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A future concept paper submitted to USMC Command and Staff College faculty in partial satisfaction of the requirements of an MS in Military Studies and a graduate certificate in Future Concept development as part of the Gray Scholars program.

14. ABSTRACT The current MAGTF lacks a resilient MACCS capable of simultaneously aggregating and operating, surviving aggressive adversary targeting efforts, contributing to maritime situational awareness, and supporting distributed engagement. Air and surface surveillance radar sensors are highly vulnerable to detection, are not deployed in sufficient numbers to absorb an attack, detect low flying threats at insufficient distances to intercept them over water or land, and continue to have limited deployment and mobility options in a maritime environment. Additionally, the MACCS is not currently organized, trained, or equipped to adaptively task-organize employed AC2 nodes by reconfiguring functional capabilities optimally accomplish the mission as the situation changes. The MAGTF as part of an integrated Naval Forces will sense, share, deceive, and engage peer adversary forces in a distributed maritime environment in the contact, surge, and blunt layers to achieve national military objectives along the competition continuum and improve survivability. The MACCS must deploy small and stealthy autonomous unmanned air and surface multi-spectral / modal sensors to augment larger air surveillance radars, employ networked hybrid AC2 nodes that can adapt during operations, and reinvigorate the Marine Corps aviation philosophy of centralized command and decentralized control. The objective is to swarm forces and fires to destroy adversary physical and psychological strength and increase friendly force survivability.

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MASTER OF MILITARY STUDIES

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MASTER OF MILITARY STUDIES

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DISCLAIMER

EXECUTIVE SUMMARY

Title: Marine Air Command and Control System: Creating Resilient Sensors, Sharers, and Shooters

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Thesis: The Marine Air-Ground Task Force (MAGTF) as part of an integrated Naval Forces will sense, share, deceive, and engage peer adversary forces in a distributed maritime environment in the contact, surge, and blunt layers to achieve national military objectives along the competition continuum. To accomplish this, the Marine Air Command and Control System (MACCS) must deploy small, stealthy, and autonomous unmanned air and surface multi-spectral / modal sensors to augment larger air surveillance radars, employ networked hybrid Aviation Command and Control (AC2) nodes that can adapt during operations, and reinvigorate the Marine Corps aviation philosophy of centralized command and decentralized control. The objective is to swarm forces and fires to destroy adversary physical and psychological strength and increase friendly force survivability.

Discussion: Department of Defense (DoD) directive 5100.01 specifies the functions of the Navy and Marine Corps, while the future security environment is described in the 2015 Marine Corps Security Environment Forecast: Futures 2030-2045, the Marine Corps Operating Concept (MCOC), as well as the Littoral Operations in a Contested Environment (LOCE) and the Navy's distributed maritime operations concept. Informed by these sources, the current MAGTF lacks a resilient MACCS capable of simultaneously aggregating and operating, surviving aggressive adversary targeting efforts, contributing to maritime situational awareness, and supporting distributed engagement. Air and surface surveillance radar sensors are highly vulnerable to detection, are not deployed in sufficient numbers to absorb an attack, detect low flying threats at insufficient distances to intercept them over water or land, and continue to have limited deployment and mobility options in a maritime environment. Additionally, the MACCS is not currently organized, trained, or equipped to adaptively task-organize employed AC2 nodes by reconfiguring functional capabilities to adjust to a changing situation and optimally accomplish the mission. Ultimately, the problem is how to grow the MAGTF and Navy's ability to sense, share, deceive, and engage adversary forces while improving survivability.

Conclusion: The U.S. military is exploring "insider" asymmetric capabilities such as swarming concepts that can operate within enemy threat rings, the Anti-Access / Area Denial (A2AD) environment. Swarming is the systematic and simultaneous temporary massing of dispersed and connected forces and fires against an adversary from all directions. The objective is to destroy adversary physical and psychological strength and increase friendly force survivability. A MAGTF needs to provide air and surface surveillance multi-spectral / modal sensing of airborne and surface threats and coordinate the prosecution of those targets at ranges for the joint force that extend into contested areas with Anti-Access / Area Denial systems. It must provide complementary sensing in a high threat maritime environment and inland to enable remote engagement (engage-on-remote). Smaller mobile air and surface surveillance multi-spectral / modal sensors are a significant targeting challenge for the adversary over water and land. They can complement larger air surveillance radars by illuminating areas not covered by larger radars due to terrain or the curvature of the earth. These smaller sensors can provide early queuing to

larger more capable radars and contribute to a common tactical picture over networks managed by resilient hybrid AC2 nodes. A large number of active and passive sensors and decoys, turning on and off at different times and constantly moving, combined with selectively activating large air surveillance radars, will stimulate the adversary's observations at a rate that will overwhelm their ability to target, while disguising friendly capabilities. Gaining superior situational awareness for lower-level ground commanders, creating greater air defense and sea control options in depth, and speeding up the processing of immediate air support requests will enable the swarming of forces and fires to decimate enemy forces. The Marine Corps has an opportunity to enhance the Joint Force's capability to sense, share, deceive, and engage threats beyond the ranges of friendly high value large radar systems by dispersing constantly moving smaller air and surface active and passive multi-spectral / modal sensors, hybrid AC2 agencies, and distributed weapon system. At the operational level, horizontally competing against the adversary across one or two theaters can increase adversary costs, forcing them to commit more resources and evaluate their interests. Avoiding tunnel vision and restricting one's actions to the exact physical point of contest does not provide the full range of options across the competition continuum that will be required to force adversary cost imposition calculations.

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PREFACE

This future functional concept paper is the result of my participation in the Marine Corps University (MCU) Command and Staff College (CSC) AY2018-2019 Gray Scholars Program. Through the course of numerous wargames focused on future Marine Corps fights with peer and near-peer adversaries, I sought an opportunity to explore a variety of ideas I had developed over the year. Additionally, I incorporated a variety of ideas from the broader Marine Corps Aviation Command and Control Community, to include the Aviation Expeditionary Enablers Branch within the Marine Corps' Department of Aviation. The nature of war remains unchanged; it is still violent, interactive, and used to achieve political ends. However, the character of war is evolving as changes in academia, culture, ethics, laws, the political environment, technology, and institutional structures influence it. While not a complete list, it is clear that as the world and people in it change, so does the ways we think about the conduct of war. The reality is that while the nature of war remains fundamentally the same, the character manifested as the ways and means continue to change and broaden. The security environment is the product of the changing character of war. Within this context, violence will continue to be used to achieve political objectives. However, the exclusive notion that states are either at war or peace is no longer valid, as we see with the rise of gray zone activities by countries such as the Russian Federation (Russia) and the People's Republic of China (PRC) that appears as a continuum.[1] Violence is being utilized in limited or indirect ways; the character of warfare is changing to achieve political objectives. This future functional concept paper will define some of the military problems of the future and describe the scheme for employing military capabilities to achieve desired end states.

This future functional concept paper is subordinate to the Marine Corps Capstone Operating Concept, Littoral Operations in a Contested Environment, and Expeditionary Advanced Base

Operations, and supports the Navy's Distributed Lethality concept. A Practical Guide for Developing and Writing Military Concepts working paper was utilized as the framework and guide for developing this future functional concept paper.

Special thanks go to professor Dr. Benjamin Jensen and Dr. Nathan Packard who led the Gray Scholars program. Thanks also to the staff at the Marine Corps Warfighting Laboratory, especially the Ellis Group. Finally, thanks to my fellow Gray Scholar colleagues for their insights that helped develop this concept.

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[1] Joint Chief of Staff, *Joint Concept for Integrated Campaigning*, 16 March 2018, 7; Headquarters US Marine Corps, *Marine Corps Operating Concept*, (Washington, DC: Headquarters US Marine Corps, 2016), 6.

INTRODUCTION

PURPOSE

The purpose of this future functional concept is threefold:

1. Describe the future problems that the MACCS will face when the Marine Corps fights peer adversaries in a maritime environment as part of a Naval Force.
2. Describe how the future MACCS will employ networked air and surface surveillance multi-spectral / modal sensors and hybrid Aviation Command and Control (AC2) nodes to provide battlespace understanding and enable rapid effects requests processing to operate, fight, and win in the future maritime environment as part of a Naval Force.
3. Create a sense of urgency and shape further MACCS material and non-material solutions to mitigate future challenges.

A great deal of work has already been done on the concept of hybrid AC2 nodes, sometimes referred to as Multi-functional AC2 nodes or as the Multi-functional Air Operations Center (MAOC) concept.[1] A group of select Marines undertook this work at MAWTS-1 (Marine Air Weapons Training Squadron) and Marine Air Command and Control Squadron – Experimental Operational Development Team (MACC-X ODT).[2] While hybrid AC2 nodes are described and utilized throughout this functional concept, their descriptions are limited to how they could be employed with MACG Sensor Teams (MST) to support a network of sensors, sharers, deceivers, and shooters. The details as to how to reorganize the Marine Air Control Groups (MACG) and Military Occupational Specialties (MOS) are missing as they go beyond the scope of this functional concept. How the MACG should man, organize, train, and equip to create hybrid AC2 nodes is an ongoing debate within the MACCS community and remains unsettled. Regarding unmanned sensors and digital interoperability, this functional concept focuses on describing them and their utilization in a maritime environment, but the specific doctrinal and technical details are missing and will require further development.

While this paper will analyze the problem, describe a future functional concept, and provide recommendations, it will not meet the required level of detail needed to implement immediately. The devil is surely in the details, but before one can develop all of the doctrinal and technical details, much work must be done to understand the concept entirely. This future functional concept paper proposes a "theory of victory" designed to address the Marine Corps' future problem. The future functional concept must be tested rigorously and evaluated to determine if it is valid. Only then can industry and government come together, unified by a valid concept, to mature the details required to produce material and non-material solutions to win in the future.

Thesis Statement

The Marine Air-Ground Task Force (MAGTF) as part of an integrated Naval Forces will sense, share, deceive, and engage peer adversary forces in a distributed maritime environment in the contact, surge, and blunt layers to achieve national military objectives along the competition continuum.[3] To accomplish this, the Marine Air Command and Control System (MACCS) must deploy small, stealthy, and autonomous unmanned air and surface multi-spectral / modal sensors to augment larger air surveillance radars, employ networked hybrid Aviation Command and Control (AC2) nodes that can adapt during operations, and reinvigorate the Marine Corps aviation philosophy of centralized command and decentralized control.

Time Horizons

This future functional concept materializes in 2030 because it is conceivable that everything that is required could be ready by then. It also is reflective of the *2015 Marine Corps Security Environment Forecast: Futures 2030-2045*, which describes “the character of future conflict.”[4] The difficulty in employing hybrid AC2 nodes is indeed bureaucracy, which has to determine the doctrine, organization, training, material, leadership, personnel, and facilities changes, while also contending with the interests of different stakeholders. The primary AC2 system already exists and only requires continued modifications to adapt it to meet the requirements outlined in this future functional concept paper.[5] Work is already being done to produce enhanced mobility solutions and radios, as well as overcome interoperability road-blocks. The radars and sensors described in this concept paper are at different degrees of technical maturity and will likely require the most significant investment. Precisely because this concept only recommends narrow Artificial Intelligence (AI), which is development, it is within the realm of the possible.

ASSUMPTIONS

Six assumptions have been made to support the continued development of this future functional concept. These assumptions are realistic and are suppositions about the future that is necessary to facilitate continued concept development.

One, passive radars will improve in capability, shrink in size, and utilize less energy by 2030. Moreover, they will match current short and medium-range active air and surface surveillance radar sensors, while also still being limited by the curvature of the earth given their low height-of-eye. It is assumed that the technical details will be further developed and refined as the concept undergoes experimentation. These sensors will fit and operate in a small watercraft, up to five meters in length, or an internally transported vehicle (ITV).

