CROW RESSURECTION:
THE FUTURE OF AIRBORNE ELECTRONIC ATTACK

BY

MAJOR MARK D. HOWARD

A THESIS PRESENTED TO THE FACULTY OF
THE SCHOOL OF ADVANCED AIR AND SPACE STUDIES
FOR COMPLETION OF GRADUATION REQUIREMENTS

SCHOOL OF ADVANCED AIR AND SPACE STUDIES
AIR UNIVERSITY
MAXWELL AIR FORCE BASE, ALABAMA
JUNE 2013

Report Documentation Page					*Form Approved OMB No. 0704-0188*	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.						
1. REPORT DATE **JUN 2013**		2. REPORT TYPE			3. DATES COVERED **00-00-2013 to 00-00-2013**	
4. TITLE AND SUBTITLE **Crow Ressurection: The Future Of Airborne Electronic Attack**					5a. CONTRACT NUMBER	
					5b. GRANT NUMBER	
					5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)					5d. PROJECT NUMBER	
					5e. TASK NUMBER	
					5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **School of Advanced Air And Space Studies,,Air University,,Maxwell Air Force Base,,AL**					8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)					10. SPONSOR/MONITOR'S ACRONYM(S)	
					11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**						
13. SUPPLEMENTARY NOTES						
14. ABSTRACT **This study examines the adequacy of the current United States Department of Defense Airborne Electronic Attack strategy regarding support to future global strike operations. Airborne Electronic Attack (AEA) is a vital element to successful global air strike operations as evidenced by operations during Vietnam and the Gulf War. Within an environment of fiscal austerity, modern day DOD Electronic Warfare Officers (EWOs) face significant Airborne Electronic Attack challenges in protecting strike assets by attempting to gain and maintain control of the electromagnetic spectrum.**						
15. SUBJECT TERMS						
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON	
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**85**		

APPROVAL

The undersigned certify that this thesis meets master's-level standards or research, argumentation, and expression.

DR. STEPHEN E. WRIGHT (Date)

LT COL RICHARD J. BAILEY (Date)

DISCLAIMER

ABOUT THE AUTHOR

Major Mark Howard is an Electronic Warfare Officer (EWO) in the United States Air Force. After receiving his commission through Officer Training School in 2000, Major Howard served as an RC-135V/W RIVET JOINT EWO at Offutt AFB, Nebraska. While at Offutt, Major Howard earned his master's degree in Aeronautical Engineering from Embry Riddle Aeronautical University. He attended the USAF Weapons School in 2006 with follow-on assignments at the squadron and wing levels. Major Howard was then assigned as an instructor at the Weapons School and also serving as Assistant Director of Operations for Electronic Warfare for the 8th Weapons Squadron. He then graduated from the Army General Command and Staff College in 2012. Major Howard graduated from the School of Advanced Air and Space Studies, Maxwell AFB, Alabama in 2013. His follow on assignment was Deputy Chief of Future Air Operations Branch, NORTHCOM. He is married and has two children.

ACKNOWLEDGEMENTS

This year has been one of the most challenging of my Air Force career. The reading, research, and writing pushed the boundaries of what I believed possible. I cannot imagine having made it through without the patience, help, and support of several people

I especially want to thank Dr. Stephen Wright, my thesis advisor for helping nail down a well-scoped project early, saving countless hours of 'bunny-trailing'. Dr. Wright helped me keep my eye on the prize of thesis completion by structuring my time and balancing my desire to stay engaged with my family during this excruciating year. His comments were always on-point and kept me on a straight and narrow track.

I would like to thank the SAASS faculty for their investment of time. Your instruction, mentorship, and critiques have made me a better student, writer, and officer. I must give a special thank-you to my reader Lieutenant Colonel Richard "Bubbles" Bailey. Your tireless editing efforts produced a much better product than was possible on my own.

I would also like to thank my wife for her unending love and support. Through all of the inconveniencies and agitations that only a military wife can understand, she has always encouraged me to excel. To my sons: you guys are the best! I hope this year has brought us closer together.

Most importantly, I want to express my sincere appreciation to God, the creator and sustainer of all things. Though I sometimes had a hard time understanding why I decided to put myself through the SAASS 'ringer', I knew I could always trust in His plans for His glory. Soli Deo Gloria!

ABSTRACT

This study examines the adequacy of the current United States Department of Defense Airborne Electronic Attack strategy regarding support to future global strike operations. Airborne Electronic Attack (AEA) is a vital element to successful global air strike operations as evidenced by operations during Vietnam and the Gulf War. Within an environment of fiscal austerity, modern day DOD Electronic Warfare Officers (EWOs) face significant Airborne Electronic Attack challenges in protecting strike assets by attempting to gain and maintain control of the electromagnetic spectrum.

The current DOD AEA strategy must adequately address support to future global strike operations for these missions to remain relevant in future conflict. The threat to strike forces has evolved significantly since the Gulf War, and the DOD must retain the capability to counter adversaries with effective AEA protection. Future global strike operations will require specific AEA mission sets and the DOD force must maintain a credible capacity to deny, degrade, and disrupt future advanced adversary air defenses. This thesis seeks to reveal critical AEA activities, capabilities, and Tactics, Techniques, and Procedures (TTPs) of the past in order to project requirements for the future employment of airborne electronic attack in support of global strike operations.

This paper analyzes historical AEA missions conducted during the Vietnam Crisis and Operation Desert Storm in order to identify key variables of AEA success. By contrasting similarities and differences from the past against the current AEA mission capability; this study seeks to identify potential gaps. The speculative literature reviewed in this study suggests some promising solutions, yet without adequate oversight and funding the DOD may delinquently neglect the often discounted field of AEA. Lastly, this study draws conclusions for the future of AEA and asserts implications for future mission development in the DOD.

The capabilities, TTPs, and missions-types of the past serve as a guide towards mission requirements of the future. AEA warriors will need to perform similar tactics, techniques, and procedures in a future large-scale conventional war and the EWOs of yesterday provide sound insights for tomorrow. An examination of past capabilities guides the analysis of what would best serve to ensure global strike platforms get to the target safely and return to base.

CONTENTS

Illustrations

INTRODUCTION

> *Instead of giving excessive emphasis to one means, which circumstances may render ineffective, it is wiser to choose and combine whichever are the most suitable, most penetrative, and most conservative of effort—i.e. which will subdue the opposing will at the lowest war-cost and minimum injury to the post-war prospect.*
>
> B.H. Liddell Hart
> *Strategy*

This thesis is about the future of airborne electronic attack in the Department of Defense. During the 1960s and early 1970s, adversaries found they could effectively defend themselves with radar-guided surface-to-air missiles against US strike aircraft. To protect their striker brethren from these enemy defenses, Electronic Warfare Officers (EWOs) flying on radar-jamming aircraft developed distinct missions and tactics to protect attacking aircraft during ingress and egress to their assigned targets. The airborne electronic attack (AEA) mission continued to prove its value as a key enabler during the Gulf War in the 1990s. However, the US military has not faced an adversary requiring the use of AEA capabilities to jam radar-guided weapons in over a decade and the memory of the essentials of this mission is fading.

Future military campaigns against near-peer competitors capable of waging a large-scale conventional war will require unique AEA missions and capabilities to conduct successful global strike operations. The threat of the 1960s and 1990s has evolved into a robust Anti-Access / Area-Denial (A2AD) menace threatening to close off international airspace and/or waterways. The risk associated with defending strike aircraft in such an environment is now greater than ever.

Today, the US Air Force has no indigenous AEA capability. Instead, the USAF relies mainly on stealth technology and standoff kinetic weapons to protect global strike assets attacking targets defended by advanced technology threats. Meanwhile, the U.S. Navy harbors all manned DOD AEA aircraft. In a future large-scale battle, naval AEA assets will likely find themselves fully occupied in protecting the fleet and unable to fill concurrent global strike support requirements should stealth and standoff weapons fall short of the required protective effects. These troubling asset scarcity concerns infer likely AEA capability gaps, leaving the DOD unprepared to defend bomber aircraft penetrating through A2AD barriers.

This research seeks to answer a vital question considering the future employment of airborne electronic attack: does the current DOD AEA strategy adequately address support to future global strike operations? If the threat has evolved, the DOD must retain the capability to counter with an effective AEA force. What types of AEA missions will future global strike operations require? The missions-types of the past can serve as a guide towards mission requirements of the future. Which tactics, techniques, and procedures (TTPs) will AEA warriors need to perform in a future large-scale conventional war? Certainly, EWOs of yesterday can provide sound insights for tomorrow. What types of capabilities will be required in an A2AD environment? An examination of past capabilities should guide the analysis of capabilities that might serve to ensure attack platforms get to the target and safely return to base.

These questions have no easy answer. However, failing to prepare for tomorrow will result in disastrous consequences for both the airmen flying global strike missions and for the associated war campaign on the whole. Current indications point to potential capability gaps in protecting strike assets from adversaries employing advanced defensive weapons. The current DOD AEA strategy inadequately addresses support to future global strike operations.

Roadmap

First, chapter one analyzes historical AEA missions conducted during the Vietnam Crisis and Operation Desert Storm in order to identify key variables of AEA success. Next, chapter two contrasts similarities and differences from the past against the current AEA mission capability in order to identify potential gaps. Chapter three reviews the probable future AEA environment and hypothesizes potential solutions by exploring the speculative literature in the AEA field. Lastly, chapter four draws conclusions for the future of AEA and asserts implications for future mission development in the DOD.

Limitations and Key Terminology

This research focuses on Electronic Attack (EA), one of three divisions of Electronic Warfare (EW). EW refers includes using electromagnetic and directed energy to control the electromagnetic spectrum or attack an enemy. The other divisions include Electronic Warfare Support (ES), the searching for, identifying, and locating of radiated electromagnetic energy for the purposes of threat recognition; and Electronic Protection (EP), actions taken to protect from effects of enemy use of the electromagnetic spectrum.[1] Although ground-based and space-based systems can provide jamming effects, this paper focuses primarily on airborne platforms. Furthermore, this paper focuses on non-kinetic radar jamming aspects of airborne electronic attack. While communications jamming, and anti-radiation missiles fall within the category of electronic attack, this essay excludes these functions for purposes of focusing the subject matter to the specified argument of counter-radar AEA in support of global strike concept of operations (CONOPS).

Global Strike CONOPS employ forces against advanced threats to ensure access for follow on forces. Commanders employ global strike operations with the intent of gaining and maintaining access to territory

[1] Joint Publication 3-13.1, "Doctrine Update for Jp 3-13.1," *Information Operations* (2012).

in neutralizing the adversary's area-denial systems.[2] Current global strike plans mainly rely on stealth platforms, standoff kinetic weapons, and precision munitions in order to gain access and minimize risk.[3]

Because adversaries would gain an advantage in battle if they had knowledge of specific capabilities, historically, much of the EW world has remained behind the fortified doors of a Sensitive Compartmented Information Facility (SCIF). This study only incorporates open-source, unclassified material and is therefore constrained by the parameters of secrecy.

A Lens for the Future

This study examines key historic snap-shots of high employment of AEA and compares their fundamental activities to the current AEA capability in order to better discern future requirements. A review of both material and non-material factors of effective AEA operations reveals the essentials of successful protection for global strike aircraft. Furthermore, the case studies aid in determining what made missions, weapons, and tactics effective and likewise provide clues to lessons of what methods do not work. Reflecting on past AEA activities also points to key acquisition and modifications of equipment, which improved operations resulting in TTP enhancements.

The review of the distilled historical analysis allows for a comparison with current day AEA capability. By buttressing AEA of the past with the present, this study aids in determining similarities and differences and identifies what the disparities may imply for future operations. Through analyzing current DOD documents outlining mission requirements and acquisition needs, this research provides a preview of the future of AEA, facilitating a general projection of capability gaps. Additionally, this study reveals recent improvements and

---

[2] Keith P. Feaga and P. A. Army War College Carlisle Barracks, *The USAF Capabilities Based Conops Construct* (Ft. Belvoir: Defense Technical Information Center, 2004), 9.
[3] Feaga and Army War College Carlisle Barracks, *The USAF Capabilities Based Conops Construct*, 9.

refinements to TTPs for currently employed AEA assets, providing a window to see how DOD leaders envision filling those capability gaps.

By first assessing the present against the backdrop of the past, this study then examines potential future solutions to address identified gaps. Capitalizing on new and integrated techniques may provide part of the solution. Producing smarter weapons and/or pods using existing technology instead of creating smarter new platforms may also offer viable solutions in today's austere fiscal environment. Solutions may also include a comprehensively integrated mix of air, low observable, space, and cyber assets working in concert.

Conclusion

This framework provides a lens for studying the future development of airborne electronic attack. Studying the how EWOs of the past used their weapons and methods to accomplish their missions will aid in shaping tomorrow's AEA future. Moreover, our current level of AEA technology may not successfully to overcome advanced enemy defenses. However, by analyzing and evaluating future options against the backdrop of a historical perspective discussed in this essay, DOD leaders may overcome the numerous challenges associated with the future of airborne electronic attack.

CHAPTER 1
As the Old Crow Flies

> *War, however, is not the action of a living force upon a lifeless mass (total nonresistance would be no war at all) but always a collision of two living forces . . . so long as I have not overthrown my opponent I am bound to fear he may overthrow me.*
>
> Carl von Clausewitz
> *On War*

Vietnam and the Gulf War were periods in history involving substantial employment of AEA. This chapter identifies both material and non-material factors historically required to meet the fundamental aim of airborne electronic attack: control the Electromagnetic Spectrum (EMS). Specific mission types, assets, and TTPs employed during these contingencies serve as guides for future decision makers and planners.

Crows over Vietnam

American involvement in Vietnam stemmed from an increasing concern over the expansion of communism. US leaders closely followed the French failure to defend colonial holdings from the communist North Vietnamese aggression in the 1950s. Within ten years, the North was conducting an insurgency against the South in an effort to unify the peninsula under its control. President Lyndon Johnson responded in 1963 stating, "It remains the central objective of the United States in South Vietnam to assist the people and government of that country to win their contest against the externally directed and supported communist conspiracy."[1] Within two years, US involvement in Vietnam would escalate to the hundreds of thousands of troops in the conflict.

The US air war against North Vietnam began in August 1964 as a response to the alleged firing of North Vietnamese patrol boats on US

[1] NSAM 273, 26 November 1963, National Security Files, National Security Action Memorandums, Johnson Library, Boxes 1-9, 1.

destroyers operating in international waters in the Gulf of Tonkin. A deliberate, yet incremental approach ensued with US navy aircraft destroying petroleum stocks, port facilities, and approximately 25 North Vietnamese vessels.[2] The North Vietnamese continued to provoke further US intervention by attacking an American airbase and bombing a South Vietnamese hotel quartering US officers. Instead of heeding the advice of the Joint Chiefs of Staff for a concerted effort against the North, President Johnson and his Defense Secretary, Robert McNamara, proceeded with their gradualist strategy. The tit-for-tat US response provided the North Vietnamese a priceless opportunity to build up their air defenses.[3]

The Threat

Initially, US strike forces enjoyed a period of uncontested air superiority while bombing North Vietnamese targets. In most cases, bombers proceeded without the support of AEA assets. However, as the war progressed, and North Vietnamese defenses improved, US tactics required adjustments to ensure aircrew and aircraft survivability and to accomplish the mission.[4] From the summer of 1965 to early fall 1966, the situation facing strike pilots over North Vietnam was indeed grim."[5] The North Vietnamese developed an Integrated Air Defense System (IADS) in the summer of 1965, when SA-2 missile sites became operational.[6] The North's IADS served as an aggregate of air and ground defensive system protecting their critical assets.

