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LOCUST employment at the tactical level, in concert with existing manned and unmanned capabilities from across the Joint Force, provides Contact Layer forces the ability to operate as a swarm within the EABO construct to develop situational awareness, complicate adversary collections and targeting efforts, and provide opportunities to selectively shape the environment, imposing costs on the adversary while reducing competition costs for the United States. LOCUST-enabled Contact Layer forces provide the Joint Force Commander the capabilities required by Joint and service concepts to better compete against great power adversaries in the Future Operating Environment.

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LOCUST SWARM EMPLOYMENT AT THE TACTICAL LEVEL
WITHININ THE CONTACT LAYER

SUBMITTED IN PARTIAL FULFILLMENT
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Executive Summary

Title: LOCUST Swarm Employment at the Tactical Level Within the Contact Layer

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Thesis: LOCUST employment at the tactical level, in concert with existing manned and unmanned capabilities from across the Joint Force, provides Contact Layer forces the ability to operate as a swarm within the EABO construct to develop situational awareness, complicate adversary collections and targeting efforts, and provide opportunities to selectively shape the environment, imposing costs on the adversary while reducing competition costs for the United States. LOCUST-enabled Contact Layer forces provide the Joint Force Commander the capabilities required by Joint and service concepts to better compete against great power adversaries in the Future Operating Environment.

Discussion: The purpose of the concept is to describe the employment of LOCUST by Marine Corps forces at the tactical level in the Contact Layer within the context of strategic competition This paper reviews related service and Joint Force concepts, strategic guidance, and historical examples of swarming and presents a concept for LOCUST swarming at the tactical level .

Conclusion: LOCUST-enabled Marine forces, employed at the tactical level within the Contact Layer provide flexibility and capability to the Joint Force under the EABO concept. Elements equipped with these low-cost, low-risk systems provide the U.S. an asymmetric advantage in competition with great power rivals, imposing costs on competitors while reducing costs for the U.S. and its allies.

DISCLAIMER

THE OPINIONS AND CONCLUSIONS EXPRESSED HEREIN ARE THOSE OF THE INDIVIDUAL STUDENT AUTHOR AND DO NOT NECESSARILY REPRESENT THE VIEWS OF EITHER THE MARINE CORPS COMMAND AND STAFF COLLEGE OR ANY OTHER GOVERNMENTAL AGENCY. REFERENCES TO THIS STUDY SHOULD INCLUDE THE FOREGOING STATEMENT.

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Preface

When reviewing the United States' strategic security documents alongside Joint and service concepts, capability gaps emerge which must be addressed to ensure the Joint Force is capable of providing the capabilities the nation requires to ensure its vital national interests. One such instance which drew my interest relates to how the Marine Corps will "operationalize" its EABO concept within the context of the Contact and Blunt Layers. Existing capabilities, programs, and platforms alone cannot meet the requirements of distributed, non-linear, and highly mobile expeditionary operations called for in the LOCE and EABO concepts without placing high value, exquisite U.S. defense platforms at risk in a strategic competition with great power rivals.

In developing this concept, I sought to apply a cost-imposition strategy to U.S. competitors that would create positional, temporal, and cognitive advantages for the United States while simultaneously reducing both cost and risk to the U.S., its allies, and partner nations through the employment of LOCUST by tactical-level Marine Forces within the Contact Layer. My intention with this concept is not to "add another rock in the pack" of Marine Corps concepts, but rather to visualize how the Marine Corps can bring existing concepts like EABO to life in way that doesn't bankrupt the force or demand radical restructuring to accomplish.

I would like to thank Dr. Ben Jensen for his continued mentorship, encouragement, and understanding, and for continuing to provide me opportunities to widen my scope of understanding and refine my thinking. I'd also like to thank the fellow members of the AY2018-2019 Gray Scholars Program at Marine Corps Command and Staff College for serving as a sounding board for ideas and sharing their concepts with me. Lastly, I must thank my wife, Ariel for her support and patient understanding as I completed this project.

INTRODUCTION AND BACKGROUND

The United States military requires new approaches to competition and the transition to limited contingencies against rival states. Low-Cost UAS Swarm Technology (LOCUST) employed at the tactical level within the Expeditionary Advanced Base Operations (EABO) construct enable the types of missions the 2017 National Security Strategy (NSS) and 2018 National Defense Strategy (NDS) envision to meet this challenge. The 2017 NSS states that the United States faces "growing political, economic, and military competitions…around the world" from great powers such as Russia and China, regionally destabilizing dictatorships such as Iran and North Korea, and transnational non-state threats such as terrorism and transnational criminal organizations (TCOs).[1] This competition takes place at a level below the threshold of traditional armed conflict through adversary actions "cloaked in deniability."[2] Examples include Russia's employment of "Little Green Men" in the Ukraine, China's "salami slicing" tactics in the South China Sea, and Iran's use of the Quds Force to provide support to terrorist groups and militia forces throughout the middle east region.[3]

