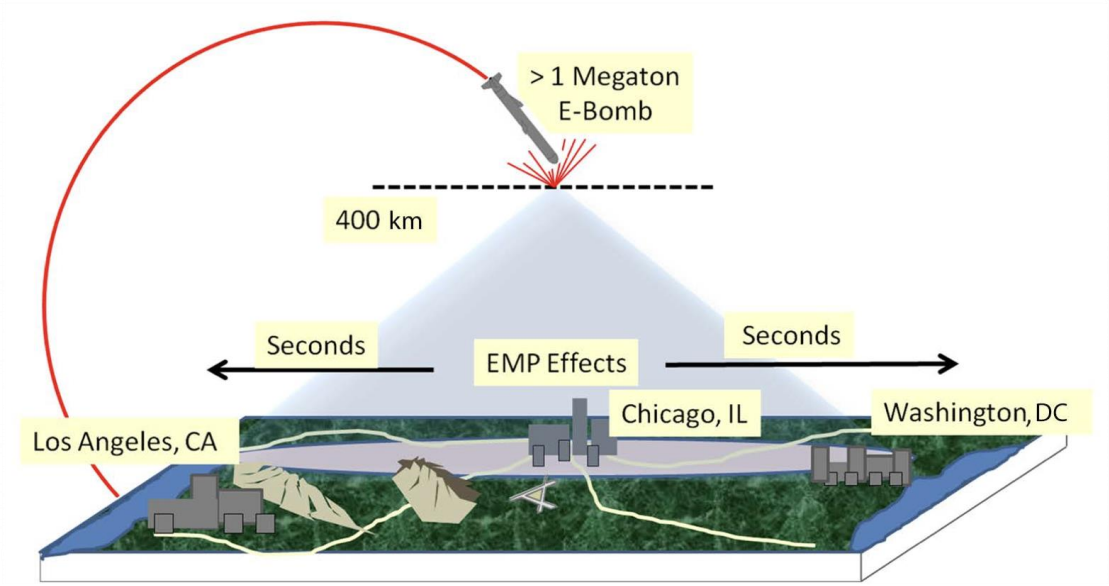

Figure 5. Effects of electromagnetic pulse. (Derived from Headquarters Department of the US Army, *Nuclear Environment Survivability* [US Army White Sands Missile Range, NM: US Army Test and Evaluation Command, April 15, 1994], appendix D.)

400 km above the earth's surface. The electromagnetic effects from the blast reached Hawaii, 898 miles away, and produced an artificial radiation belt that began damaging orbiting weather and communications satellites.[28] Figure 5 depicts the same scenario if the detonation occurred above the continental United States. There are also nonnuclear means of employing weaponized EMPs capable of producing temporary interference and destruction to systems. Ballistic missiles, submarines, aircraft, satellites, and man-packed systems can all deliver electromagnetic effects to a target.[29] The electromagnetic effects generated by an EMP pose a significant threat to space-based capabilities that Marine Corps systems heavily rely upon, and peer-competitors, such as China, possess the capability to produce these damaging electromagnetic effects on the battlefield.

In addition to electromagnetic effects, satellites are vulnerable to kinetic strikes as they follow a very predictable path while in orbit. Russia, Iran, North Korea, and China have all heavily invested in several ballistic and supersonic cruise missiles designed to challenge the United States' conventional superiority.[30] The militarization of space created an asymmetrical advantage for the US military for decades as peer-competitors lacked the technology to contest that domain. By closing the technology gap, however, space is no longer an uncontested environment enjoyed by US forces. On January 11, 2007, China conducted its first successful direct-ascent antisatellite weapons test by launching a ballistic missile to destroy the Fengyun-1C weather satellite in low Earth orbit at about 530 miles (see Figure 6).[31]

Figure 6. Successful Chinese Anti-satellite Weapon (ASAT) Intercept. (Maj. Miguel Cruz, "Saving the Nation is Serious Business," *US Air Force Space Command*, [June 1, 2007].

http://www.afspc.af.mil/News/Commentaries/Display/Article/252603/saving-the-nation-is-serious-business/.