To combat US strike forces, the North Vietnamese constructed a highly capable IADS a within short span of time. By fusing together a

---

[2] Benjamin S. Lambeth, *The Transformation of American Air Power: A Rand Research Study* (Ithaca: Cornell University Press, 2000), 15.
[3] Lambeth, *The Transformation of American Air Power*, 17.
[4] CHECO Division United States Air Force. Pacific Air Forces. Directorate of Tactical Evaluation, *Tactical Electronic Warfare Operations in Sea, 1962-1968: Special Report*, ed. Robert M. Burch (S.l.1969), 18.
[5] CHECO Division United States Air Force, *Air Tactics against Nvm Air/Ground Defenses* (1967), 18.
[6] United States Air Force. Pacific Air Forces. Directorate of Tactical Evaluation, *Tactical Electronic Warfare Operations in Sea, 1962-1968: Special Report*, 17.

complex web of communication systems, the North connected early warning and ground control intercept radars with target-tracking and acquisition assets. This effort created a consolidated and shared defensive picture for operators to engage the American enemy. With much help from their Soviet suppliers, in three short years the North Vietnamese air defense grew from only six fire control radars to 450 radars of all types by 1967 including ground control intercept (GCI) radars to guide Vietnamese aircraft.[7] The IADS capability provided advanced and adaptable defensive tactics and techniques capabilities to the North Vietnamese.

A classic example of the North Vietnamese IADS revealed their high levels of competence and unpredictability. Colonel Morris Shiver, an EB-66 EWO, reported the IADS would use radars other than the Fan Song target-tracking radar to feed data to the SA-2 fire control center.[8] This tactic gave the IADS a distinct advantage. Instead of detecting the American strike force at the standard range of approximately 35 nautical miles, using the early warning and acquisition radars allowed the IADS to track and engage at much longer distances.[9] EWOs expecting to hear the double-pulse repetition frequency of the Fan Song target-tracking radar instead were surprised to encounter the missile guidance radar just as the American aircraft came within missile range.[10] This tactical adaptability demonstrated the clear danger of becoming complacent when facing a thinking enemy.

Although not considered a mobile threat by today's standards, the SA-2 of the Vietnam era served as a sufficiently moveable weapon. Even

---

[7]Gilles Van Nederveen and Research Air University. College of Aerospace Doctrine, *Sparks over Vietnam: The Eb-66 and the Early Struggle of Tactical Electronic Warfare* (Maxwell Air Force Base, Ala.: College of Aerospace Doctrine, Research and Education, Air University, 2000), 36.
[8] Bernard C. Nalty, *Tactics and Techniques of Electronic Warfare: Electronic Countermeasures in the Air War against North Vietnam 1965 - 1973* (Office of Air Force History, 1977), 10.
[9] Nalty, *Tactics and Techniques of Electronic Warfare: Electronic Countermeasures in the Air War against North Vietnam 1965 - 1973*.
[10] Nalty, *Tactics and Techniques of Electronic Warfare: Electronic Countermeasures in the Air War against North Vietnam 1965 - 1973*.

without an extensive surfaced road network, the North Vietnamese were fully capable of transporting the 25 assigned assets typically consisting of one acquisition radar, a Fan Song target-tracker, electrical generators, a fire control computer, and 18 Guideline missiles and six launchers.[11]

In March 1965, airborne electronic attack assets protected strike aircraft flying into "one of the most complex electromagnetic defense threats ever to be combatted by the USAF tactical forces."[12] As the US strikers and their jamming escorts approached, the North Vietnamese had almost completely encircled the capital city of Hanoi with defensive SAM systems.[13]

Airborne Electronic Attack Assets

The DOD intended to counter the North's radar threat with both dedicated jamming aircraft and self-protection jamming pods affixed to striker assets. For a dedicated airborne radar-jammer, the US Air Force opted to modify an obsolete bomber, the B-66 Destroyer, retrofitting the aircraft with jamming equipment and dubbing it the EB-66. The capabilities of the EB-66 were limited as the aged airframe was at the end of its lifecycle. In addition, the Air Staff would not fund additional required modifications to extend its air-worthiness.[14] Instead, the DOD drew heavily on non-deployed assets for parts.[15] One EB-66 EWO reported there was nothing wrong with the electronic equipment on the aircraft itself, though some of it was also antiquated.[16] He bluntly stated the EB-66s were a flying hazard due to their age.

---

[11] Nalty, *Tactics and Techniques of Electronic Warfare: Electronic Countermeasures in the Air War against North Vietnam 1965 - 1973*.

[12] United States Air Force. Pacific Air Forces. Directorate of Tactical Evaluation, *Tactical Electronic Warfare Operations in Sea, 1962-1968: Special Report*, 16.

[13] United States Air Force. Pacific Air Forces. Directorate of Tactical Evaluation, *Tactical Electronic Warfare Operations in Sea, 1962-1968: Special Report*, 39.

[14] Van Nederveen and Air University. College of Aerospace Doctrine, *Sparks over Vietnam*, 21.

[15] Van Nederveen and Air University. College of Aerospace Doctrine, *Sparks over Vietnam*, 12.

[16] Lyn R. Officer, *Oral Interview of Capt James L. Hendrickson, Interview #646* (Maxwell AFB: United States Air Force Oral History Program, 1973), 7.

Maintenance crew procedures compounded the aging airframe problem. As modifications were required, flight-line maintainers simply tacked on new equipment instead of removing old wiring and unused parts. While manufacturers originally designed the B-66 airframe for a take-off weight of approximately 58,000 pounds, EB-66s were loaded to around 82,000 pounds due to the excess electronic equipment, leaving very little thrust for a margin of safety.[17] One veteran pilot warned that losing an EB-66 engine on take-off meant an inevitable crash-landing.[18]

In their defense, maintenance crews were overwhelmed with the EB-66. Jamming equipment required constant modification to keep pace with the North Vietnamese counter tactics. Furthermore, the aged EB-66 fleet required substantial attention to keep the planes airborne. Maintenance statistics from 1970 reported three man-hours of maintenance were required for every hour of flight time.[19] Even if maintenance could keep the jets airborne, the EWOs operating the equipment had difficultly executing the mission due to lack of training.

Training on the EB-66 was a continuing issue for crews deploying to the Vietnam Theater. Equipment configurations onboard training aircraft for EB-66 EWOs did not match the jet the Air Forced used in combat. In addition, training bases in the early years of the Vietnam War had no flight simulators. As a result, much of the training EWOs received was in the combat zone over North Vietnamese territory.[20] Although the EB-66 was old and difficult to maintain and train crews to operate, the requirement for the asset far exceeded production.

The US Navy and Marine Corps responded to the North Vietnamese air defense threat in similar fashion to the Air Force. The Skywarrior

---

[17] Officer, *Oral Interview of Capt James L. Hendrickson, Interview #646*.

[18] Nalty, *Tactics and Techniques of Electronic Warfare: Electronic Countermeasures in the Air War against North Vietnam 1965 - 1973*, 28.

[19] Van Nederveen and Air University. College of Aerospace Doctrine, *Sparks over Vietnam*, 82.

[20] Van Nederveen and Air University. College of Aerospace Doctrine, *Sparks over Vietnam*, 19.

EKA-3B/TACOS aircraft first flew in 1952.[21] Like the Air Force modification to the EB-66, the Navy originally designed the EKA-3B as a twin-engine bomber.[22] The Marines also employed the EF-10B between 1965 and 1969; an outdated aircraft which first flew in 1948 and was used during the Korean conflict as a night fighter.[23]

The DOD did introduce two AEA aircraft during Vietnam conflict to lighten the heavy AEA requirement load. The USMC introduced the two-seat, EA-6A Electric Intruder, in late 1966.[24] Additionally, an elongated the A-6 version was produced to add seating for two additional EWOs in EA-6B Prowler which first flew operational sorties over Vietnam in 1972.[25] While dedicated jamming platforms supported the ingressing strike aircraft, the strike aircraft had another layer of defense as they were also fitted with self-protection jamming pods.

Pods

The DOD also developed self-protection pods for striker aircraft as a layered defense effort to counter the North Vietnamese threat. Initial attempts in 1965 to mount devices on reconnaissance versions of the F-101 and F-4 achieved marginal success.[26] Internal electro-magnetic countermeasures (ECM) testing also failed to produce satisfactory results. By mid-1966, the DOD determined ECM pods mounted beneath fighter aircraft provided the best protection results.[27]

As strikers began to fly with ECM pods in January of 1967, the drawbacks to self-protection became obvious. To make the jamming most effective, strikers flew tighter formations, which both increased their probability of detection by enemy radar and their vulnerability to

---

[21] Kenneth P. Werrell, *Archie to SAM: A Short Operational History of Ground-Based Air Defense* (Maxwell Air Force Base, Ala.: Air University Press, 2005), 122.
[22] Nalty, *Tactics and Techniques of Electronic Warfare: Electronic Countermeasures in the Air War against North Vietnam 1965 - 1973*, 20.
[23] Werrell, *Archie to SAM: A Short Operational History of Ground-Based Air Defense*, 122.
[24] Werrell, *Archie to SAM: A Short Operational History of Ground-Based Air Defense*, 123.
[25] Van Nederveen and Air University. College of Aerospace Doctrine, *Sparks over Vietnam*, 90.
[26] Werrell, *Archie to SAM: A Short Operational History of Ground-Based Air Defense*, 125.
[27] Werrell, *Archie to SAM: A Short Operational History of Ground-Based Air Defense*, 125.

enemy aircraft. Additionally, each pod took up an ordinance station, decreasing the kinetic weapons load capability of the aircraft.[28] However, the value in self-protection pods became seemingly apparent as the Air Force losses in a heavily SAM protected area decreased from 50 to 16 percent after adding self-protection pods.[29] In contrast, the Navy lost 50 percent by failing to use pods in the same area.[30]

Pods served various specified functions against the defending radar system to include noise, barrage, deception jamming, and track breaking. Table 1 below displays various pods US forces employed in Vietnam, their purpose, and their associated aircraft.

Table 1: Vietnam Pods

Pod	Function	Aircraft
ALQ-71	2 Channel Noise Jammer	**RF-101C** **EB-66** **B-52** **F-4** **F-105F**
QRC-160-8	Barrage Jamming Pod	**F-100** **F-101** **F-105** **F-111**
ALQ-51	Deception Jammer and Track Breaker	**F-4** **RF-101**
ALQ-100	Track-Breaker	**EA-6B** **F-4** **F-111**
QRC-335	Combined Noise Jamming and Deception System	**F-4** **F-105**

Source: CHECO Division United States Air Force. Air Tactics Against NVM Air/Ground Defenses 1967 and Andreas Parsch, "AN/ALQ to AN/ALT - Equipment Listing," U.S.

[28] John R. Murray, *Project Corona Harvest End-of-Tour Report* (1971), 5.
[29] Werrell, *Archie to SAM: A Short Operational History of Ground-Based Air Defense*, 126.
[30] Werrell, *Archie to SAM: A Short Operational History of Ground-Based Air Defense*, 126.

Military Aviation Designation Systems, http://www.designation-systems.net/usmilav/jetds/an-alq2aly.html (accessed April 4, 2013).

The Linebacker II air campaign highlights the validity of self-protection pods. North Vietnamese SAMs downed a total of 15 B-52s, America's primary strategic bomber. While the Air Force only upgraded half of the G-models with new ECM equipment, they did upgrade all D-models. Although the North fired 1,285 SAMs at more B-52Ds, more B-52Gs were hit and downed.[31] The aggregate effects of self-protection pods and dedicated AEA platforms working in concert proved vital to strike success.

Missions/Activities (Deny, Degrade, Disrupt)

The EWOs overarching goal in applying AEA was gaining and maintaining control, even if only temporarily, over the electro-magnetic spectrum and limiting its use for the adversary. Both dedicated support assets and self-protection pods performed their AEA mission to deny, degrade, and disrupt the North Vietnamese air defense system. Denying track correlation and force assessment data to the enemy warning network and ground-control intercept operators robbed the enemy of alertness.[32] Degrading enemy radars reduced the effectiveness or efficiency of adversary operations seeking to induce a sense of complacency and fatigue. Disruption intended to increase North Vietnamese uncertainty by interrupting operations, limit enemy combat capability and looking at the contest as jammer versus radar.[33]

Key factors in performing any of deny, degrade, and disrupt mission activities hinges on achieving an adequate 'jam-to-signal' (J/S) ratio. The J/S ratio refers to the amount of power required from the jamming asset in order to mask the radar return received by the hostile

[31] Werrell, *Archie to SAM: A Short Operational History of Ground-Based Air Defense*, 135.
[32] Murray, *Project Corona Harvest End-of-Tour Report*, 1.
[33] CHECO Division United States Air Force, *Air Tactics against Nvm Air/Ground Defenses*, 11.

radar.[34] J/S ratio varies with distance relationship between the jammer and its associated receiver; for example, jammer effectiveness will decrease as distance from the target radar increases.

The support jamming aircraft denied the enemy detection and tracking information by achieving the required J/S ratio against early warning and fire control radars.[35] The denial in turn, shortened the enemy's response time to act. The introduction of the pods further complicated the targeting solution for SAM operators. Self-protection pods caused SAM operators to adopt new procedures such as track-on-jamming. As track-on-jamming only provided azimuth information, the US strikers in effect, denied range information, which significantly decreasing the enemy probability of hit. [36] If full denial of enemy air picture was not achievable due to reduced J/S ratio, the ECM support aircraft and pods sought to reduce enemy effectiveness or efficiency by induce a sense of complacency and fatigue.

Support jamming aircraft were effective at degrading early warning radars at longer distances. Planners carefully integrated jamming equipment and tactics to generate as much confusion as possible within the critical time window when strikers were vulnerable.[37] Any degradation of enemy effectiveness or efficiency at the right time enhanced mission success and increased survivability. For example, during Operation Rolling Thunder, the strike force ingress lasted approximately ten minutes; even if support jammers failed to completely mask friendly aircraft radar returns, any confusion or delays in the IADS led to diminished US loss rates.[38]

---

[34] Rebecca Grant, *The Radar Game* (Arlington, Va.: IRIS Independent Research, 2010), 27.
[35] Grant, *The Radar Game*.
[36] Werrell, *Archie to SAM: A Short Operational History of Ground-Based Air Defense*.
[37] United States Air Force. Pacific Air Forces. Directorate of Tactical Evaluation, *Tactical Electronic Warfare Operations in Sea, 1962-1968: Special Report*, 58.
[38] United States Air Force. Pacific Air Forces. Directorate of Tactical Evaluation, *Tactical Electronic Warfare Operations in Sea, 1962-1968: Special Report*, 59.

From the enemy perspective, the confusion complicated target identification and limited tracking quality data by disrupting operations. Without reliable acquisition data, target-tracking radars reluctantly searched, acquired, and selected their own targets. The extended time taken to accomplish these acts made the target-tracking radars vulnerable to attack from F-105 Wild Weasels with anti-radiation missiles.[39] The disruption was two-fold against an area and a terminal threat. Support aircraft employed noise jammers, deception jammers, decoys, and chaff combined in a layered effect to disrupt general enemy target sequencing in over a large area, while self-protection pods disrupted the SAM and AAA radars in the target area.[40] The North Vietnamese continually adapted and adjusted to the denial, degradation, and disruption of their IADS, while US EWOs likewise countered with varied tactics, techniques, and procedures to ensure the safety of the strike forces, continuing a deadly tit-for-tat throughout the long years of the war.