Responding to great power competitors requires more flexible Joint teams. Addressing this issue, the 2018 National Defense Strategy (NDS) states that "[t]he central challenge to U.S. prosperity and security is the *reemergence of long-term, strategic competition* by…revisionist powers [emphasis in the original]."[4] To meet the challenges inherent to strategic competition the 2018 NDS calls for "Dynamic Force Employment" options to improve flexibility and scalability while helping the Joint Force maintain the initiative in strategic competition. Building on this premise, the 2018 NDS describes a new paradigm for employment of the Joint Force within a layered "Global Operating Model" consisting of "contact, blunt, surge, and homeland" layers "designed [respectively] to help us compete more effectively below the level of armed conflict;

delay, degrade, or deny adversary aggression; surge war-winning forces and manage conflict escalation; and defend the U.S. homeland."[5] To operate within the paradigm, Marine Corps forces will fight as part of a "Navy-Marine Corps-SOF team…organized, trained, equipped, integrated and synchronized to provide combatant commanders an inside force capable of contact and blunt layer activities with the foundational elements that will enable crisis response and surge."[6]

The Marine Corps, as part of the Joint Force, will conduct actions within the Global Operating Model in a Future Operating Environment characterized by "persistent disorder" and "contested norms" likely to produce the following six "contexts for future conflict":

> 1. **Violent Ideological Competition**. Irreconcilable ideas communicated and promoted by identity networks through violence.
> 2. **Threatened U.S. Territory and Sovereignty**. Encroachment, erosion, or disregard of U.S. sovereignty and the freedom of its citizens from coercion.
> 3. **Antagonistic Geopolitical Balancing**. Increasingly ambitious adversaries maximizing their own influence while actively limiting U.S. influence.
> 4. **Disrupted Global Commons**. Denial or compulsion in spaces and places available to all but owned by none.
> 5. **A Contest for Cyberspace**. A struggle to define and credibly protect sovereignty in cyberspace.
> 6. **Shattered and Reordered Regions**. States unable to cope with internal political fractures, environmental stressors, or deliberate external interference.[7]

To operate within these contexts, the Joint Force will pursue four strategic goals by performing four enduring military tasks. The figure below demonstrates the linkage between goals, tasks, and contexts:

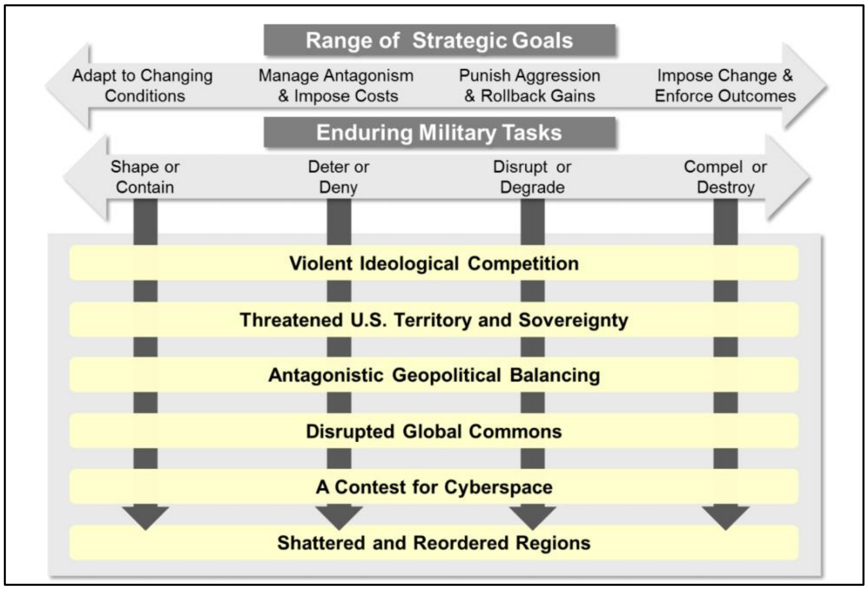

Figure 1: Enduring Strategic Goals, Military Tasks, and Contexts of Future Conflict Taken from Joint Operating Environment 2035.[8]

The Marine Corps will operate in this environment primarily through activities in the Contact and Blunt Layers under the Littoral Operations in Contested Environments (LOCE) concept, conducting Expeditionary Advance Base Operations (EABO), summarized below:

> The EABO concept espouses employing mobile, relatively low-cost capabilities in austere, temporary locations forward as integral elements of fleet/JFMCC operations… Expeditionary advanced bases may be used to position naval ISR assets, future CDCMs, anti-air missiles (to counter cruise and ballistic missiles as well as aircraft), and forward arming and refueling points (FARPs) and other expedient expeditionary operating sites for aircraft, critical munitions reloading teams for ships and submarines, or to provide expeditionary basing for surface screening/scouting platforms, all of which serve to increase friendly sensor and shooter capacity while complicating adversary targeting. They may also control, or at least outpost, key maritime terrain to improve the security of sea lines of communications (SLOCs) and chokepoints or deny their use to the enemy, and exploit and enhance the natural barriers formed by island chains. The EABO concept provides the opportunity to "turn the sea denial table" on potential adversaries and deter fait accompli actions.[9]

