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Conclusion: The TACC is sound as an agency construct to facilitate centralized command for the Air Combat Element commander but its concept of employment must change to be survivable in an operating environment characterized by A2AD threats. A solution would include distributing TACC functionality both within A2AD threat areas, and outside threat areas, as well as utilizing rarely-used radio propagation techniques, introducing signature management as task, and adding tactical mobility to the agency. Survivability would be enhanced through dispersion across the operating environment and managing the signature of the agency, thereby retaining the effectiveness of the agency while mitigating enemy targeting. The overall aim will be to decrease the

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Title: MARINE AVIATION COMMAND AND CONTROL FOR THE WAR OVER THE HORIZON: THE MARINE TACTICAL AIR COMMAND CENTER IN AN A2AD ENVIRONMENT

Author: Maj Nathaniel T. Lauterbach, United States Marine Corps

Thesis: For the Tactical Air Command Center (TACC) to be survivable in a future operating environment characterized by anti-access and area-denial capabilities presented by peer competitors, the Marine Tactical Air Command Center must become a more geographically and physically distributed agency, able to modify its physical, electronic, and cyber signatures with the ambient operating environment, and become a more tactically mobile agency.

Discussion: While the United States has been deeply engaged in the Middle East over the first decades of the 21st century, China and Russia, in particular, have developed what are characterized as Anti-Access and Area-Denial (A2AD) capabilities, and combined these capabilities with updated Information Operations (IO) capabilities that can prevent Marine Corps units from executing Command and Control (C2) over its aviation forces. A response for the Marine Corps is to address shortcomings in its legacy TACC agency to make this agency viable in an operating environment characterized by threat A2AD systems.

Conclusion: The TACC is sound as an agency construct to facilitate centralized command for the Air Combat Element commander, and to decentralize control to the other Marine Air Command and Control System agencies, but its concept of employment must change to be survivable in an operating environment characterized by A2AD threats presented by peer competitors. Elements of a solution would include distributing TACC functionality both within A2AD threat areas, and outside threat areas, as well as utilizing rarely-used radio propagation techniques, introducing signature management as task the TACC must undertake, and adding tactical mobility to the agency. Survivability would be enhanced through dispersion of the agency across the operating environment, and managing the signature of the agency, thereby retaining the effectiveness of the agency while mitigating effects of enemy targeting efforts. The overall aim will be to decrease the targetability of the TACC, while increasing the resilience of its ability to conduct C2, and to communicate. The Marine Corps should immediately conduct tactical demonstrations and experiments to prove this improved TACC concept of employment in a simulated operating environment.

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There are dozens of superior Marine aviation C2 officers and enlisted Marines who deserve mention but will go unnamed here for the sake of brevity. The occupational fields supporting Marine aviation C2, principally the 72xx and 59xx fields, are small, specialized, and are the very glue which holds the Marine Air-Ground Task Force together. They are the unsung heroes of "MAGTFery." Without their leadership by example, intellectual gravitas, and sense of service to a cause greater than themselves, I would not be the officer I am today, and this paper would not exist. To each of you: Thank you.

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Introduction

The operational and tactical environment has changed in ways that were not broadly apparent while America was engaged in Iraq and Afghanistan. During those decades of American engagement in the broader Middle East, America's competitors have militarily advanced. The United States now faces declining relative national power, especially military power, as competitors race to modernize their forces by integrating information age technology, and by strategically and tactically integrating other domains of conflict with novelty unexpected by the United States.[1] These *sui generis* combinations of cheap but advanced technology, innovative use of reconnaissance and sensing technology, cyber operations, and availability of inexpensive precision long range fires will present complex military problems to American and allied forces operating against these adversaries and enemies. Many of these military technologies can be broadly characterized as Anti-Access and Area Denial (A2AD) technologies. These military problems are not simply tactical problems, relating to fire and maneuver of American forces engaged in battle—these are also operational problems, negating the ability of American and allied forces to conduct force closure into the theater.

Fortunately, the Marine Corps has recently made strides against these problems, by focusing on updating the infantry units with new technology, converting the MEF Headquarters Group (MHG) to a MEF Information Group (MIG), dedicating structure to advocate for Information Operations (IO) at the service headquarters level, and creation of the cyberspace occupational field.[2] These changes have not been radical enough. A critical capability of American military units is to command and control (C2) units across domains and space to achieve unity of effort, but the C2 system (including all DOTMLF considerations, not merely hardware) has not been updated for the threat.[3] Marine air C2, furthermore, is particularly

vulnerable, due to reliance on wireless communications, large cyber infrastructure, radiating sensors, large physical footprint, and critical components which are fundamentally immobile once emplaced. For the Marine Air Ground Task Force (MAGTF) to be relevant in combat against the United States' strategic competitors, fundamental change to the Marine Air Command and Control System (MACCS) will be essential.[4] Some reforms, particularly in terms of materiel, have been implemented in the MACCS, as well as experimentation in MACCS agency concept of employment.[5] One MACCS agency, however, has not kept pace with the changes to the threats and operating environment: the Tactical Air Command Center (TACC). For the TACC to be survivable in a future operating environment characterized by A2/AD threats, the TACC must become a more geographically and physically distributed agency, able to modify its physical, electronic, and cyber signatures with the ambient operating environment, and become a more tactically mobile agency.

This paper will explore the operating environments in which the TACC must be prepared to operate, specifically identifying similarities and differences between each of those operating environments. This paper will then analyze the existing TACC, and then provide a way ahead toward a reconceived TACC capability given the challenges of those operating environments.

Description of the Operating Environment

The National Security Strategy identifies key strategic competitors which the United States and its allies must contend with: China, Russia, Iran, North Korea, and Violent Extremism.[6] While each of these threats offers unique challenges, only China and Russia have the mix of technology, manpower, sufficient weapons of mass destruction, combined with desires "antithetical to US values and interests," that special attention must be accorded to them.[7] Russia and China specifically have an ability to threaten "critical infrastructure and our

command and control architecture."[8] The NSS also states that, as a strategic move, the United States will "pursue threats to their source," "share responsibility [with allies and partners]," and "defend in depth," and "deploy layered defenses."[9] Each of these moves implies a strategy of forward-deployed operations and interoperability with allies. In a military contest with either of these competitors, the Marine Corps, due to its high readiness forward-deployed forces and capabilities, will be expected to fight.

For the purposes of this study, fighting North Korea, Iran, and violent extremists should be viewed, for the near future, as an "included capability" to a MACCS and TACC that is able to prevail in a conflict with Russia and China. However, as technology proliferates, the capability of regional powers and violent extremist actors should be expected to become increasingly similar to that of Russia and China. For the TACC to be survivable in the near future, even against a regional foe like Iran, or against a state-sponsored violent extremist organization, the Marine Corps should consider modernizing its TACC capabilities for use against the entire spectrum of threats.

The Chinese Case

Over the last several decades, China has grown more prosperous and has undergone a significant modernization of its military. It has also resolved, or at least tabled discussion of its landward border disputes, allowing a strategic turn to the sea for expansion, including areas of the South China Sea, the East China Sea, and Taiwan.[10] It has undergone significant bureaucratic an organizational reform, with leadership changes and reorganization affecting virtually every major command of the Chinese People's Liberation Army (PLA.) The PLA has also prioritized procurement of advanced technology systems designed to inhibit operational access to China's periphery, while investing in capabilities to project power beyond China's

immediate environs. The military might of China is rapidly increasing and is presenting a qualitatively different threat today than it has in any time in recent Chinese history.

Over the last several years, China has executed significant reforms of its defense establishment, including disestablishment of its older system of quasi-independent bureaus which governed planning, procurement, discipline, and other functions, in favor of a system of committees which are more functional in nature and defer more to guidance of the Chinese Central Military Commission.[11] Other reforms include the upgrading of the 2nd Rocket Artillery Force, which is responsible for land-based nuclear and conventional missiles, from that of a branch of the PLA to a full service, co-equal with the PLA land, naval, and air forces.[12] The logistical branch of the PLA, the *Strategic Support Force* was also upgraded to a full branch. The PLA ground forces headquarters was formerly administered directly by the PLA, was demoted to a separate service within the PLA, co-equal with the navy, air, and rocket forces.[13] This has the strategic effect of lessening the stature of the land forces and increases the political clout of the naval and air forces in strategy formation. Lastly, and perhaps most operationally significant, was the abolition of the seven military regions used to manage military affairs across China, and the creation of five joint commands, responsible for the integrated use of land, air, naval, and missile power in their areas of responsibility. Previously, PLA ground units in an area would report to the regional military headquarters, while air force and naval units reported to their separate service headquarters. Now, all services—ground, air, naval, and rocket—report to a geographical joint headquarters. Each of these joint commands is organized around specific missions which it is responsible for, thus adopting the western technique of using joint task forces to accomplish military missions.[14] These reforms will allow the PLA to integrate military

power in the land, sea, and air domains while effectively task-organizing those forces to the missions at hand. The Chinese military has reformed around "jointness."