Tactics, Techniques, and Procedures

Orientation relative to the target radar was a key tactical factor to effective jamming. Early in the war, airborne support jammers flew escort role tactics oriented parallel to the strike fighters and concentrating their jamming on target-tracking radars for SA-2s and AAA.[41] Blanket coverage of certain threat radars required three to four of the less powerful Marine EF-10Bs to encircle a radar system.[42] As the North Vietnamese attained greater numbers of SAM systems, the DOD restricted support-jamming aircraft to orbits outside the target envelope of the SAM threat.

---

[39] Murray, *Project Corona Harvest End-of-Tour Report*, 3.

[40] United States Air Force. Pacific Air Forces. Directorate of Tactical Evaluation, *Tactical Electronic Warfare Operations in Sea, 1962-1968: Special Report*.

[41] Van Nederveen and Air University. College of Aerospace Doctrine, *Sparks over Vietnam*, 81.

[42] Nalty, *Tactics and Techniques of Electronic Warfare: Electronic Countermeasures in the Air War against North Vietnam 1965 - 1973*, 21.

The standoff tactic variation called for jamming from farther distances, yet allowed for wider coverage areas. Due to its greater size, the EB-66 could carry larger, more powerful jammers and still maintain an effective J/S ratio.[43] On a typical mission supporting strikes in North Vietnam's panhandle, one EB-66 jammed from the neighboring country of Laos oriented from the west, while another EB-66 in concert transmitted an additional layer of jamming from the Gulf of Tonkin to the east.[44] Reports indicated jamming was so effective against the early warning systems that the enemy gained no knowledge of the incoming attack until strikers were within approximately ten miles of their targets.[45]

Chaff tactics by the support jamming aircraft were widely used to confuse North Vietnamese radar operators. Crews developed chaff tactics to simulate additional aircraft and mask the true strike force. Electronic Warfare Officers carefully studied wind data and drop characteristics of chaff in order to create 'clouds' to hide behind for strike aircraft.[46] However, once the North Vietnamese caught on to the chaff tactic, they adjusted their radar frequencies to counter the chaff effects and were once again successful at firing at ingressing US aircraft.[47]

Rather than employing the same technique repeatedly, EWOs attacking North Vietnamese air defenses employed a combination of tactics, such as dropping chaff and routinely changing aircraft orbits. Mission planners devised tailored jamming packages which provided

---

[43] Grant, *The Radar Game*, 27.
[44] Nalty, *Tactics and Techniques of Electronic Warfare: Electronic Countermeasures in the Air War against North Vietnam 1965 - 1973*, 28.
[45] Nalty, *Tactics and Techniques of Electronic Warfare: Electronic Countermeasures in the Air War against North Vietnam 1965 - 1973*, 28.
[46] Van Nederveen and Air University. College of Aerospace Doctrine, *Sparks over Vietnam*, 81.
[47] Van Nederveen and Air University. College of Aerospace Doctrine, *Sparks over Vietnam*, 81.

frequencies to jam, optimal transmit and chaff release times.[48] In doing so, the jammers effectively disrupted hostile radar systems.

In addition to jamming ground radar operations, support jammers also targeted attacking enemy aircraft. Support jamming crews would layer their effects by dropping chaff corridors while also using internal jamming equipment to degrade enemy aircraft radar screens.[49] Evolving tactics were key to gaining advantage over a persistent enemy, varied jamming techniques were also required maintain the lead in this tit-for-tat fight.

Spot jammers, which made their debut during the Korean War in 1951, were transmitters that concentrated all their available power in a narrow frequency range to disrupt defensive radar scopes.[50] Spot jamming was effective until defending radar operators gained the ability to change their radar frequencies. During the Korean War, B-29s carried three spot jammers and a radar warning receiver to detect when enemy tracking occurred. The spot jammers were capable of adjusting to several programmed frequency settings, allowing EWOs to blind various radars. However, even in the 1950s, defending radar operators discovered they could escape the narrowly focused spot jamming by shifting frequencies over a wider range of options.

The game of cat-and-mouse continued to evolve and become more sophisticated. Another technique known as 'barrage jamming' attempted to cover a wider swath of the frequency spectrum, but generally American transmitters produced a signal too weak to blanket the radar return on the enemy radar scopes. Engineers then developed swept noise jammers, allowing EWOs to shift a concentrated beam along a wider range of the spectrum and chase the frequency used by the

---

[48] Nalty, *Tactics and Techniques of Electronic Warfare: Electronic Countermeasures in the Air War against North Vietnam 1965 - 1973*, 29.
[49] Van Nederveen and Air University. College of Aerospace Doctrine, *Sparks over Vietnam*, 24.
[50] Nalty, *Tactics and Techniques of Electronic Warfare: Electronic Countermeasures in the Air War against North Vietnam 1965 - 1973*, 15.

enemy.[51] Additionally, the EWOs most effective jamming techniques were highly directional and concentrated jamming from assets with steerable antennas. The EKA-3Bs touted this capability in 1967 and the Air Force later modified the EB-66s to perform this technique.[52]

Sequencing AEA procedures were key to successful strike operations as strike missions keep into North Vietnamese territory always required a coordinated effort.[53] Support jamming aircraft often crossed their flight paths as a pre-strike maneuver to interrupt EW/GCI tracking on the striker targets.[54] Next, the support aircraft set up orbits to degrade the North Vietnamese air picture, while the strike force provided self-screening with their associated pods. Just prior to weapons release, the striker aircraft had to cease jamming lower frequency radars to ensure clear friendly communications between their aircraft and ground guidance radar sites.[55] During that time, the support aircraft were the only committed platforms against the warning and acquisition radars and followed carefully timed procedures to maximize jamming effects. The support aircraft continued jamming until all strike aircraft were clear of the SAM threat.

Through both escort and standoff jamming, dedicated AEA assets provided sufficient power to deny the enemy radars ability to track strike forces and robbed the enemy of alertness. Despite their aged condition, the AEA support assets of Vietnam provided a vital, layered protection to strike aircraft with their self-protection pods. Together, their combined jamming impacts prevented effective and efficient use of the North Vietnamese IADS, reducing losses by causing the enemy to work through degradation. Furthermore, AEA planners meticulously sequenced the

---

[51] Nalty, *Tactics and Techniques of Electronic Warfare: Electronic Countermeasures in the Air War against North Vietnam 1965 - 1973*, 15.
[52] Van Nederveen and Air University. College of Aerospace Doctrine, *Sparks over Vietnam*, 38.
[53] National Museum of the USAF, "Blinding the Enemy: Eb-66 Electronic Warfare over North Vietnam," http://www.nationalmuseum.af.mil/factsheets/factsheet.asp?id=18099.
[54] Murray, *Project Corona Harvest End-of-Tour Report*, 2.
[55] Murray, *Project Corona Harvest End-of-Tour Report*, 2.

timing of forces and effects in relation to strike assets, with prescriptive and non-prescriptive methods to disrupt the shooting sequence of the radar guided SAM and AAA systems. These key variables of AEA in Vietnam would continue as tenets for the Gulf War over twenty years later.

Crows over the Gulf

Iraqi regional ambitions and the economic crisis on the heels of the Iran-Iraq War, which ended in 1988, formed the roots of the 1991 Gulf War. Iraqi President Saddam Hussein became confrontational to neighboring Arab states following the fall of the Soviet Union and the end of the Iran – Iraq War. Hussein believed the United States would use its singular hegemonic power to impose their will upon the region and therefore called for Arab states to join Iraq in consolidating regional power as the Gulf played a key role in the growing international demand for oil.[56] Consequently, Hussein demanded the US remove its naval presence in the region and initiated an invasion of its southern neighbor Kuwait on August 2, 1990.[57]

By invading Kuwait, Iraq hoped to gain twenty percent of the world's oil reserves and ease internal financial burdens following the Iran-Iraq War with $208 billion in Kuwaiti financial assets.[58] Hussein found Kuwaiti wealth and vulnerability irresistible and believed a US led Coalition would be unable to sustain a prolonged war effort to defend against his offensive.[59]

In response, the US led Coalition moved to counter the acts of aggression by expelling Iraqi forces with an overwhelming air campaign followed by a subsequent ground offensive. The campaign, Operation Desert Storm, intended to first gain air control by negating Iraq's air

[56] Eliot A. Cohen, *Gulf War Air Power Survey Vol.1 Planning, and Command and Control* (Washington D.C.: GPO, 1993), 55-57.
[57] Cohen, *Gulf War Air Power Survey Vol.1 Planning, and Command and Control*, 57.
[58] Cohen, *Gulf War Air Power Survey Vol.1 Planning, and Command and Control*, 59.
[59] Cohen, *Gulf War Air Power Survey Vol.1 Planning, and Command and Control*, 61.

defenses and neutralizing Iraqi air power to keep them from attacking the Coalition's rear flanks.[60]

The Threat

The Iraqi air defense system prior to the initial Coalition attacks was a formidable threat. Widely dispersed, it consisted of hundreds of SAMS and thousands of AAA guns. The key to the system was the computerized command and control network referred to as KARI.[61] The French designed the KARI system to handle tracking and targeting of twenty to forty aircraft, but the system proved capable of handling 120 simultaneous tracks during the Iran-Iraq War.[62] KARI was user friendly, redundant, and supported by radar coverage of all of Iraq and much of its neighboring countries up to 20,000 feet. The Iraqis fielded about 500 radars at 100 sites including the Chinese Nanjing low-frequency radar with suspected capability to detect stealth aircraft.[63] Moreover, the Iraqi air force was also among the largest in the world, equipped with the latest French and Soviet fighters. At the time, many pundits felt the three squadrons of Iraqi MiG-29s could possibly prove an air combat match for the US F-15s and F-16s.[64]

---

[60] Lambeth, *The Transformation of American Air Power*, 113.

[61] KARI is the French translation of Iraq spelled backwards. The French were the developers and installers of the system.

[62] Werrell, *Archie to SAM: A Short Operational History of Ground-Based Air Defense*, 218.

[63] Werrell, *Archie to SAM: A Short Operational History of Ground-Based Air Defense*, 219.

[64] David A. Fulghum, "U.S. Mounts Swift Response to Iraq's Invasion of Kuwait," *Aviation Week and Space Technology* (1990): 18-21.

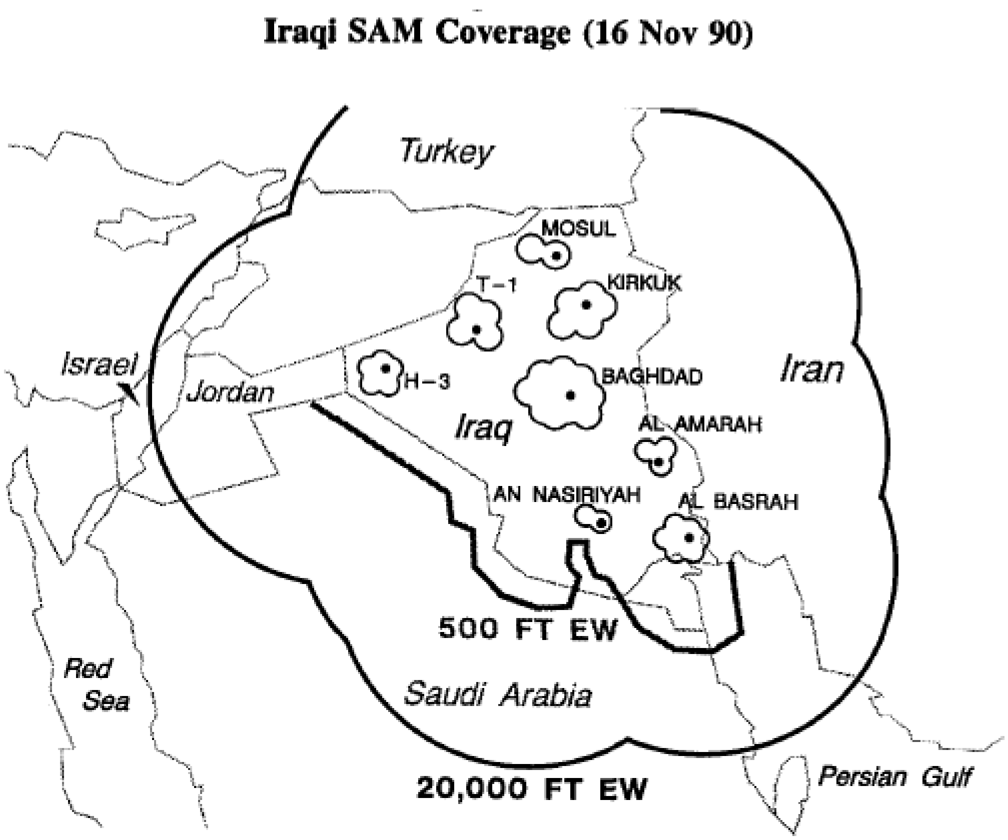

Figure 1: Iraqi SAM Coverage

Source: 1993 Gulf War Air Power Survey Vol IV

While Iraq's IADS boasted impressive numbers and advanced capability, Iraq overlooked some serious deficiencies. The KARI system was highly centralized and required continual advisement and support from the political structure.[65] This hindered the initiative of lower ranking personnel in making time-critical decisions. Additionally, with exception of a few pieces of newer equipment, most of the air defense network was old in comparison to the Coalition's level of technology.[66] Furthermore, many of the Iraqi personnel were poorly trained conscripts. Additionally, Iraqi fighter pilots, trained under Soviet doctrine, were highly dependent on ground control intercept controllers and their

[65] Eliot A. Cohen, *Gulf War Air Power Survey Weapons, Tactics, and Training and Space Operations*, vol. IV (Washington D.C.: GPO, 1993), 1.
[66] Cohen, *Gulf War Air Power Survey Weapons, Tactics, and Training and Space Operations*, IV, 1.

associated radars.[67] Thus, on paper Iraq's defenses appeared to pose a daunting task for the Coalition; however, Iraq was about to face off against the "strongest, largest, and most modern air force in the world, bolstered by [its] allies."[68]

Airborne Electronic Attack Assets

Analogous to the plan in Vietnam, the US Defense Department intended to attack Iraq's radar defenses with specified AEA jammers, and self-protection pods, only this time they would add the additional capability of stealth. As with Vietnam, jamming platforms were in short supply. The Air Force used 36 EF-111F Ravens while the Navy and Marine Corps employed 39 EA-6B Prowlers.[69] Aircraft were always in limited supply and maintenance crews often cannibalized for parts from non-deployed aircraft. However, as more assets arrived in theater, the AEA strategy became more sophisticated.[70]

The Air Force intended the fielding of the EF-111 in 1981 to fill the capability void created by the retirement of the EB-66 in1973.[71] The EF-111 outperformed its EB-66 predecessor and could escort strike aircraft to their targets even under heavy SAM threat. In its penetrator role, the Raven flew alongside striker aircraft providing required countermeasures against surveillance and acquisition radars.[72] As a standoff jammer platform, the EF-111 also degraded enemy detection and identification radars from a safe distance in relation to the ground threat. As a third option, the EF-111 could also perform a close-in jamming role by neutralizing enemy battlefield acquisition radars as the strike force

---

[67] Lambeth, *The Transformation of American Air Power*, 110.
[68] Werrell, *Archie to SAM: A Short Operational History of Ground-Based Air Defense*, 219.
[69] Werrell, *Archie to SAM: A Short Operational History of Ground-Based Air Defense*, 224.
[70] MG Larry Henry Briefing. Subject: Electronic Combat in Desert Shield/Desert Storm, 8 September, 2000.