The EABO concept requires development of future capabilities and novel employment methods to become a viable force employment concept. One such development is the incorporation of Low Cost UAV Swarm Technology (LOCUST), employed by Marine forces in the Contact Layer within the EABO construct, to develop situational awareness, complicate adversary collections and targeting efforts, and provide opportunities to selectively shape the environment, imposing costs on the adversary while reducing competition costs for the United States.

PURPOSE

The purpose of the concept is to describe the employment of LOCUST by Marine Corps forces at the tactical level within the Contact Layer within the context of strategic competition. Actions in the contact layer during competition with a peer competitor require the ability to observe, orient, decide, and act across multiple domains at greater tempo than the adversary in an information-degraded environment employing low-cost, low-risk systems. The ability to deter or de-escalate conflict or set conditions for transition to the blunt layer are dependent on a flexible "inside force" capable of sensing adversary actions and taking appropriate friendly actions within an operational or strategic framework. This requires a capability that can be rapidly deployed and employed, operate both ashore and in a maritime environment, and place high-cost, exquisite adversary capabilities at risk before committing friendly ones. LOCUST employment at the tactical level, in concert with existing manned and unmanned capabilities from across the Joint Force, provides contact layer forces the ability to operate as a swarm within the EABO construct to achieve this end.

Swarming, defined as the "deliberately structured, coordinated, strategic way to strike from all directions, by means of a sustainable pulsing of force and/or fire, close-in as well as from stand-off positions," has been documented in campaigns from antiquity to the present day, and a summary of air and ground swarming can be found in Appendix A of this document.[10] This concept proposes the incorporation of LOCUST at the tactical level, and explores how LOCUST-enabled forces could be employed in the contact layer within the EABO concept as a swarming force. This concept, in its preliminary stages of development, has been initially tested and refined during a series of wargames conducted at the Marine Corps Warfighting Lab (MCWL) by students of the Marine Corps Command and Staff College, MCWL, and the Ellis Group. A summary of the implications derived from these wargames conducted from the fall of 2018 to the spring of 2019 is included in the Central Idea section of this document.

TIME HORIZONS, ASSUMPTIONS, AND RISKS

The technology behind LOCUST still remains in testing and evaluation, yet multiple demonstrations have been conducted focused on component aspects of the technology. It is reasonable to assume that this concept could be ready for experimentation in the field in as little as 5 years, and employment across the force in as little 10 years assuming that:

- LOCUST testing and evaluation will continue until the technology meets the thresholds required for fielding
- Once the technology is sufficiently matured, LOCUST will be funded by the Marine Corps at sufficient levels to allow fielding at the battalion level within the Ground Combat Element
- Associated individual and collective training requirements are codified in Training and Readiness standards, incorporated into the Programs of Instruction at applicable Training and Education venues, and incorporated into service-level evaluations
- LOCUST is developed with joint interoperability in mind from the beginning, meaning that LOCUST sensors, C2 systems, and software are capable of integrating with existing platforms

The adoption of any new concept brings inherent risks, which must be balanced against the perceived benefits. Risks inherent to this concept include:

- Unintentional escalation or the creation of a security dilemma as adversaries react to the existence of LOCUST swarms in the new status quo environment in strategic competition with the U.S.
- Vulnerability of individual LOCUST drones to electronic attack
- Opportunity costs associated with pursuing LOCUST concept and impact to funding of other programs
- Complexity of command and control, airspace deconfliction, and approval authorities associated with a swarm of drones launched from dispersed sites, capable of influencing multiple domains, and achieving effects across several warfighting functions

As this concept and its associated technology are further refined, these assumptions and risks will be revisited and updated, but they provide a starting point for future development.

DESCRIPTION OF THE MILITARY PROBLEM

Current employment options to adequately address the requirements outlined by the service and Joint Force concepts referenced previously. Specifically the Marine Corps needs concepts that contribute to:

- Providing flexible response and employment options to the Joint Force commander within the construct of Contact and Blunt Layers

- Gaining and maintaining tempo and initiative in the context of strategic competition with adversaries whose capabilities, access, and influence match or exceed those of the U.S and its allies in a given theater of operations
- Maintaining competition at a level below armed conflict while creating advantage and setting conditions in the event of conflict escalation
- Increasing competition costs for adversaries while reducing competition costs for the United States and its allies, placing adversary High Value Targets at risk while protecting friendly ones
- Integrating Navy and Marine Corps actions to influence and control environments at sea and in the littorals, strengthening screening and scouting elements enhancing sensor-shooter integration, coordination, and deconfliction

The LOCUST swarm concept addresses these components of the problem set by providing a novel employment option for Marine forces within the EABO construct.