Other organizational changes include cutting the PLA land forces by over 30 percent and reorganizing remaining forces away from corps- and division-centric models to more deployable combined arms brigades and battalions. The PLA land forces also sacrificed force structure to stand up additional units in the PLA Navy's Marine Corps. The Chinese Marine Corps now numbers 36,000 personnel distributed among the navy's fleets.[15] Other significant naval power projection capabilities include an improved, quieter diesel submarine force, and an aircraft carrier.[16] China now has a significant aircraft and naval overmatch over its immediate neighbors, and it has also practiced using civilian naval vessels in concert with flagged PLA Navy vessels, including the employment of artillery placed aboard civilian ships.[17] Again, this represents a change in Chinese strategic thinking from a ground-combat army-centric force to a balanced joint force, built around power projection around China's periphery, including Taiwan and the South and East China Seas.[18]

China has invested heavily in A2/AD technologies, including short range ballistic missiles—over 1000 of them—directly aimed at Taiwan.[19] These missiles, in the past, were relatively immobile liquid-fueled missiles located in silos. These missiles have been largely replaced by mobile solid-fuel rockets, which require substantially less maintenance effort while presenting a very challenging targeting problem to any adversary, due to the mobility of their launchers.[20] It has also invested heavily in precision-guided land-attack and anti-ship cruise and ballistic missiles, cued by a networked targeting capability. These missiles could potentially cripple any intervening air or naval force, and destroy critical forward infrastructure that would enable an American counter-intervention.[21] Even if such a missile attack were not completely

militarily successful, the mass psychological shock of such an attack could discourage the United States from continuing its intervention.[22] China has also invested in counter-space capabilities, and information operations capabilities designed to disrupt or disable enemy command and control system.[23] China's integrated air defense system is one of the most layered and dense in the world. Lastly, the Chinese Navy has invested heavily in submarines and offensive mining capabilities. All of these would serve to hamper US access to the maritime and littoral areas by land, sea, and air. Space operations, which are relied on for precise position, navigation, and time services would be hampered. Cyber operations could also imperil American computer networks, its surveillance and reconnaissance capabilities, and its ability to target the adversary. Access to the operating area will not be assured, and, even if access is attained, ability to tactically maneuver would be problematic.

Overall, the Chinese military reforms have been a major challenge for the PLA, with decreased focus on land operations in favor of operations on the periphery of China using naval power. Advanced A2AD technology has been integrated, complicating military action in China's immediate environment, and its military has become more deployable, with increased emphasis on joint task force operations. This represents a qualitative shift in Chinese military power. Furthermore, these shifts in Chinese military power are of the magnitude that they require rethinking of American tactical C2 capabilities, including the Marine TACC.

The Russian Case

In the wake of the self-assessed poor showing of the Russian military in the 2008 Georgia War, Russia has undertaken a series of military reforms aimed at creating forces which are leaner, more employable, and more integrated with Russian strengths in information operations.[24] In recent years, Russian military operations have been employed to achieve

deniability until the conflict is essentially decided, and it does so with highly integrated use of information operations using social media, public affairs, propaganda, and cyber operations. These reforms were not merely focused on tighter integration their military forces with other instruments of Russian national power; they also included upgraded air defenses, electronic warfare capabilities, and long-range precision strike capabilities.[25]

Russia maintains a robust information, cyber, and electronic warfare capability which operates in both peace and wartime and is integrated with other elements of their national power. They have spread propaganda and false news reports and have affected public opinion in directions advantageous to Russia. Russian cyberspace operations have been used to degrade or disrupt computer networks, steal data and information, and even disable systems.[26] Russian electronic warfare capabilities are designed specifically to counter NATO combat systems, including defeating precision strike capabilities, degrading position, navigation, and timing systems, hindering electronic communications, and disrupting radar-fused artillery rounds.[27] Russia maintains impressive capabilities against radar and communications systems, including jamming capabilities.

The Russian land forces have added agility to their command structures, modernized equipment, increased the intensity and frequency of their exercises, and professionalized, to a degree, their personnel. Russian military forces have built on their traditional strength in their artillery arm. They have innovated in using unmanned systems to conduct reconnaissance, target acquisition, and fires adjustment for their artillery. They also have a wide assortment of artillery systems, including rocket artillery in several calibers up to 300mm.[28] Russia has developed a long-range precision strike capability, including systems which both complied with and violated the Intermediate Nuclear Forces treaty. Both ballistic and cruise missiles have been developed

with ranges up to 1,200 miles. Some have interpreted development of these missiles to be a counter to NATO installations and units which could be established in Poland, Romania, and the Baltic republics of Latvia, Lithuania, and Estonia.[29] Russia has also built on its traditional strength in air and missile defense systems. The relatively new S-400 system (effective range: roughly 250 km) is fielded and proliferating. It can receive inputs from systems designed to detect opposing stealth systems. The S-300 systems are also fielded, and much more mobile. The extended range of these systems can directly threaten NATO air superiority in countries along the Russian frontier without violating land borders.[30] Russia also has an inherent ability to conduct anti-space operations using its ballistic missile interceptors. Russian anti-space operations can disrupt nuclear and conventional command and control architecture, communications, and air and missile defenses.[31]

The Russian Navy is built around a concept of sea denial, in order to counter NATO and especially American strength in the maritime domain. This has caused the Russian Navy to develop surface combatants with heavy anti-ship armaments (for their class), and a large submarine force. Included in their accelerated shipbuilding plan are *Lider*-class destroyers, which are specifically designed to cut NATO's transatlantic sea lines of communications, and to destroy carrier groups and troop transport ships.[32] This operational concept extended back to the Soviet era, and it continues to inform Russian naval strategy today. While the Russian fleet is of uneven quality, Russia maintains some submarines believed to be nearly equal to US submarines in terms of performance. The Russian navy has great potential to deny operational mobility and tactical sea maneuver in the maritime space around Russia.[33]

Russia maintains a "forward deployed" presence in Kaliningrad Oblast, and exclave located on the Baltic, southwest of the Baltic Republics of Estonia, Latvia, and Lithuania.

Kaliningrad has large quantities of offensive and defensive capabilities positioned to thwart NATO action in the Baltic, and potentially able to destroy targets throughout central Europe. Suppressing those capabilities would require military force employed on Russian soil itself (even if the weapons are fired from standoff ranges in NATO countries), significantly increasing the probability of escalation. The resident military capability in Kaliningrad means NATO must maintain a deterrent posture against those capabilities and must harden itself against military action originating from Kaliningrad.[34] Additionally, Belarus is a close Russian ally, with high levels of cooperation between their respective security services.[35] This alliance could allow for further forward operations of Russian military forces.

Russia's military reforms have allowed it to weave military power with other instruments of Russian national power to take advantage of seams and cleavages that Russia's competitors present. This mixing of military power with Russian strengths in political warfare have allowed it to generate success on Russia's periphery in Ukraine, Crimea, and, to a degree, Syria. As such, Russia's military reforms compel us to respond with similar reforms, especially in tactical C2 architecture.

Common Themes and Key Differences of the Chinese and Russian Cases

There are common themes between the Chinese and Russian A2/AD cases for the MACCS, and key differences. Areas for consideration include susceptibility to targeting of C2 nodes detecting MACCS signatures, difficulty in accessing the operating environment, and difficulty in tactically operating in the operating environment.

For both the Russian and Chinese cases, they seek to target command and control facilities by locating signatures of the facilities and placing fires or effects on them. With

improved sensing abilities, improved stand-off ranges of kinetic fires, and ability to use offensive cyber operations against C2 nodes, both China and Russia are credible in these areas. Therefore, consideration must be given to controlling signatures, and to complicating the targeting problem should signatures be detected. Adding tactical mobility is also a viable alternative, thereby constantly changing the physical location of the emissions source.

Both China and Russia seek to prevent operational access to the nearby theaters of combat, though by distinctly different means. The Chinese case has a more naval character, requiring operations on island chains off the Chinese coast, aviation operations, and naval operations. There are forward bases located on the island chains off the Chinese coast, so making use of these bases would be critical in a campaign against China. These bases, however, must be assumed to be threatened from Chinese A2AD systems, especially air defense systems, surface-to-surface missiles and aircraft, and naval units.

Russia is a more tactically land-focused fight in Europe, and a naval campaign around the Russian periphery. Europe is a populated continental area, with a highly advanced transportation network, dense populations, omnipresent civilian and military use of the electromagnetic spectrum, military and civilian radars at may airports. Seaports and airports are plentiful. The climate ranges from temperate to arctic, with a possibility of operating in urban areas, marshes, plains, alpine, and forested areas. Use of networked computer systems, including wireless, and otherwise, is common. The MACCS, including the TACC, must therefore blend into a different tactical environment than has previously been the case. The MACCS can likely afford to have a larger electromagnetic signature in such an environment, while maintaining hardened cyber infrastructure, and physically distributing within the various Weapons Engagement Zones (WEZ) and placing some infrastructure outside of the weapons engagement zones.