Two, the Chinse and Russians will continue to invest in high-end Anti-Access / Area Denial (A2AD) capabilities and significantly improve their ability to target at longer ranges.[6] They will focus on expanding their long-range precision fires (anti-ship and land strike) capabilities, air defense systems, electronic warfare capabilities, and both armed Unmanned Aerial Systems (UAS) and Unmanned Surface Vehicles (USV).[7] The future maritime environment will compress, the decision space will decrease, and the cost to operate will increase.

The assumption is that A2AD weapon systems, combined with the massing of U.S. forces and their emitting combat systems, present readily targetable signatures for the PRC and Russia.[8] Additionally, non-state actors will continue to expand their capabilities that will restrict U.S. freedom of maneuver on land, in low-altitude airspace, and in the information domain. They will have access to weapon systems that threaten armored vehicles, helicopters, and low flying UAS. They will also grow their capability to operate in the low-altitude airspace with the use of UAS for Intelligence, Surveillance, and Reconnaissance (ISR) and offensive air support.[9]

Three, the Marine Corps will employ a digital interoperability solution and Software Reconfigurable Payload (SRP) radios by 2030. The SRP is a multi-mode, multi-band, software reprogrammable radio capable of supporting up to seven simultaneously operating waveforms. The SRP is critical for future Joint and Coalition interoperability. An example of a current Marine Corps aviation solution in development is the MAGTF Agile Network Gateway Link (MANGL), which works with Digital Interoperability – Full Motion Video (DI-FMV), Network-on-the-Move (NOTM), and the Fused Integrated Naval Network (FINN), amongst others.[10]

Four, the MACG will either acquire the MAGTF UAS Expeditionary (MUX) or receive dedicated MUX sorties that support specialized MACCS modules for voice and data communications or battlefield sensing. Additionally, the Marine Air Wing (MAW) will acquire weapons payload modules and specialized Intelligence, Surveillance, and Reconnaissance (ISR) modules. By 2030, the MAGTF will have a group five UAS capable of vertical take-off and landing – matching the capabilities of the MV-22 – and possess the ability to change mission modules.

Five, wherever MACCS capabilities are originate from, they will be able to come together and task-organize upon arrival and immediately start to employ because of already existing network architectures. The future maritime environment, physical and electromagnetic, will continue to be contested. It will require the MACCS to maintain an organizational and network architecture in various areas of operations that will enable them to arrive organized to employ and fight immediately. The MACCS will not be able to deploy near the area of operations, accept additional forces, and setup and rehearse on data and voice networks. Then redeploy into the AO, setup, fight, and win. The MACCS will need to deploy into theater already networked and ready to fight.

Six, the MCOC and LOCE both capture the Marine Corps' analysis as to what the future security environment will look like in 2025, as well as other service-level challenges. As such, the assessments provided in both documents are assumed to be accurate and provide a baseline from which to develop this future functional concept.

RISKS

There are two risks for failing to address the problems presented in this future functional concept.

1. There is a high probability that an adversary force will be able to easily target and eliminate the MAGTF's and Navy's few large and highly capable air and surface surveillance radars. This threat to vital assets will significantly impact the United States' (U.S.) ability to conduct sea control and power projection.
2. There is a high probability that the MACCS will not be able to continue to provide critical AC2 services to the MAGTF and the Navy after the adversary eliminates a few nodes. A lack of MACCS resiliency significantly impacts the U.S.' ability to conduct sea control and power projection.

3. Not resolving the challenge around establishing adaptable and robust data and voice communications that work immediately upon arrival will significantly impact the MACCS. Not doing so will force the MACCS to have to spend time establishing and validating networks upon arrival in theater, delaying support to the MAGTF and putting at risk sea control and power projection.

MILITARY PROBLEM

THE PROBLEM STATEMENT

Given the Navy and Marine Corps' functions specified in the Department of Defense (DoD) directive 5100.01, and the future operating environment as described in the MCOC and LOCE, the current MAGTF lacks a resilient MACCS capable of simultaneously aggregating and operating, surviving aggressive adversary targeting efforts, contributing to maritime situational awareness, and supporting distributed engagement. Distributed engagement is nothing more than the use of distributed forces to utilize superior situational awareness and mission type orders to take the initiative and coordinate with other forces to engage the adversary. Air and surface surveillance radar sensors are highly vulnerable to detection, are not deployed in sufficient numbers to absorb an attack. They cannot detect low flying threats at sufficient distances to intercept them over water or land, and continue to have limited deployment and mobility options in a maritime environment.[11] Additionally, the MACCS is currently not organized, trained, or equipped to adaptively task-organize employed AC2 nodes by reconfiguring functional capabilities to adjust to a changing situation and optimally accomplish the mission. Ultimately, the problem is how to grow the MAGTF's and Navy's ability to sense, share, deceive, and engage adversary forces while improving survivability against aggressive adversary targeting efforts.

Problem Elements

Air and Surface Surveillance Multi-Spectral / Modal Sensors

Large Air Surveillance Radar Sensors. Current large air surveillance radars (Examples, AN/TPS-59 and AN/TPS-80) can detect and share high-end airborne threats, such as adversary cruise missiles, manned and unmanned aircraft, and intercontinental ballistic missiles. Moreover, they are large, require a great deal of energy, are very expensive, have trouble detecting small and low flying aircraft, and either operate from fixed positions or move relatively infrequently. While low flying cruise missiles are difficult to detect at far ranges, the odds of detection increase as they get closer to an air surveillance radar and visual sensors. These radars are very vulnerable to adversary detection and attack, require stand-off distance for protection, and have limited use depending on threats. Given the criticality of these assets, there is a constant tension between detecting threats and avoiding destruction. Due to their limited numbers, they are considered critical assets and their destruction potentially creates an air surveillance radar sensor gap.

Small Air Surveillance Radar Sensors. A variety of newly developed and deployed small air surveillance radar sensors have filled the immediate need to detect many airborne threats, ranging from adversary helicopters to low flying airplanes and UAS. These solutions – equipped with multiple sensors (radar and electro-optical), require less energy to operate, can be mobile, are highly moveable, can fit inside of helicopters, and perform on the move – making them harder to detect and fix when compared to much larger radars (Examples, AN/TPS-59 and AN/TPS-80). Additionally, because they are much cheaper more can be purchased and deployed. Since they have shorter sensor ranges relative to much larger radars, more sensors will need to be purchased. Given their low cost and abundance, their loss will have less of a financial and operational impact compared to the loss of a larger sensor. The current Marine Corps version, Light Marine Air Defense Integrated System (L-MADIS) – currently serving as a stand-alone system tied to short-range air defense weapons (electronic attack or kinetic FIM-92 Stinger missile) – are land-based and characterized by the above description.

Electronic Emissions. All current active air surveillance radars emit a signal to detect aircraft and are vulnerable to detection. The larger and more capable the active radar, the larger the electronic signature. While smaller radars are harder to detect and can use quantity to build in resiliency into an air surveillance sensor network, they still give off an electronic signature. The reality is that active radars are more mature and have a proven record of higher performance. Utilizing other types of passive sensors have the potential of improving the survivability of actively emitting systems by reducing detection.

Land-Based Air Surveillance Radar Sensors. Current Marine Corps large and small air surveillance radars are restricted to the land. Highly capable Navy radars on large ships are on open waters; it is difficult for a ship to "conceal" itself. While the curvature of the earth does provide some over the horizon concealment, it is dependent on the size of ship – cruisers and destroyers to aircraft carriers. Large radars require larger vehicles and sources of power, while smaller radars require a higher number of smaller vehicles and sources of power. Marine Corps and Army radar sensors are restricted to land. Navy radars are attached to ships with a tremendous number of weapons, which presents a lucrative target and thus uses standoff distance to protect itself from threats. Deploying unmanned surface vessels (USV) with large radars to sense ahead of the rest of a Naval force would be beneficial but face the above described large radar sensor problems. None of the land-based large radars are capable of detecting low flying aircraft or cruise missiles hundreds of miles off of a coast. This reduces decision-making time as these low flying threats are undetectable off the coast until they are within range of the smaller mobile land-based air surveillance sensors. While large sensors could be improved, they emit a large signature and cannot detect low flying objects over the horizon. Additionally, situational awareness of low flying friendly aircraft off of the coast or away from a ship is extremely low. Additionally, the Marine Corps has no way of detecting surface threats to improve overall Navy-Marine Corps situational awareness.

Real-Time Fire Control Quality Data. All air and surface surveillance radar sensors require constant real-time communications to share data, as it is used to track adversary threats and transmit fire control quality data as part of a larger Integrated Air Defense System (IADS). This high rate of communications requirement makes these sensors vulnerable to detection by the adversary. While this is necessary for the prosecution of targets as part of an IADS, it is also not necessary to continually transmit at all times, especially if the threat situation does not warrant it.

Short-range air defense (SHORAD) is a capability residing under the umbrella of Anti-Air Warfare's Defensive Counter Air (DCA) function. It provides lower level tactical commanders the ability to defend themselves, but also influence the air battle for the entire MAGTF. This is similar to a platoon commander – acting on mission-type orders and commander's intent – utilizing anti-armor weapons to disproportionately impact the adversary with armor in a ground battle. The future operating environment necessitates greater standoff from adversary weapon systems and distances between sensors, command and control (C2) centers, and shooters. Ground forces will likely operate within the adversary's weapons engagement zone, while larger aircraft and naval forces may need to move out of it to reduce risk. Greater distances in a communication contested environment presents the need for the development of ways to support expanded tactical initiative. Leaders at the operational level need to understand the campaign to provide guidance and resource – intelligence, materials, forces, or fires – to tactical leaders as required. Although the time to detect, decide, deliver, and assess (D3A) will increase for those larger C2 centers, the same will not be true for close-in ground forces who are not necessarily equipped to manage the expanding three-dimensional threat, which now includes airspace. Threats from the air are an increasing problem for lower level tactical forces, who do not currently have the resources to defend themselves, let alone understand their air environment.

Forward deployed and distributed ground forces will deploy with SHORAD and anti-armor capabilities that are hard for adversary forces to detect but may have to still operate in a centralized C2 system. Authorities for engagement need to be pushed down to the lowest levels possible. Local commanders may not possess the capabilities needed to prosecute all the targets they identify. They have to contend with air and surface threats beyond their small battlespace and may not have ownership of the space over the water or in the air. They will need to handle inbound airborne or surface threats that may not directly threaten them but could impact more substantial and critical assets, such as Navy ships. Adaptive C2 with AI needs to be developed to adjudicate and optimize target engagement. Understanding that resources will always be limited, never infinite, the challenge is how to efficiently distribute sensors, sharers, shooters, and authorities to engage threats across a large battlespace.

MACCS ORGANIZATION

MACCS AC2 Functional Nodes. The MACCS today provides the MAGTF with AC2 nodes. For example, a Marine Air Support Squadron is capable of task organizing AC2 nodes (Centers, Elements, and Teams) that can provide any combination of capabilities as described by the squadron’s functional Mission Essential Tasks (MET). Over the past few years the

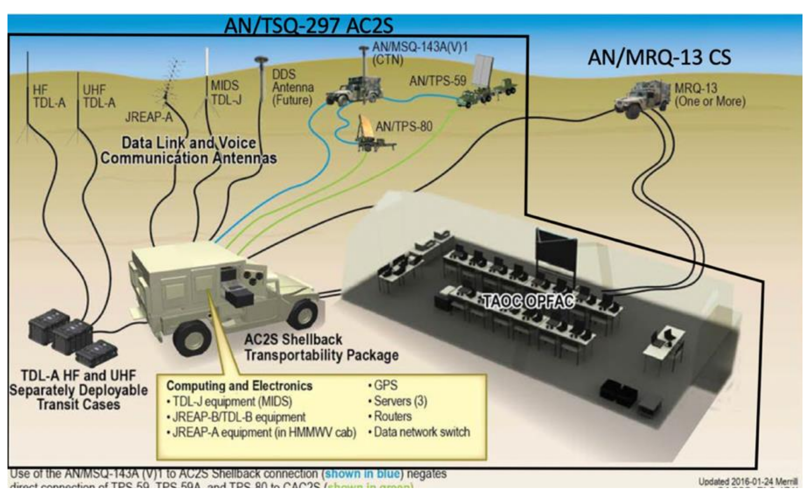

Illustration 1: CAC2S Systems & Subsystems

MACCS has been rewriting METs to best describe the capabilities provided by each squadron to accomplish two things: first, facilitate a move towards improving a squadrons ability to task-organize AC2 nodes; and second, to better communicate to those capabilities that reside in each squadron to outside stakeholders. Additionally, the Common Aviation Command and Control System (CAC2S) is being fielded to improve interoperability and reduce maintenance and supply requirements. *Illustration 1* depicts the current version of the system being fielded, but it lacks the necessarily scalability and modularity that deviates from the provided Aviation Command and Control Subsystem (AC2S) shellback and Operational Facility (OPAC) setup. Certainly, it provides the capabilities the MACCS needs today, however its next upgrade should consider how it will best support this future functional concept. How AC2 nodes choose to set up and utilize CAC2S should informs how they will configure their software, along with what radars - external sensors - to connect.