[71] Alfred Price and Association of Old Crows (AOC), *The History of Us Electronic Warfare*, 1st ed., 3 vols. (Arlington, VA: Association of Old Crows, 1984), 274.
[72] Bruce D. Nordwall, "Electronic Warfare Played a Greater Role in Desert Storm Than Any Conflict," *Aviation Week and Space Technology* 134, no. 16 (1991): 68.

delivered munitions on enemy targets.[73] The EF-111s flew 1,105 combat missions during the Gulf War and sustained only one non-combat loss.[74] The US Navy and Marine EA-6Bs also performed some of the same roles as the EF-111. While the Raven had advantages in speed and range, the Prowlers had more powerful and effective jammers.[75]

The EA-6B Prowlers supported Coalition strikes of every type and planners considered their support essential for every Navy and Marine strike.[76] As they had during Vietnam, Prowlers effectively denied Iraqi IADS early warning and disrupted SAM firing solutions from both standoff ranges and in direct support missions.[77] Throughout the Gulf War, Prowlers forced Iraqi radar systems to resort to highly ineffective modes of operation.

AEA assets may fly in between the target and the attack force. A similar tactic positions the AEA aircraft jamming behind the strike force. For example, during the early phases of the Gulf War, EF-111s provided target area suppression between the threat and inbound strikers while EA-6Bs generally flew behind their strike groups.[78] EA-6Bs flew 1,630 combat sorties with no combat losses.[79] The jamming provided by EA-6Bs and EF-111s also contributed to the success of a new type of weapon in the AEA game -- stealth.

Air Force F-117 stealth fighters were part of the first wave of attacks in Operation Desert Storm. Apparently, Iraqi radar never tracked an F-117 as Iraqi operators referred to the aircraft as 'the ghost' over intercepted communications.[80] While the F-117 was not invisible to Iraqi radar operators, it was very difficult to observe because other non-

---

[73] Cohen, *Gulf War Air Power Survey Weapons, Tactics, and Training and Space Operations*, IV, 95.
[74] Werrell, *Archie to SAM: A Short Operational History of Ground-Based Air Defense*, 226.
[75] Werrell, *Archie to SAM: A Short Operational History of Ground-Based Air Defense*.
[76] Cohen, *Gulf War Air Power Survey Weapons, Tactics, and Training and Space Operations*, IV, 94.
[77] Direct support refers to providing target area suppression for strike aircraft.
[78] Cohen, *Gulf War Air Power Survey Weapons, Tactics, and Training and Space Operations*, IV, 190.
[79] Cohen, *Gulf War Air Power Survey Weapons, Tactics, and Training and Space Operations*, IV, 94.
[80] Nordwall, "Electronic Warfare Played a Greater Role in Desert Storm Than Any Conflict," 2.

stealthy aircraft produced greater radar returns. Additionally, AEA aircraft provided a combined effect by masking the F-117 on radar scopes. The stealthy F-117 proved to both Iraq and the world that modern AEA added a new wrinkle to defending strike aircraft in mystifying enemy radars as well as denying, degrading, disrupting them with support jammers and self-protection pods.[81]

Pods

Similar to the pods used in Vietnam, countermeasures mounted on aircraft for Operation Desert Storm provided terminal protection by jamming enemy missile guidance radars.[82] The use of pods allowed aircraft to operate more effectively at higher-altitudes instead of requiring them to fly nap-of-the-earth profiles in order to terrain mask in order to hide from threat radars.[83] The pilots employing the self-protection pods claimed that the SAMs fired at them went 'stupid' as soon as the pod went into transmit mode.[84] The result was the missile headed off in the wrong direction. According to one pilot, fifty percent of US aircraft would not have returned were it not for self-protection pods.[85] Fortunately, badly needed pod upgrades delivered just in time for combat.

Following years of development and production delays, the Air Force installed the ALQ-184 ECM pod on its fighters, such as the F-16, just prior to aircraft departure for Desert Storm.[86] The ECM pod received much credit for contributing to the Air Force's astonishingly low loss rates during the air campaign. However, had the Air Force waited until all testing was complete, the self-protection pod would have missed the war.[87]

[81] James W. Canan, "Electronic (Warfare in Desert) Storm," 74, no. 6 (1991): 26.
[82] Canan, "Electronic (Warfare in Desert) Storm."
[83] Hal Gershanoff, "EC in the Gulf War," *Journal of Electronic Defense* 14, no. 5 (1991).
[84] Nordwall, "Electronic Warfare Played a Greater Role in Desert Storm Than Any Conflict," 68.
[85] Nordwall, "Electronic Warfare Played a Greater Role in Desert Storm Than Any Conflict," 68.
[86] Canan, "Electronic (Warfare in Desert) Storm."
[87] Canan, "Electronic (Warfare in Desert) Storm."

The ALQ-135 internal jammer, developed for the F-15C air-superiority aircraft, also delivered on short notice. The maintenance crews were still installing the self-protection jammers on F-15E strike aircraft as the coalition commenced the Gulf War air campaign. However, official records indicate only one shoot-down against all F-15Es carrying the ALQ-135, and "most likely it was by a lucky shot from an antiaircraft gun."[88]

Similar to the shortage in AEA support jamming aircraft, self-protection pods were in limited supply. The Air Force seldom engaged their pods in full-scale using during peacetime and discovered wartime support required additional pods and maintenance capacity.[89] One home station unit reported only four operation pods left for training; units deployed all remaining pods to the Gulf Theater.[90]

Both the EF-111 and EA-6B carried versions of the ALQ-99 jamming pod. The ALQ-99 scans frequency bands both manually through EWO intervention and by computer automation. As the pod identifies threats, it initiates jamming waveforms either automatically or with EWO assistance.[91] The ALQ-99 allowed support jammers effective denial and degradation of threat radars at distances of approximately 120 miles.[92]

Drones

Although airmen had demonstrated the usefulness of drones for reconnaissance during the Vietnam War, Remotely Piloted Aircraft (RPAs) also played a key jamming role in the Gulf War. Drones drew premature fire from enemy radars, divulging enemy locations and making them

---

88 Canan, "Electronic (Warfare in Desert) Storm."
89 Raymond Pyles et al., *United States Air Force Fighter Support in Operation Desert Storm* (Santa Monica, CA: Rand, 1995), 91.
90 Pyles et al., *United States Air Force Fighter Support in Operation Desert Storm*, 91.
91 Cohen, *Gulf War Air Power Survey Weapons, Tactics, and Training and Space Operations*, IV, 95.
92 Grant, *The Radar Game*, 26.

vulnerable for strikes.[93] This tactic opened a corridor for follow on strikes by penetrating bombers.[94] Drones also flew 'figure eight' patterns over targets in major Iraqi cities, drawing an average of ten SAMs per drone, until they ran out of fuel or Iraqi defenses shot them down.[95]

US forces launched 175 drones during the first three days of Operation Desert Storm and intelligence estimates noted an increase of approximately twenty-five percent in SAM and AAA activity during decoy operations.[96] Navy and Marine aircraft also launched up to eight Tactical Air Launched Decoys (TALD) with the capability to simulate various American aircraft and even drop chaff.[97] Consequently, the Iraqi IADS suffered from overwhelming numbers of targets effectively degrading targeting solutions.

Missions/Activities (Deny, Degrade, Disrupt)

Coalition efforts against Iraqi air defenses were undeniably effective and electronic warfare supremacy was perhaps the most significant reason for the air campaign's stunning success. AEA assets cleared the way for strike aircraft to prosecute targets with near unimpeded access. The electronic combat primary goals set by then Brigadier General Larry Henry were, 1) destroying the Iraqi IADS by attacking it as a whole, 2) destroy the command and control system, and 3) completely integrate all AEA assets to accomplish the mission.[98] By all accounts, the air campaign met their objectives after only seven days of action; the Iraqis used only ten percent of the SAM, EW, and GCI radars employed during the opening of the war.[99] After decades of development and exploitation of the electromagnetic spectrum, AEA assets finally vindicated the DOD's EW acquisition community.

---

[93] Cohen, *Gulf War Air Power Survey Weapons, Tactics, and Training and Space Operations*, IV, 104.
[94] Cohen, *Gulf War Air Power Survey Weapons, Tactics, and Training and Space Operations*, IV, 104.
[95] Werrell, *Archie to SAM: A Short Operational History of Ground-Based Air Defense*, 224.
[96] Werrell, *Archie to SAM: A Short Operational History of Ground-Based Air Defense*, 224.
[97] Werrell, *Archie to SAM: A Short Operational History of Ground-Based Air Defense*, 223.
[98] MG HenryMG Larry Henry Briefing, subject: Electronic Combat in Desert Shield/Desert Storm, 8 September 2000.
[99] Martin Streetly, "Battle of the Airwaves (Electronic Warfare)," *Janes Defense Weekly* 15(1991): 186.

To prevent the Iraqis from employing their IADS, commanders charged US AEA assets with denying, degrading, and disrupting radar coverage in three major areas of concern. The first area covered the capital city of Baghdad, which the Iraqis heavily defended with multiple types of SAMs and AAA pieces. The second was designated H2-H3 covering the western portion of Iraq where the Iraqis were firing Scud missiles at Israel. Planners labeled the third area the Kuwait Theater of Operations (KTO) which covered the southern portion of Iraq and Kuwait itself. Additionally, instead of intending to destroy every SAM in a particular area of the country, the goal was localized air-superiority over Baghdad while the KTO and H2-H3 areas required complete control, as large bombing missions were continually ongoing.

Some AEA assets denied initial detection in the Baghdad area by jamming EW/GCI radars from orbits just outside enemy territory. Others escorted strikers to their targets and denied target-tracking and fire-control radars. The Iraqi ability to detect, track, and pass targetable information was seriously impaired as Pentagon officials reported no "SAM ever 'locked-up' an attacking aircraft while being escorted."[100] The KTO and H2-H3 areas of operation required immediate denial upon detection of any SAM radar activity as complete control was required to protect the multitude of striker assets charged with reducing enemy land forces in the area.[101] In addition to jamming the radars, A-10s, and Army Apache helicopters were also used extensively early in the war to target early-warning radars on the Iraqi border and deny as much information as possible to the Iraqi air defenses.[102] If strict denial was not achievable in certain areas of the KARI network, then degradation of the IADS slowed efficiency and forced the enemy to attempt to work through the effects of the jamming.

[100] Nordwall, "Electronic Warfare Played a Greater Role in Desert Storm Than Any Conflict," 68.
[101] Gershanoff, "EC in the Gulf War," 42.
[102] Cohen, *Gulf War Air Power Survey Weapons, Tactics, and Training and Space Operations*, IV, 54.

In addition to degrading the IADS effectiveness by AEA jamming assets, planners desensitized Iraqi defenders through a well-coordinated deception strategy prior to the initial attacks. During the build-up to the Desert Storm air campaign, a consistent mix of Coalition aircraft flew standard tracks on a regular basis. On the night of the initial attack, Iraqi radar operators observed similar patterns as the previous months as attack aircraft marshaled south of Iraqi long-range early warning coverage. Meanwhile, the feint had allowed collection assets to locate many of the radar positions as the Iraqi's activated their air defense system in response to the aircraft amassing at the border.[103] Once strikes began, operators launched drones extensively to flood Iraqi radar screens with false targets, further degrading Iraqi EW/GCI ability to acquire incoming manned Coalition aircraft.[104]

Disrupting the Iraqi target sequencing proved vital to successful mission accomplishment as it had been in Vietnam. One B-52 EWO provided self-protection jamming reported:

> One of the most important decisions an EWO ever makes during a combat sortie is when to commence countermeasures. I had a single, manually operated transmitter (jammer) to use against any and all threat radars in that particular frequency range. The operating frequencies of the two SAMs were close but not close enough to cover them both with one jamming package, so as each signal appeared. I manually jammed it--carefully centering the package on the signal and setting the modulation--then called it to the crew and to the cell. And, of course, I was repeating this sequence every few seconds. I was as busy as a one-armed paperhanger.[105]

Tactics, Techniques, and Procedures

The tactics and prescriptive and non-prescriptive methods of employment to perform the AEA tasks during the Gulf War proved

---

[103] Nordwall, "Electronic Warfare Played a Greater Role in Desert Storm Than Any Conflict," 68.
[104] Cohen, *Gulf War Air Power Survey Weapons, Tactics, and Training and Space Operations*, IV, 103.
[105] Robert C. Franklin, "First Person ... Singular," *Journal of Electronic Defense* 27, no. 7 (2004): 74.

critical to the sweeping success of the air campaign. Although the Iraqi air defenses fired thousands of missiles, the Coalition lost only nineteen aircraft to radar-guided SAMs and AAA, due in part to effective employment of airborne electronic attack tactics, techniques, and procedures.

To support gaining and maintaining air superiority, AEA asset tactics included a two-phased approach: the first, supporting the initial attacks; the second, responded to mobile and target area threats while supporting roving bands of SAM killers in the KTO. The first phase of opening attacks proved vital for follow-on operations. F-117 stealth aircraft and Tomahawk Land Attack Missiles targeted air defense operation centers and their supporting electrical power grids. The second phase included a force package of strikers, with fighter escort to attrite the air threat and escort jammers to shield against ground defenses.[106] Unlike Vietnam where AEA assets remained outside enemy airspace, US forces were confident in their ability against Iraqi aircraft allowing for direct AEA support to striker aircraft as they flew into downtown Baghdad.[107]

Another tactic used by the coalition sought to overwhelm the KARI system by degrading sectors of the system and forcing the remaining sectors to attempt to process hundreds of targets at a time. Simultaneously, jammers in support of the KTO and H2-H3 area to the west jammed from their orbits, degrading EW/GCI radars and causing individual SAM operators to rely on their indigenous target-tracking radars to acquire targets. Additionally, aircraft launched decoys to cause SAM operators to react to the unmanned targets and thus give away their locations.

AEA tactics simultaneously supported conventional and stealth strike missions. The F-117 stealth platform hit targets well within

---

[106] Cohen, *Gulf War Air Power Survey Weapons, Tactics, and Training and Space Operations*, IV, 188.
[107] Gershanoff, "EC in the Gulf War," 40.

heavily defended areas of Iraq, many times without AEA. Yet, as the war progressed, F-117 crews welcomed AEA support. Low observable (LO) aircraft are easier to cloak than conventional ones, as they require less power from the jammer.[108] "An aircraft that reduces its front-aspect signature by a factor of ten cuts the notional detection range by forty-four percent. The power required in the ECM jammer also decreases in proportion. For the same amount of power, ECM can jam more effectively."[109] The jammers could then standoff at a safe distance and provide an additional layer of protection the F-117s in harm's way.

Furthermore, the jamming effects on Iraqi radar scopes complicated the detection of the LO aircraft as it raised the noise-floor above the return of the LO aircraft. Most current-generation radars employ computer-generated displays, which de-clutter the screen by removing noise and false returns from the display. In effect, the operator increases display clarity, but tends to eliminate the weak and ambiguous returns a stealthy platform such as the F-117 produces.[110] None of these jamming tactics would have been effective were it not for timely intelligence updates to calibrate the jammers.