Electromagnetic radiation from radars and radios should be positively controlled (though not necessarily reduced to nothing). Additionally, a key focus of effort will be to counter Russian countermeasures. The naval character of the operating environment around Russia and Europe is a factor, but it is primarily an issue of operational access to the theater, vice a tactical issue one the MACCS is deployed in a theater.

The Chinese case is different. While most of the islands in the island chains are inhabited, there is a relative dearth of electromagnetic radiation compared to Europe. Use of the electromagnetic spectrum will likely be much more apparent to Chinese electronic warfare units, and therefore more attention will be required on reducing use of the electromagnetic spectrum, as opposed to merely controlling it, as in the Russian case. The physical environment is tropical to temperate, operating on islands with beaches, forested vegetation, some and some cities. Options to tactically maneuver are more limited, because moving from one island to another necessitates moving by air or sea connector, or a combination thereof, and doing so generates exposure to air and coastal defense systems. There are fewer airports and seaports than in the European case, further reducing opportunity to maneuver. Therefore, distributing TACC infrastructure both inside and outside the WEZs makes sense, across land and naval surface units, while making efforts to closely control electromagnetic and cyber signatures. Any infrastructure within a WEZ should be resilient, redundant, and physically dispersed. There will be a premium on keeping electromagnetic radiation to a minimum, and to ensure that radiation that does occur is intermittent, purposeful, encrypted, and, if possible, disguised. The naval character of a fight near China is a factor, both tactically and operationally.

Current Marine Aviation C2 Architecture: Does It Meet the Challenge?

The objectives of Marine aviation C2 are to enhance unity of effort, integrate elements of the command and control system, and disseminate common situational awareness.[36] It serves as an integrating function, and one of the six functions of Marine aviation integrating the other five functions in support of overall MAGTF objectives.[37] Its philosophy is one of centralized command and decentralized control. Centralized command means that a single aviation commander plans, directs, and coordinates all aspects of aviation employment in support of the MAGTF. Decentralized control means allowance for optimized flexibility, versatility, and responsiveness of aviation.[38] The MACCS, as a system of agencies, facilitates both centralized command and decentralized control. The TACC is the senior MACCS agency, and serves to provide the centralized command functionality, while supervising decentralized control by various MACCS agencies (including the DASC, TAOC, air traffic control detachments, air defense units, and other agencies. See *figure 1.*[39]). The major exception to decentralized control is control of deep air support missions forward of the Fire Support Coordination Line —in this case, the TACC often exercises centralized control of these missions, though the DASC and TAOC, and are capable of this.[40] Together, the MACCS agencies serve to provide centralized command and decentralized control of Marine aviation, with the TACC as the principal agency providing command authority for direction, planning, and resourcing Marine aviation in support of the MAGTF.

Additionally, within the MACCS, there is often a Sector Air Defense Commander (SADC), which is doctrinally the commanding officer of the Marine Air Control Squadron.[41] The SADC is responsible to the Regional Air Defense Commander, and the Area Air Defense Commander for command and control of air defense within the assigned sector. Since the

Marine Corps, as a service, is capable of fielding SADC functionality, it can exercise C2 of air defense units, including anti-air warfare sorties and ground-based air defense units.[42] This integrated air defense capability must be planned with consideration given to the larger aviation effort for the MAGTF.

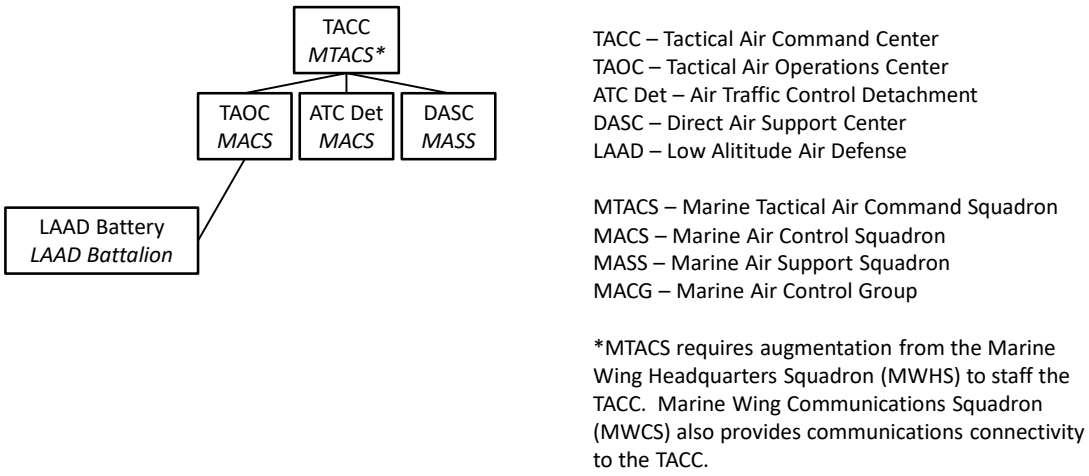

Figure 1: Principle agencies of the Marine Air Command and Control System, and their associated parent squadrons.

To support a MEF, a Marine Aircraft Wing (MAW) would be employed to provide the functions of Marine aviation and to conduct aviation operations (*figure 2).* To provide an operational command post, the Marine Tactical Air Command Squadron (MTACS) for that MAW would deploy in order to provide infrastructure for a TACC and provide a portion of personnel to the TACC's Current Operations (COPS) section. A TACC to support such a MAW, with staff augmentation, would include 130 officer and 91 enlisted watch standers.[43] This does not include maintenance, logistics, and other essential functions. Additionally, the supporting Marine Wing Communication Squadron (MWCS) would deploy its headquarters and one of its

two detachments to the TACC's location to provide communications infrastructure. The Marine Air Control Group (MACG) headquarters would also deploy to this location, to support the various Marine air C2 squadrons deployed in the field (including the Marine Air Support Squadron, Marine Air Control Squadron, Low Altitude Air Defense battalions, MTACS, and MWCS). The Marine Wing Headquarters Squadron (MWHS) would still provide G-1, G-4, G-6, and Aviation Logistics Division (ALD) personnel and facilities, while the MAW G-2 and MAW G-3 provide manning to the TACC. Since the TACC would likely deploy to an operating airfield, one or several Marine Aircraft Groups (MAGs) and component squadrons, along with a Marine Wing Support Squadron (MWSS) and Marine Air Traffic Control Detachment should also be considered as physically co-located.[44] Units providing force protection would also be present, ranging from Law Enforcement Battalions, Marine Logistics Group personnel, infantry units, air defense units, and even the MAW band (which is tasked with providing force protection while in combat). The TACC's location could easily contain several thousand personnel.

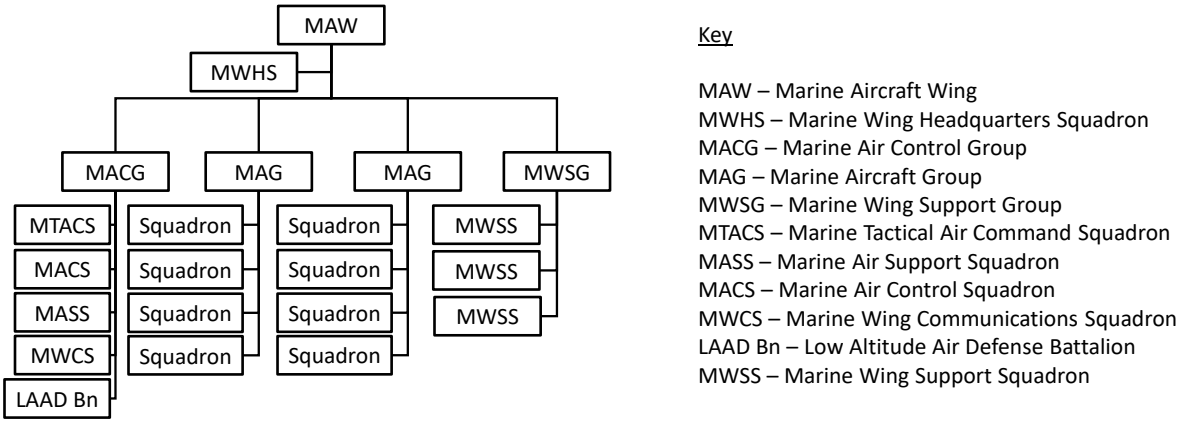

Figure 2: Marine Aircraft Wing and Marine Air Control Group Organization

The TACC is divided into four sections: Future Plans, Future Operations (FOPS), Current Operations (COPS), and Air Combat Intelligence (ACI).[45] (*See figure 3.)* While the TACC is doctrinally "modular" and "scalable," able to be sized and tailored to meet the specific mission[46], the reality is that TACCs deploy and employ with those four sections in a single, consolidated location, though the internal composition, size, and physical layout of the sections can be adjusted to meet mission requirements. This is particularly true for COPS, which is further divided into a cellular structure, including the Close Battle Cell (CBC), Deep Battle Cell (DBC), Interface Coordination Cell (ICC), Air Defense Cell (ADC), Assessment Cell, Airspace Control Cell, and Rescue Coordination Cell (RCC), all operating under the supervision of a Senior Watch Officer (SWO), Senior Air Coordinator (SAC), and Crew Chief. *(See figure 4.)* COPS cells can be activated and deactivated as the mission requires.[47] Future Operations also has a subdivided element, the ATO Development Section, which is responsible for constructing

ATOs for use by COPS for upcoming days of operations.[48] Almost all sections of the TACC are centralized under the control and direction of the Air Combat Element's (ACE) G-3 Operations Officer. ACI reports to the ACE G-2 Intelligence Officer but is intertwined in all other TACC functions.