CENTRAL IDEA

Augmenting the Contact Layer with small, low cost, multi-spectrum ISR enables increased multi-domain awareness, allowing the contact layer to better frame the operating environment prior to transition to Blunt or Surge operations. In the Contact Layer, LOCUST-enabled units can develop civil and adversary baselines across domains, assessing gaps or opportunities for potential exploitation. LOCUST launchers can be surreptitiously introduced to the environment, either brought ashore by the amphibious force, drawn from prepositioned stocks during Receiving, Staging, Onward Movement and Integration (RSO&I) in non-descript containers similar to those transporting supplies required by the current mission, or launched directly from amphibious ships, connectors, or vehicles such as retrofitted AAVs or variants of the Amphibious Combat Vehicle (ACV). Tactical units ashore and afloat can rapidly prepare and launch the LOCUST swarms from multiple sites, which would then fly to pre-designated Named Areas of Interest (NAIs) autonomously through Artificial Intelligence (AI) aided navigation. Swarm controllers maintain the ability to dynamically retask the swarm - or elements of it - as required, or simply monitor the swarm's progress using a process of scaled autonomy discussed in the Swarm Theory and Case History section of this document.

LOCUST drones are consumable items, meaning each drone is only used once, either detonating or self-zeroing and inerting upon completion of the mission. This limits friendly signature and force protection concerns as the launch team is capable of fire and forget operations, launching the swarm and then quickly displacing from the launch site, handing off control to the AI-assisted navigation and/or swarm control team. Data collected can be transmitted real time in-flight to ground stations for exploitation, and data from each drone can be composited to build a multi-spectrum intelligence picture.

As the situation develops, and the requirement to transition to blunt or surge operations arises, drones within the LOCUST swarm can support the targeting effort by acting as observers for shaping or preparatory fires, cueing for more advanced, higher-value collections assets to further develop situational awareness, or be used as loitering munitions, directly attacking targets on land, at sea, or in the air to interdict adversary actions or limit adversary capabilities. Each drone is a disposable, low-cost, one-time use platform that places exquisite, high value adversary platforms at risk while allowing the friendly force to selectively employ their own high value assets with greater understanding of the threat environment.

Each drone within the LOCUST swarm can be configured with a variety of payloads to achieve the parameters of the mission. Envisioned payloads include ISR, EW, anti-ship, land-attack, targeting, counter-drone, and decoy. Aside from navigation, AI-assisted swarm control manages placement, cueing, and tasking of individual drones within the swarm based on preset mission parameters programmed by the launch team. This allows the swarm to sense changes to the operating environment and adapt to achieve its mission, completing this OODA loop cycle at a rate orders of magnitude greater than human cognition.

LOCUST swarms disrupt the adversary in multiple ways. The relatively low cost of individual LOCUST drones, or even the swarm as a collective, compared to the potential adversary capabilities they place at risk (capital ships, fixed sites, high-demand/low-density assets such as high-end A2AD platforms) imposes both costs and risks on adversaries. Operating forward in a security area or in the Contact Layer, the swarm disrupts adversaries' attempts to develop situational awareness. Masking friendly capabilities behind a cloud of "cheap mass" these swarms send decoy signatures to adversary collections platforms and force adversaries to sift through a cloud of friendly signatures to determine order of battle and intent. Launched from multiple, temporary sites, the LOCUST swarm frustrates adversary targeting efforts against launch sites while the inherently low-cost drones make individually targeting them cost-prohibitive for adversaries.

SWARM THEORY AND CASE HISTORY

This section offers a brief review of the evolution of swarming theory and provides historical cases of swarming in both ground and air campaigns to highlight opportunities and implications for the application of LOCUST swarming at the tactical level within the Contact Layer.

Evolution of Swarming Theory

In their 2000 report, *Swarming and the Future of Conflict*, John Arquilla and David Ronfeldt of RAND layout a compelling concept referred to as "Battleswarm Doctrine."[11] Arquilla and Ronfeldt argue that the history of conflict can be grouped into four general doctrines of gradually increasing complexity: melee, massing, maneuver, and swarming. The greater the complexity, the greater the requirement for information sharing, enabled by both technology and organization. Swarming requires the highest level of information sharing, achieved through a concept Arquilla and Ronfeldt refer to as "topsight" wherein small units maintain situational awareness of the broader operation or campaign and their role in it, while commanders maintain situational awareness of subordinate elements without having to direct every action taken.[12] This concept of topsight-enabled swarming is supported by the Marine Corps' maneuver warfare doctrine through concepts such as decentralized command and control, mission tactics, and commander's intent.[13] Swarming requires a force specifically trained and organized to operate in small, dispersed, highly mobile groups, linked together through a command and control architecture that facilitates topsight. Given these requirements, the swarming force is capable of executing "sustainable pulsing" of forces and/or fires originating from dispersed locations, massing for an attack, then dispersing again to preserve the force for a subsequent pulse.[14]