Friendly system calibration procedures prior to ingress were critical to ensuring effective enemy radar disruption. During preparations for electronic combat, the use of border runs for real-time electronic intelligence reconnaissance allowed flexibility in gaining the latest updates for jammers.[111] Spot jammers with enough power to deny, degrade, or disrupt an adversary radar required continual updates as the Iraqi's changed their radar configurations. The manned platforms provided the flexibility to receive data from onboard sensors as well as communicated updates from other collection assets.

Conclusion

---

[108] Grant, *The Radar Game*, 51.
[109] Grant, *The Radar Game*, 51.
[110] Cohen, *Gulf War Air Power Survey Weapons, Tactics, and Training and Space Operations*, IV, 248.
[111] Cohen, *Gulf War Air Power Survey Weapons, Tactics, and Training and Space Operations*, IV, 183.

The Vietnam air campaign witnessed the use of old planes to accomplish the challenging AEA task. Gaining and maintaining at least temporary advantage in the electromagnetic spectrum proved a continual requirement to support strikers inbound to their targets. As the enemy quickly adapted to the denial, degradation and disruption of their defensive systems, AEA operators responded in kind with frequent TTP modification in reaction to adversary counter-moves. US AEA assets were able to escort strikers initially, until SAM threat forced support AEA assets to safe distance stand-off orbits reducing the relative power output for an effective jam-to-signal ratio. Additionally, strike assets with dedicated AEA support and self-protection pods took significantly fewer losses than those without; signaling the legitimacy of carefully planned and adequately layered AEA. Difficulties in funding obsolete aircraft would continue into the Gulf War era as AEA assets were in high demand.

During the Gulf War, electronic attack specialists expertly integrated and sequenced jamming effects to maximize protective measures for ingressing strike forces. Although some DOD proponents viewed stealth as a sole means to defeat Iraqi radar, others wisely exploited the value of adding the additional layer of sequenced and integrated AEA in support of stealth operations. Integrating and sequencing drones into the strike packaging also aided in overwhelming Iraqi air defenses by adding an additional layer of false targets for ground radar operators. AEA undoubtedly assisted in creating favorable conditions for effective strike operations against challenging opponents during Vietnam and the Gulf War.

The Vietnam and Gulf War case studies serve as guideposts, allowing for comparison to today's current capability discussed in the next chapter. The essential mission activities, capabilities, and TTPs for effective global strike protection highlight the requirement for AEA quantity, variety, and distributed capability. However, looming budget cuts and decisions reduced DOD's AEA force to its current status.

CHAPTER 2
Modern Day Crows

History doesn't repeat itself, but it does rhyme.

Mark Twain

The case studies of Vietnam and the Gulf War provide a useful backdrop for contrasting similarities and differences to the current AEA mission. As acquisition plans evolved disproportionally to operational stresses on the existing AEA inventory, the historical framework assists in identifying potential mission capability gaps. Limits in both quality and quantity increase levels of difficulty and risk in accomplishing the AEA mission. Thus, the modern day DOD electronic warfare officer faces significant AEA challenges in protecting strike assets by attempting to gain and maintain control of the electromagnetic spectrum.

The Current Electromagnetic Environment

The context of today's EMS evolved significantly following the Vietnam and Gulf Wars. The EMS now entails an increasingly complex, contested, and congested environment; and the DOD cannot simply assume full access, especially during major combat operations against an advanced adversarial threat. Moreover, DOD investments in the billions on capabilities, which use the information passed through the EMS to conduct global strike operations in a denied-access environment, highlight the importance of retaining spectrum control. Thus, the ability to gain and maintain maneuver space within the EMS is vital to global strike operations.[112]

Additionally, rapidly developing challenges in the global marketplace threaten DOD lethality and survivability. For example, the pace of technology advancement led to the increasing potential for

---

[112] Briefing. Joint Electronic Warfare Center. Subject: Electromagnetic Battle Management, 3 November 2012.

technological surprise and worldwide availability of advanced technology, providing U.S. adversaries with complex and sophisticated means to operate in the EMS.[113] Much like the North Vietnamese surprising EB-66 EWOs by integrating their radar systems, a modern-day adversary is likely to employ tactics and techniques unfamiliar to DOD operators. Exacerbating the problem, as adversaries gain access to U.S. secrets through cyber-espionage, they gain an asymmetric advantage in military systems.[114] Meanwhile, the DOD currently faces multi-billion dollar budget cuts.

While stealth provides some advantages for Global Strike operations, a conventional force remains a necessary. The employment of an all-stealth strike force is conceivable for certain operations; yet, factors such as the related political objectives, scale of attack, assets available, and acquisition schedules will dictate if such an option is feasible. Recent operational exercises have invalidated the theory of stealth assets attacking heavily defended targets 'alone and unafraid'. More likely, a Global Strike CONOPS occurring within the next decade will employ a mix of conventional and stealth assets against a current adversary. Conventional forces remain vulnerable to the current era's defensive systems, and therefore any inclusion of conventional assets against a current-day defensive threat will likely require AEA protection.

Limitations in stealth technology should highlight the DOD requirement for AEA. "There is no such thing as an invisible airplane, in the radar spectrum or any other."[115] Nor can technology overcome poorly planned and executed tactics. Errors or miscalculations may divulge the location of an aircraft with a suppressed radar signature, negating the technological effect. Additionally, building an aircraft with low

---

[113] Briefing. NDIA 8th Annual Disruptive Technologies Conference. Subject: Electronic Warfare / Electronic Protection Science and Technology Steering Council, 8 November 2011.

[114] Briefing. NDIA 8th Annual Disruptive Technologies Conference. Subject: Electronic Warfare / Electronic Protection Science and Technology Steering Council, 8 November 2011.

[115] Cohen, *Gulf War Air Power Survey Weapons, Tactics, and Training and Space Operations*, IV, 242.

observable characteristics is exceedingly expensive, especially for employment against an integrated adversary radar system. Moreover, the U.S. currently maintains limited stealth assets, and the DOD's budget is shrinking. Thus, DOD dependence on an exclusive stealth force for all Global Strike missions may lead to mission failure and disaster.

Airborne Electronic Attack Assets

Defense cuts by Congress and the Office of the Secretary of Defense in the 1990s led the U.S. Air Force to cancel the EF-111 and its B-52 Standoff Jammer (SOJ) replacement. The USAF then depended solely on the Navy's 1960s vintage EA-6B for the AEA mission. While the Navy planned to retire the EA-6B in 2012, replacing it with the EA-18G Growler, the high demand for AEA assets and the cancellation of the B-52 SOJ, led to the extension of EA-6B service life through 2016.[116] Rather than investing an indigenous AEA support asset, the USAF opted to maintain a cadre of qualified EWOs who fly on the Navy owned EA-18Gs and EA-6Bs.[117] The Growler is a modified F-18 two-seat Super Hornet designed to carry the same ALQ-99 pods as the EA-6B. The Next Generation Jammer (NGJ), which uses Active Electronically Scanned Array (AESA) technology, is expected to replace the ALQ-99 for the EF-18G in 2020.[118]

Many current aircraft such as the F-35, F-22, F-18, F-16, and F-15 use AESA radar technology; however, aerospace engineers designed those particular radars to detect air and ground targets, rather than jam threat radars in support of global strike missions. For example, Northrop Grumman designed the F-16 APG-80 AESA radar to

---

[116] Airborne Electronic Attack: Achieving Mission Objectives Depends on Overcoming Acquisition ChallengesMichael J. Sullivan et al., "Airborne Electronic Attack: Achieving Mission Objectives Depends on Overcoming Acquisition Challenges," (2012), 43.

[117] John Tirpak, "Seeking Growler Backseat, No Buff SOJ," *AirForce-Magazine.com*, October 20, 2009. http://www.airforcemag.com/DRArchive/Pages/2009/October%202009/October%2021%202009/Seeking GrowlerBackseat,NoBUFFSOJ.aspx (accessed January 18, 2013).

[118] Tirpak, "Seeking Growler Backseat, No Buff SOJ".

continuously search and track multiple targets for air-to-air and air-to-ground targeting; however, the radar's capability is limited to the forward hemisphere of the aircraft.[119] Furthermore, pilots flying AESA equipped aircraft will likely focus on other designated missions, such as air-supremacy, and will lack the ability to concentrate on the near continuous jamming required to deny, degrade, and disrupt enemy radar threats. In addition, stealth aircraft with AESA may not prove ideal candidates for emitting powerful jamming waveforms. The theory supporting stealth involves mitigating the detection of enemy radar; whereas emitting jamming signals makes the stealth aircraft a bigger target, hence negating the stealth effect.[120] Therefore, while AESA may invalidate the requirement for an external self-protection pod for stealth aircraft, AESA's high bandwidth, rapid scanning, and response times, make it an unlikely candidate for complete replacement of AEA coverage for a Global Strike mission.[121]

The Next Generation Jammer makes uses AESA technology to actively scan for and aggressively jam threats to strike aircraft.[122] The NGJ with AESA technology shares the same basic characteristics as the jammers and pods employed during Vietnam and the Gulf War regarding performance characteristics as an effective jammer. The NGJ must have the right waveform generators, pre-programmed with specific radar frequencies and specified wavelengths for the various threat radars, and must be capable of processing intercepted signals and accepting operator

---

[119] "AN/APG-80 F-16 AESA Radar," *www.northrupgrumman.com*, http://www.northropgrumman.com/Capabilities/ANAPG80AESARadar/Pages/default.aspx (accessed February 13, 2013).

[120] Sydney Freedberg, "Will Stealth Survive as Sensors Improve? F-35, Jammers at Stake," *www.defense.aol.com*, http://defense.aol.com/2012/11/27/will-stealth-survive-as-sensors-improve-f-35-jammers-at-stake/ (accessed March 6, 2013).

[121] "AESA Radar: Revolutionary Capabilities for Multiple Missions," *www.northropgrumman.com*, Http://www.es.northropgrumman.com/ASD/combat/AESA.html (accessed January 22, 2013).

[122] Sydney Freedberg, "Navy Bets On 'Baby Steps' to Improve Electronic Warfare; F-35 Jamming Not Enough," *www.defense.aol.com*, http://defense.aol.com/2012/12/06/navy-bets-on-baby-steps-to-improve-electronic-warfare-f-35-ja/ (accessed March 2, 2013).

modifications.[123] Additionally, just as effective jamming past during past wars required AEA systems to achieve an effective Jam-to-Signal ratio, the NGJ requires sufficient power and cooling capacity to deny enemy threat radars.

Unfortunately, the DOD is not expecting to field the NGJ until 2018.[124] Furthermore, the DOD plans to field mid-band, low-band, and high-band frequency capabilities in incremental block dates, the latest date of release being the high-band block in 2024.[125] Consequently, the DOD does not expect to replace the vintage and "woefully-inadequate" ALQ-99 jamming pods for more than another decade.[126] Furthermore, due to its lack of stealth characteristics, some experts maintain the Growler will become obsolete as the F-35 Joint Strike Fighter develops as a viable alternative within the next five years.[127] While current escort and standoff jammers of still require significant upgrades to keep pace with future threats, rethinking the decoy assets used in Vietnam and Gulf Wars may provide a partial solution to the current AEA shortage.

The Miniature Air Launched Decoy-Jammer (MALD-J) is an expendable decoy capable of emitting a radar signature that represents various aircraft types on enemy radar operator screens, and carries the additional capability to jam the adversary radars at close range. This close range capability decreases the power output required for effective J/S ratio in order to deny tracking data for target radars. The MALD-J has an endurance capability of approximately 45 minutes and a flight

---

[123] Freedberg, "Navy Bets On 'Baby Steps' to Improve Electronic Warfare; F-35 Jamming Not Enough".

[124] Richard Dudley, "Australian Growler Crews Have a Heavy Workload Ahead," *defense-update.com*, http://defense-update.com/20120907_ausi_growlers.html (accessed March 5, 2013).

[125] Sullivan et al., "Airborne Electronic Attack" 57.

[126] David Ellery, "Growler Obsolete in 5 Years, Expert Says," *www.smh.com.au*, http://www.smh.com.au/national/growler-obsolete-in-5-years-expert-says-20120823-24pb0.html (accessed March 5, 2013).

[127] Ellery, "Growler Obsolete in 5 Years, Expert Says".

ceiling of approximately 40,000+ feet. As of 2012, the U.S. Air Force plans to acquire 2,404 MALD-J units.[128]

The basic airborne electronic attack mission includes protecting strike aircraft to and from the target area. AEA assets mask strike platforms from initial detection by jamming early warning and ground control intercept radars and subsequently defeating the surface-to-air missile engagement by jamming the target tracking and missile guidance radars. These basic functions of AEA have not changed since Vietnam. However, the communications capability to employ these functions has evolved significantly, enabling possibilities for enhanced TTPs.

Tactics, Techniques, and Procedures

The TTPs designed for the current DOD AEA fleet to meet mission requirements were originally developed as a System of Systems (SoS). A SoS approach would allow the independent AEA assets to integrate as a larger interconnected network, delivering unique capability as a synergistic aggregate in support of strike operations. A SoS makes use of concepts such as Electromagnetic Battle Management (EMBM), which could employ a dynamic capability to share real-time data among platforms.

[128] Sullivan et al., "Airborne Electronic Attack," 68.

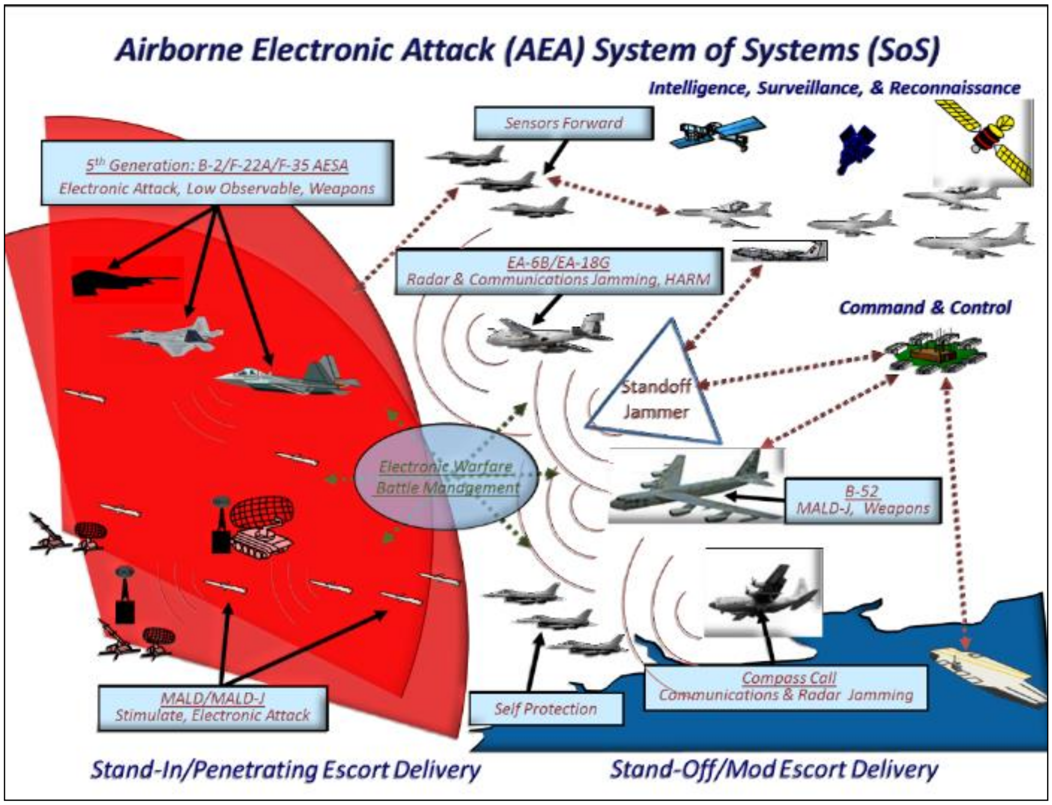

Figure 2: System of Systems Operational Concept
Source: Dr. J. Michael Gilmore, 2011 Association of Old Crows AEA Symposium Slides: Key Issues with Airborne Electronic Attack (AEA) Test and Evaluation

Unfortunately, with subsequent budget cuts and the cancellation of replacement AEA programs such as the B-52 SOJ, the DOD opted for a downgraded Family of Systems (FoS) model. A FoS is fundamentally different from a SoS approach in that it does not create capability beyond the aggregate sum of the individual capabilities.[129] Member systems in a FoS model may only be connected to the whole with respect to sequenced timing. In adapting the FoS model, the DOD traded potential long-term synergistic effects for short-term budget savings.[130]

[129] Sullivan et al., "Airborne Electronic Attack," 8.
[130] Sullivan et al., "Airborne Electronic Attack," 8.