Then on May 13, 2013, China fired a missile into space that reached an altitude of over 6,000 miles and potentially over 20,000 miles.[32] This is significant because GPS satellites orbit in mid Earth orbit at an altitude of about 12,550 miles.[33] Even if China only targeted GPS satellites, the effects on the battlefield could be catastrophic for the Marines. Precision weapons, navigation systems such as Blue Force Tracking that depicts friendly forces across the battlefield through GPS, and even timing for radio and data networks would experience degradation or inoperability if a peer-competitor began targeting GPS satellites. Blue Force Tracking alone is a vital command and control capability that provides Marines both their location in relation to other friendly forces, and serves as a communications asset when radio communications become degraded. Critical communications and intelligence satellites also orbit in low and mid Earth orbit placing them within the crosshairs of China's weapons systems. The Marine Corps' next fight with a peer-competitor is likely to involve the targeting of US space-based capabilities as they are an integral component to the Marine Corps' information environment. As adversaries' technologies advance and strategies develop, the space domain could become just as contested as a heavily defended beachhead.

Posturing for Dominance

As its adversaries recognize the significance of the information environment and develop technology to dominate it, Marine Corps leadership has begun to realign its efforts to ensure maneuver space within a contested information environment. In 2016, senior Marine leaders highlighted the lack of operational focus on the information environment in Marine Corps

warfighting and maneuver concepts. They identified that Marine Corps information capabilities are disparately developed, ineffectively integrated, and inadequately addressed in Service decision-making and MAGTF planning and execution.[34] The Commandant of the Marine Corps (CMC), General Robert B. Neller, emphasized the contested nature of the information environment in *The Marine Corps Operating Concept* by stating, "We must practice the devolution of authority and the prioritization of C2 applications under contested conditions in order to ensure our resilience."[35] In an effort to organize the Marine Corps for a greater operational focus on dominating the information environment, the CMC directed the establishment of a Deputy Commandant for Information (DC I) in 2017. DC I is designated as the lead Marine Corps advocate for integrating and coordinating activities, capabilities, and enablers with the joint and mission partner community to dominate the information environment. This effort is known as information environment operations (IE Ops), and the Marine Corps defines it as,

> The integrated planning and employment of MAGTF, Naval, Joint, and interagency information capabilities, resources, and activities that enhance the Marine Corps single-battle concept and provide defensive, offensive, exploitative effects and support in order to operate, fight and win in and through a contested information environment.[36]

With the establishment of the DC I, what was previously an assortment of unsynchronized and compartmented efforts to operate within the information environment, a single Deputy Commandant now aligns IRCs in support of Marine Corps operations. The DC I structure provides unity of effort by looking across functional areas, synchronizing efforts, and providing a holistic vision for the information environment.[37] A holistic approach to employing IRCs across functional lines of effort and coordinated between the deep, close, and rear areas on the battlespace enhance the Marine Corps single-battle concept that states, "Operations or events in

one part of the battlespace often have profound and consequent effects on the other areas and events."[38] The functional lines of effort for Marine Corps IE Ops are introduced in the MAGTF