The problem today is that AC2 nodes cannot be reconfigured once deployed in combat; they are task-organized before deploying. Indeed, it is true that AC2 nodes can be scaled, but that is the extent of it. These AC2 nodes are designed to work together as part of a system, but the nodes themselves cannot be combined to create fewer nodes with the same capabilities. How can the MACCS provide "varying degrees of air command and direction, air support, air control, air defense/surveillance," and digital interoperability services with the smallest sustainable footprint possible?[12] How can the MACCS tailor AC2 nodes throughout all phases of an operation and layers of competition?

There is little resiliency in the MACCS. While there may be a Direct Air Support Center (DASC) and a Tactical Air Operations Center (TAOC) operating – with each having a sister center moving to the next location – there are typically only one of each providing their functional capabilities to the entire MAGTF. If the adversary destroys the TAOC, the entire system would be left reliant on the one remaining TAOC that may need to move frequently to survive. There is no way to add a few Marines to the DASC and plug in a few air surveillance radars to create a hybrid – multi-functional – AC2 node for a temporary period.

More importantly, AC2 nodes conducting positive control as part of Anti-Air Warfare (AAW) require the connection of an air surveillance radar sensor to the CAC2S. There is currently limited to no ability to separate the AC2 node from the sensor to improve hybrid AC2 aggregation options and survivability. The reality is that MACCS AC2 nodes are not resilient or adaptable once combat operations are underway. It is difficult to aggregate various AC2 capabilities while AC2 nodes are operating. While the MACCS has proven itself to work effectively in the past, the MACCS does not have the doctrine, training, or equipment to effectively aggregate, operate, and adapt while portions of it are being destroyed; it lacks resiliency.

Another example would involve the aggregation of two Marine Expeditionary Units (MEU) with MACG detachment Air Support Elements (ASE). Currently, the combination of the two does not result in a Direct Air Support Center or really anything except two ASEs. If they wanted to forward deploy ashore, they would not have the organic ability to detect objects in the air. While a LAAD section may deploy ashore with their organic L-MADIS air surveillance radar, it does not connect to the ASE or the Navy's N-TACC. One also could not deploy a dozen AN/TPS-42 air surveillance radars separate from a LAAD, as they are designed for SHORAD only. They cannot be networked into the ASE and contribute to a CTP that the N-TACC may access. Additionally, one could not combine the Marine Mobile Air Traffic Control Team (MMT) and ASE with an AN/TPS-42 to create a hybrid AC2 node at an airfield, and then network the deployed L-MADIS from both MEUs, to improve situational awareness of the airspace for both the AC2 node, ground units, and the N-TACC. The inability to create multi-functional nodes with the freedom to distribute air surveillance sensors hinders MACCS employment options.

Communications Architecture. While it may be required to have a network capable of passing fire control quality data, there is still a problem as to how to correctly identify, correlate, and fuse plot and track data from over twenty mobile air and surface surveillance radar sensors. Additionally, there is a constant tug and pull between the desire for high-refresh fire control quality data and near-real-time situational awareness. There is a heavy communications burden placed on the MACCS to share fused fire control quality track data derived from multiple sources with the rest of the Marine Air-Ground Task Force (MAGTF) and Navy. To meet this requirement a beyond line of sight (BLOS) communications solution with a high enough bandwidth to pass a lot of data, which produces a relatively high signature, will be required. Additionally, if BLOS is not available, a LOS communications system which necessitates a retransmission or gateway capability will also be required. On top of all of this, a communication denied or degraded environment full of electronic attack capabilities threatens the high demand signal for fire control quality data.

Lastly, there are problems with talking to aircraft, especially rotary-wing aircraft, in a distributed environment because of the distances between ground forces, ships, and airfields. Often aircraft are forced to revert to BLOS satellite communications, which are not on all aircraft, or utilize fixed-wing to help relay communications. There is no airborne network capable of supporting BLOS and LOS voice and data communications between aircraft, ships, AC2 agencies, and ground forces that do not rely on satellites. Ultimately the problem is how can the MACCS meet the MAGTF’s and Navy's requirement to be aware of adversary forces and threats beyond the capabilities of large sensors on land and ships. While also facilitating the engagement of adversary forces, operating in a communication denied environment, and ensuring the survivability of forward deployed radar sensors.

Manual Air Support Request Process and Decision Making. Immediate air support request processing requires the Direct Air Support Center (DASC) or the Supporting Arms Coordination Center (SACC) to receive and prioritize requests, assign resources, and route aircraft to requesting units. Processing immediate requests and routing aircraft without the aid of decision making and automated communications tools is time-consuming and fraught with possible points of human error. The process is centralized, requiring that the information eventually flow into a decision-making center. Nearly the entire process is manual and requires a human to input, process, and extract data. There are no tools available to aid with decision making.

CENTRAL IDEA

Nations with sophisticated militaries are capable of detecting and engaging adversaries utilizing large ships and aircraft with advanced air and surface radars, sensors, and precision-strike weapons.[13] The U.S., like other nations, uses distance to increase survivability while investing in more powerful radars, sensors, and weapons to maintain lethality – a seemingly endless cycle. This problem will only worsen into the future. In response, the U.S. military is exploring "insider" asymmetric capabilities such as swarming concepts that can operate within enemy threat rings, the Anti-Access / Area Denial (A2AD) environment. Swarming is the systematic and simultaneous temporary massing of dispersed and connected forces and fires against an adversary from all directions. The objective is to destroy adversary physical and psychological strength and increase friendly force survivability.[14] Operational and tactical swarming of MAGTF and Naval force and fires has been witnessed throughout history.

The reality is that swarming is not a dramatically new way of warfighting for the Marine Corps. Instead, it is a response to the evolving future operating environment that is defined by complex terrain, technology proliferation, information warfare, electronic signatures, and an increasingly contested maritime domain.[15] This future functional concept does not replace Marine Corps doctrine; rather it emphasizes the continued application of maneuver warfare as espoused in Marine Corps Doctrinal Publication One (MCDP 1), Warfighting.[16]

There are five core variables to successful swarming: superior situational awareness, elusiveness, standoff, envelopment/encirclement (multi-directional attacks), and simultaneity.[17] Based on the five core variables, there are two requirements for successful swarming. First, swarms must have many small dispersed units capable of quickly and effectively striking an adversary from multiple distances and directions. Second, units must serve as sensors and communicators to generate situational awareness and simultaneity.[18] The overall objective of swarming is to improve friendly survivability and weapons effectiveness to defeat the enemy where they are weak over time in a series of smaller victories, adding up to an operational and ultimately strategic victory.[19]

During World War II (WWII), allied Patrol Torpedo (PT) boats utilized swarming tactics at night with great effect against axis power coastal supply ships, cruisers, and destroyers.[20] While submarines likely had an even more significant impact, they did not employ swarming tactics in the same way at the PT boats. Nor did they utilize radars as PT boats did, which created superior situational awareness for the group of PT boats. With the incorporation of radars – designed primarily to detect surface ships and occasionally some aircraft – and radios, PT boats were able to detect adversary forces and coordinate dispersed attacks by employing swarming tactics.[21] Radars and radios on PT boats provided superior situational awareness that facilitated improved elusiveness, standoff, encirclement, and simultaneity, enabling the swarming of forces and fires on adversaries and enhancing the capabilities of larger, more conventional military forces.

U.S. PT boats belonged to one of the forty-seven U.S. Navy Motor Torpedo Boat (MTB) Squadrons formed during WWII. Each squadron consisted of ten to fifteen PT boats that typically operated in divisions of three.[22] The British similarly developed Coastal Forces, which utilized their own PT boat variants. British PT boats were defined by their primary weapons capabilities, either a Motor Torpedo Boat or Motor Gun Boat (MGB). The British did not combine both capabilities until 1942, with the introduction of the Fairmile D boats MTB.[23]

PT boats were designed to be fast, heavily armed, lightly armored, and maneuverable while being relatively low cost compared to other Navy ships. They had a low profile, could function in shallow waters, and operated at night to avoid detection and being hit by enemy fire while within effective torpedo range. Night time operations reduced the likelihood that PT boats would be visibly detected. They also took advantage of the relatively low performance of enemy radars and the fact that they were not as prolific as today. The primary mission of U.S. PT boats was to attack surface ships, but they were also capable of attacking submarines, rescuing vessels, escorting other ships, laying mines, and supporting commando operations.[24] Additionally, PT boats also rescued downed pilots and scouted and screened for larger ships.[25] They carried torpedoes, machine guns, and depth charges. Their small size, speed, and maneuverability – combined with their ability to detect ships at night and employ smoke – made them perfect for conducting surprise ambushes.[26] They mostly targeted supply and support ships, light

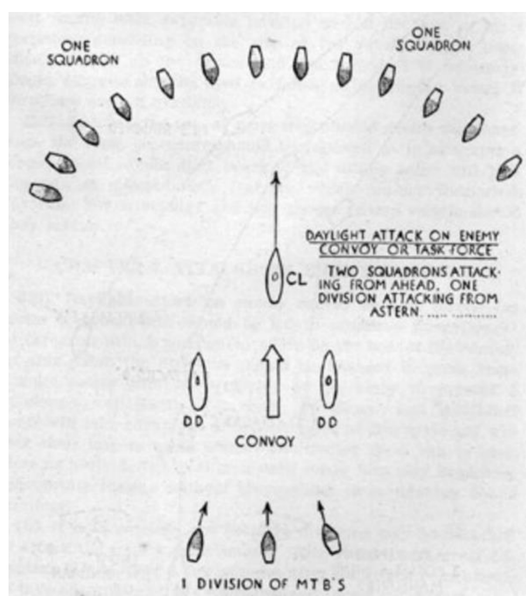

Illustration 2: Example of Daytime PT Boat Attack

cruisers, and light destroyers.[27] PT boats operated from distributed advanced naval bases, in groups near the coasts, and utilized radars and radios to locate, converge, and attack adversaries, quickly leaving to avoid a sustained engagement.[28]

The tactics employed were similar to what a Fighter Direction Officer (FDO) would use in the British Royal Airforce to control aircraft swarms against German Air Force aircraft over Great Britain.[29] Coastal radars, larger ship radars, or PT boat radars were used to direct other PT boats. American and British PT boats attacked ships with heavy machine guns and torpedoes (their standoff ship killing weapon), defended themselves from low flying aircraft, and used smoke to obscure their egress.[30] The larger lesson is that surface radars and radios were utilized to direct PT boats, and once engaged their collective situational awareness allowed smaller formations to conduct reattacks from various directions as part of a larger swarm. While not all cases involved larger numbers of PT boats, the general tactics and use of technology remained the same.

Larger naval ships were highly capable of destroying other similar ships, but had difficulty operating in the shallower coastal waters and targeting small boats. They were also readily detectable by enemy forces. Enemy supply ships avoided deceive engagements by moving along the coasts with protection from smaller escort ships and shore-based weapons. PT boats operated where larger U.S. Navy ships could not and inflicted tremendous damage on German and Japanese supply trains. Early during WWII, air and surface surveillance and targeting radars were developed for use on land and on large navy ships. By the mid-1940s, similar capabilities had made their way to PT boats.