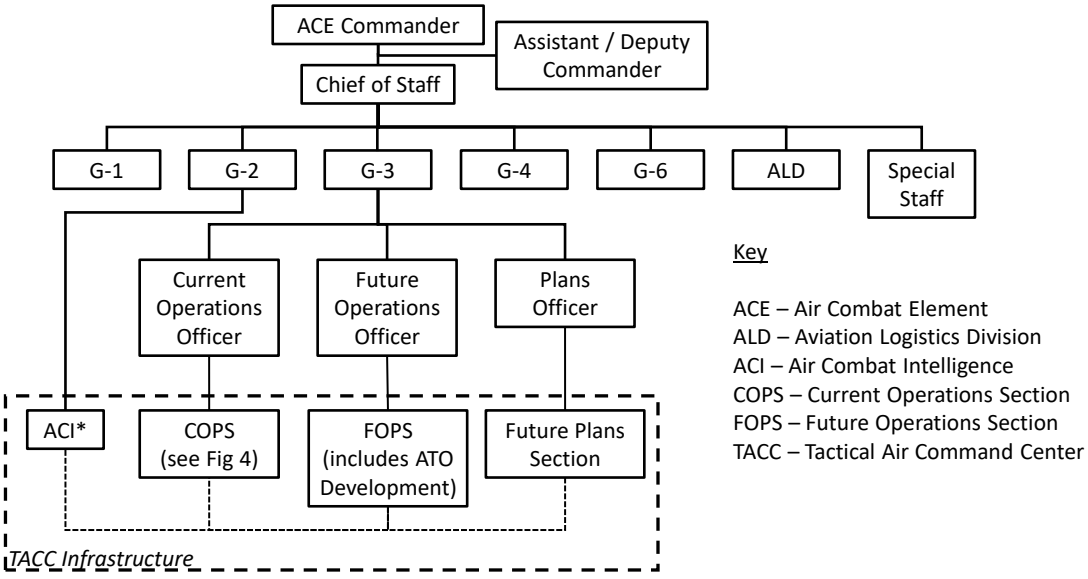

Figure 3: TACC Structure and the Air Combat Element Battlestaff

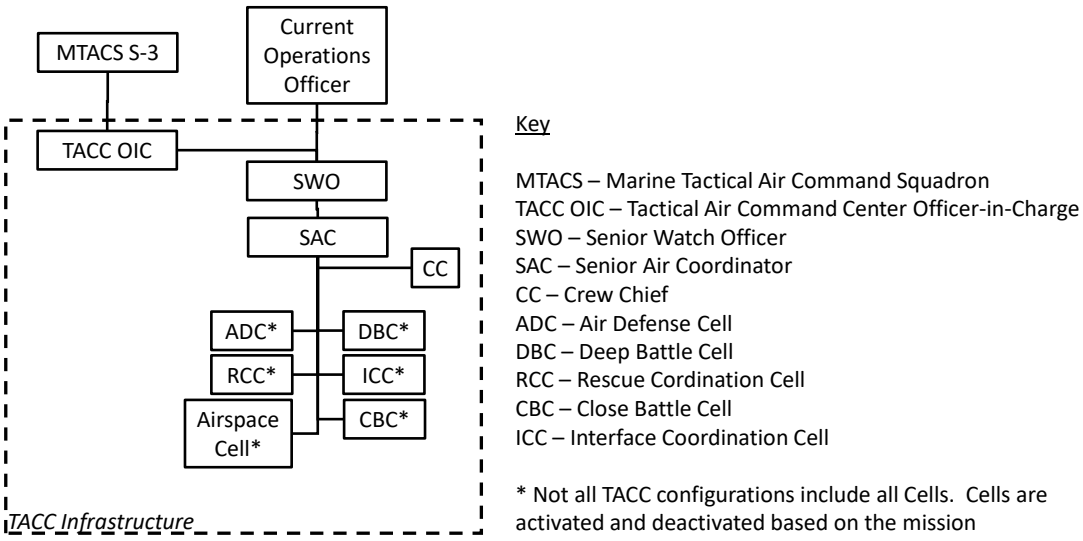

Figure 4: Existing organization of Current Operations (COPS)

The TACC has some significant strengths. It is relatively austere compared to the Combined Air and Space Operations Centers, is operationally mobile (if not tactically mobile), and is much more scalable to the scope of MAGTF operations. It can provide centralized command of air operations, which is its purpose. The concept for the TACC is sound.

The TACC also has significant liabilities, including casualty procedures, tactical mobility, and in signature management. These liabilities preclude its operation inside an A2AD WEZ, thwarting effective centralized command of Marine aviation inside of such denied areas. Doctrinally, the should the TACC become a casualty, responsibility would fall on the TAOC.[49] However, the TAOC is only able do so for "limited periods of time," and likely with augmentation.[50] The TAOC does not have capabilities to conduct the functions of FOPS, ACI, or Future Plans, as these sections are not resident within the TAOC. The TAOC's ability to control anti-air warfare would be degraded if forced to assume TACC functionality due to a casualty. Though the TACC is operationally mobile, in that it can be deployed and introduced to

a theater of operations, it is not tactically mobile; it is not able to move once emplaced. MTACS units do not have enough motor transportation assets to conduct a movement, and are reliant on external support for both transport, heavy equipment handling (forklift support, for example), and other essential logistical services. This lack of mobility means that the TACC will have to cope with unexpected changes to the operating environment without displacement.

A deployed TACC would represent an incredibly inviting target. It has many personnel, including dozens field grade officers and, likely, several general officers (i.e. the Wing Commander and Assistant Wing Commander) always present. It is physically co-located with other units, including the rest of the MWHS, MACG, MWSG (if present), MWCS headquarters, and an MWCS communications detachment. It is likely located at an operating airfield, with several flying squadrons present, and an air traffic control detachment. It has a significant cyber footprint, with many servers operating across many digital enclaves, hundreds of user accounts, and many pieces of critical software and databases. The electromagnetic signature is enormous, with dozens to hundreds of radio channels operating across the HF, VHF, UHF, and SHF spectrum, and perhaps several air defense, air surveillance, and air traffic control radars emitting. The logistical footprint is significant, as provision of life support services, energy, and maintenance support are required. Force protection, in the form of an interior guard force and quick reaction forces, add to the battlefield signature. The overall battlefield signature is colossal, detectable, and therefore targetable. If the enemy has long range munitions, electronic warfare capabilities, or offensive cyber capabilities, the TACC is vulnerable to degradation, disruption, or destruction. China and Russia both field such capabilities in quantity. Regional actors, like Iran and North Korea, as well as violent extremist organizations, will likely have such capabilities in the future.

The TACC, as currently conceived, is too large, too physically concentrated, and too detectable by the enemy. It is an immense target of enormous value. To be survivable, it must be reconceived while maintaining its functionality and adding resilience. The TACC's signature, in the physical, cyber, and the Electromagnetic Spectrum (EMS) must be controlled and modulated with that of the surrounding environment. It must be made more resilient to physical attacks. An element of tactical mobility should be added. Force protection, as a function of warfighting, must be fully integrated into the TACC's functionality.

Features of a Possible Solution

For the TACC to be a survivable agency, it must be reconceived while maintaining essential purpose of providing centralized command, facilitating decentralized control by various air control agencies, all while integrating elements of the C2 systems, and disseminating common situational awareness. It must do this in the context of highly varied physical environments, advanced cyber threats, degraded or denied use of the EMS. Its signature must be closely controlled, ruthlessly balancing the need to share information with the need to avoid detection.

The TACC must be more than a simple location or facility from where the ACE commander executes his or her duties. Rather, it should be a capability, distributed across the battlefield, with some elements located outside the enemy's long-range WEZ, and some elements located within. In this respect, the TACC should actualize its doctrine – it should become truly modular, with modules spread across the battlespace. To this end, the TACC should be organized as a TACC (Forward) and TACC (Main). This would serve to reduce the physical vulnerabilities of having all TACC functionality located at a single physical site.