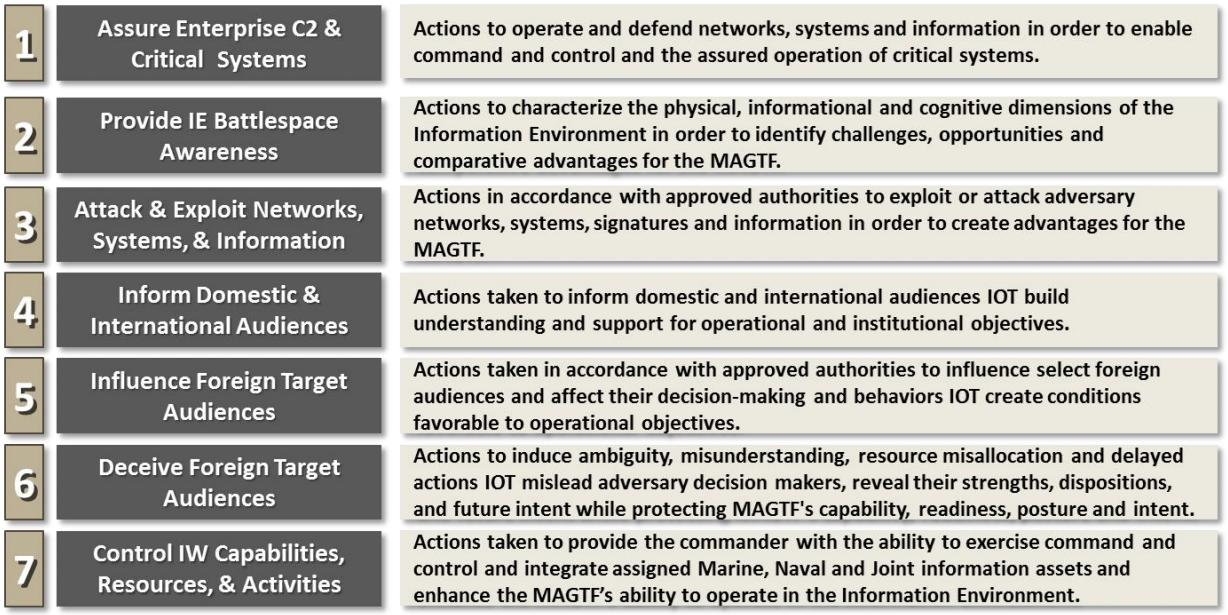

Figure 7. Seven Functions of IE Ops. (Headquarters Marine Corps, *Marine Air Ground Task Force Information Environment Operations Concept of Employment*, [Quantico, VA: July 2017], 2).

Information Environment Operations Concept of Employment. Figure 7 outlines and defines the seven lines of effort. Additionally, the Marine Corps established the Marine Expeditionary Force (MEF) Information Group (MIG) and charged it with the mission of ensuring friendly maneuver space within the information environment and denying the same to the enemy. Comprising the MIG is a repurposed MEF Headquarters Group (MHG) expanded with new force structure provided under an initiative called *Future Force 2025* (see Figure 8).[39] The establishment of a seventh Deputy Commandant and the creation of the MIG signify an emerging paradigm shift in how the Marine Corps intends to fight its next fight. As the Marine Corps shifts its focus to the information environment it is important to note that it is still a new development, one that requires identifying essential capabilities across the doctrine, organization,

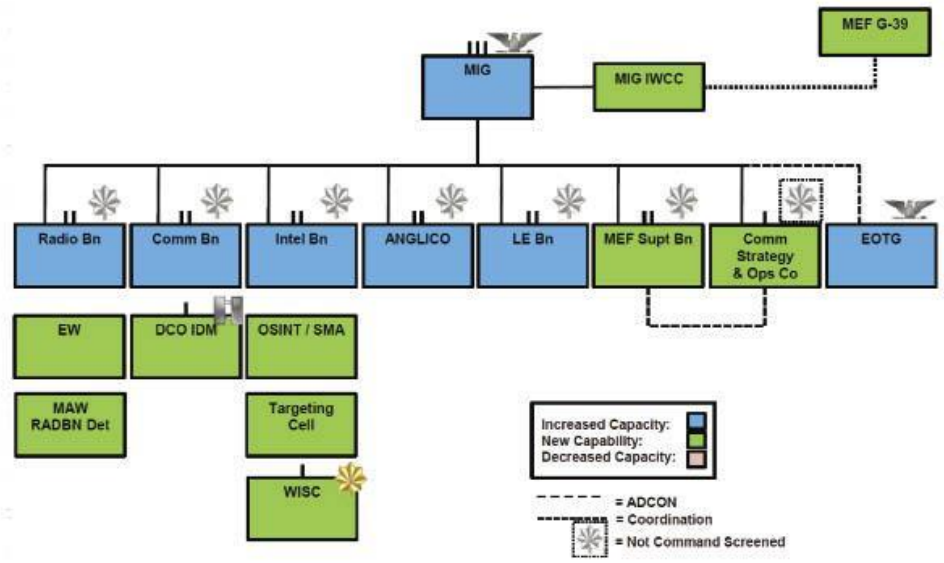

Figure 8. Marine Expeditionary Force (MEF) Information Group (MIG) Organization Chart. (Staff, Deputy Commandant for Combat Development & Integration (DC CD&I), and Marine Corps Intelligence Activity (MCIA). "The Future Starts Now," *Marine Corps Gazette*, vol. 101, Iss. 8, [Quantico, VA: August 2017]).

training, materiel, leadership and education, personnel, facilities, and policy (DOTMLPF-P) framework. It is currently a concept requiring trial and error, as well as war-gaming to advance to fruition.