Surface and air surveillance radars and radios on PT boats provided superior situational awareness that facilitated improved elusiveness, standoff, encirclement, and simultaneity. They enabled the swarming of forces and fires on adversaries and enhanced the capabilities of larger more conventional naval military forces. WWII PT boats exercised sea control in the littorals.

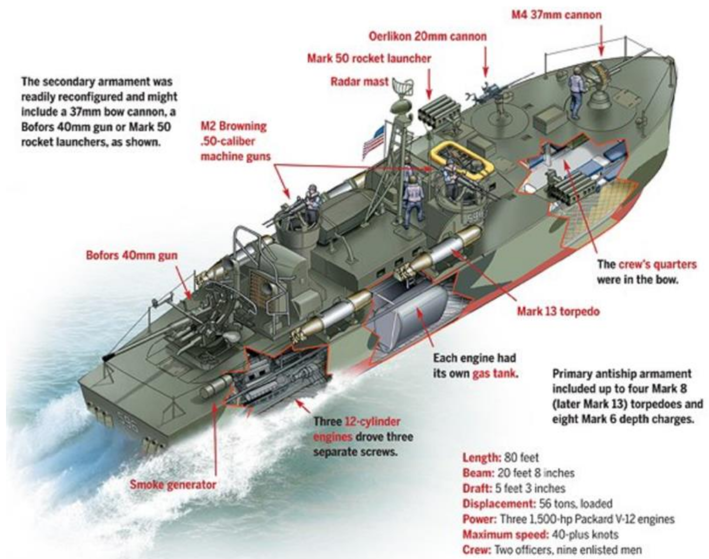

Illustration 3: Electric Boat Company (ELCO) PT Boat 1945 (Illustrated by Gregory Proch)

During the interwar period radars made huge technological advancements, but remained large and heavy, which presented one of the biggest obstacles for adoption on PT boats. For the British, surface radars were first added to the MTBs and MGB in 1941, with their most advanced version (Type 291U) added between 1942 and 1943. The Type 291U was able to provide aircraft warning and navigation in the daytime, as well as surface warning and limited torpedo control at night.[31] All U.S. PT boats, in contrast, came equipped with the 10cm type “SO” radar with a Plan Position Indicator (PPI) display and power-rotation by 1943, which were superior to the British radars.[32] Later, newer “SJ” radars were fitted on new PT boats while electronic friend-or-foe identification (FFI) devices were also added towards the end of WWII.[33] Both U.S. radars were 3,000 MHz with 50kw pulse surface search Raytheon radars capable of detecting ships out to 25 nautical miles.[34] The U.S. SO radars with PPI displays allowed PT boats to not only find adversary ships, but also more accurately and quickly vector boats.[35]

Radars and radios provided U.S. and British PT boats with the ability to locate, converge, and attack adversaries.[36] PT boats utilized an AM VHF radio that transmitted between 1.5 and 12 MHz frequencies, which provided them with a long-range communications capability up to 70 miles on a good day.[37] After identifying adversary ships, PT boats would coordinate multi-direction pulsing attacks against cruisers and destroyers or would form a column and engage the broadside of barges that operated near the coasts.[38] Radio direction finders were utilized in conjunction with radars to help locate other boats at night, as it was difficult to see and coordinate in the dark.[39]

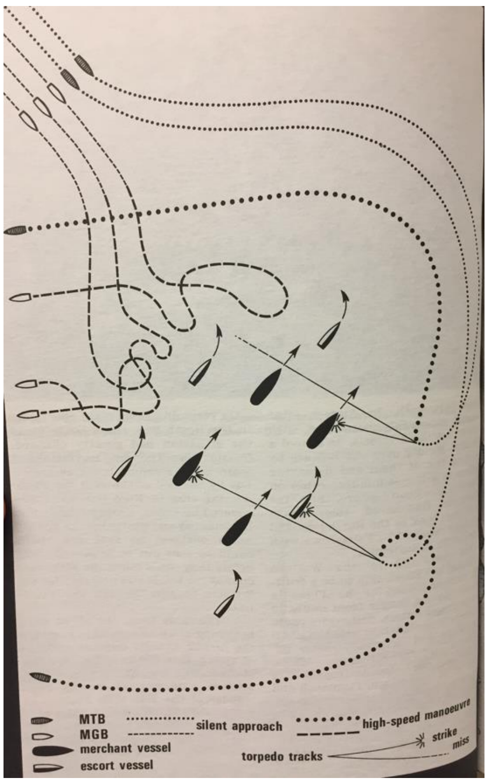

Illustration 4: Example of Nighttime MTB/MGB Engagement

PT boats would often move in a mass and then break up before the final approach on the adversary. Illustration 4 depicts a tactic that combined an MGB feint attack with multi-directional striking blows from the MTBs.[40] The following two historical events depict the usefulness of surface radars and radios in coordinating PT boat swarming attacks.

On the nights of 24 and 25 April 1944, a combined force of three British Landing Craft Gun (LCG) boats, three MGBs, three MTBs, and seven U.S. PT boats departed Bastia, Corsica to attack German supply convoys off the coast of Italy near Elba, Capraia island, and the Vada Rocks.[41] The boats left at different times because of the different speeds and courses, planning to converging within their operating area near the Vada Rocks.[42] Once en route, Commander Robert Allan of the United Kingdom’s Royal Navy Reserve (RNVR) provided vectors to the other ships from the U.S. PT boat.[43] In doing so, he was able to set up ambush positions from which to attack two convoys of German F-lighter barges, tugs, and trawlers pulling barges from multiple directions. Over the course of two nights, the combined force sunk five barges, one tug, and one German torpedo boat, which hit its mine during the engagement.[44] Given the weakness of British MTB/MBG radars, the British often utilized Coastal Forces control ships, which were destroyers and frigates with much more capable radars, and shore-based coastal radars to vector PT boats to swarm the adversary.[45]

One of the best examples of U.S. Navy PT Boat swarming utilizing radars occurred on 24 October 1944 when the boats ambushed the Japanese Navy's approaching southern force led by Vice Admiral Shoji Nishimura at the Surigao Strait in the Philippines during the Battle of Leyte Gulf. The day prior, fifteen PT boats were forward positioned at Liloan on Panaon Island, at the entrance to the Surigao Straight.[46] The Fifteen PT boats, five divisions of three ships each, were deployed in the eastern portion of the Mindanao Sea.[47] Each division served as a forward scout (sensors and communicators) for their assigned sector and helped to develop superior situational awareness for the rest of the U.S. Navy. They then were given mission-type orders to attack as divisions to break up the cohesion of the Japanese force, to not become decisively engaged, and report the location of southerly approaching adversary forces.

Meanwhile, during the day of 24 October, twenty-four PT boats operating as eight divisions were deployed along the western and eastern coasts of the straight to report on enemy ship positions and help degrade their capability, softening them for the final battle in the Leyte Gulf.[48] At approximately 2215, PT boat 131 detected multiple radar contacts south of the strait and passed a report of visual contact, but it could not raise anybody on the radio.[49] Throughout the night and morning, as the battle raged, PT boats reported enemy ship locations, conducted pulsing attacks from each side of the strait, and sowed confusion in the Japanese southern force. The PT boats effectively utilized their radars and radios to navigate and coordinate swarming attacks against the Japanese Navy as well as provide situational awareness to the rest of the U.S. 7th fleet lying in ambush.

The use of radars alone was not the only novel characteristic of PT boat tactics. PT boats combined onboard and offboard radars and their unique boat designs to remain elusive and achieve surprise. Boat and shore-based radars and radios provided them with superior situational awareness, allowing them to encircle adversaries and prepare stealthily for a multi-directional simultaneous attack. PT boats had to slip into the threat rings of many adversary ships stealthily to utilize their primary stand-off weapon, the torpedo. PT boats operated best in the littorals, where the coasts and islands provided locations to hide and from which to search for the adversary. The use of Coastal Force Control Ships and shore-based coastal radar and radios provided extended surface surveillance capabilities beyond that found on PT boats. PT boats demonstrated that distributed elusive forces with superior situational awareness can surprise the enemy and engage with a combination of close-in and standoff fires with destructive effect. The historical examples above informed the development of this future functional concept.

A lesson from the use of PT boats is that units do not necessarily need to be the complete package of sensor, sharer, and shooters. Radars do not necessarily have to be with the main force to conduct attacks, but superior situational awareness does facilitate swarming forces and fires to effectively engage the adversary. Sensors and fires can be spread out on the battlefield and do not need to always be co-located with maneuvering swarming forces as long as they are communicating and contributing to situational awareness. Unmanned surface and air surveillance drones can contribute as part of a network to provide superior situational awareness of enemy and friendly forces, allowing for large distributed force and fires to swarm.

Not every boat, team, or aircraft needs to be armed, they just need to be any combination of a sensor, sharer, deceiver, or shooter. Vignette one. Multiple unmanned air/surface surveillance multi-spectral / modal USVs detect, identify, and report enemy ships. While they do not have weapons, they do contribute to superior situation awareness. Meanwhile, another USV and team of Marines on an island launch three dozen LOCUST drones to swarm the ships. As they target antennas and fire control radars, long-range anti-ship missiles are fired from multiple air and surface platforms situated at different locations. As adversary aircraft proceed to assist their ships a UAS with an air surveillance multi-spectral / modal sensor detects, identifies, tracks, and reports their location to the MAGTF and Navy. As the LOCUST remove the ability of adversary ships to defend themselves, they also stimulate the ships defensive systems. F-35s pulse forward, detect and track adversary aircraft, and engage. Anti-ship missiles converge from multiple directions on the target while the F-35s, complete with their engagements, utilize their sensors to collect battle damage assessment (BDA) data. Meanwhile, one of F-35 detects a missile launch from another island and passes the information the MAGTF and Navy for another system to engage, and departs the threat area to an EABO Forward Arming and Refueling Point (FARP) to refuel and reload to prepare for the next engagement.

This future functional concept supports EABO and the Navy's distributed lethality concept by forward employing mobile and relatively low-cost air and surface surveillance sensors and AC2 capabilities in austere and temporary land and surface locations as integral elements of the fleet/JFMCC operations.[50] Operating from expeditionary locations, these unmanned air and surface surveillance sensors will be employed on land, Unmanned Ground Vehicle (UGV, or the surface, Unmanned Surface Vehicle (USV). These UGV/USV air and surface surveillance sensors will screen and scout in hostile areas that may be considered too risky for manned critical forces and assets to operate. Moreover, an airborne module variant could be produced to attach to the MUX to detect and identify both surface and air objects. These scouts, paired with decoys, will "impose increased battlespace complexity on the adversary and confound his decision calculus by forcing him to allocate sensors and shooters against a wider – and more dispersed – set of threats."[51]

Scouts have historically been utilized to develop superior situational awareness so that commanders at various levels can make timely decisions. Scouts provide reports based on information requirements, which connected to important decisions. For the MAGTF as part of a naval force, it will need to deploy capabilities to win the "scouting competition" to establish a maritime balance sufficient enough to accomplish key missions.[52] Employing superior scouting capabilities, which can include manned and unmanned sensors or human reporting, is only part of the competition formula. Equally as significant is the impact of corrupting or providing misleading information and data that compels the enemy to act in a way that is advantages to friendly forces. For forces to employ long-range precision weapons, scouting forces are critical; deploying more friendly assets while corrupting the adversary allows friendly forces to temporarily paralyze the enemy long enough to conduct swarming attacks and then disperse for survival.

Vignette two. After identifying adversary ships, forward deployed Low-Cost UAV Swarm Technology (LOCUST) with kinetic warheads would again degrade or neutralize adversary sensors and weapons. Simultaneously, the adversary would see decoys on the surface but have difficulty in differentiating what is real or not. After creating a gap, the MAGTF or the Navy could then pulse forward a combination of ships and armed drones to destroy the ship. The Navy's distributed lethality increases the offensive power on individual ships and allows them to pulse forward a "hunter-killer Surface Action Group" to engage the "wounded" adversary ship with anti-ship missiles that converge from different directions.[53] Additionally, the MAGTF could use land-based anti-ship missiles in combination with attack submarines to attack other adversary ships near-by and then repositions for the next engagement.