The TACC (Forward) would operate inside the A2AD WEZ. TACC (Main) would operate somewhere outside the WEZ, either embarked on naval shipping, operating on a remote island, or another secure site. This split-site concept of employment would mitigate much of the risk to the TACC, as dispersion will lessen the probability of any single threat to the whole agency. It would also present an opportunity to control the signature of elements of the TACC inside the WEZ while other TACC-related tasks can continue outside the WEZ, irrespective of signature. This will place a premium on leadership, smart distribution of authorities among C2 agencies, use of mission command, and creative use of communications circuits, but it is a viable concept of employment in an environment characterized by A2AD threats.

The sections of the TACC would remain the same, though some distribution of functionality of the sections between Forward and Main TACCs would be required. TACC (Forward) would be austere, tactically mobile, and would have primary responsibility for COPS. ACI would have some representation, both as a node for collection of information from COPS, as well as dissemination of fused intelligence from the ACI section located at TACC (Main). While the TACC (Forward) is a more austere facility, and it operates from a relatively "forward" position in a battlefield framework, this does not mean it should intentionally be placed as far forward on the battlefield as possible. Rather, it exists as a C2 node and facility from which to provide command authority and disseminate common situational awareness of the battlefield to aviation units within the WEZ. It should be sited in a location with good cover, camouflage, and concealment, in defilade, with good communications characteristics relative to the key locations on the battlefield, with a strong force protection posture. Security of the TACC (Forward) site is a key consideration. TACC (Main) would have responsibility for FOPS (including ATO Development), the Future Plans Section, and ACI. COPS would have representation at the

TACC (Main) but would be responsible primarily for same-day planning efforts, maintaining awareness of the efforts of TACC (Forward), and dissemination of the ACE's air tactical picture to elements of the MAGTF located outside the WEZ. In this, TACC (Main) would closely mirror existing physical TACC architecture, though the Main TACC's COPS section would act in a supervisory role over TACC (Forward), as opposed to directly managing and directing air operations inside the WEZ. This distribution of sections between the TACC (Forward) and TACC (Main) would complicate enemy targeting efforts while allowing critical aviation C2 functions to be executed.

There are surely drawbacks to split-siting the TACC. Chief among these is that communications between the two TACC facilities will likely be limited, and sometimes cut entirely. This will place a premium on effective C2 planning, on the empowerment of subordinate agencies with the correct authorities to act without immediately informing higher agencies, and on the technical skills of our communications Marines. It will be necessary to emphasize the tenants of our doctrine which demand that we place the correct authorities at the appropriate level, so, in the event of degraded communications, no impact is felt to operations.

An additional cell should be added to COPS—the Information and Signature Management (ISM) Cell. This cell would monitor, in real time, the signature of the TACC (Forward), and balance the requirement to build and disseminate situational awareness and conduct information management functions, with the requirement to closely manage the signature of the TACC (Forward). Force Protection of the TACC (Forward) would be directly managed from this cell, including any guard forces, and tactical control of any quick reaction forces responsible for local security. This cell would manage queued messages for transmission, dissemination of ATO and ACO changes and electronic message traffic, monitor tactical radio

channels for appropriate use and exercise control of communications circuits, monitoring the signature of tactical data links, and exercise of emissions control of radars in real time. In this respect, this cell could manage the signature of the elements of the MACCS which are within the WEZ while ensuring that the essential purpose of the TACC is accomplished. If the TACC (Forward) is fighting in an environment where the EMS is degraded, or is fighting under cyber-denied conditions, coordination could be effected with the MIG, electronic warfare units, and Marine Corps cyber units to tunnel through enemy offensive capabilities, rapidly disseminate and receive information, and then rapidly return to a signature-controlled posture that denies the enemy's ability to target the MACCS, and the TACC (Forward) in particular.

This distributed posture of the TACC should make it easier for the TAOC, or other air control agency, to assume temporary TACC (Forward) functionality in case it becomes a casualty. Furthermore, if the TACC (Forward) needed to tactically move, an element of it could move, emplace, establish communications, transfer responsibility, then allow the other elements of TACC (Forward) to move to the new location. Tactical mobility could become a feature of TACC elements in the WEZ, provided the total TACC functionality (between Forward and Main) is distributed. In order to achieve the degree of tactical mobility required, the Forward echelon of the TACC must be outfitted with tactical vehicles, trailer-mounted equipment, and be sized so that it can be transported in a single convoy of vehicles without need for material handling equipment (i.e. forklifts). The Marines of this forward echelon will need to be trained to rapidly move, establish security, establish the TACC site, establish communications, and pass control between agencies, and do so in adverse weather. These skills are already resident in the Marine Air Support Squadron, which routinely operates in forward positions with infantry and artillery units. The TACC should acquire many of these same skills.

Managing air defenses is an inherent problem of the MACCS and is facilitated by the SADC. Capability to serve as a SADC is function that should be retained by Marine aviation, but the placement of the SADC on the battlefield should be a deliberate decision. While Marine Corps doctrine designates the MACS Squadron Commanding Officer as the SADC, SADC designation should migrate to the ACE commander. The MACS squadron's facilities lack the resources to plan an air defense sector for a MEF, while the ACE commander has sufficient planning resources at his or her disposal. Planning for SADC functionality should therefore reside at the TACC (Main), while real-time management of the SADC's responsibilities could be held either at the TACC (Forward) or TACC (Main). Placement of the real-time management of SADC operations should be placed based on the resiliency of communications architecture and the consequent requirement to manage the signature.

ACE commanders, MACG commanders, squadron commanders, Weapons and Tactics Instructors (WTIs), and MACCS watch standers should train their units to function in an environment where timely information is scarce and unclear. Fortunately, Marine Corps Maneuver Warfare doctrine, as prescribed in MCDP-1, and Marine Corps doctrine on mission command, prescribed in MCDP-6, provides for such an eventuality. However, over the last several decades of largely static MACCS operations in Iraq and Afghanistan, with assured communications, plentiful data throughput, reliable satellite communications, and negligible ability for the enemy to disrupt Marine aviation C2 systems, expectations for immediate information satiation have grown too high. Emphasis should be placed on using only the minimum information required to make a command decision. However, knowing *when* you have reached that minimum level of information to make a decision is more challenging. Therefore, to the maximum extent possible, decisions should be anticipated before they need to

be made, and the minimum information to make that decision should be known, not only by a given watch-stander, but also by the agency, and the entire system. Such planning is not new to aviation. Pilots pre-plan decisions as an inherent part of their work. For example, pilots will always compute something called a "bingo fuel state", which is the minimum fuel required to return to base. Knowing that fuel state reduces the cognitive load on the pilots while flying. When "bingo fuel" is reached, the decision is already made: It's time to return to base. C2 agencies should routinize such planning for all possible decisions. This will serve to reduce the requirement for extra information for all C2-related decisions. Furthermore, additional guidelines should be adhered to in the conduct of C2. Negligent transmissions of any kind should be investigated and treated with the same gravity as the negligent discharge of a personal weapon. If a commander makes a request for a piece of information, the commander should balance the need for that information with the increased risk that gathering information causes, in consultation with the ISM cell of COPS.

TACC watch-standers, especially those fighting at TACC (Forward), should embrace an identity as warfighters that are *in direct contact* with the enemy. While the physical effects of enemy fires are hopefully not directly experienced by TACC personnel, the Marines of the TACC must realize that their vigilance against enemy action, especially in the EMS and the cyber domain, are crucial to TACC mission accomplishment. Commanders should reward such vigilance, particularly when paired with accomplishment of the mission of the TACC.

A mindset shift for communications, radar, and cyber Marines is needed. There are tactical and technical themes which communications and C2 Marines have employed in pursuit of assured radio communications to guarantee that communications are always "up." This implies that reliable, responsive, and degradation-resistant communications are always available.

While laudable, these desires have led to easily targetable, jammable, intrudable communications, particularly since the end of the Cold War. There has been a move away from wired and messenger communications to modes which use radio and digital media, increasing EMS and cyber signatures. Additionally, the desire for reliable communications has led to use of high-powered, omnidirectional radio transmissions using radio propagation techniques that are highly predictable, trackable, and targetable. Unfortunately, high power, omnidirectionality, and predictability aid both the friendly forces as well as adversaries. Like TACC watch-standers, these communication, radar, and cyber Marines should embrace an identity as warfighters who are in direct contact with the enemy and should base their technical and tactical decisions on that identity.

A new communications ethic should be internalized into our communications Marines. Instead of seeking assured radio communications, communications Marines should seek communications while being wary of enemy actions to intrude, jam, or otherwise counter our communications. Radio and internet-based communications should be used, but only as a last resort. Reliable methods of achieving radio communications should be avoided with the same sense that combat units often exercise light discipline, avoid using the same, predictable patrol routes, and avoid obvious avenues of approach. Unpredictable communications, including frequency hopping, encryption, and exotic propagation modes should be practiced and used. Use of exotic radio propagation is something relatively new to military communicators, but it is not unknown to all.