Visualizing the Information Environment

MAGTF commanders rely on visual representations of the battlefield to employ their forces and make decisions as the battle unfolds. Fog of war, friction, and the human element all add to the uncertainty of war, and commanders require a collection of command and control systems to provide a common operational picture (COP). Current technology gives commanders this COP by providing satellite imagery through intelligence, surveillance, and reconnaissance (ISR), locations of friendly forces through Blue Force Tracking, and communications through tactical radio and data networks. Integrating and coordinating IE Ops across functional lines of effort in support of Marine Corps operations requires a visual depiction of the information

environment to enable commanders to make holistic decisions. Currently, there exists no such visual representation of the information environment, but many initiatives are underway. The IE Ops running estimate is the Marine Corps' approach to visualizing the information environment. The IE Ops running estimate aims to enable an agile distributed command and control mechanism by leveraging automation, advanced algorithms, and artificial intelligence (AI) to foster near-real time collaborative planning and execution coordination environments that span the MAGTF.[40] Through the advanced algorithms and machine-to-machine interface, AI will enable the IE Ops running estimate to make decisions based on detected characteristics of the information environment and learned patterns to present the commander with optimal recommended courses of action. Automation and AI are critical to achieving a near-real time representation of the information environment simply due to processing speed, meaning a machine-to-machine interface to process a tremendous amount of data in mere seconds is the only way to provide a commander actionable information. The Marine Corps compares this automation to that of a smartphone navigation application which in near-real time, produces possible routes, highlights the predicted optimal route based on the current traffic situation, and provides continuous monitoring of the traffic situation during travel. As traffic conditions change, the application automatically presents the driver with alternate routes to make an informed decision.[41] While this analogy is over-simplistic, it provides a clear example of how MAGTF commanders can eventually visualize the information environment in near-real time to make informed decision across all functional lines of effort.

The Marine Corps is not alone in its efforts to visualize the information environment, as the Joint Staff and other Services are pursuing similar efforts. For example, a spokesman for the vice chairman of the Joint Chiefs of Staff explained that the Pentagon is exploring ways for

commanders to coordinate, synchronize, and integrate the use of the EMS across the range of military operations. The Joint Staff expects a solution to reach initial capability in 2022 and full capability in 2028, at a total life-cycle cost of $193 million.[42] The Air Force sought US industry technology solutions for electromagnetic battle management (EMBM) capabilities in a notice published in November 2016. It seeks EMS technologies capable of real-time policy based spectrum management, advanced electronic order-of-battle presentation, and state-of-the art modeling, simulation, and course of action analysis.[43] The Army is developing an electronic warfare information system (EWIS) that intends to allow operators to coordinate operations, integrate with multiple databases for intelligence and spectrum management, perform targeting, and model the effects of EW actions.[44] Figure 9, below, is a proposed visual representation of the EWIS. A visual representation of the information environment, specifically the EMS, and the ability to integrate IE Ops across the range of military operations are vital to commanders' decision-making process throughout the Department of Defense. While several efforts are currently ongoing, US military commanders still lack this capability. Additionally, with each service and the Joint Staff independently pursuing solutions to the same problem, interoperability of these emerging capabilities within the joint community will most certainly become the next problem. Visualizing the information environment on the battlefield does not eliminate the natural fog and friction of warfare, but serves to shed light on a currently multifaceted and convoluted aspect of warfare. Actions within the information environment move at the speed of light, but through machine-to-machine interface and AI, commanders can make educated decisions based on otherwise unattainable data.