Supporting and building on Arquilla and Ronfeldt's work, Sean J. A. Edwards' *Swarming on the Battlefield: Past, Present, and Future* and 2005 doctoral dissertation, *Swarming and the Future of Warfare*, examine nearly two dozen cases of swarming in conflict, from 329 BC through the modern era with Operation Iraqi Freedom. Edwards' cases focus almost exclusively on land-based ground swarming, but he identifies three key variables of successful swarming that could be applicable to swarming in any domain: elusiveness, superior situational awareness, and standoff.[15] He posits that swarming is consistent with a broader form of "non-linear dispersed operations" or NLDOs, characterized by units that "move and fight in multiple directions, they are widely separated, and they are capable of supporting each other by concentrating mass or fires."[16] The section on ground swarming contained in this appendix provides specific historical examples illustrating the concepts of topsight-enabled battleswarming, sustainable pulsing, and NLDOs conducted by land-based military forces.

More recently, LtCol Jonathan E Burdick (USAF) examines historical instances of swarming in aviation to support his 2016 thesis *Instantly Basing Locust Swarms: New Options for Future Air Operations*. Burdick argues that aviation swarming requires thee elements: aircraft with sufficient range, robust command and control systems, and a logistics system capable of sustaining a small, dispersed force.[17] Given these requirements a swarm can operate as part of a man-machine team across a range of "sliding autonomy," as depicted in Table 1.[18] The section on air swarming provides historical examples illustrating these concepts.

Level	Name	Description
1	Human Operated	A human operator makes all decisions. The system has no autonomous control of its environment although it may have information-only responses to sensed data.
2	Human Delegated	The vehicle can perform many functions independently of human control when delegated to do so. This level encompasses automatic controls, engine controls, and other low-level automation that must be activated or deactivated by human input and must act in mutual exclusion of human operation.
3	Human Supervised	The system can perform a wide variety of activities when given top-level permissions or directions by a human. Both the human and the system can initiate behaviors based on sensed data, but the system can do so only if within the scope of its currently directed tasks.
4	Fully Autonomous	The system receives goals from humans and translates them into tasks to be performed without human interaction. A human could still enter the loop in an emergency or changes the goals, although in practice there may be significant time delays before human intervention occurs.

Table 1. The Four Levels of Autonomy[19]

Given this overview of swarming theory, examination of historical cases of both ground and air swarming provides insight into how these principles have been applied in the past and how swarming theory can be applied to the concept of LOCUST swarming employed at the tactical level within the contact layer, as described earlier in this document, to help deter conflict or shape the operational environment in the case of conflict escalation.

Ground Swarming

The Mongols provide a textbook example of the asymmetric advantages a ground swarming force can generate. Using a combination of warriors on horseback and long-range attack from archers, both employed along multiple, converging axes against their adversaries, the Mongols perfected the art of swarming by both force and fires. They maintained “topsight” through the employment of battlefield messengers, enabling initiative at the subordinate level while maintaining leaders’ situational awareness of the overall battle.[20]

The Vietnam War demonstrated the effects of swarming employed by both sides. Communist forces routinely swarmed by force, using infiltration routes and concealment within the local population to attack U.S. forces from multiple axes, obscuring their movements and enjoying much greater mobility relative to their adversary. After attacks, these forces would rapidly withdraw, disappearing into the physical and human terrain to preserve the force for follow-on action, embodying the principle of sustainable pulsing. The United States, in turn, used swarming by fires to mass artillery, mortar, direct fire, and aviation fires from multiple firebases and aviation attack headings onto North Vietnamese Army (NVA) and Vietcong (VC) positions once identified.[21] While communist forces enjoyed superior elusiveness, the United States achieved greater stand off. Neither side, however, achieved a definitive advantage in situational awareness, demonstrating a delicate balance of Edwards three key variables in swarming.[22] The Mongols, NVA, VC, and U.S. military in Vietnam each demonstrated the ability to conduct NLDO, albeit in a unique combination of ways and means tailored to the specific military situation presented to each force.