Vignette three. Unmanned sensors report the location of adversary ships. It is determined that they are approaching a choke point and would be vulnerable to attack. Rather than utilizing larger weapon systems or surface-based unmanned "suicide" drones and long-range precision weapons from land-based batteries, distributed platoons of infantry are given orders to engage. As the adversary ships approaches, unmanned "suicide" drones are launched from multiple locations, swarming and attacking the ships. As a result, the ships ability to defend itself is eliminated and their ability to navigate is degraded. At this point, the adversary could choose to retreat. If they do no, other MAGTF and Navy could utilize land-based or ship fires, escalating the conflict. The distributed infantry Marines are tied into the CTP, giving them situational awareness of the adversary and capable of determining the best locations to position and engage enemy forces that meet the commander's intent.

Vignette three combines unmanned air and surface surveillance multi-spectral / modal sensors with a "warbot" concept that was proposed by a small multi-disciplined group of Marine Corps Offices. The warbot concept "… imagines lean, lethal, survivable, and highly distributable teams of naval sharpshooters…" and "…argues that rapidly maneuverable teams of marines properly trained, educated, and equipped with artificial intelligence-enabled, autonomous weapons systems and loitering munitions can support naval maneuver to project power and enable sea control."[54]

Illustration 5 is one of many possible examples of how unmanned air and surface surveillance sensors could be forward deployed to operate as deep reconnaissance teams. The illustration provides a visual to better understand the prior described vignettes. USVs with sensors would move around, screening forward, and reporting back information based on information requirements that are given to them. Meanwhile, land-based sensors would be performing multiple roles. While some UGV sensors would perform a similar role as their USV counterparts, others would be co-located with AC2 nodes to provide continuous real-time information and facilitate either positive control or enhanced procedural control. The larger land-based sensors would remain off in high threat environment with lots of low flying fast threats. Even though they may be off, they would be established and prepared to start emitting based on queuing from the distributed smaller sensors. Furthermore, additional passive sensors on the large land-based sensors could provide them with an additional means for air surveillance that provides extra protection until it is time to turn on their very capable radar.

Also depicted are naval ships to the southeast, who are remaining away until threats have

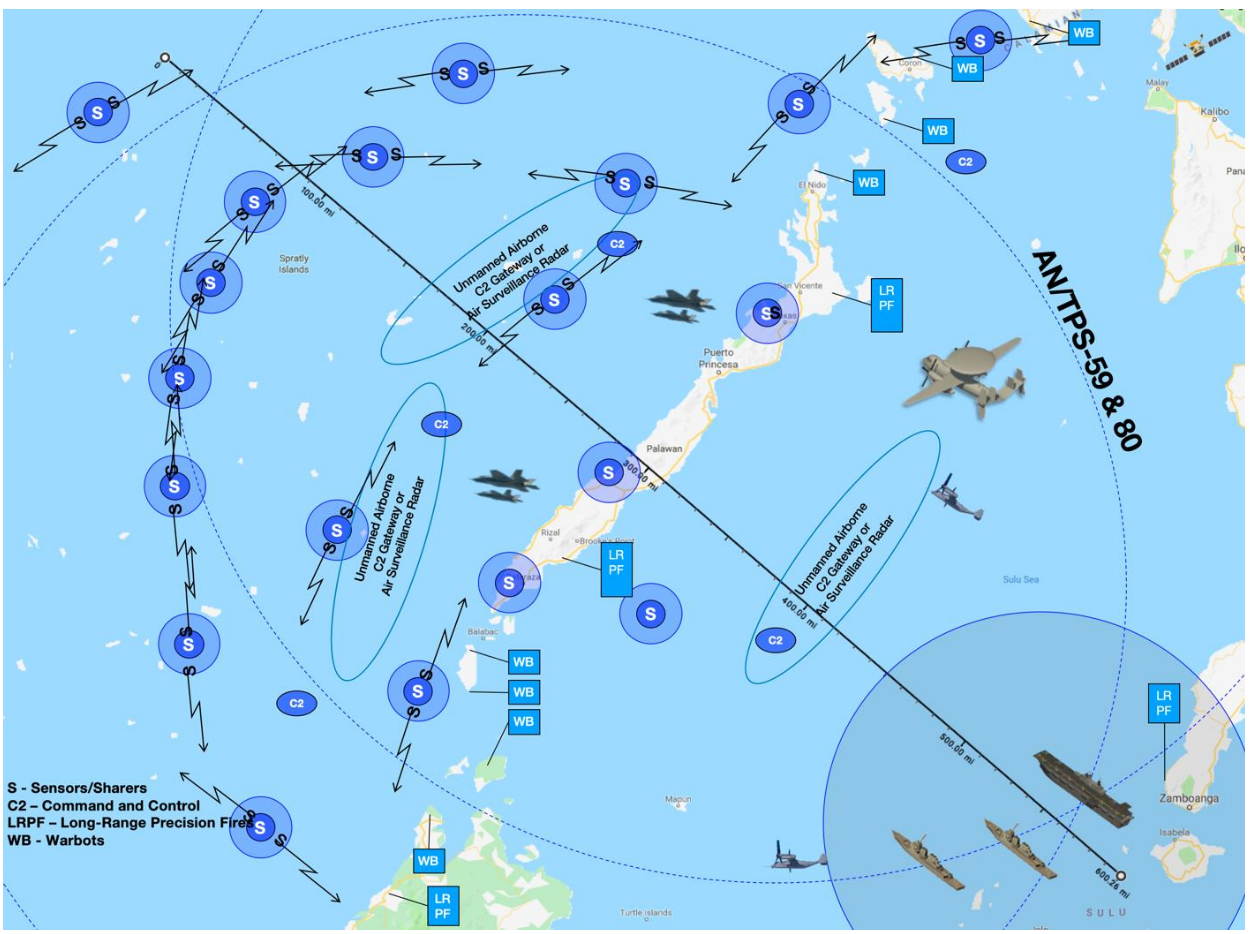

Illustration 5: Future Functional Concept Example Overview

been reduced to the point where they can comfortable project forward. Meanwhile, warbot teams and long-range precision fires systems position themselves and are prepared to engage the adversary. For all intents and purposes, the MAGTF is forward deployed and distributed to project power and aid in sea control, which includes forward sensing that contributes to the Common Operational Picture (COP).

APPLICATION AND INTEGRATION OF MILITARY FUNCTIONS

To extend the detection range of threats beyond that of current land-based and large ship radars, with ships remaining as far away from highly capable threats as possible – small, mobile, resilient, and survivable radar sensors will be deployed to detect air and surface threats. The smaller radar sensors complement large land-based and ship radars, providing early warning of those things that are either not detected by larger radars or when the larger radar is not emitting because of survivability concerns. These "scouts" provide information that drives decision making. A combination of large radars and smaller mobile radars enhances situational awareness for various levels; contributing to the CTP and COP.

Illustration 6: ERA's VERA-NG Passive Surveillance Sensor

The combination of active and passive multi-spectral sensors, such as infrared (IR) sensors, improves system accuracy.[55] While passive radar sensors detect and identify air and surface objects, narrow AI will assist with improving detection and identification of objects that may be flying within the detection range. Small multi-spectral / modal sensors, a combination of multiple types of sensors, can assist with improving sensor accuracy, survivability, and contribute to enhancing situational awareness against more aggressive peer adversaries targeting efforts. Passive radars have the potential to reduce sensor emissions significantly, involve less power, and do not require the allocation of a frequency band to sense.[56] *Illustration 6* depicts an example of a current passive electronic support measure tracker capable of air defense and passive surveillance to detect, locate, track, and identify air, ground, and naval targets.[57] One could combine passive radars, electromagnetic spectrum detectors, IR, or even light detection and ranging sensors (LIDAR) to detect and identify threats.

A combination of active and passive radars, multi-spectral / modal sensors and narrow artificial intelligence improves situational awareness. Emitting decoys can create signatures that will corrupt, deceive, and complicate adversary targeting efforts to conceal real sensors and critical assets. Stimulating adversary actions and then collecting on their responses enhances understanding of their capabilities and limitations and offer opportunities for exploitation.

AI facilitates adaptive communications, which is the automatic adjustment of communications paths as well as data fusion. Track data fusion will be vital in correlating multiple sources of track data generated by all of the different air surveillance radars with tactical data links. Data fusion will occur at the various AC2 nodes and gateways. Furthermore, AI facilitates smart communications, allowing it to communicate based given parameters, such as information requirements. Depending on the threat environment, the phase of an operation, or layer, AI can be utilized to best support the commander information exchange requirements while also reducing risk to the sensor. For example, USV/UGV scouts may detect many surface and air tracks, but only report aircraft and ships from the People's Liberation Army Navy or Air Forces. Alternatively, it may only report those aircraft that meet the criteria for UAS and helicopters below 8,000ft. Perhaps they will only report objects that meet the criteria of a cruise missile. Regardless, unmanned scouts should be given reporting requirements in the same way deep reconnaissance scouts would know what and when to report something.

A critical component of these UGV/USV air and surface surveillance systems is that they cannot become so exquisite that the MAGTF cannot accept their loss. The reality is that they will not be cheap, but they will be cheaper compared to a regular navy ship, a JLTV, or the AN/TPS-

80 G/ATOR. The reason for this is that they need to be produced in adequate numbers to be deployed to cover enough terrain to satisfy information requirements. Additionally, during a conflict, one must assume that many will be found and destroyed by the adversary. However, while this is occurring this should also allow the MAGTF and Navy to much more rapidly target adversary forces while they essentially waste their resources. In terms of force protection, the UGV/USVs need to have the ability to avoid other objects. USVs need to always avoid other ships from getting too close. They should be like the elusive mosquito that never seems to die. The UGVs are a bit harder and may need to be paired with the actual MSTs, following and deploying nearby instead of operating autonomously. Additionally, the USVs need to be tamper-proof if caught, maybe even sink themselves as well as zero out their computers, radios, and sensors.

Given that the tempo of warfare and the range of engagement is increasing, it is critical that the MAGTF and Navy buy more time to make decisions for commanders at all levels, to include those forward deployed tactical commanders, ship commanders, and operational level commanders. Buying more time does not necessarily mean the growth of centralized command and control, which is counter to maneuver warfare. Decentralizing the engagement of air and surface threats and delegating authorities to forward deployed and dispersed units will provide more responsive self-defense but also layered threat engagement from unexpected positions. Early detection provides more time to develop weapon-target solutions and allows higher level commanders to move resources to shore up weak spots and reinforce success. Feeding situational awareness information to a commander and combining it with AI to identify targets, process requests for effects, and assist with optimizing weapon-target pairing, will improve a lower level tactical commanders' ability to prosecute threats regardless of if they have an organic sensor or weapon to engage it.

A MACCS capable of tailoring hybrid AC2 as the situation changes while incorporating MSTs with different types of radars will significantly improve MACCS agility and resiliency while providing more employment options across the Range of Military Operations (ROMO) to the MAGTF. The MACG will be able to task-organize AC2 capabilities to create hybrid nodes based on multiple factors; such as what nodes already exist, node locations, available equipment, available radars, and the threat environment.

The MACCS should be a collection of small building blocks that represent unique capabilities. The MACG can combine these blocks to build hybrid nodes based on scalable and modular command hardware that can accept various types of air and surface surveillance radars and multi-spectral / modal sensors. As well as be employed by a range of light to heavy mobility options. For this future functional concept multiple Air Support Elements (ASE) with CAC2S – Light (more modular and scalable hardware), each with an MST with a small air surveillance passive multi-spectral / modal sensor, could deploy to two different locations in their own ITVs. One ASE links up with an already deployed TAOC who also has an MST with an AN/TPS-80 G/ATOR air surveillance radar, which is not active. The ASE sets up inside the TAOC and forward positions their MST with the smaller air surveillance sensor to provide queuing for the larger air surveillance radar. The ASE and TAOC combined have formed a hybrid AC2 node capable of air support, air defense, and air surveillance. *Illustration 7* depicts the relationship between capabilities, size, and logistical requirements. The future challenge will be in how to expand capabilities while reducing logistical requirements and size, as well as improving mobility.