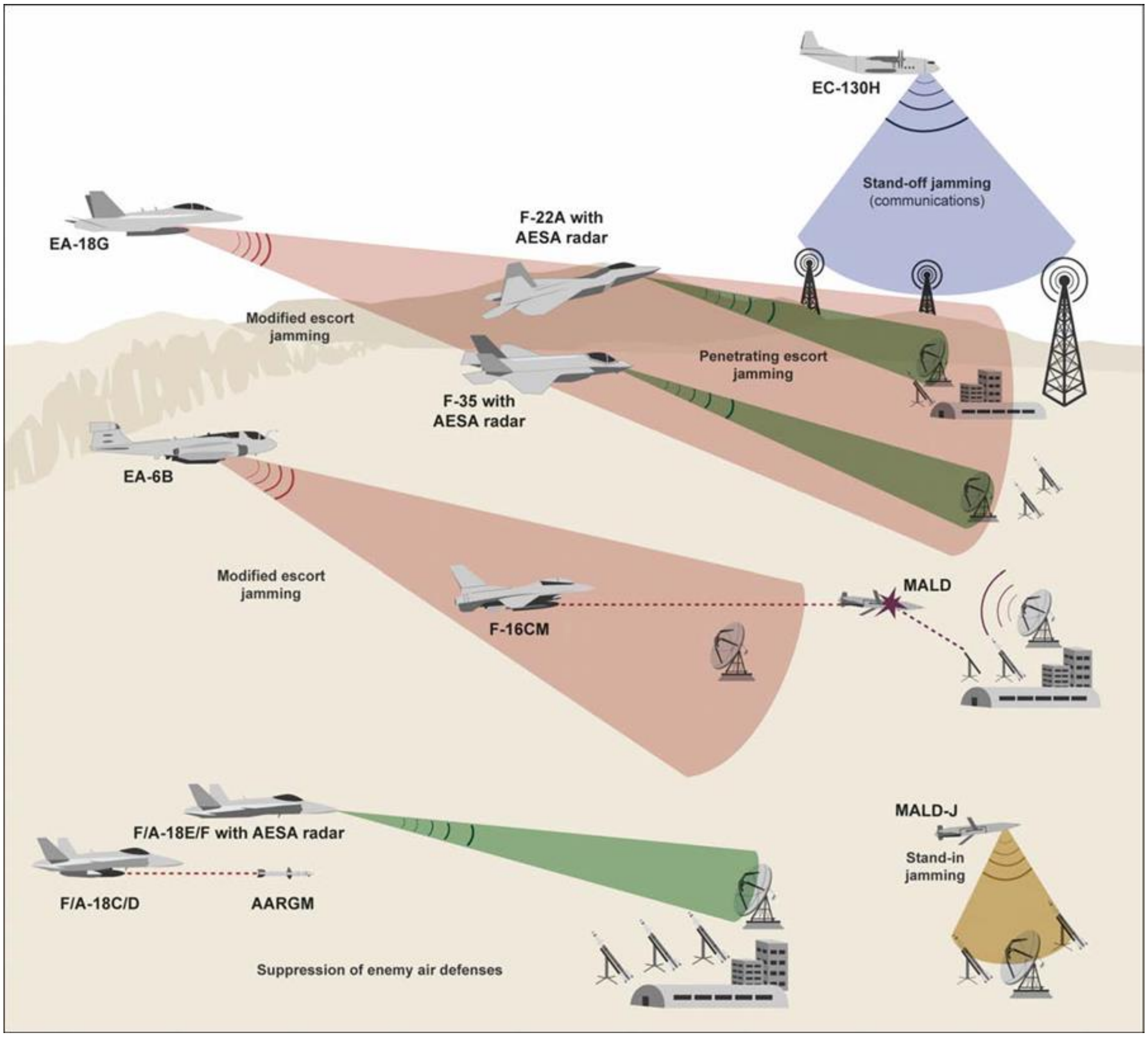

Figure 3: Family of Systems Operational Concept
Source: March 2012 GAO Report 12-175 Airborne Electronic Attack

Cost savings were also the dominant factor behind the cancellation of the F-22 production line, which provides threat denial capability through limited penetrating escort jamming.[131] Similar to the self-protection role of the pods used during Vietnam and the Gulf war, penetrating escort tactics occur inside the intercept range of known SAMs. Both the F-22 and F-35 with AESA radar and stealth design, provide advanced and unprecedented capability against future threats.

[131] US Senate. *Hearing to Consider the Nominations of General James E. Cartwright, USMC, for Reappointment to the Grade of General and Reappointment as the Vice Chairman of the Joint Chiefs of Staff; and Admiral Robert F. Willard, USN, for Reappointment to the Grade of Admiral and to be Commander, United States Pacific Command.* 111th Cong., 1st sess., 2009.

However, considering stealth characteristics alone does not make any aircraft 'invisible' to radar; other classical components of AEA remain vital to Global Strike operations.

The navy EA-18G and EA-6B aircraft currently fill the tactical role of modified escort in order to degrade an enemy at a safe distance. The Growler and Prowler, carrying the ALQ-99 pod, are capable of jamming from inside defended airspace while remaining outside of the engagement range of SAMs. Ideally, the EF-18G, with its nine hard-points, could provide penetrating escort jamming, if required, as the aircraft is much faster and more capable than the aging EA-6B.

However, findings from a 2009 Congressional Report, described the EA-18G as "capable for all mission areas, except for missions that require a full escort profile against an active air defense system."[132] The tactical limitation was due "to the excessive time required to display situational awareness information and the AEA suite's lengthy response time for making reactive jamming assignments."[133] The ALQ-99 was also found to degrade the EF-18G's AESA radar performance.[134]

Furthermore, the report articulated other shortcomings. It determined that a two-man crew on the EF-18G might have difficultly handling the workload of a traditional four-man EA-6B crew in a dense signal environment. In addition, some experts are concerned that without indigenous stealth capability, no aircraft can survive an advanced 'anti-access/area-denial' defense, even with an AEA asset providing jamming from a safe distance.[135] While AEA assets of the past could provide escort jamming for strikers, it seems no dedicated variant is capable of accomplishing this task at the present time.

Standoff jamming has persisted as a valuable tactic since the Vietnam and Gulf Wars. The Air Force's EC-130H Compass Call, a

---

[132] US House. *EA-18G Electronic Attack Aircraft.* 112th Cong., 2nd sess., 2012. H.R. 112-493.
[133] US House. *EA-18G Electronic Attack Aircraft.* 112th Cong., 2nd sess., 2012. H.R. 112-493.
[134] Dudley, "Australian Growler Crews Have a Heavy Workload Ahead".
[135] Freedberg, "Navy Bets On 'Baby Steps' to Improve Electronic Warfare; F-35 Jamming Not Enough".

platform historically employed as a communications jammer, recently received upgrades allowing for radar jamming.[136] However, considering that as of 2013, only 14 Compass Call aircraft are fielded for operations and the propeller driven aircraft fly at about have the speed of the Vietnam era EB-66, the current DOD standoff jamming capability suggests limited flexibility. Additionally, much like EB-66 was an outdated airframe prior the start of the Vietnam conflict, the EC-130H is a "hard-used and old platform" that the Air Force has deployed non-stop for twenty years.[137] With the cancellation of the B-52 SOJ program in 2009, the DOD pivoted toward stand-in tactics to cover the capability gap.[138]

Stand-in jamming tactics occur inside highly contested airspace and electro-magnetic environment. In the near future, expendable MALD-Js are designed to stimulate, saturate, and deceive an enemy IADS thus increasing the survivability of coalition strike aircraft.[139] MALD-Js, flying in a simulated operational environment have demonstrated the ability to provide protection for a full complement of manned aircraft.[140] Unlike the AEA escorts used early in the Vietnam War and during the Gulf War, various aircraft carrying MALD-J can launch the decoys from approximately 500 nautical miles from their pre-determined targets and leave them to hover above target radar systems with reduced concern about their being shot down.

Conclusion

---

[136] Freedberg, "Will Stealth Survive as Sensors Improve? F-35, Jammers at Stake".

[137] John Tirpak, "Electronic Warfare Meets Austerity," *www.airforcemag.com*, http://www.airforcemag.com/MagazineArchive/Pages/2010/January%202010/0110electronic.aspx (accessed April 5, 2013).

[138] Stephen Trimble, "Us Air Force Cancels Sam-Jamming EB-52 for Second Time," *www.flightglobal.com*, http://www.flightglobal.com/news/articles/us-air-force-cancels-sam-jamming-eb-52-for-second-time-323298/ (accessed March 6, 2013).

[139] System Development and Demonstration RDT&E Project Justification. EW Development. MALD-J, May 2009.

[140] Journal of Electronic Defense, The Monitor News: MALD-J Successfully Demonstrates Manned Aircraft Protection Capability, October 2011, 15.

Accomplishing the core airborne electronic attack mission of controlling the electro-magnetic spectrum includes the fundamental activities of denying, degrading, and disrupting an adversary integrated air defense system has not changed since the Vietnam conflict. Current AEA assets should be capable of accomplishing these mission activities with the TTPs of penetrating and modified escort, along with standoff and stand-in jamming to protect Global Strike operations in any future Global Strike operation. AEA sequencing will likely remain an important tactical factor to successful AEA. Likewise, orientation to the target radar with regard to distance to attain an effective jam-to-signal ratio remains a key factor.

From Vietnam, to the Gulf War, to today, a consistent theme of DOD budgetary shortages continues to play a significant role in determining the capability provided to accomplish the AEA mission. For example, substituting the System of Systems mode for the Family of Systems approach further limited AEA's capability to perform its mission of protecting strike aircraft against future advanced threats. Meanwhile, the adversary is exacerbating the AEA challenges by continually upgrading and adapting their strategies and through continued technological innovation.

CHAPTER 3
As the Crow Flies into the Future

Prediction is very difficult, especially if it's about the future.

Neils Bohr

The speculative literature in the AEA field provides potential solutions to the capability gaps noted in chapter two. Governing strategic documents, the rebalance to the Pacific region, and budget constraints will shape the future of AEA. Preserving the most important capabilities to protect strike operations must remain DOD's top priority for a future AEA strategy.

Anticipated Future Challenges

The aggregate of the rise of modernized competitor states, competition for resources, regional instability, and the threat of rogue nation-states implies armed conflict requiring Airborne Electronic Attack will be inevitable in the future. Furthermore, the diffusion of advanced technology due to globalization means even middle-weight militaries can now threaten United States' interests with weapons previously available only to major powers. States employing anti-access and area-denial strategies may inflict devastating losses to US assets during global strike operations. Consequently, the AEA capability advantage the US maintained during the Vietnam and Gulf Wars may narrow in the future, especially when factoring in growing US economic restraints.

Future Requirements

The US National Security Strategy (NSS) and National Military Strategy (NMS) provide guiding requirements for the future of AEA. For example, the NSS specifies requirements for the DOD to prepare power projection capabilities in response to a rising nation's military modernization programs to ensure US interests, both regionally and globally, are not negatively affected.[1] Additionally, the DOD must prepare forces capable of preventing rogue nations from developing nuclear weapons.[2] The NSS also calls for deepening regional alliances as a bedrock principle of US national security.[3] Alliances infer potential for required DOD protection for friendly states and probable integrated AEA cooperation with coalition partners. Rising superpower states, rogue nations, and alliances imply complicated future requirements for DOD AEA strategy. The DOD AEA strategic plan for ensuring continued advantage must therefore retain maximum flexibility in order to protect global strike assets in future engagements. Along with the NSS, the NMS further specifies AEA requirements to defeat aggression.

According to the National Military Strategy, the core future requirement of the Armed Forces remains to defend our nation and win its wars.[4] Specifically, the strategic environment requires AEA to assist in protecting access to the Global Commons by ensuring access to, and US adversaries are increasingly challenging freedom of maneuver within the shared areas. States developing A2AD strategies and capabilities constrain DOD freedom of action by acquiring technologically advanced surface-to-air missiles and remotely piloted platforms, which challenge DOD's ability to project power and increase DOD operational risk.[5] In the words of SAASS professor Dr. Stephen Wright, "when I hear the word 'risk', this equates to 'I see dead people'."[6] Thus, increased risk implies the equivalent of additional American lives lost. Quite possibly the most

---

[1] White House. 2010. National Security Strategy. Washington, DC: White House. http://www.whitehouse.gov/sites/default/files/rss_viewer/national_security_strategy.pdf., 43.
[2] White House. 2010. National Security Strategy. Washington, DC: White House. http://www.whitehouse.gov/sites/default/files/rss_viewer/national_security_strategy.pdf., 23.
[3] White House. 2010. National Security Strategy. Washington, DC: White House. http://www.whitehouse.gov/sites/default/files/rss_viewer/national_security_strategy.pdf., 42.
[4] Michael G. Mullen and Staff United States. Joint Chiefs of, *The National Military Strategy of the United States of America, 2011: Redefining America's Military Leadership* (Washington, D.C.: Joint Chiefs of Staff], 2011), 8.
[5] Mullen and United States. Joint Chiefs of, *The National Military Strategy of the United States of America, 2011: Redefining America's Military Leadership*, 3.
[6] Dr. Stephen Wright, interview by the author, 11 December 2012.

difficult DOD challenge power projection in the Pacific region is the tyranny of time and distance.

In 2011, the President of the United States directed "presence and mission in the Asia Pacific a top priority."[7] The rebalancing or pivoting to the Indo-Asia-Pacific region presents significant challenges of time and distance for global strike operations and its associated AEA protection strategy. The region stretches from California to India, encompassing over half the Earth's surface and well over half of its population.[8] As an example to emphasize the region's vastness, a Carrier Strike Group takes three weeks to transit from the US West Coast to the Philippines, and a C-17 takes fifteen hours to make the journey.[9] The Indo-Asia-Pacific region generates a full-spectrum of security challenges ranging from rapidly growing military capabilities, to nuclear developments, to unresolved territorial disputes, creating the potential requirement to respond to the spectrum of conflict ranging from limited strikes to major combat operations. For instance, North Korea repeatedly violates UN Security Council resolutions by building and testing strategic weapons, China is rapidly developing advanced military capabilities. To compound the issue, these states often exhibit unclear intentions, supporting the requirement for DOD's global strike capability and its affiliated AEA support.