Air Swarming

World War II provides two examples of air swarming. British Royal Air Force (RAF) swarming against the German Luftwaffe during the Battle of Britain, and Japanese swarming in the form of Kamikaze attacks in the Pacific against the United States Navy provide interesting case studies that demonstrate the utility of swarm tactics from the air. Focusing first on RAF swarming during the Battle of Britain, British fighters, cued to German attacks by early warning radar, launched from multiple basing sites and formed up in flight to attack incoming Luftwaffe bombers. The distributed British launch sites reduced the risk to British aircraft on the ground, provided sustainable logistics support, and when combined with early warning radar and in-flight communications provided a decisive advantage in situational awareness and command and control compared to that of the Luftwaffe. German bombers approached targets along pre-planned, fix attack corridors, whereas the RAF fighters, flying to engage from dispersed launch sites were able to close on multiple, unpredictable routes. Designed and outfitted specifically for air to air combat, RAF fighters enjoyed a mobility and weaponeering advantage relative to the heavier, slower, ground attack Luftwaffe bombers.[23]

Japanese Kamikaze fighters employed similar tactics against the U.S. Navy, launching from a combination of land and carrier-based sites to intercept U.S. vessels from multiple, unpredictable approaches. The lighter, more mobile swarming Kamikaze aircraft were weapons in and of themselves, designed for one-way suicide missions. This allowed the swarming aircraft to focus purely attacking their targets, with no regard for force protection, recovery, or rearmament after the engagement. This asymmetric advantage allowed the Japanese to mass in waves of small, light attacks designed to defeat targets through a series of crippling blows rather one decisive knockout punch, however their effectiveness was limited by the range of Kamikaze aircraft and unsustainable expenditure rates of fuel, ammunition, aircraft, and personnel.[24]

By distributing attack capability across large swarm of small, highly mobile units, attacking from multiple axes to converge on targets both the British RAF and Japanese Kamikaze swarms demonstrated the "sustainable pulsing" concept forwarded by Arquilla and Ronfeldt and the non-linear dispersed operations concept posited by Edwards. The ability, or inability, to achieve Burdick's three key elements of sustainable aviation swarming (range, command and control, and distributed logistics support) heavily influenced the levels of success each of these approaches to swarming achieved.

Conclusions and Implications

The case studies examined here, examples of both ground and air swarming, illustrate the fundamentals of swarming put forth by Arquilla, Ronfeldt, Edwards, and Burdick. From these historic cases, a concept for Low Cost UAS Swarming Technology (LOCUST) employed at the tactical level within the context of the Contact Layer emerges. Incorporating "sustainable pulsing" through non-linear dispersed operations, contact layer forces at the tactical level employ LOCUST to flip the cost-imposition paradigm onto potential adversaries of the United States. Highly mobile, small-scale, distributed ground forces employ LOCUST from temporarily occupied positions to enhance friendly force situational awareness and create "topsight". This concept enables contact layer forces to collect intelligence and selectively shape the environment from multiple, dispersed, locations converging on targets from unpredictable avenues of approach. The disposable and autonomous nature of LOCUST technology reduces both cost and risk to the force, while allowing for reconstitution and follow-on operations through land or sea-based tactical logistics. Using the concept of sliding autonomy to increase resilience in a communication-challenged environment by limiting the dependence on man-in-the-loop command and control in favor of automation, human supervised or fully autonomous LOCUST swarms become "fire and forget" elements capable of performing a multitude of roles including: multi-domain Intelligence, Surveillance, and Reconnaissance (ISR); strike; and Electronic Warfare. Historical precedent shows that swarming can provide an asymmetric advantage with flexible employment options, limiting risk while disproportionately imposing costs upon the adversary. The United States' current National Security and Defense Strategies require just such a capability, as demonstrated through wargaming and experimentation.

INSIGHTS FROM WARGAMES AND EXPERIMENTATION

From the fall of 2018 to the spring 2019, a group of Marine Corps Command and Staff College students participating in the Gray Scholars Program conducted a series of planning and wargaming exercises in conjunction with members of the Marine Corps Warfighting Lab and the Ellis Group to examine the implications of great power competition with China at the tactical and operational levels of war. One of concepts developed by the group focused on the employment of MARFORPAC forces as the Contact Layer in competition with China within the South China Sea to ensure access and influence in the area for the U.S., its allies, and partners. Among many other findings, this experiment provided insight into the utility and feasibility of employing LOCUST swarms at the tactical level within the Contact Layer to support multi-domain situational awareness and help secure access through a cost-imposition strategy employing Expeditionary Advance Base Operations (EABO) concepts. This section provides an overview of those findings from the exercise with implications on LOCUST swarm employment at the tactical level.

Operational Design

The South China Sea should be considered key terrain in strategic competition with China. The ability to access and influence this key terrain can be addressed through a strategy of cost imposition in the South China Sea using MARFORPAC as the Marine Component to Contact Layer forces in which the seven Competition Mechanisms outlined in the Joint Concept for Integrated Campaigning (JCIC) are applied.[25]

The primary problem for the U.S. in competition with China in the South China Sea is one of access and influence. China currently maintains a multi-layered persistent presence of advanced bases, People's Liberation Army Navy (PLAN), Coast Guard, and maritime militia to control access under the narrative of historic ownership of the "9 Dash Line." In contrast, U.S. Navy Freedom of Navigation patrols and Joint Force participation in recurring named Theater Security Cooperation exercises provide the U.S. limited, intermittent access to the South China Sea and surrounding areas capable of influencing it. This access is both fleeting and predictable, providing little flexibility to the U.S. and ceding initiative in the region to the Chinese.