Amateur "ham" radio operators often emphasize low power, directional, communications using exotic radio propagation methods.[51] They often use sky wave propagation, bouncing signals off ionized layers of the atmosphere, greatly increasing the range. Others have bounced

signals off the moon, the ionized meteor trails, airplanes, rainclouds, and the aurora borealis (the "Northern Lights"). Others use naturally-occurring "ducts" of moist air and temperature inversions to greatly increase radio communication distances over surprising distances.[52] Doing so can allow for highly efficient radio communications, using low power, and often obscuring the precise location of the transmissions. While these modes are less predictable and reliable than ground wave propagation and line-of-sight communications, they are eminently practical with appropriately trained personnel, favorable conditions, appropriate techniques and procedures, with the right equipment.

The Marine Corps also tends to use high power radio transmission to increase communication path reliability. Use of high-power radios generates significant electromagnetic signatures. Electronic warfare units are capable of direction-finding these transmitting units, either directly cueing fires onto the general area of the transmission location or allowing cueing of surveillance systems to that area for exploitation for precise fires.

Omnidirectional transmission is another method which adds predictability to tactical radio communications. Omnidirectional transmissions are predicated generally on the design of the antenna systems and radiate approximately equally in all directions. Such antennas are generally very user-friendly, low-maintenance, rugged, often broadband, easy to erect, and simple to troubleshoot.[53] They are, however, inefficient, in that they radiate much unused power that is "wasted" by transmitting power to areas where there are no receiving units. In reception, omnidirectional antennas tend to be less effective than directional antenna systems, and are more liable to receiving noise and interference, often requiring greater skill on operators to separate the signal from the static. Additionally, the broadband nature of many military omnidirectional

systems means that, while these antennas may be optimized for a large range of frequencies, they are inefficient radiators and receiving antennas.

Today, only the most reliable and predictable propagation modes tend to be used by Marines. On many frequencies, the preferred propagation mode is ground wave, which is a mode where radio signals move along the surface of the earth, from the transmitting antenna, through the air adjacent to the surface of the earth, to the receiving antenna. Line-of-sight communications tend to be used for ground-to-air and ground-to-ground communications.[54] These propagation modes are highly reliable, but also highly predictable.

Marine Corps communicators should make maximal use of exotic propagation modes, and shift modes of propagation as natural conditions and the tactical situation permits. They should also seek to use the barest minimum of radio power required, and only as a last resort if messenger, wired, fiber optic, or other means cannot meet the requirement. Signals should be aimed at the specific direction a receiving unit is; as this decreases the required power while increases the sensitivity of our receivers, reducing ability of the enemy to jam or otherwise interfere with our transmissions.

Beyond propagation modes, Marines should make use of exotic waveforms and digital signal processing techniques for low-bandwidth and low-power communication. Again, this is an area where the amateur radio community has excelled, developing digital communications modes which are able to be transmitted with such low power that the transmitted signal is indistinguishable from natural static.[55] These modes require only a radio, a personal computer, and the correct software for use, and precise time.[56] While such modes are not suitable for many military applications, it is likely that a well-conceived C2 system would feature such modes as a

primary or secondary means of some communications, particularly within range of enemy direction finding and precise long-range fires.

Use of exotic radio propagation techniques goes beyond different radio waveforms and operator skill; it also depends understanding, in real time, the nature of the radio communications medium: the atmosphere. Factors such as local time of day, the presence of solar flares, solar magnetic storms, the number and strength of sunspots, temperature inversions, and humidity levels, can all affect radio propagation, either inhibiting it or enhancing it. The ability to observe, interpret, and forecast these factors so that C2 and communications Marines can best make sue of these conditions should become a task and capability of the intelligence Marines in the MAGTF.

Every attempt should be made to physically separate transmitters (of all types, including radio transmitters, radars, tactical data link transceivers) from the command and control units they serve. Additionally, these transmitters should be networkable, and usable by any Marine aviation C2 agency on the battlefield, in accordance with direction from the TACC. For example, radios used by the DASC should be able to be accessed by the TACC and TAOC.[57] The TACC should likewise oversee radar emissions, with emphasis on using the fewest radiating radars at any given moment and radiating only in specific directions. Like radios, radars should be physically decoupled with the agency using them whenever possible, and radars should frequently change position. The Marine Corps should also investigate use of airborne air surveillance radars launchable from amphibious ships and make maximum use of airborne and shipborne radars provided by joint and coalition partners. Use of procedural control, vice positive control, should likewise be emphasized by controlling agencies when possible.[58]

Leaders at all levels, and especially commanders, should have a thorough knowledge of the nature and characteristics of electronic communications. Simple wire diagrams showing connectivity between agencies are insufficient. Rather, they should strive to know the frequency, waveforms, the nature of the messages transmitted and received, and the broader effect of communications on the MAGTF. For example, they should know that a simple request for information, transmitted by radio, can expose both the transmitter of the request, and the receiver of the request, to the enemy. Furthermore, should the receiver of the request be forced to contact other units for the required information, the other units could be exposed, too. Therefore, commanders need to be aware that simple requests to other units can expose those units to enemy effects, and therefore the need for information must be balanced against the risk of exposure. It cannot be emphasized enough the degree which commanders must be aware that their desires for information can place their units at risk, and therefore they must make efforts to mitigate these risks. This requires detailed knowledge of the nature of electronic communications, of C2 as an art, and in the pre-planning of decisions so that information is structured so a decision can be made with only the minimum information needed. Commanders will need to take the art of "Command and Control" seriously; but this should not be difficult, for "Command" is inherent in being a commander. Simply stated, they must do their jobs of putting "command" into "commander."

Description of Refined Capability

It is clear, based on the characteristics of the operating environment, that the legacy TACC is not tenable. There are substantial changes that can be made to the TACC to make it survivable in the A2AD operating environment. Given this, how should the Marine Corps realize this concept of a distributed A2AD-survivable and signature-aware TACC? A three-

phase approach is recommended, implementing changes in the immediate and near term, a middle term (2-5 years), long term (greater than five years). Such a phased approach would be able to capitalize on existing equipment while allowing the Marine Corps supporting establishment to implement any necessary changes over time.

In the near term, the focus should be on employing existing equipment in a manner that makes it the most survivable. Fortunately, each MTACS is fielded with two variants of the Common Aviation Command and Control System (CAC2S). One variant is designed to provide spaces for the entire legacy TACC infrastructure, and the remaining variant is to facilitate C2 in more limited contingencies, such as echeloning a TACC. These CAC2Ss could be employed, with personnel augmentation, as the TACC (Forward) and TACC (Main). Many aspects of the distributed TACC could be exercised today, with existing material solutions.

ACE commanders, MACG commanders, WTIs, and MACCS watch-standers should immediately address their assumptions about assured communications. While this is already implied in the 2016 Marine Operating Concept, this has not been operationalized by tactical leaders in Marine Corps units. To this end, communications Marines can immediately test the mindset of using the minimum power available, exotic radio propagation techniques, and directionalized radio communications. A new model of communications discipline, aimed at balancing EMS and cyber signature, with the need to communicate, should be embraced, monitored, tracked, and graded during training. Marine Aviation Weapons and Tactics Squadron (MAWTS) 1 should immediately commence study of the problem.

Lastly a tactical demonstration should be organized at a major training exercise to demonstrate and evaluate the distributed TACC functionality as a concept. MAWTS-1 could likely provide a venue for this during a semi-annual WTI course. Lessons learned from such a

demonstration could inform necessary doctrinal, training, materiel, and organizational changes. A tactical demonstration could also validate the updated TACC in a simulated threat environment.

In the medium term, the emphasis should be on training and developing the future force which will be required to fight in a distributed manner while controlling their signature. Training institutions, such as Marine Corps Communications-Electronics Schools (MCCES) and MAWTS-1 should focus on updating and refining their curricula. Additionally, all levels of officer training and education, from The Basic School (TBS), through Expeditionary Warfare School and Marine Corps Command and Staff College, should train and educate their student personnel on balancing requirement to communicate with the need to control signature. Personnel changes to Marine Corps units may be necessary, particularly the MTACS and the MWCS. Changes to the tables of organization of these units should be made only after experimentation with the distributed TACC concept.

In the long term, the Marine Corps should seek any necessary changes to MACCS. While the existing TACC equipment should not require significant overhaul, some equipment (including both hardware and software) would likely be helpful for the ISM cell to exercise its signature management functionality. Such systems would allow for control of communications circuits of the TACC, as well as the entire MACCS. Additionally, sensors and user interfaces should be procured to monitor the ambient EMS, so that the TACC may coordinate its emissions with those of the operational environment. Radio propagation observation and forecasting capabilities should be researched, developed, and procured. These changes need not take on the scope of new Marine Corps programs-of-record, but rather should be Engineering Change Proposals (ECP) to existing equipment.