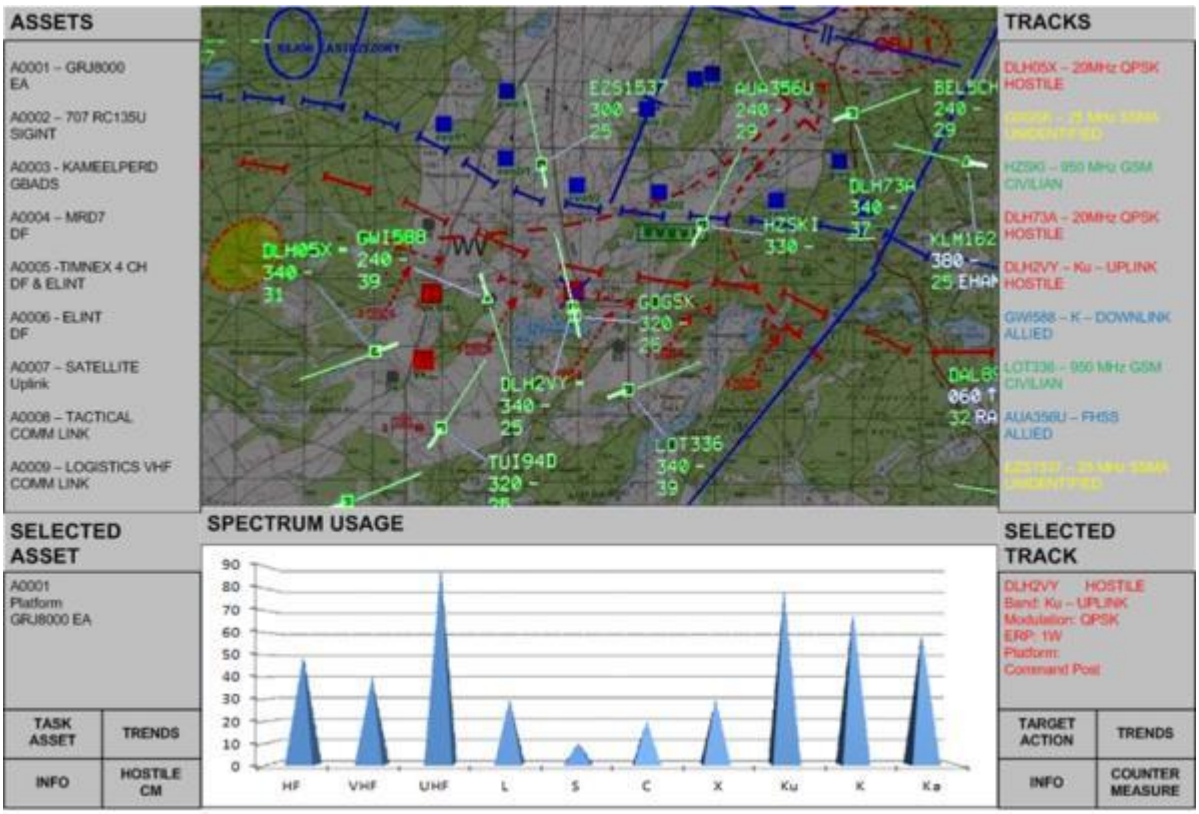

Figure 9. Proposed dashboard for an EWIS. (Brett van Niekerk et al., "Management Information Systems for Electronic Warfare Command and Decision Support," *Journal of Information Warfare*, [2015], 72).

Emissions Control, Dispersion, and Obfuscation

To avoid detection, secure maneuver space within the information environment, and deceive the enemy, the Marine Corps must adapt new tactics, techniques, and procedures with regards to EMS signature management. As previously stated, the Marine Corps has been operating with very little semblance of radio frequency emissions control due to the enemy's lack of technological capabilities to locate and target the signal's source. Against a peer-competitor, the Marine Corps will need to implement emission control measures, which is to deliberately manipulate their EMS signatures into specific profiles that prevent enemy detection. The Navy currently utilizes emissions control by employing decoy or deception capabilities

designed to lure enemy attention toward false objects of interest.[45] Taking a similar approach to avoid detection and overwhelm enemy ISR capabilities, the Marine Corps must adapt its emissions control measures to account for an enemy capable of locating and striking its ground forces. The Marine Corps should expect a peer-competitor to gain access and monitor data networks through computer network operations. Simulating the computer network activity of deployed Marine forces through emulators on the battlefield to mimic the use of local telecommunications networks by Marines and simulating false targets on Blue Force Tracker are just a couple examples of how Marines can employ decoys in cyberspace.[46] Emissions control also includes EMS discipline to significantly reduce the amount of transmissions broadcasted over the EMS. To coordinate operations while in a limited or restricted emissions control status, the Marine Corps should rely more heavily on mission-type orders, in which individual units operate based on commander's intent and pre-plan de-confliction and responses with one another.[47] MAGTF commanders have grown accustomed to continuous communications with their maneuver elements and this could prove dangerous against a peer-competitor.