Chinese advantages in the South China Sea can be countered through application of the seven Competition Mechanisms outlined in the JCIC: Strengthen, Create, Preserve, Weaken, Position, Inform, and Persuade.[26] While a ultimately a mission for the Joint Force in concert with other instruments of U.S. power, MARFORPAC can provide Contact Layer forces capable of achieving multi-domain situational awareness and the ability to selectively engage to shape Chinese behavior, while setting conditions for follow-on actions.

Under this construct MARFORPAC would provide flexible response and employment options to INDOPACOM through persistent access to and presence in the South China Sea. MARFORPAC actions would contribute to: gaining and maintaining U.S. initiative in contact layer competition; increasing completion costs for China while decreasing costs for the U.S. and regional allies and partners; creating and strengthening regional partnerships; enforcing freedom of navigation and the international Law of the Sea; and maintaining competition with China below the level of armed conflict while creating positional, temporal, and cognitive advantage in the event of escalation.

This construct would create a future state in which the U.S. can more effectively compete with China, characterized by: a permanent U.S. access and presence in the South China Sea region; deeper interoperability with regional partners such as the Republic of the Philippines; persistent multi-domain awareness forcing China to operate under constant observation and removing their ability to "salami slice" through a series of fait accompli; and flexible U.S. and partner employment options, creating uncertainty for the Chinese while generating initiative for the U.S.

LOCUST Swarm Employment at the Tactical Level

MARFORPAC actions along the Competition Mechanisms of Strengthen, Preserve, and Create include: reinvigorating and expanding Enhanced Defense Cooperation Agreement (EDCA) basing access and CIV/MIL coordination with the Philippines; military sales to the Philippines coupled with mil-mil training focused on the employment of Low Cost UAS Swarm Technology (LOCUST) such as COYOTE, small unmanned surface and sub-surface drones, and small UAVs for sensing and cuing; and increasing the frequency and scope of theater security cooperation exercises with the Philippines. These activities build capacity to exert persistent sea control, using low-cost or expendable platforms in a contact layer to sense activity and cue higher-cost manned or unmanned platforms to further develop the situation or selectively engage. As increased U.S. presence and access in the region becomes normalized, MARFORPAC could establish a Southeast Asia Rotational force, based out of the Philippines and recapitalizing UDP forces, to provide ready forces to build a more robust contact layer. The goal of these actions is to create the perception of omnipresence by demonstrating persistent access, operational and tactical flexibility, and multi-domain sensing/striking capability while making Contact Layer forces difficult to locate and target without expending or exposing disproportionately more valuable adversary capabilities.

The above activities support actions along the Competition Mechanisms of Position and Weaken, which include: expanding U.S. and partner influence through operations information environment; eroding China's relative influence over regional stakeholders vis-à-vis the U.S.;

and leveraging enhanced U.S. positioning in the contact layer to guarantee regional access for the U.S., its allies, and partners. The use of LOCUST swarming by MARFORPAC Contact Layer forces executing NLDO from temporary sites, such as those envisioned in the Expeditionary Advanced Based Operations (EABO) concept, allow U.S. forces to establish positional and temporal advantage by maintaining multi-domain situational awareness, selectively engaging threats, and complicating adversary targeting. This form of "sustainable pulsing" allows MARFORPAC forces to interdict Chinese activities with low-cost, low-risk friendly action, placing High Value Targets at risk with expendable assets launched from distributed and temporarily occupied sites by small units.[27]

Implications

LOCUST swarms represent only a portion of the required capabilities in the Contact Layer to achieve the desired future state. Within this construct these swarms are used to sense, cue, and selectively shape adversary actions, but must be integrated with larger, more capable manned and unmanned platforms to achieve desired effects. Managing airspace, coordinating and approving strikes, and synchronizing actions across multiple domains from elements across the joint force requires a robust, resilient, and flexible command and control architecture. To maximize the inherent capabilities of the LOCUST swarm it must be capable of autonomous action and able to communicate with individual swarm members and external elements. The swarm is best employed within a set of mission parameters, within which it is allowed to make a series of defined decisions aided by a collective artificial intelligence, yet also able to be dynamically retasked by human controllers. Ground units can quickly establish LOCUST launch sites and deploy the swarm, but control of the swarm and defining its mission parameters should be held at a higher level to ensure synchronization of action across distributed sites and to limit the force protection risk to the launch teams to enable follow-on tasking. The launch team must be capable of configuring individual drones with a payload mixture appropriate for the mission to include ISR, strike, EW, anti-ship, counter-drone, decoy, and C2 payloads.