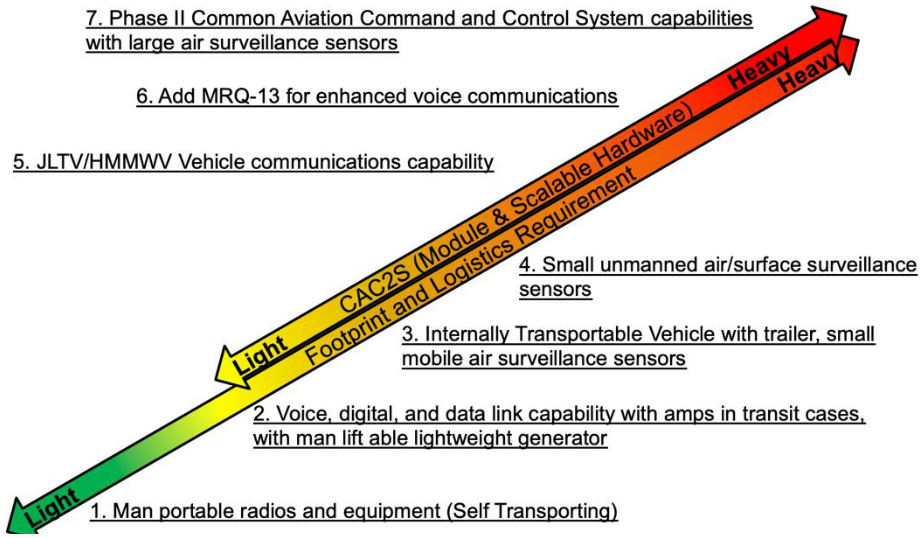

Illustration 7: MACCS Size, Logistics, and Capabilities Diagram

This employment concept does not propose the elimination of the MACG structure or current agencies. Preferably it builds on the current "centers and elements" model and adds capabilities-oriented task organized "cells," and less capable but highly valuable "teams" to augment, advise, coordinate, liaise, or train.[58] Greater emphasis should be placed on creating employment more employment options out of the MACG. The best examples of this is the Multi-functional Air Operations Center (MAOC) concept developed by MACCS-X and MAWTS-1, which was previously described.

Illustration 8: PPM's Tethered Antenna Drone

Each AC2 node with CAC2S can serve as a gateway capable of tactical network data communications and voice communications. MACCS AC2 nodes help develop and maintain the CTP and process information between the ACE and GCE. They can receive data from multiple air surveillance sensors and transmit it on Link 16. While the MSTs can deploy small mobile air and surface surveillance multi-spectral / modal sensors on land (UGV) and sea (USV), they will communicate over a local line of sight mesh network to relay data to an AC2 "gateway," either airborne (E2D or MUX with a MAGTF Agile Network Gateway Link

(MANGL)) or on land. A narrow artificial intelligence built into CAC2S and AC2 gateways will fuse the sensor data and transmit it either over the line of sight Composite Tracking Network (CTN) and RF Link16, or beyond line-of-sight radio using Joint Range Extension Protocol (JREAP).[59] To extend the range of communications utilizing LOS, “gateway” vessels will utilize a Towed Airborne Lift of Naval Systems (TALONS) communications antenna or a small tethered drone capable extending the communications range of a USV/UGV when they need to communicate.[60]

Illustration 9: DARPA's TALONS

It will be difficult to talk to aircraft, especially rotary-wing aircraft, in a distributed environment because of the distances between ground forces, ships, and airfields. Often aircraft are forced to revert to BLOS satellite communications, which not all aircraft have, or utilize fixed-wing to help relay communications. Utilizing the MUX with MANGL, the digital interoperability gateway with a voice relay module, AC2 agencies will be able to talk to aircraft, especially helicopters, between ships and airfields in a distributed EABO environment and receive sensor data. Additionally, MSTs may need to operate as gateways as they will operate multiple air/surface surveillance sensor UGVs and USVs.

The hybrid AC2 nodes would serve as voice and data communications gateways that correlates and fuse multiple sources of data, and forwards it utilizing the small form factor (light) CAC2S, which has a Multi-Source Correlator Tracker (MSCT), and various air surveillance radar sensors.[61] AC2 nodes from the Marine Air Control Group (MACG) Detachment on a MEU, and other fly-in AC2 nodes, operate as extensions of the Navy Tactical Air Control Center

(N-TACC), as well as fill critical AC2 positions aboard ship.[62] They also coordinated with various Composite Warfare Commanders, such as the Strike Warfare Commander and Air and Missile Defense Commander.[63]

AC2 Marines trained in TDL and radar sensor management, as well as air control and airspace management, will manage the fused data with CAC2S and communicate with the rest of the MEU and Navy aboard ship via CTN/CEC, satellites, or unmanned airborne gateways.[64] An Enhanced ASE can be augmented by fly-in personnel and equipment to create a DASC if need be. Simultaneously, TAOC Marines with an AN/TPS-80 G/ATOR air surveillance radar could also be flown in and connected to the DASC to create a hybrid AC2 node. The objective is to process information from sensors, aid decision makers by providing options rather than just situational awareness, and ensure the connections with shooters are maintained to facilitate rapid engagement.[65]

The hybrid AC2 node will favor passive radar systems over active radar systems in high threat environments, internally transportable vehicles for early mobility, smaller form factor AC2 systems (CAC2S and CTN), and SDPs to increase communications and digital interoperability capabilities. While also utilizing relatively less energy by reducing fuel requirement types and amounts. Generators and vehicles that utilize hydrogen could reduce noise, heat, and smell signatures.[66] Recent advancements in aluminum fueled engines that produce hydrogen and heat for propulsion provide great promise and could reduce logistical burdens.[67]

Besides data fusion and adaptive communications, narrow AI driven by deep learning will also support the AC2 node with making decisions. Creating automated decision support tools that incorporate narrow AI will aid Marines with processing information, making simple decisions, and providing recommendations to distributed MACCS nodes regardless of when and where they are operating. Immediate air support requests will be submitted digitally or over voice with the assurance that it will make it to the appropriate agency, the DASC or SACC. Relying on one physical AC2 node to receive and process data is a single point of failure. AI built into CAC2S will automate the immediate air support request process while providing Aviation C2 experts with enhanced understanding to make decisions. AI will listen to the radio and convert requests into data, voice to data, then evaluate available resources; the location of aircraft resources, their weapons and fuel status, and reference the attack guidance matrix, and then provide a variety of options to the DASC. Narrow AI will only be possible through active deep learning that uses training simulations back at bases to train the AI continuously. Simulations centers will not just train Marines, but also the AI in CAC2S.

The DASC and SACC should supervise and facilitate the process, ensuring the parameters CAC2S's AI decision tool is correct and that all recommendations presented are sound. Simple data processing, which today consumes much of a DASC Marines time, would be significantly reduced and multiple options could then be automatically offered. CAC2S's AI would communicate with aircraft to pass along the request information and negotiate optimal routing based on the threat environment and fuel available. The controllers within the DASC would then verify the data and send it digitally to the aircraft or over voice, as we do it now. Either way, confirmation of acceptance is always required. Regardless of where multiple agencies are or which DASC is operational, the process should continue to provide enhanced MACCs resiliency. Another DASC or hybrid AC2 will pick up primary DASC responsibilities in the event one DASC is destroyed because of the network of sensors and sharers that continues to operate. This process should be seamless to requesting units; immediate air support requests would adapt its communications path to the next primary hybrid AC2 agency responsible for receiving immediate air support requests.

NECESSARY CAPABILITIES

Unmanned Surface Vehicle (USV) Air/Surface Surveillance Multi-Spectral / Modal Sensor. A five-meter-long vessel capable of operating up to sea state four and surviving up to six.[68] A passive air and surface surveillance radar with a 360-degree IR sensor capable of detecting, tracking, and identifying objects up to 30,000ft and out to 30km. Current active radar examples include the AN/TPS-42 on the L-MADIS, SAAB's Giraffe 1X, and SRC Incorporated's "SkyChaser" On-the-Move Multi-Mission Radar and Gryphon R1410 Active Electronically Scanned Array (ESA) 3-D Radar.[69] Each USV sensor will utilize Adaptable Navigation Systems (ANS) devices to derive its location in a GPS denied environment.[70] Additionally, advancements in quantum sensing with diamonds are highly sensitive and can accurately detect the smallest changes in magnetic fields. Many laboratories have already started to use this technology to develop navigation systems, altimeters, or even gyroscopes.[71]

The USV Air/Surface Surveillance Multi-Spectral / Modal sensor must meet current short and medium-range active air and surface surveillance radar sensors, and utilizes less energy by 2030. Incorporates alternative energy sources that do not rely on fossil fuel or battery power as the primary source of energy. Alternatives such as aluminum fueled engines have the potential of providing more power for longer durations for the same about of weight as a fossil fuel engine.[72] They would exceed current battery-powered capabilities. Capable of ten days of autonomous operations, including transition time, before requiring refueling. Capable of avoiding all other ships and vessels.

These sensors will fit and operate in a small watercraft, up to five meters in length, or an internally transported vehicle (ITV). AI that facilitates adaptive communications, automatically adjusting communications paths to transmit tracks. AI that is advanced enough to fuse radar and IR data and identify the object. AI that facilitates smart communications, allowing it to communicate based given parameters, such as information requirements. AI incorporation should be narrowly defined and balance the need for highly complex computing with the state and reliability of communications at distances between 200 to 300 nautical miles from AC2 nodes.

Illustration 10: iXblue's DriX USV (Left) and XOcean's XO-450 USV (Right)

Depending on the threat environment, the phase of an operation, or layers, AI can be utilized to best support the commander information exchange requirements while also reducing risk to the sensor. A critical component of these UGV/USV air and surface surveillance is that they cannot become so exquisite that the MAGTF cannot accept their loss. The reality is that they will not be cheap, but they will be much cheaper compared to a regular navy ship, a JLTV, or the AN/TPS-80 G/ATOR. The reason for this is that they need to be produced in adequate numbers to be deployed to cover enough terrain to satisfy information requirements. Additionally, it is assumed that during conflict many will be found and destroyed by the adversary.

Unmanned Ground Vehicle (UGV) with Air Surveillance Multi-Spectral / Modal Sensor. An ITV sized wheeled vehicle that is capable of accepting different types of modules on top, a universal superstructure. A passive air surveillance radar with a 360-degree IR sensor capable of detecting, tracking, and identifying objects up to 30,000ft and out to 30km. Meets current short and medium-range active air and surface surveillance radar sensors, and utilizes less energy by 2030.

Illustration 11: Hunter Wolf UGV

Capable of ten days of semi-autonomous operations before requiring refueling. The sensor module can operate on the UGV's universal superstructure, allowing for the swapping of UGV or the sensor module if either fails. Like the USV, the sensor module will operate off of the UGV's power. *Illustration 12* is the Silent Utility Rover Universal Superstructure (SURUS) platform developed by General Motors in partnership with the United States Army.[73] It is a hydrogen-fueled superstructure capable of accepting different modules to perform a variety of functions. The SURUS platform could be configured to be a UGV with the Air Surveillance Multi-Spectral / Modal Sensor module and autonomous operations module. The SURUS can move, provide power, and even off-board power as well as provide water – with the addition of a filter.