Conclusion

The TACC, as both a concept and an agency, as stood the test of combat in military engagements and operations going back decades. As an agency, it has evolved, particularly with some improvements in materiel, but not sufficiently to keep up with changes in the operating environment. Marine Corps forces have successfully employed TACCs in Afghanistan and Iraq over the last decades, America's strategic competitors have emerged with new techniques, novel operational concepts, and advanced technology of their own, which, combined with long-range fires, can destroy the inherent ability of the Marine Corps' MAGTFs to conduct air-ground operations. Military reforms, implemented by the United States' pacing threats described in the National Security Strategy, compel the Marine Corps to embrace additional change to its C2 architecture—especially its aviation C2 architecture, including the TACC.

By retaining the concept of the TACC, as a senior aviation C2 agency, and by modifying its physical implementation, Marine aviation C2 can once again become a resilient and capable integrator of the other functions of Marine aviation in the context of an A2AD operating environment. The implementation of the TACC needs to be reconceived along several lines. Physically distributing the TACC across the depth of the battlespace, both inside and outside the range of the enemy's weapons will present a more difficult target for the enemy to destroy. Managing the use of the electromagnetic spectrum, physical signature, and cyber signature, in real time, against the requirements to distribute commands, orders, and common situational awareness, will serve to present a present an ambiguous target to the enemy. The use of less predictable radio communications modes, where possible, mixed with a greater reliance on mission command and decentralization of command authorities, will make the TACC less predictable in the EMS while preserving its necessity to communicate. Most importantly, a

change in culture is mandatory to succeed in combat in the future. The Marine Corps must emphasize mission command as articulated in MCDP-1 and MCDP-6, construct its C2 architecture so that it can thrive in the face of enemy action, and reconceive communications to be resilient in the face of the threat.

Some equipment changes may be necessary, particularly to for the new Information and Signature Management cell, to manage signatures and information in real time, but the existing equipment sets that make up the bulk of existing TACC infrastructure can be maintained. New paradigms of what constitutes effective communications will need to be created, migrating from a philosophy of high-powered, omnidirectional, and reliable communications to one where only enough power to effect communications is used, using unpredictable communications paths and modes, in a signature-constrained manner, needs to be the metric of communications success. Commanders, watch-standers, communicators, cyber, and radar Marines will need to embrace a mindset that they are *always* in contact with the enemy in information domain and are always fighting against threats in the EMS and cyber realms.

By implementing the proposed reforms, and experimenting with this new TACC operating concept, Marine aviation will be able to function effectively in an environment characterized by A2AD capabilities used by United States' peer competitors.

Endnotes

[1] Key trends of near peer competitors include the professionalization of the officer and NCO corps and use of certain information-age technologies like social networking, unmanned systems. The domain of information warfare has also become important for near-peer competitors, as has space.
[2] https://www.c4isrnet.com/it-networks/2017/12/05/why-the-marine-corps-needed-a-new-deputy-commandant/

https://defensesystems.com/articles/2017/07/05/marine-corps-cyber.aspx

https://www.marines.mil/News/Messages/MARADMINS/Article/1454562/establishment-of-the-cyberspace-1700-occupational-field-occfld/

[3] DOTMLPF is a construct used to identify concepts for developing combat power. They include Doctrine, Organization, Training, Materiel, Leadership, Personnel, and Facilities.
[4] The Marine Air Command and Control System (MACCS) consists of various air command and control agencies designed to provide the MAGTF's Aviation Combat Element commander with the ability to monitor, supervise, and influence the application of Marine aviation's six functions. The Marine Air Control Group (MACG) is responsible for providing, operating, and maintaining principal MACCS agencies.
[5] The Common Aviation Command and Control System (CAC2S), consisting of the AN/MRQ-13v1 Communications System (CS), and the AN/TSQ-297 Aviation Command and Control System (AC2S, in several configurations) has reached initial operational capable (IOC) status as the writing of this paper. The AN/TPS-80 Ground/Air Task-Oriented Radar (G/ATOR) is also IOC in the operating forces. The AN/MSQ-143AV Composite Tracking Network (CTN) is fully fielded. These three systems are a near-total replacement of the principle end items used in the MACCS.

The May 2013 issue of the *Marine Corps Gazette* contained two articles discussing transformation of existing MACCS agencies. One article, titled simply as "MACCS" discussed merging the functions of two Marine air control agencies into, generically, "multifunction air control agencies" which would conduct air control tasks for both anti-air warfare, and for offensive air support and assault support.
[6] Trump, Donald J., *The National Security Strategy of the United States of America* (Washington DC, 2017), 2-3
[7] Trump, *National Security Strategy*, 25
[8] Trump, *National Security Strategy*, 8
[9] Trump, *National Security Strategy*, 10-13
[10] Jim Thomas, John Stillion, Iskander Rehman *Hard ROC 2.0: Taiwan and Deterrence Through* Protraction (Center for Strategic and Budgetary Assessments, 2014), 5.
[11] Phillip Saunders, et al., *Chairman Xi Remakes the PLA: Assessing Chinese Military Reforms* (National Defense University, 2019), 5-6
[12] Saunders, et al., *Chairman Xi Remakes the PLA*, 5
[13] Saunders, et al., *Chairman Xi Remakes the PLA*, 6
[14] Saunders, et al., *Chairman Xi Remakes the PLA*, 8
[15] Saunders, et al., *Chairman Xi Remakes the PLA*, 10
[16] Saunders, et al., *Chairman Xi Remakes the PLA*, 131
[17] Thomas, Stillion, and Rehman, *Hard ROC 2.0*, 7
[18] Saunders, et al., *Chairman Xi Remakes the PLA*, 56-57
[19] Thomas, Stillion, and Rehman, *Hard ROC 2.0*, 6
[20] Saunders, et al., *Chairman Xi Remakes the PLA*, 393
[21] Carl Rehberg and Mark Gunzinger, *Air and Missile Defense at a Crossroads: New Concepts and Technologies to Defend America's Overseas Bases* (Center for Strategic and Budgetary Assessments, 2018), 3-4
[22] Thomas, Stillion, and Rehman, *Hard ROC 2.0,* 8
[23] Thomas, Stillion, and Rehman, *Hard ROC 2.0*, 8
[24] Heather A. Conley, et al, *Enhanced Deterrence in the North: A 21st Century European Engagement Strategy* (Center for Strategic and International Studies, 2018), 6

[25] Conley, et al., *Enhanced Deterrence in the North, 6-7*
[26] Thomas G. Mahnkin, Ross Babbage, and Toshi Yoshinhara, *Countering Comprehensive Coercion: Competitive Strategist Against Authoritarian Political Warfare* (Center for Strategic and Budgetary Assessments, 2018), 21-23
[27] Conley, et al., *Enhanced Deterrence in the North, 14-15;* Roger McDermott, "Russian Navy Procures New Electronic Warfare Capabilities" *Eurasia Daily Monitor* 16:14: https://jamestown.org/program/russian-navy-procures-new-electronic-warfare-capabilities/
[28] Conley, et al., *Enhanced Deterrence in the North, 8-9*
[29] Conley, et al., *Enhanced Deterrence in the North, 9-10*
[30] Conley, et al., *Enhanced Deterrence in the North, 11-12*
[31] James N. Miller, Jr. and Richard Fontaine, *A New Era in U.S.-Russian Strategic Stability: How Changing Geopolitics and Emerging Technologies are Reshaping Pathways to Crisis and* Conflict (Center for a New American Security, 2017), p 18
[32] Pavel Felgenhauer, "Russian Navy Preparing to Take on the US" *Eurasia Daily Monitor* 15:116: https://jamestown.org/program/russian-navy-preparing-to-take-on-us/
[33] Conley, et al., *Enhanced Deterrence in the North, 12-13*
[34] Andrew F. Krepinevich, *Preserving the Balance: A U.S. Eurasia Defense Strategy* (Center for Strategic and Budgetary Assessments, 2017), 87
[35] Center for European Policy Analysis, *Power Vertical: The Baltic Front* (podcast), 8 February 2019
[36] Headquarters US Marine Corps, *Control of Aircraft and Missiles.* MCWP 3-25, Washington, DC: Headquarters US Marine Corps, February 26, 1998, 1-4 – 1-5
[37] The six functions of Marine aviation are aerial reconnaissance, anti-air warfare, electronic warfare, offensive air support, assault support, and control of aircraft and missiles.

Headquarters US Marine Corps, *Control of Aircraft and Missiles*, 1-1 – 1-7.
[38] MCWP 3-25 p 2-1 – 2-2.
[39] The Direct Air Support Center (DASC) is the principal air control agency responsible for the direction of air operations that directly support ground forces. It functions in a decentralized mode of operation but is directly supervised by the Marine Tactical Air Command Center.

The Tactical Air Operations Center (TAOC) is the principal air control agency responsible for the conduct of anti-air warfare. The TAOC is responsible for airspace control and management. It detects, identifies, and controls the intercept of hostile aircraft and missiles and provides navigational assistance to friendly aircraft. The TAOC provides real-time surveillance of assigned airspace and direction, positive control, and navigational assistance for friendly aircraft. It performs real-time direction and control of antiair warfare operations involving aircraft and surface-to-air weapons.