Dispersal of Marine ground forces is also a critical component to ensuring maneuver space within the information environment. Just as units learned to disperse in the American Civil War due to the smoothbore musket evolving to the more accurate rifle, the advancements in current adversary technology strengthen the requirement for Marines to adapt to evolving technology. Employing many small decoys to mimic dispersed forces is much more effective than attempting to mimic large concentrations of forces. Dispersed forces also reduce the EMS signature of each maneuver element, aiding in creating confusion in enemy ISR sensors. A highly mobile and dispersed force, operating on mission-type orders, and demonstrating EMS

discipline offer a MAGTF commander less probability of an enemy detecting their ground forces through the information environment.

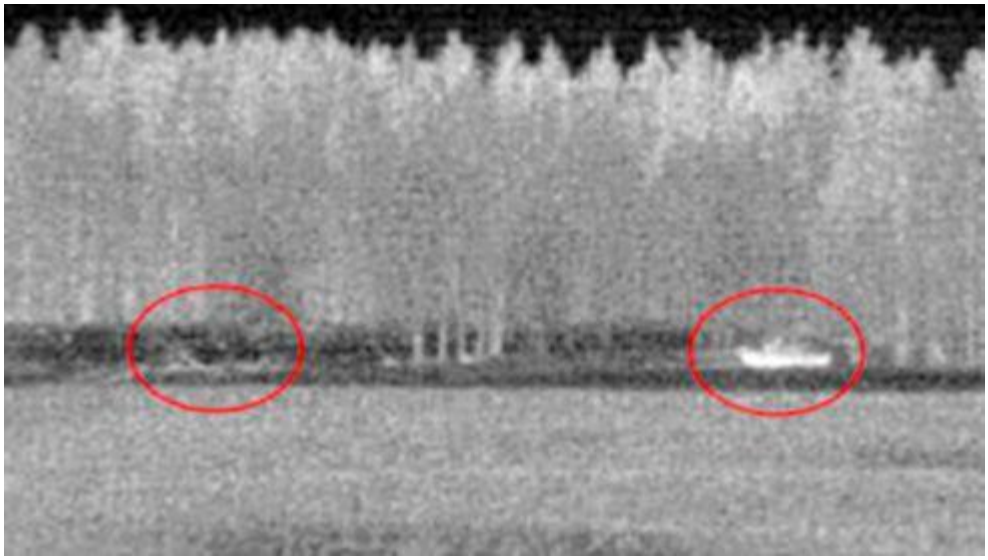

Figure 10. Thermal Infrared Camouflage (left image). (Image courtesy of Saab Barracuda, "MCS Mobile Camouflage System: Protection on the Move," Saab.com. https://saab.com/land/signature-management/platform-integrated-systems/mcs_mobile_camouflage_system/. [accessed January 18, 2018]).

Physically obscuring these dispersed and mobile forces within the EMS is also vital to avoiding detection and targeting. Vehicles and relocatable systems such as artillery pieces covered with multi-spectral camouflage netting that does not inhibit the operation of the equipment obscure them to ISR capabilities within the EMS.[48] Technological advancements such as Saab Barracuda's Mobile Camouflage System not only provide visual obstruction, but also obscures thermal infrared and radar reconnaissance.[49] Figure 10 depicts this thermal infrared camouflage. Obscuring larger formations of ground forces potentially requires different approaches. The employment of smoke and other obscurants to reduce the signature of vehicles and larger formations by reflecting or absorbing electromagnetic energy utilized by the enemy to find their target is one example.[50] Emerging technologies are improving obscurant capabilities by incorporating new particles and materials that can reflect RF energy.[51] Obscuring actual

friendly forces and decoys would further confuse ISR sensors and compel the enemy to engage false targets. This could also force the enemy to shift from passive ISR sensors to active RF seekers that would be easier for Marine Corps ISR assets to detect, target, and deceive the enemy through jamming.[52] Emissions control, dispersion, and obfuscation within the EMS all contribute to securing maneuver space within a contested information environment while denying the same to the enemy.