Illustration 12: SURUS UGV

Depending on the threat environment, the phase of an operation, or layer, AI can be utilized to best support the commander's information exchange requirements while also reducing risk to the sensor. A critical component of these UGV air surveillance sensor is that they cannot become so exquisite that the MAGTF cannot accept their loss. The reason for this is that they need to be produced in adequate numbers to be deployed to cover enough terrain to satisfy information requirements. Additionally, it is assumed that during conflict many will be found and destroyed by the adversary. UGVs will be useful because they can follow ground forces or be offset to ground forces to not only provide early warning of objects in the air but also be the focus of targeting away from individual Marines.

MUX with Battlefield Sensing Module. An air and surface surveillance multi-spectral / modal sensor module attached to the MUX. The MACG will either acquire the MAGTF UAS Expeditionary (MUX) or receive dedicated MUX sorties that support specialized MACCS modules for AC2 communications and battlefield sensing. MACCS modules are in addition to other modules such as the specialized Intelligence, Surveillance, and Reconnaissance (ISR) modules the Marine Air Wing (MAW) will acquire. A group five UAS capable vertical take-off and landing, capable of keeping up with an MV-22, and can change mission modules. The MUX must have an eight hour on station time at 350 nautical miles from the ship, with a top speed between 175 and 200 knots.[74] The MUX is a program of record and requirements are relatively mature.

Illustration 13: Lockheed Martin / Sikorsky UAS Rendering

"The concept of employment will be shipboard capable and expeditionary MUX will be multi-sensor and will provide early warning, electronic warfare, and C4 bridge, ISR, strike capability and logistics at ranges complementary to those of the MV-22 and F-35, giving MAGTF commanders flexible, persistent, and lethal reach."[75] The air and surface surveillance module can be active, preferably passive, with a 360-degree IR

Illustration 14: Bell V247 MUX

sensor and must be capable of detecting, tracking, and identifying objects on the surface (sea) and in the air.[76] It must be nearly comparable to the capabilities of the E-2D and considered a "number-one top-tier requirement" for the MUX.[77] It must be capable of operating from EABO locations and transmit data to AC2 nodes, AWACS, the E2, and the Navy. The MUX with the air and surface surveillance multi-spectral / modal sensor module must incorporate a small CTN/CEC antenna to extend the range for the CEC network and support Integrated Fire Control (IFC).

Multi-Spectral / Modal Decoys. A decoy module that can be attached to a USV, UGV, UAV, or manually placed on the battlefield to mimic the electronic signature of various AC2 systems, sensors, and weapons will corrupt, deceive, and complicate adversary targeting efforts and conceal real sensors and critical assets. Stimulating adversary actions and then collecting on their response enhances understanding of their capabilities and limitations and offer opportunities for exploitation. Decoys should be able to impersonate the movement and electronic signature of those things they are mimicking. Specifically, USV decoys should look like the forward-deployed USV air/surface surveillance sensors they are mimicking because of their relative proximity of operations to the adversary. Decoys should be expendable and smart enough to react to enemy electronic warfare efforts in the same way the items they are mimicking would. While the objective is not to make they optically look like a U.S. Navy destroyer, the objective would be to make it appear that way based on a variety of adversary sensors.

MUX with AC2 Communications (Data and Voice Gateway) Module. A digital interoperability data and voice gateway that "receive network signals through compatible radios, decipher the messages (from their original waveforms and message formats), translate them, and then retransmit them via separate radios using different waveforms and forms. Processors within the gateways translate all messages and pass them on to the correct radios."[78] MANGL should incorporate a voice retrains capability and a smaller form CTN/CEC antenna to improve IFC. Although the system is reliant on radio frequency transmissions, there are opportunities for airborne gateways to incorporate LED light or laser communications[79]

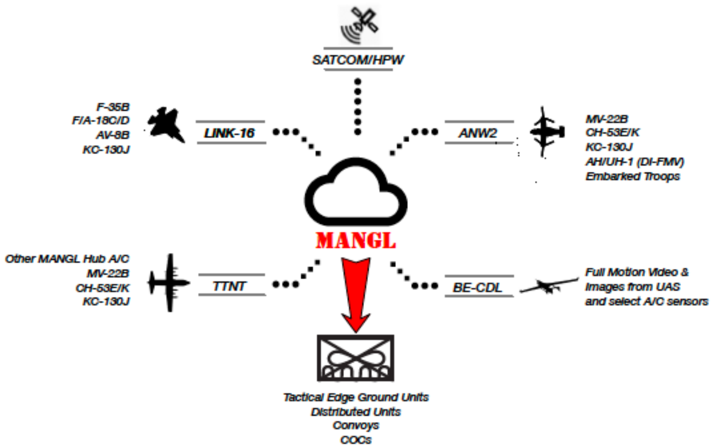

Illustration 15: MAGTF Agile Network Gateway Link (MANGL)

The inclusion of CTN/CEC in the MUX MANGL would enable the transmission of track data from distributed USV/UGV air/surface surveillance multi-spectral / modal sensors. MANGL provides a detailed list of capabilities and can be best described as an intelligent airborne retrains site that can tap into multiple different networks and transmit data across all.[80] AC2 Marines trained in TDL and radar sensor management, as well as air control and airspace management, will manage the fused data and communicate with aircraft and ships well BLOS of their respective nodes via CTN/CEC, satellites, or AC2 communications modules.[81]

Previously the DASC(A), airborne, utilized a specialized shelter within a C-130 to be an airborne AC2 node. However, that capability has disappeared for a variety of reasons. This ranges from equipment interoperability / compatibility problems, changing threat environment, and advancements in communications. The AC2 communications module attached to a MUX can be deployed in greater numbers than the old DASC(A). The loss of a MUX would obviously disrupt services, however it would be of less significance in terms of loss of life and regeneration capability, as another can be launched to replace.

Hybrid AC2 Nodes. The MACG needs to adjust doctrine, training, or equipment to effectively aggregate, operate, and adapt while portions of it are being destroyed; it lacks resiliency. The CAC2S is providing the baseline AC2 system that is both modular and scalable to support hybrid AC2 nodes. A combination of ITVs, HMMWVs, JLTVs, and 7-Tons provide a wide range of mobility options. The AN/TPS-59 and AN/TPS-80 provide high-end air surveillance coverage. Smaller air surveillance radar sensors have been acquired only for SHORAD. However, there is a capability gap that exists for the pairing of those smaller air surveillance radar sensors with AC2 nodes to expand the mission beyond SHORAD.

The MACCS is a collection of small building blocks that represent unique capabilities. The MACG needs to develop doctrine to combine these blocks to build traditional AC2 and hybrid AC2 nodes. The MACG is already developing and acquiring a baseline scalable and modular common hardware system (CAC2S) that can accept various types of air surveillance radars and multi-spectral / modal sensors and can be employed given a range of light to heavy mobility options. The MACG needs to develop doctrine that articulates how the MACCS will absorb attacks that eliminate a percentage of AC2 nodes, reorganize while operating, and continue to fight. Additionally, the MACG must train to employ hybrid AC2 nodes. Hybrid AC2 nodes will require the development of detailed SOPs as to how different combinations of nodes are set up, and how crews will operate.

A hybrid AC2 node need to be capable of serving as voice and data communications gateway that correlates and fuses multiple sources of data and forwards it utilizing the small form factor (light) CAC2S, which has a Multi-Source Correlator Tracker (MSCT), and various small and large air and surface surveillance multi-spectral / modal sensors.[82] Hybrid AC2 nodes on a MEU come from the Marine Air Control Group (MACG) Detachment and can be extensions of the Navy Tactical Air Control Center (N-TACC), as well as fill critical AC2 positions aboard ship.[83] AC2 Marines trained in TDL and radar sensor management, as well as air control and airspace management, will manage the fused data with the rest of the MEU and Navy aboard ship via CTN/CEC, satellites, or unmanned airborne gateways.[84] The objective is to process information from sensors, aid decision makers by providing options rather than just situational awareness, and ensure the connections with shooters are maintained to facilitate rapid engagement.[85]

As MACCS agencies will require the ability to aggregate, operate, and adapt they will also need a limited on the move communications capability to at least maintain situational awareness. This would include an on the move CTP and voice communications with other AC2 agencies. Allowing portions of CAC2S to continue operating while on the move will also enable faster setup time as the core computing, and communications capabilities would not need to be turned off while displacing. AC2 Marines are not communications Marines, they are true professional C2 Marines that are intimately versed in information exchange requirements, information processing, and battle management in dynamic environments.

CAC2S Artificial Intelligence Decision Support Tools. AI supports the AC2 node with making decisions and process information from multiple data sources – such as Link 16, TBMCS, CTN/CEC, FBCB2, and AFATDS, to name a few. AI built into CAC2S automates the immediate air support request process to improve human decision making. AI will listen to the radio and convert requests into text and data, then evaluate available resources, the location of aircraft resources, their weapons and fuel status, reference the attack guidance matrix, and then provide a variety of options to the DASC. This means improving interoperability between the various data sources and allowing AI to transmit between both.

Spatial and Temporal Dimensions

This portion of the paper will cover how the MACCS could execute this future functional concept within the Global Operating Model's contact and blunt layers along the competition continuum.[86]

Illustration 16: Competition Continuum

Contact Layer

Contact layer forces are "designed to help us compete more effectively below the level of armed conflict."[87] Persistent MACG presence supports engaging in training with host nations to advance partnerships, increase interoperability, expand Joint Force access, and improve host nation capabilities and capacity. Integrate MACG efforts with competition mechanisms, even if it does not appear to be directly related to the objectives of the training. Being creative about adding value to training by understanding operational and strategic level competition will help to counter and contest adversary forces with the intent of deterring further aggression.

MACGs deploy MACCS liaison teams, AC2 nodes, and MSTs to support training but also validate the C2 and networks required to set conditions for escalation to the blunt and surge layer. Seamlessly increasing competition into armed conflict is critical to not creating seams for the adversary to exploit. Liaison teams deployed to the Navy, to include Cruisers and Destroyers, help to integrate the MACCS into the Composite Warfare Commander (CWC) Concept in the event networks need to be established. When deploying AC2 agencies to an exercise, opportunities should be considered to connect with other AC2 agencies that are part of different exercises. Efforts should also be made to network AC2 nodes with each other, with MAGTF fires agencies, available air surveillance radar sensors, and the Navy CWC to validate communications networks across a theater. While these actions may be secondary to the various training objectives, and unnecessary for specific exercises, they are opportunities to compete against adversaries.

The addition of forces from two MEUs entering a theater are ways of deterring adversary activities and validating aggregation.

> These MEUs could drop off all or some of their MACCS capabilities, tailoring deployment. An Enhance MEU Air Support Element that can share information with ships, joint forces, and potentially host nation forces provide limited air control in the theater, but more importantly becomes an information gateway for the aggregated MAGTF enabling distributed C2 on a smaller scale. Marine Air Traffic Control Mobile Teams provide MMT services at additional FARPS and enable flexible options for aircraft and ground force basing. LAAD units provide close-in counter UAS and manned aircraft protection of maneuver forces and sites. Interface Control Officers and other elements of the MACG detachments would remain with the Amphibious Ready Group to provide reach back capability if required and keep the landward units tied together and into the rest of the naval force.[88]

MST on MEUs or ashore should deploy small air and surface surveillance multi-spectral / modal sensors throughout different parts of a theater to compete horizontally with adversary forces. For example, the MACG sets up a DASC and TAOC in the Philippians as part of an exercise. Simultaneously, a MEU southeast of Vietnam deploys five small air and surface surveillance multi-spectral / modal sensor USVs to collect on adversary activities. While data is transmitted to the MEU, it is networked with the MACG in the Philippians, giving them situational awareness of adversary activities west of the training area. This example similarly could be executed in nearly any theater. USVs that were sent out to operate are collected up seven days later and then redeployed a few days later in another part of a theater. They continuously present an opportunity to collect a tremendous amount of intelligence while causing adversary forces to commit more resources.