Future Advanced Threats

In order to maintain future ability to project power and assure access to global regions such as the Pacific, AEA assets must be able to overcome challenges presented by advanced threats. The most dangerous threat is arguably the state employing advanced capabilities

---

[7] House Armed Services Committee, *The Posture of the US Pacific Command and the US Strategic Command, 2013*, 113th Cong., 1st sess., 2013, 1.

[8] House Armed Service Committee, *The Posture of the US Pacific Command and the US Strategic Command,* 1.

[9] House Armed Service Committee, *The Posture of the US Pacific Command and the US Strategic Command,* 3.

in an anti-access, area-denial strategy. States using anti-access capabilities/strategies seek to prevent the contesting state's ability to project and sustain combat power into a region.[10] States employing area-denial strategies and weapons seek to limit a contesting states freedom of maneuver.[11] A state's overarching A2AD strategic objective is to make other states believe it can close off the Global Commons of international airspace and waterways to contesting forces.[12] A2AD strategy anticipates US military forces will not be willing or able to pay the cost to reopen these hazardous areas or come to the aid of allied regional partners. A state utilizing an A2AD strategy and weapons even retains advantage in peacetime over their neighbors, potentially reducing US regional influence.[13]

The A2AD environment heavily influences the types of assets the DOD can safely employ in the area of operations.[14] A2AD environments increasingly challenge non-stealthy, fourth-generation fighters and legacy bomber's ability to penetrate contested airspace to gain and maintain Air Superiority. Likewise, AEA assets protecting global strike assets in an A2AD environment face challenges in protecting these assets while attempting to achieve an effective J/S ratio. Even a combined approach, employing a broad range of assets and employment tools will likely only provide localized, temporary air superiority to achieve the desired global strike effects.[15] Confronting these challenges will require better Joint Force AEA integration, advanced weapons, and refined TTPs.

---

[10] Mullen and United States. Joint Chiefs of, *The National Military Strategy of the United States of America, 2011: Redefining America's Military Leadership*, 8.

[11] Mullen and United States. Joint Chiefs of, *The National Military Strategy of the United States of America, 2011: Redefining America's Military Leadership*, 8.

[12] Jonathan Greenert, "Projecting Power, Assuring Access," The Official Blog of Chief of Naval Operations Admiral Jonathan Greenert, entry posted May 10, 2012, http://cno.navylive.dodlive.mil/2012/05/10/projecting-power-assuring-access/ (accessed March 6, 2013).

[13] Jonathan Greenert, "Projecting Power, Assuring Access," The Official Blog of Chief of Naval Operations Admiral Jonathan Greenert, entry posted May 10, 2012, http://cno.navylive.dodlive.mil/2012/05/10/projecting-power-assuring-access/ (accessed March 6, 2013).

[14] Department of the Air Force, *Fiscal Year 2013 Air Force Posture Statement*, 28 February 2012, 15.

[15] Department of the Air Force, *Fiscal Year 2013 Air Force Posture Statement*, 15.

Budgetary Concerns

On March 1, 2013, the US Congress failed to approve an alternative to resolve the national deficit reduction plan and DOD Sequestration budget cuts went into effect, adding $470 billion to the $487 billion in defense spending cuts through 2023.[16] The DOD's AEA mission set has always suffered the stigma as a fringe capability.[17] While the DOD does not treat AEA as unimportant nor unnecessary; in general, the DOD does not associate AEA with its essence. Thus, Sequestration will likely hit AEA equipment maintenance and training related activities hard. Major AEA programs such as the EA-18G could experience severe funding cuts.[18] Congress may soon call the future of the F-35 into question, likewise threatening acquisition plans for the Next Generation Jammer as discussed in chapter two. Taking into account the dark shadow cast by fiscal restraints, lower cost alternatives for AEA will likely receive much attention in the near future.

Alternative AEA Options

While several AEA alternatives exist, not all are feasible or fundable in the near term. In 2002, the DOD conducted a comprehensive Airborne Electronic Attack Analysis of Alternatives (AoA) focused on required capabilities for collective DOD air superiority during the 2010-2030 timeframe.[19] The study concluded two critical AEA components were required to provide a comprehensive solution.

The first component was a recoverable platform or combination of platforms intended to provide core component capability able to detect

---

[16] Jim Garamone, "Panetta Notifies Congress Dod Preparing for Furloughs," www.defense.gov, http://www.defense.gov/news/newsarticle.aspx?id=119328 (accessed March 13, 2013).
[17] William F. Dobbs, Air Air University . School of Advanced, and Studies Space, "Reclaiming Lost Ground: The Future of Electronic Warfare in the USAF" (School of Advanced Air and Space Studies, 2008), 4.
[18] Daniel Goure, "Man-Made Disasters: The Impacts and Implications of Sequestration and a Year-Long Continuing Resolution" (webinar, Sponsor: Association of Old Crows).
[19] Department of Defense, Airborne Electronic Attack Analysis of Alternatives (AEA AoA), Unclassified Synopsis (Washington, DC: Department of Defense, June 2002), 1.

and perform battle management functions for reactive jamming.[20] The second component was an expendable air platform intended to perform a stand-in jamming function against advanced threats in environments not accessible to the core component.[21] The AoA study also identified approaches to survivability are collectively more effective when employed in a layered, balanced, and comprehensive manner.[22]

Yet funding a comprehensive approach may prove problematic. For example, the EA-18G is currently the only AEA platform with a research and development funding budget, however its upgrades are mostly focused on targeting future low-band threats. The USAF EC-130H Compass Call recently acquired some radar capability, but this change of target will likely require a trade off in power-output against the Compass Calls primary task of communications jamming.[23] The F-35B might operate in the medium-band of the EMS, while an air vehicle yet to be determined could be capable of covering the higher-frequency threats.[24] If budgetary constraints permit, this air vehicle might develop as a Remotely Piloted Aircraft (RPA).

RPAs

The AEA mission profile lends itself nicely to the use of RPAs. Generally, EB-66s and EA-6Bs of the past flew out ahead of their associated strike groups and established orbits, denying, degrading, and disrupting enemy radars in timed sequence to cover the striker's ingress

[20] Department of Defense, Airborne Electronic Attack Analysis of Alternatives (AEA AoA), Unclassified Synopsis (Washington, DC: Department of Defense, June 2002), 1.
[21] Department of Defense, Airborne Electronic Attack Analysis of Alternatives (AEA AoA), Unclassified Synopsis (Washington, DC: Department of Defense, June 2002), 1.
[22] Department of Defense, Airborne Electronic Attack Analysis of Alternatives (AEA AoA), Unclassified Synopsis (Washington, DC: Department of Defense, June 2002), 1.
[23] Sydney Freedberg "Will Stealth Survive as Sensors Improve? F-35, Jammers at Stake," *www.defense.aol.com*, http://defense.aol.com/2012/11/27/will-stealth-survive-as-sensors-improve-f-35-jammers-at-stake/ (accessed March 6, 2013).
[24] Sea Air Space 2011: USN Spells Out Future for Airborne Electronic Attack, *Shephard Media*, 12 April 2011. http://www.shephardmedia.com/news/uv-online/sea-air-space-2011-usn-spells-out-future/ (accessed March 13, 2013).

and egress. RPAs generally have much longer loiter times than manned aircraft and could service multiple strikes from their operational orbits.

However, developing an AEA designated payload for RPAs faces three obstacles: priority, technological limitations, and flexibility.[25] RPAs are tremendously popular in the DOD and gaining priority for an AEA capability on RPA platforms in the near term would likely prove impracticable. While the USAF may desire a multi-role RPA, the DOD on whole focuses on mission sets such as Full Motion Video (FMV) capability and kinetic weapons.[26]

Technological limitations may hinder an AEA RPA variant, at least in the short term. In fiscal year 2013, the USAF cancelled the MQ-9 Reaper Electronic Attack Pod program designed for irregular warfare EA. "Program officials stated that electromagnetic interference caused by the pods jamming the MQ-9 command and control systems posed a key technical challenge."[27] Designers must also significantly miniaturize the size of AEA pods to allow for current the iteration of RPA to carry them. For example, just one of the ALQ-99 jamming pods employed by the EA-6B and EA-18G weighs over 1,000 pounds. These AEA platforms carry up to five pods each to cover various threat frequency bands. In contrast, the RQ-1 *Predator* can only carry 450 pounds of cargo.[28]

Finally, any future RPA jamming platform with enough power to render adversary radar ineffective will require real-time updates and in-flight reprogramming. The true value of the current AEA core component platforms comes from their flexibility to adjust to counter-moves by a thinking enemy during combat. A manned platform provides the

---

[25] James Rentfrow, "EC Support for an Expeditionary Air Force: The Lessons of History" (master's thesis, Air University, 2000), 28.

[26] Sherrill Lee Lingel and Corporation Rand, *Methodologies for Analyzing Remotely Piloted Aircraft in Future Roles and Missions* (Santa Monica, CA: RAND, 2012), vii.

[27] Sullivan et al., "Airborne Electronic Attack," 20.

[28] "RQ-1A/MQ-1 Predator UAV," defense-update.com, http://defense-update.com/products/p/predator.htm (accessed April 8, 2013).

flexibility to receive data from onboard sensors as well as forwarded updates from other collection assets. Of course, RPAs have the advantage that crewmembers could not be shot-down or captured. However, the current model of RPA such as the MQ-1 and MQ-9 has limited maneuverability and may face survivability challenges in an advanced threat environment. Once RPAs prove their ability to cope with the time critical demands of Airborne Electronic Attack, their use as an alternative may prove feasible.

Space-Based Electronic Attack

Another alternative explores relocating the jamming domain altogether by placing EMS jamming assets in outer space. A low-earth orbit jammer could serve as a persistent presence solution with non-persistent effects. The temporary, non-kinetic effects of jamming adversary radars might even prove a favorable option from an international community perspective. In addition to attacking enemy radars on the Earth, perhaps space-based EA assets could defend US and allied satellites.

Technologically speaking, space-based Electronic Attack is feasible.[29] A space jammer could collect huge amounts of solar power and employ much larger antenna arrays than those currently employed on aircraft.[30] A space-based jammer's increased antenna size could theoretically overcome the distance dissipation problem to the target from low-earth orbit.[31] However, placing satellites in low-earth orbit to increase the probability of a higher J/S ratio also presents a timing coordination challenge of ensuring the asset is positioned overhead the target at the appropriate moment.

---

[29] Christopher Bolkcom and Service Library of Congress. Congressional Research, "Electronic Warfare Ea-6b Aircraft Modernization and Related Issues for Congress," Congressional Research Service, Library of Congress, http://opencrs.com/document/RL30639.

[30] Bolkcom and Library of Congress. Congressional Research, "Electronic Warfare Ea-6b Aircraft Modernization and Related Issues for Congress".

[31] Bolkcom and Library of Congress. Congressional Research, "Electronic Warfare Ea-6b Aircraft Modernization and Related Issues for Congress".

Furthermore, some speculative research concluded legal considerations regarding space weapons do not restrict space-based electronic attack assets.[32] The legal lines of the weaponization of space are blurry with respect to military support and military weapons. For instance, the Outer Space Treaty only prohibits Weapons of Mass Destruction in space.[33] However, while perhaps technologically possible, and legally permissive, and some even profess the net effects of fielding a space-based jamming system justifies the staggering costs, others contend such assets are not economically viable.

A space-based jammer system is likely cost prohibitive in the near-term. Industry would need to reduce the cost of constructing the solar arrays to collect the jamming power required by a factor of 100.[34] Additionally, "the cost of building jamming transmitters and miscellaneous spacecraft and components would need to be reduced by a factor of 10.[35] Factor in declining military budgets and the probability of a space-based EA capability seems slim.

Critics concede, however, space-based EA may not remain cost prohibitive indefinitely. Studies at NASA expect the costs of development, maintenance, and satellite operation are expected decrease considerably by 2020 due to advances in miniaturization, energy, and materials.[36] Additionally, as private industrialists explore space travel, the costs for placing defensive weapons in space may become less

---

[32] Kurt M. Schendzielos, Command Army, and K. S. General Staff Coll Fort Leavenworth, "Electronic Combat in Space: Examining the Legality of Fielding a Space-Based Disruptive Electromagnetic Jamming System," Defense Technical Information Center, http://handle.dtic.mil/100.2/ADA471399.

[33] Assembly United Nations. General and Manfred Lachs, *International Co-Operation in the Peaceful Uses of Outer Space : Report of the Committee on the Peaceful Uses of Outer Space. Conclusion of an International Treaty on Principle Governing the Activities of States in the Exploration and Use of Outer Space, the Moon and Other Celestial Bodies. Treaties Governing the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies* ([New York]1967).

[34] Bolkcom and Library of Congress. Congressional Research, "Electronic Warfare Ea-6b Aircraft Modernization and Related Issues for Congress".

[35] Bolkcom and Library of Congress. Congressional Research, "Electronic Warfare Ea-6b Aircraft Modernization and Related Issues for Congress".

[36] Bolkcom and Library of Congress. Congressional Research, "Electronic Warfare Ea-6b Aircraft Modernization and Related Issues for Congress".

expensive and further justified. Alternatively, the future of Airborne Electronic Attack may take on a quasi-kinetic feel.

Advanced Missiles

The emerging ability to kill an adversary's computers and radar electronics non-kinetically while averting damage to their personnel and structures may add a new dimension of *destroy* to the fundamental AEA activities of deny, degrade, and disrupt. Doctrinally, directed energy weapons fall under the Electronic Attack pillar of Electronic Warfare.[37] A directed energy weapon uses directed energy to incapacitate, damage, or destroy enemy equipment, facilities and/or personnel.[38] Advancements in directed energy weapons missile technology may potentially produce game-changing results for the future of AEA.

Similar to MALD-J, which launches as an unmanned stand-in capability, the Counter-electronics High Power Microwave Advanced Missile Project (CHAMP) weapon does not explode or kinetically destroy its target. However, CHAMP differs from MALD-J's temporary jamming characteristics in that CHAMP emits a high power microwave (HPM) signal, producing hard-kill effects.[39] CHAMP program mangers claim this innovative weapon could yield a new era in modern-day warfare by destroying or scrambling an enemy's electronics and data systems before the first troops or aircraft arrive.[40]

During tests in October 2012, researchers and USAF personnel launched the CHAMP from the wing of a B-52 towards predetermined coordinates where it emitted a powerful electromagnetic microwave pulse, which shut down electronics and rendered data systems within

---

[37] Joint Publication 3-13.1, "Doctrine Update for Jp 3-13.1," I-4.

[38] Joint Publication 3-13.1, "Doctrine Update for Jp 3-13.1," GL-6.

[39] David Fulghum, "Leave Them Sitting in Silence, in the Dark," www.aviationweek.com, http://www.aviationweek.com/Blogs.aspx?plckBlogId=blog:27ec4a53-dcc8-42d0-bd3a-01329aef79a7&plckPostId=Blog:27ec4a53-dcc8-42d0-bd3a-01329aef79a7Post:347da0db-c427-4928-85ff-da01662523fe (accessed March 18, 2013).