Headquarters US Marine Corps, *Tactical Air Command Center* Handbook. MCRP 3-20F.2, Washington, DC: Headquarters US Marine Corps, May 2, 2016, 1-7
[40] Headquarters US Marine Corps, *Tactical Air Command Center* Handbook. 1-7
[41] While beyond the scope of this paper, there are numerous problems with this arrangement. First, the JFACC is typically dual-hatted as the Area Air Defense Commander (AADC). If the Marine ACE commander is to function analogously, he or she should also be designated the SADC, with centralized command of the air defense mission coincident with command of the entire ACE. Second, the MACS commander has significant span-of-control problems, responsible for providing several tactical air control agencies, air traffic control detachments, and meteorological forecasting and observation support. Last, the CO of the MACS could easily find himself or herself operating outside of their specialty, since the commander can be from any of several MOSs, including air defense, but also officers specializing in providing command and control of offensive air support and assault support, or air traffic control. There has been recent discussion with moving SADC functionality to the ACE commander, to be resident in the TACC, however. The author supports such a move.
[42] Offensive Counter Air (OCA) and Defensive Counter Air (DCA) sorties are included in this.
[43] Headquarters US Marine Corps, *Tactical Air Command Center* Handbook. A-2 – A-12
[44] Marine Wing Support Squadrons provide aviation ground support for airfields, including airfield operations and engineering support, messing, medical support, motor transportation, passenger and cargo handling, military

police support, communications, and other functions. In recent years MWSSs have fallen under the command of Marine Aircraft Groups, with one usually assigned to each MAG. Prior to that, a headquarters unit, called the Marine Wing Support Group, led by a Colonel, consolidated all aviation ground support under his or her command, with all the MWSSs for a Marine Aircraft Wing. The Marine Corps is in the process of reactivating these MWSGs. If this reactivation is completed, this would add an additional headquarters likely physically co-located with the TACC, MACG Headquarters, and MAW Headquarters.

[45] The Future Plans Section is responsible for planning aviation and aviation support for the next MEF mission.

The Future Operations Section is responsible for developing future Air Tasking Orders and prepares operations orders and fragmentary orders for the next ACE mission.

The Current Operations Section is responsible for the overall operations of the ACE, including execution of the current ACE operations order or fragmentary order, and the execution of the Air Tasking Order, and assessing its effectiveness.

The Air Combat Intelligence section provides timely, tailored, and fused intelligence, and is integral to the future of the Future Plans, Future Operations, and Current Operations sections. It produces and disseminates aviation-specific all-source intelligence, including assessments of enemy capabilities and vulnerabilities, target analysis, battle damage assessment, and the current status and priority of assigned targets to assist in changes to execution of combat operations.

Headquarters US Marine Corps, *Tactical Air Command Center* Handbook. 2-1

[46] Headquarters US Marine Corps, *Tactical Air Command Center* Handbook. 1-8

[47] The author served as the Marine Air Control Group-38 Forward Detachment Commanding Officer in late 2014, supervising the entire MACCS in Regional Command (Southwest) in Operation Enduring Freedom. During that time, the Marine TACC Current Operations section consisted only of a Close Battle Cell and Airspace Control Cell, supervised by the Senior Watch Officer and Senior Air Coordinator.

[48] The Air Tasking Order is a document produced by the Combined Air and Space Operation Center (CAOC) which is the synchronized plan of aviation support for a 24-hour period in a theater. Subordinate joint task forces, and MAGTFs can have their own ATOs, which are consolidated into the theater ATO. ATOs typically contain all fixed-wing sorties flown in a 24-hour period, along with other critical information, including aircraft callsign, take-off and landing locations, air-to-air refueling coordination information, targeting data, mission type, ordnance loadout, time of launch and recovery, etc. Marine Corps ATOs also include rotary wing and tiltrotor sorties, as the MAGTF's ACE commander is responsible for employment of these sorties, too. Generally, air component commanders outside of the Marine Corps are not responsible for rotary wing sorties.

[49] Headquarters US Marine Corps, *Tactical Air Command Center* Handbook. 5-11 – 5-12

[50] Headquarters US Marine Corps, *Tactical Air Operations Center Handbook.* MCRP 3-20F.6, Washington, DC: Headquarters US Marine Corps, September 13, 1996, 3-10 – 3-11

Headquarters US Marine Corps, *Marine Air Command and Control System Handbook.* MCWP 3-25.3, Washington, DC: Headquarters US Marine Corps, December 2, 1997, 2-1—2-25

[51] Commanders should emphasize licensure of C2 Marines, including communications Marines, as amateur radio operators. The author has been a licensed amateur radio operator and has profitably utilized skills related to that hobby while deployed to Iraq in 2005-6. There is no better training and education available in radio communications, including exotic radio propagation techniques, troubleshooting, and basic radio operator skill than becoming licensed as a ham radio operator, and then practicing that hobby.

In the practice of ham radio, the author, on several occasions, has communicated, with the batteries required of a flashlight, a radio, and home-made wire antenna, over incredibly long distances. On several occasions, he communicated from remote areas of California to areas as far as Europe, distancing over 9000 statute miles with 5 watts of power. From his home station in Stafford, Virginia, he has had two-way communication with over 170 countries using homemade wire antennas and 100 watts of power (enough power to light an incandescent light bulb). He has communicated with stations on all seven continents, throughout the Pacific, in sub-Saharan Africa, and the Middle East. Many radio contacts were using frequencies typically thought of as "line of sight" only, but with very extended ranges. For example, on the 50 MHz amateur radio band, a VHF

so-called “line of sight” band, he has communicated with stations on the American West Coast, the Caribbean, Portugal, South America, and Canada. While these types of communications seem exotic to some, they are repeatable if one knows how to make best use of natural conditions, radio capabilities, and uses good operator technique.

[52] To be fair, both the military and amateur radio services use troposcatter communications, where UHF and microwave communications are scattered off the upper areas of the troposphere, increasing ranges to several hundred miles. However, most tactical military communications are reliant on satellites, line-of-sight propagation, or ground wave propagation.

[53] Broadband antennas allow transmission across ranges of frequencies.

[54] Note that radio line-of-sight tends to be slightly longer than visual line of sight, as signals tend to hug the surface of the earth while visual light does not. Radio line-of-sight tends to increase with decreases in frequency. High Frequency radios, operating from 3-30 MHz, can occasionally support ground wave propagation of tens to hundreds of miles, well beyond any visual line of sight. Very High Frequency radios, operating from 30-300 MHz, generally support ground wave communications only to slightly farther than the visual horizon, provided there are no obstructions (mountains, trees, buildings, etc.) Ultra High Frequency radios, operating from 300-3000 MHz, generally have a radio line-of-sight that is coincident with visual line-of-sight, making them optimal for ground-to-air communications, but less effective for ground wave circuits between two terrestrial stations.

[55] Nobel laureate, Princeton physics professor, and radio amateur, Joe Taylor, has developed several of these modes. The most popular is known as FT8, with others known as JT65, JT4, WSPR, and others. They all require precise time, so transmitters and receivers know “when” to transmit or receive, though the precise time only generally needs to be +/- one second. The messages must be pre-formatted, too. However, it is possible that an encrypted version of these modes, and a standardized message set could be developed for use by DOD, for ultra-low power communications that can possibly evade detection and direction-finding.

[56] Currently, DOD uses the Global Positioning System for precise time. However, precise rubidium atomic clocks are available cheaply as commercial off the shelf items, often for only a few hundred dollars per unit. Such clocks should be considered in case of enemy anti-satellite action, GPS jamming, etc.

[57] Currently, radio communications in the MACCS are mostly handled by the AN/MRQ-13v1 Communications System (CS), a sheltered system transported by a light tactical vehicle and capable of simultaneous operation of 11 VHF/UHF radios, and 2 HF radios. These vehicles can be networked so radios from several vehicles can be used in concert. This is common practice, but only at the agency level (all CSs supporting the TACC, or DASC, or TAOC, for example). They typically are not networked together *across* MACCS agencies. If all CSs in the MACCS were networked on a tactical network, all connected Marine Air C2 agencies would be able to use the networked radios in a synergistic fashion. All such CSs would then be in general support of the MACCS, and communications resources could be controlled in a way to best support the efforts of ACE commander. Such a setup would allow for physical movement of communications across the battlespace irrespective of agency and allow for the physical decoupling of transmitters and agencies, especially if reliable network connections are available.

[58] Positive control is a method of airspace control that relies on positive identification, tracking, and direction of aircraft within an airspace, conducted by electronic means by an agency having responsibility therein. (Joint Pub 1-2). Typically, positive control requires use of radars. Procedural control is a method of airspace control that relies on previously agreed upon and promulgated orders and procedures (Joint Pub 1-02). Procedural control does not require electronic means required by positive control. Though not *always* required, two-way radio communications are often needed to direct and procedurally control aircraft. Procedural control has the benefit of not requiring a radar. Positive control is preferred when executing anti-air warfare, however.

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