All MACG activities during the contact layer should shape the operational environment and set conditions for victory during armed conflict. The MACG will aggregate, operate, and adapt during training exercises and Humanitarian Assistance / Disaster Relief (HA/DR) efforts to continuously validate and demonstrate capabilities. It is critical during the contact layer to move beyond merely executing the specified task. The new implied task is that the MACG must also develop activities to compete against the regional adversary and identify what must be validated to support the transition to the blunt and surge layers, ultimately assuring victory during armed conflict. The deployment of USV sensors compels the adversary to react, to commit more and more resources. Placing relatively inexpensive MAGTF assets that do not have organic weapons on them and are replaceable forces the adversary to commit more resources. Any time the adversary has to commit more expensive assets and weapons against a less expensive asset or weapon the cost-imposition is applied. The example competition mechanisms in the Joint Concept of Integrated Campaigning (JCIC) provide suggested tasks to consider when determining and developing implied tasks.[89]

Blunt Layer

Blunt layer forces "delay, degrade, or deny adversary aggression."[90] If more forces are required, a MACCS fly-in echelon could deploy while other capabilities on ships move into the theater.

> This MACCS echelon would be far more extensive than any other Aviation C2 entities in theater and would provide a substantial upgrade in capability, but would need to maintain the survivability and persistence of the smaller force. A "Hybrid Node" task organized for the mission at hand would be based on the CAC2S Phase 2 V1 system. This node would have streamlined MACCS capabilities to keep the footprint as small as possible while providing more robust capabilities. These nodes could potentially be employed in pairs or only "activated" when required, remaining dormant until the moment enhanced AC2 is required. One or more sensor teams could be put ashore to extend the range of the CTN/CEC network and provide situational awareness to the JFMCC and the rest of the Joint Force. The rest of the MACCS FIE consists of more MMTs and LAAD as required. MACCS

> EABO Detachments will be task organized detachments capable of providing select AC2 capabilities in a highly mobile platform.[91]

Those insider forces already within the theater focus on establishing their survivable hybrid AC2 nodes, deploying air surveillance sensors, and establishing networks to contribute to the air surveillance picture as part of the CTP for the MAGTF and Navy. Distributed LAAD sections with L-MADIS / MADIS deploy with the GCE and defend critical EABO sites. During this period the objective for the MACCS is to establish critical AC2 capabilities and execute survivability tactics and aggressively delay, degrade, or deny adversary aggression. The MACCS with their distributed hybrid AC2 nodes and USV/UGV air/surface surveillance multi-spectral / modal sensors will quickly provide situational awareness to the MAGTF and Navy. MAGTF sensors combined with the Navy's sensors will facilitate the swarming of fires and forces at different levels.

CONCLUSION

This future functional concept paper has identified a series of problems and made a variety of recommendations that contribute to the larger conversation of how the MAGTF will need to fight in the future. MAGTF needs to provide air and surface surveillance multi-spectral / modal sensing of airborne and surface threats and coordinate the prosecution of those targets at ranges for the joint force that extend into contested areas with Anti-Access / Area Denial systems. It must provide the entire range of networked air and surface surveillance needs in a high threat maritime environment and inland. Smaller mobile air and surface surveillance multi-spectral / modal sensors would present a significant targeting challenge for the adversary over water and land while improving sensing resiliency. They can complement larger air surveillance radars by illuminating areas not covered by larger radars due to terrain blockage or the curvature of the earth. These smaller sensors can provide early queuing to larger more capable radars and contribute to a Common Tactical Picture (CTP) over networks managed by resilient hybrid AC2 nodes. A large number of active and passive sensors and decoys, turning on and off at different times and continually moving, combined with selectively activating large air surveillance radars, will stimulate the adversary's observations at a rate that will overwhelm their ability to target and disguise true friendly capabilities.

Gaining superior air and surface situational awareness for lower level ground commanders, creating numerous air defense and sea control options, and speeding up the processing of immediate air support requests will enable the swarming of forces and fires to decimate enemy forces. Overall, the Marine Corps has an opportunity to double down on maneuver warfare and enhance the Joint Force's capability to sense, share, deceive, and engage threats beyond the ranges of friendly high value large radar systems by distributing constantly moving smaller air and surface active and passive multi-spectral / modal sensors, hybrid AC2 agencies, and weapon systems.

Certainly, much more detail will be demanded by many readers, but this future functional concept paper is merely proposing a concept. It is not a detailed list of technical performance parameters. It is a concept from which others should experiment with its contents to validate, modify, or eliminate. From these experiments detailed requirements can be written, which will trigger the acquisitions process. While this paper provides some references to already existing technology, they are merely imperfect examples designed to trigger thought. Regardless, this paper should spur conversation and thinking that will inform how the MACSS can better organize, train, equip, and operate in the future to support the MAGTF and Navy with sea control and project power in a maritime and landward environment.

ENDNOTES

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APPENDIX A: FALL 2018 GRAY SCHOLARS PROGRAM WARGAME OBSERVATION

Military Problem: Networking Mobile Air and Surface Surveillance Radar Sensors

There were four problems related to air and surface (water) situational awareness and Aviation Command and Control (AC2) that were for the most part assumed to have been resolved by 2025. The overarching problem is how the Aviation Combat Element (ACE) can provide the Amphibious Ready Group (ARG) / Marine Expeditionary Unit (MEU) with a forward deployed adaptive and resilient means to find, fix, and track potential enemy and demonstrate credible capabilities to deter further aggression. One, how to create a sensor-shooter network to detect potential airborne and surface (water) targets in a contested environment over a large area and then investigate and/or target them with drone swarms or other weapon systems from aircraft, ships, or ground vehicles. Forward deployed radar sensors can provide cueing for larger more capable systems.

Two, given a working network capable of passing near-real time track data, there is a problem as to how to correctly identify, correlate, and fuse plot and track data from over twenty mobile air and surface surveillance radar sensors. Additionally, this process also has to occur with multiple tactical data networks, such as Link16, Multifunction Advanced Data Link (MADL) and Force XXI Battle Command Brigade and Below (FBCB2). Three, how to share fused track data derived from multiple sources with the rest of the Marine Air-Ground Task Force (MAGTF) and Navy. This requires beyond line of sight communications and high enough bandwidth to pass a lot of data, which produces a relatively high signature. Four, a lot of energy is required to power the radar sensors, vehicles, and AC2 nodes; making sustainment a problem.

Opportunity: Integrated Air-Ground Command and Control Gateway

Distribute adaptive and resilient small mobile manned and unmanned active and passive air and surface surveillance radar sensors on land and water capable of detecting items up to 30,000ft and out to 30km, similar to an AN/TPS-42 on the Light Marine Air Defense Integrated System (L-MADIS).[1] Each sensor will utilize Adaptable Navigation Systems (ANS) devices to derive its location in a GSP denied environment.[2] They will also communication over a local line of sight mesh network to transmit data to a "gateway" vessel that will then utilize artificial intelligence to fuse the data and transmit it either over the line of sight Composite Tracking Network (CTN) and RF Link16, or beyond line of sight radio using Joint Range Extension Protocol (JREAP).[3] Radar sensor emission parameters and communications transmission paths and occurrence will be set by humans based on the autonomy setting of drones, decision makers need for information, and if a target is beyond the drone swarms' capabilities. To extend the range of communications utilizing LOS, "gateway" vessels will utilize a Towed Airborne Lift of Naval Systems (TALONS) communications antenna or airborne gateways such as the E-2D or a MUX with a MAGTF Agile Network Gateway Link (MANGL) and voice relay module.[4] Transmitted data will route over a mesh network to hybrid AC2 nodes, an example called a Tactical Air Control Element (TACE) was employed. The TACE was a task-organized multifunctional Marine Air Command and Control (MACCS) agency that was a combination of an Air Support Element with a small portable air surveillance radar combined with either a Marine Mobile Air Traffic Control Team (MMT) or a Low Altitude Air Defense (LAAD) section.

The hybrid AC2 node could be capable of serving as voice and data communications gateway that correlates and fuses multiple sources of data and forwards it utilizing the small form factor Command Aviation Command and Control System (CAC2S), which has a Multi-

Source Correlator Tracker (MSCT), and various air surveillance radar sensors.[5] TACEs on a MEU come from the Marine Air Control Group (MACG) Detachment and can be extensions of the Navy Tactical Air Control Center (N-TACC), as well as fill critical AC2 positions aboard ship.[6] AC2 Marines trained in TDL and radar sensor management, as well as air control and airspace management, will manage the fused data with the rest of the MEU and Navy aboard ship via CTN/CEC, satellites, or unmanned airborne gateways.[7] The objective is to process information from sensors, aid decision makers by providing options rather than just situational awareness, and ensure the connections with shooters are maintained to facilitate rapid engagement.[8]

Hybrid AC2 nodes are customizable multi-functional AC2 nodes, they will be able to adapt to various threat conditions by frequently moving, splitting responsibilities between each other, altering how they communicate, and which node or nodes will be operational at a time. Besides data fusion, AI will also support the hybrid AC2 node with interacting with the mesh networks and processing immediate air support requests and integrating fires with aviation assets. The hybrid AC2 node will favor passive radar systems over active radar systems, internally transportable vehicles, and smaller form factor AC2 systems (CAC2S and CTN), and software defined radios (SDP) to increase communications and digital interoperability capabilities utilizing relatively less energy, fuel requirement. Generators and vehicles that utilize hydrogen could reduce noise, heat, and smell signatures.[9] In the contact layer, networked air and surface surveillance radar sensor layer combined with a robust AC2 gateway provides the MEU with a credible capability to transition to the blunt and surge layers far beyond just a few stand-alone radar sensors and procedural air controllers with radios.

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APPENDIX B: NAVY AND MARINE CORPS FUNCTIONS

THE FUNCTIONS OF THE NAVY

The Navy shall develop concepts, doctrine, tactics, techniques, and procedures and organize, train, equip, and provide forces to perform those specific functions as directed by DOD Directive 5100.01:

1. Conduct offensive and defensive operations associated with the maritime domain including **achieving and maintaining sea control,** to include subsurface, surface, land, air, space, and cyberspace.
2. Provide **power projection** through sea-based global strike, to include nuclear and conventional capabilities; interdiction and interception capabilities; maritime and/or littoral fires, to include naval surface fires; and close air support for ground forces.
3. Conduct ballistic missile defense.
4. Conduct ocean, hydro, and river survey and reconstruction.
5. Conduct riverine operations.
6. **Establish, maintain, and defend sea bases** in support of naval, amphibious, land, air, or other joint operations as directed.
7. Provide naval expeditionary logistics to enhance the deployment, sustainment, and redeployment of naval forces and other forces operating within the maritime domain, to include joint sea bases, and provide sea transport for the Armed Forces other than that which is organic to the individual Military Services and USSOCOM.
8. Provide support for joint space operations to enhance naval operations, in coordination with the other Military Services, Combatant Commands, and USG departments and agencies.

9. Conduct nuclear operations in support of strategic deterrence, to include providing and maintaining nuclear surety and capabilities.

THE FUNCTIONS OF THE MARINE CORPS

The Marine Corps shall develop concepts, doctrine, tactics, techniques, and procedures and organize, train, equip, and provide forces, normally employed as combined arms air ground task forces, to serve as an expeditionary force-in-readiness, and perform those specific functions as directed by DOD Directive 5100.01:

1. **Seize and defend advanced naval bases or lodgments** to facilitate subsequent joint operations.
2. Provide close air support for ground forces.
3. **Conduct land and air operations essential to the prosecution of a naval campaign** or as directed.
4. Conduct complex expeditionary operations in the urban littorals and other challenging environments.
5. **Conduct amphibious operations, including engagement, crisis response, and power projection operations to assure access.** The Marine Corps has primary responsibility for the development of amphibious doctrine, tactics, techniques, and equipment.
6. Conduct security and stability operations and assist with the initial establishment of a military government pending transfer of this responsibility to other authority.
7. Provide security detachments and units for service on armed vessels of the Navy, provide protection of naval property at naval stations and bases, provide security at designated U.S. embassies and consulates, and perform other such duties as the President or the Secretary of Defense may direct. These additional duties may not detract from or interfere with the operations for which the Marine Corps is primarily organized.

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