Resilient Communications

Peer-competitors will employ a large range of passive and active sensors in highly contested information environments, requiring a combination of ingenuity and technology to circumvent the enemy and demonstrate resiliency. Marines could employ low-probability of intercept/low-probability of detection (LPI/LPD) line-of-sight (LOS) radio and data links to minimize intercept and detection. LOS communications systems are much less vulnerable to detection and jamming, as their transmission are more directional and limited by the horizon.[53] LOS transmissions are less vulnerable, but not immune to detection. Therefore, employing multiple small, low-altitude unmanned aerial vehicles (UAV) equipped with C2 systems serving as communications relay sites through LPI/LPD transmissions could be one solution. In a highly contested information environment, the detection of these transmissions is still possible. In this scenario, the source of the detected transmission would be the UAV, and not Marines on the ground.[54] Another form of resilient communications in a highly contested information environment involves a more time-honored approach. Mobile ground-based HF radios and tropospheric scatter microwave systems could broadcast to deployed Marine forces located hundreds of miles over the horizon, a method used by the US during the Cold War.[55] Ingenuity

coupled with new technology open doors the enemy intends to close through exploiting the EMS, and Marines will need to adapt to this new information environment.

Conclusion: Mindset, Tactics, Technology

The consensus among top military leaders throughout the Department of Defense is that peer-competitors have been preparing to dominate the information environment by leveraging their technological advancements to restrict or deny US forces' freedom of maneuver and secure their own maneuver space. While the Marine Corps remains battle-hardened through more than a decade of fighting, the advantages experienced fighting in an uncontested information environment has ill-postured it against a peer-competitor nation state capable of relentlessly contesting the information environment. To win its next fight, the Marine Corps must take a combined approach to dominate the information environment and negate the closed technological gap it once enjoyed. Emerging threats posed by peer-competitors' technological advances require a combination of evolving MAGTF commanders' mindset, tactics, and technologies. The establishment of the DC I and the MIG is a significant step in the right direction to evolving the mindset of MAGTF commanders, but the MIG's operational effectiveness is yet to be realized. An evolution in the mindset also involves an emphasis on mission-type orders, decentralized execution, EMS discipline, and training Marines how to fight in a contested information environment, for example, no GPS, no SATCOM, no Blue Force Tracker. Evolving tactics require avoiding large concentrations of forces and operating in smaller dispersed units, capitalizing on LPI/LPD LOS radio and data links to avoid detection, and employing physical and logical decoys on the battlefield and in cyberspace to confuse enemy ISR. The nature of war never changes, but recent advancements in technology are changing the

character of warfare. The Marine Corps must acquire the capability to visualize the EMS for its commanders. The IE Ops running estimate is a promising initiative, but so far it is just that, an initiative. The Marine Corps must get this right, and soon. New technology also provides emerging ways to conceal friendly forces within the EMS and confuse enemy ISR. Ingenuity combined with new technology can negate enemy technology (UAVs, Cold War HF). If the Marine Corps fought a peer-competitor today, it would experience a highly contested information environment, severe fog of war and confusion on the battlefield, and a quick realization that something needs to change. Now is that time to make the changes.

Just like Fleet Landing Exercises prepared Marines for amphibious operations during the interwar period, realistic exercises with a focus on operating in a contested information environment must be a focus. Refinement and calibration of Marine Corps doctrine and technology require numerous iterations of war-gaming and practical application to produce a force capable of winning the next fight. The Marine Corps' next fight will necessitate maneuver warfare within a contested information environment. The Marine Corps has perfected maneuver warfare as it applies to the physical battlespace. Adapting that same concept to the electromagnetic spectrum and the information environment as a whole to shatter the cohesion of the enemy is the next evolution in the changing character of warfare.

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