PROPOSED CAPABILITIES, APPLICATION, AND INTEGRATION

To help visualize the application and integration of LOCUST-enabled tactical-level forces operating in the Contact Layer, proposed capabilities and applications inherent to this concept are grouped below by warfighting function.

Force Protection: LOCUST launchers do not need to be consolidated into section or platoon firing positions like artillery or mortars. Infantry squads or platoons can individually operate LOCUST launchers from distributed sites, with each site launching multiple drones to form the swarm in flight. This limits the force protection risk to the launch team by limiting their physical footprint on the ground. In this construct platoons could conduct coordinated LOCUST raids from multiple sites: rapidly setting up a launch site, releasing their swarm, and then displacing to another location. Once launched, the drones follow pre-programed mission parameters under the guidance of AI-assisted navigation and control to further reduce risk through exploitation of the electromagnetic signature of a ground control station. The variable payloads can be configured with a counter-UAS payload (either EW or anti-air) to protect contact layer forces from enemy observation. Because they are both unmanned and expendable, there is no need to risk contact layer forces to recover LOCUST systems.

Logistics: Due to their small size, LOCUST systems are easily transportable ashore by contact layer forces, launched from amphibious ships, or launched from variants of amphibious vehicles configured as LOCUST hives. Additional drones can be pre-staged in depots, afloat, or mobile-loaded in logistics vehicles to provide magazine depth and access as well as distributed sustainment of LOCUST swarm operations.

Fires: The LOCUST swarm can operate as a multi-function hunter-killer team, with some drones outfitted with targeting payloads sensing and cueing other drones in the swarm outfitted with anti-armor, anti-personnel, or anti-ship payloads. LOCUST like the Coyote system are capable of travelling up to 80km and loitering for up to one hour, greatly enhancing the range, flexibility, and responsiveness of the contact layer's organic fire support, without the risk to traditional observers.[28] When used in a fires capacity, these munitions would be deconflicted through the use of traditional Fire Support Coordination Measures and clearance procedures such as final attack headings/cones. The swarm can also handoff targeting data, designate targets, and serve as observers for platforms outside the swarm.

Maneuver: Maneuver elements operating LOCUST ashore in support of ground operations can employ the swarm as the advance guard or screening force, employing drones in advance of their position to develop the situation, gain contact with the enemy, and attrite high payoff targets to set conditions for manned maneuver. In a maritime setting, these maneuver elements would conduct LOCUST swarm raid operations, rapidly deploying from amphibious ships via connectors or amphibious vehicles to launch the swarm from the sea or from expeditionary, temporary sites ashore to contribute to maritime situational awareness and the establishment of sea control. As infantry squads restructure to include a squad systems operator as well as an assistant squad leader, platoons will have additional capacity for manned-unmanned teaming such as this without stripping away vital combat power. Maneuver elements would be responsible for launching the swarm, but control and decision authority for swarm mission would be reserved at the Composite Warfare Commander (CWC) level to ensure synchronization and unity of effort across the force, as described in the LOCE concept.[29]

Intelligence: Multiple collections payloads can be employed within the swarm, collecting across several spectrums simultaneously. The LOCUST swarm can relay collected information from drone to drone and ultimately back to a collection station ashore or at sea to be fused into a cohesive multi-spectrum intelligence picture. Assisted by Artificial Intelligence, the LOCUST swarm collection station could produce an interactive graphic display with spectrum "layers" to help analysts assess the battlespace in real time. This collections node will serve as the conduit through which information from the swarm is synthesized into intelligence and disseminated across the Joint Force.

Command and Control: The biggest challenge in employment of LOCUST at the tactical level is command and control. As previously discussed, while platoons are capable of launching the LOCUST swarm, authority to launch and swarm tasking will be retaining at the CWC-level. As with existing fire support doctrine, approval authority, deconfliction procedures, and cross-boundary coordination requirements must be articulated and thoroughly rehearsed prior to execution. This requires explicit Rules Of Engagement covering LOCUST swarm employment coupled with clearly defined commander's intent to enable this technology to be employed in a manner truly consistent with maneuver warfare theory. Incorporating AI-assisted swarm navigation and control through scaled autonomy brings new challenges to our understanding of man-machine teaming and traditional command and control processes.

CONCLUSION

LOCUST employment at the tactical level, in concert with existing manned and unmanned capabilities from across the Joint Force, provides Contact Layer forces the ability to operate as a swarm within the EABO construct to develop situational awareness, disrupt adversary collections and targeting efforts, and provide opportunities to selectively shape the environment, imposing costs on the adversary while reducing competition costs for the United States. LOCUST-enabled Contact Layer forces provide the Joint Force Commander the capabilities required by Joint and service concepts to better compete against great power adversaries in the Future Operating Environment.

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[19] Table reproduced by Burdick from DOD, Unmanned Systems Integrated Roadmap FY2011-2036 (Washington, DC: DOD, 2011).
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