[40] David Axe and Colin Clark, "New Air Force Missile Turns Out Lights with Raytheon Microwave Tech," defense.aol.com, http://defense.aol.com/2012/10/23/new-air-force-missile-turns-out-lights-with-raytheon-microwave-t/ (accessed March 19, 2013).

the building useless.[41] While early efforts in AEA focused on the pursuit of greater jamming power, and later focusing on jamming beams, a HPM pulse missile essentially transitions from a 'flamethrower' mentality to an "electronics-frying sniper rifle."[42]

CHAMP's various qualities make the weapon an appealing AEA alternative. The missile can navigate a complex flight path, selectively turn on and off the microwave, and potentially renew its charge in-flight allowing for selectively aiming the beam to deliver multiple bursts of microwaves against various targets.[43] If CHAMP designers and engineers can successfully produce a predictable and easy to direct HMP beam, along with designing a payload, which weaponry crews can retrofit on various cruise missiles or RPAs, counter-electronic weapons may change the look of AEA.

For instance, the key AEA activities of deny, degrade, disrupt, would transition to include *destroy*. This new era might also greatly reduce adversary post-reconstruction costs.[44] In the interim period while Electronic Warfare Officers anticipate the fielding of these new technologies, improved AEA integration with DODs cyber capabilities may offer some promising results.

Integrated TTPs

Airborne Electronic Attack has close ties to cyberpower. While the fight for control of cyberspace, which uses the EMS, has arguably been

---

[41] David Axe and Colin Clark, "New Air Force Missile Turns Out Lights with Raytheon Microwave Tech," defense.aol.com, http://defense.aol.com/2012/10/23/new-air-force-missile-turns-out-lights-with-raytheon-microwave-t/ (accessed March 19, 2013).

[42] David Axe and Colin Clark, "New Air Force Missile Turns Out Lights with Raytheon Microwave Tech," defense.aol.com, http://defense.aol.com/2012/10/23/new-air-force-missile-turns-out-lights-with-raytheon-microwave-t/ (accessed March 19, 2013).

[43] David Fulghum, "Leave Them Sitting in Silence, in the Dark," www.aviationweek.com, http://www.aviationweek.com/Blogs.aspx?plckBlogId=blog:27ec4a53-dcc8-42d0-bd3a-01329aef79a7&plckPostId=Blog:27ec4a53-dcc8-42d0-bd3a-01329aef79a7Post:347da0db-c427-4928-85ff-da01662523fe (accessed March 18, 2013).

[44] David Fulghum, "Leave Them Sitting in Silence, in the Dark," www.aviationweek.com, http://www.aviationweek.com/Blogs.aspx?plckBlogId=blog:27ec4a53-dcc8-42d0-bd3a-01329aef79a7&plckPostId=Blog:27ec4a53-dcc8-42d0-bd3a-01329aef79a7Post:347da0db-c427-4928-85ff-da01662523fe (accessed March 18, 2013).

ongoing since the mid-1990s, the fight for the EMS has been underway since 1940. Electronic Warfare Officers are therefore the tribal kinsmen of Cyber Officers, especially Cyber Officers involved in Computer Network Attack (CNA) operations. CNA involves offensive cyber warfare activities, such as attacking adversary computer systems connected to their IADS.[45] As both areas use the EMS to conduct operations, AEA and cyberpower share many of the same aspects of warfare.

The key difference between the two areas is networks. Cyberspace, by its design, requires networked electronics while AEA more broadly focuses on any electronic system operating in the electromagnetic environment.[46] At any rate, any military use of cyberpower should integrate theory, lessons, tactics, techniques, and procedures learned from practitioners who have operated in the electro-magnetic spectrum for over sixty years. The same holds true for newly developed TTPs from today's cyber warriors. Interestingly, the Chinese seem to have made this connection in recent years; while unfortunately, the US Defense Department appears intent on keeping EW and cyber in separated fields.[47]

In the future, states lagging in cyberpower technology may find themselves at a disadvantage when engaged in asymmetric warfare with a competitor with superior offensive and defensive cyberpower weapons. However, the potential exists equally for overconfidence in cyberpower as states may succumb to the hazard of over reliance on cyber weapons. The perceived relative low costs of cyberpower may entice states to default to its use, rather than dropping kinetic strike weapons on the

---

[45] Derek S. Reveron, *Cyberspace and National Security: Threats, Opportunities, and Power in a Virtual World* (Washington, DC: Georgetown University Press, 2012), 209.
[46] Robert J. Elder and Association of Old Crows, *21st Century Electronic Warfare* (Alexandria, Va.: Association of Old Crows, 2010), 4.
[47] Franklin D. Kramer, Stuart H. Starr, and Larry K. Wentz, *Cyberpower and National Security* (Washington, DC: National Defense University Press: Potomac Books, Inc., 2009), 470.

ground of an adversary nation.[48] Integrating effects such as cyberpower and AEA offers a more robust solution, rather than wholehearted dependency on any one weapon.

As an illustration, an enemy may be fully aware they are under cyber-attack and turn off their radar systems in order to lure global strike assets into a false sense of security. Then, at the opportune moment, the radar systems turn back 'on' as the first wave of strike assets appear.[49] In this example, and conceivably many others, an integrated approach, fusing AEA and cyberpower capabilities may serve the DOD well in supporting future global strike operations.

One option to integrate TTPs recently proposed by the Joint Electronic Warfare Center is the Electromagnetic Battle Manager (EMBM) concept. EMBM seeks to dynamically monitor, assess, plan and direct within the joint electromagnetic spectrum of operations.[50] Through networked sensor/decision/target/engagement systems, the battle management function intends to achieve comprehensive protection of friendly access to the EMS while denying the same to the adversary.[51] One method of actualizing the EMBM concept proposes the inclusion of a non-kinetic operations duty officer to the air operations center construct with a complementary tactical-level non-kinetic operations commander on an airborne EW platform.[52] This construct could harness a combined, adaptive approach including elements of air, LO, space, and cyber effects to overcome adversary challenges to EMS control. While EMBM is currently in its infancy stages, comprehensive integration of existing platforms may provide the best near-term solution to current AEA capability gaps.

---

[48] David E. Sanger, *Confront and Conceal: Obama's Secret Wars and Surprising Use of American Power* (New York: Crown Publishers, 2012), 244.

[49] Reveron, *Cyberspace and National Security: Threats, Opportunities, and Power in a Virtual World*, 209.

[50] Joint Publication 3-13.1, "Doctrine Update for Jp 3-13.1," I-7.

[51] Joint Publication 3-13.1, "Doctrine Update for Jp 3-13.1," I-7.

[52] Jeffrey Crivellaro, "Combined Arms in the Electro-Magnetic Spectrum: Integrating Non-Kinetic Operations" (master's thesis, Air University, 2012), 18.

Conclusion

The historical case studies of Vietnam and the Gulf War highlight periods of prominent AEA employment. By assessing today's DOD AEA capability against the backdrop of the past, one may more clearly identify potential gaps and assess future solutions. As the 2002 AoA study cited, dedicated, core component AEA platforms with complementary striker self-protection pods provide the foundational capabilities to maximize global strike success.

The current shortage of airborne core component jammer capabilities will limit future AEA options. As DOD's only core component jammer aircraft, the Navy's EF-18Gs and EA-6Bs may lack capability and capacity to cover future global strike mission requirements versus states employing A2AD strategies. Additional radar jamming capability for EC-130H Compass Call will likely fail to fill the gap, as radar jamming would likely require a power-output tradeoff from the Compass Call's primary communications jamming role. Moreover, potential cancellation of the F-35 leaves the future of a host air vehicle for the Next Generation Jammer in a state of uncertainty. Several future AEA alternatives seem to share this questionable outlook. Table 2 below charts likely gap filling capabilities, possible solutions, and likely future gaps.

Table 2: AEA Essentials Chart

<u>Essential AEA</u>	<u>Capabilities</u>: *With What*			<u>Activities</u>: *What*			<u>TTPs</u>: *How*
	Aircraft	Pods		Deny	Degrade	Disrupt	
Vietnam	CCJ-USAF CCJ-USN	SSP	Support Jx	Unable escort b/c A-A and SAM threat	Standoff	Standoff	Orientation Chaff Spot Jx Barrage Jx
Gulf War	CCJ-USAF CCJ-USN Stealth	SSP	Support Jx	Escort capable w/ lack of A-A threat	Standoff	Standoff	Sequencing ISO Stealth
Current Day	CCJ-USN* Stealth	SSP w/ AESA	Support Jx MALD-J	Limited escort w/no IADS Stand-in	Mod escort Standoff-limited flexibility	Standoff	FoS ISO Stealth
Future	CCJ? RPAs Space-EA** Stealth*** CHAMP	SSP w/ AESA****	NGJ***** MALD-J******	No escort capable w/ A2AD Stand-in	Standoff	Standoff	SoS w/ Cyber ISO Stealth EMBM

<u>Acronyms and Terms</u>
A2AD – Anti-Access Area-Denial
A-A – Air-to-Air
AESA – Active Electronically-Scanned Array
CCJ – Core Component Jammer
CHAMP - Counter-electronics High-powered Microwave Advanced Missile Project
Deny – Preventing adversary radar system use
Degrade – Reducing adversary radar effectiveness, enemy must try to work through the jamming
Disrupt – Upsetting adversary kill-chain engagement timing sequence
EA – Electronic Attack
EMBM – Electromagnetic Battle Management
FoS – Family of Systems
ISO – In support of
Jx - Jamming
MALD-J – Miniature Air-Launched Decoy Jammer
NGJ – Next Generation Jammer
RPA – Remotely Piloted Aircraft
SAM – Surface-to-Air Missile
SoS – System of Systems
SSP – Striker Self-Protection

<u>Notes</u>
1. While the USAF EC-130H Compass Call recently gained limited radar jamming capability, the aircraft's primary role is communications jamming. Furthermore, radar jamming will likely necessitate a power-output tradeoff.
2. Space-based EA unlikely due to cost through at least 2020
3. Stealth may be negated by future advanced radar capabilities
4. AESA jamming emissions from a stealth platform may negate the stealth effects
5. High-band threat coverage not projected until 2024; host air vehicle in question with F-35 future in question
6. MALD-J has limited flexibility with only 45 minutes of operational flight time

<u>Legend</u>
Probable Gap filling capability
Possible Gap filling capability
Probable future gap in capability

Source: Author's Original Work

RPAs, space-based EA, and CHAMP provide some optimistic potential as AEA alternatives; yet, each option has associated uncertainties. Priority given to other mission areas, bulky jammer payload size, and RPA limited flexibility may limit their potential as an AEA replacement in the near term. The probability of the development of space-based EA is low due to the exceedingly high cost of such endeavors through at least 2020. The potentially directional High Powered Microwave pulse of the CHAMP weapon sounds promising and may in fact change the AEA game.

However, like RPAs, CHAMP will also require a demonstrated capability to autonomously navigate complex flight paths and receive in-flight updates in order to fry critical enemy circuits, assuming commanders intend global strike operations to follow. Moreover, unless developers produce stealth versions of the CHAMP, its HMP beam would likely require exceptionally powerful range capability and directionality in order to operate inside advanced threat arrays while hitting only specific targets. Barring potential game-changing outcomes of CHAMP, AEA core activities of future support to global strike operations will likely resemble those of Vietnam and the Gulf War.

The most important future AEA activities will still likely consist of preventing adversary radar use, reducing effectiveness in order to cause the enemy to try to work through the jamming, and upsetting adversary kill-chain engagement timing sequences. In other words: deny, degrade, and disrupt. Today, the DOD faces challenges in these areas and this trend is likely to continue into the future.

The ability to deny adversary radar system use improved from Vietnam to the Gulf War as the Iraqi air-to-air threat failed to prevent coalition forces from overflying enemy territory. The gained and maintained Air Superiority allowed EF-111s to escort striker aircraft to their targets. However, current studies determined the EA-18G could not provide striker escort in a dense IADS environment, much less when matched up against a future A2AD competitor. While stand-in jamming from MALD-J may provide a level of enemy radar denial for strikers, MALD-J's 45-minute time of flight may limit its utility. Furthermore, the MALD-J will likely require frequency change adaptability to match changes of enemy counter-moves.

Future integrated and advanced surface-to-air threats with extensive ranges already restrict the effectiveness of core component jammers, such as EA-6Bs and EA-18Gs, by pushing the limits of how close commanders are comfortable orbiting the CCJs in relation to the global strike target area. The father a jammer orbits from the target, the lower the J/S ratio, in turn reducing the possibility of degradation and disruption to adversary radar systems. Eventually, the technology level of the threat may negate the non-stealthy AEA assets entirely.

However, well-planned and executed TTPs can overcome certain technological challenges. As discussed in chapter two, the DOD opted for the less expensive AEA Family of Systems, rather than a System of Systems. The cost savings constricted communication options between AEA platforms and command and control agencies. If the DOD were to revitalize the SoS approach and initiated integration with cyberpower, DOD's capability to protect global strike assets in a highly-contested advanced threat environment would likely improve.

While stealth is beneficial to global strike assets in an A2AD environment, it does negate the requirement for AEA by making aircraft these invisible to the adversary. AESA jamming emissions generated from stealth platforms may negate the aircrafts stealth effects, further validating the requirement for dedicated AEA assets. Thus, the Next Generation Jammer may require a host air vehicle other than the indigenous stealth global strike asset. In addition, developers do not expect to field the high-band threat coverage for the NGJ until 2024, while a war in a contested A2AD environment could occur much sooner.

While current AEA trends make for an apparently bleak future, these trends are reversible. However, DOD must convince Congress of the high-priority of AEA for fiscal allocations to improve, especially in recent times of Sequestration. Focusing on AEA key variables with regard to activities, capabilities, and TTPs should assist in ensuring improved protection for global strike operations.

CHAPTER 4
Conclusion

Look carefully then how you walk, not as unwise but wise, making the best use of the time, because the days are evil.

Ephesians 5:15

If the DOD strategic end for AEA is control of the electromagnetic spectrum in order to maintain a continued advantage over an adversary, it must correspondingly maintain the enduring AEA principles. The key material and non-material means to support global strike operations against a future advanced adversary threat include the ability to deny, degrade, and disrupt the enemy with dedicated jamming assets, self-protection pods, and using sequenced and specified TTPs.[53] Control infers the ability to conduct operations at the time and place of the commanders choosing. AEA assets must therefore maintain the capability to challenge the contesters of the EMS to achieve control of the spectrum. The advanced future threat, with vastly extended range and highly connected communications network creates significant challenges for DOD's current AEA capability if a future conventional war were to occur.

This research intended to answer a vital question regarding the future employment of airborne electronic attack: does the current DOD AEA strategy adequately address support to future global strike operations? The threat to operations evolved and DOD must parry with a capability including an effective AEA force. The essential types of AEA missions supporting global strike operations will likely mirror classic

[53] This essay discusses the ability to destroy advanced defensive systems non-kinetically with anticipated future weapons such as the Counter-electronics High Power Microwave Advanced Missile Project (CHAMP) missile, later in this conclusion and also in chapter three. This future shift capability may potentially add the core function of *destroy* to AEA jamming.

demonstrations of the past. The historical mission-types serve as guideposts towards mission requirements of the future. The TTPs AEA warriors will need to perform in a future large-scale conventional war will generally reflect those of the past.

This essay asserts current indications point to potential gaps in DOD's AEA capability to address support to global strike operations from advanced threats in future combat. Comparing the historic lens of events including heightened levels of AEA alongside the current capability provides warrant for concern and justification for discovering solutions. The analysis of the current documentation against the backdrop of the historical accounts points to key acquisition and equipment modifications with their associated TTP enhancements. The review of material and non-material factors of effective AEA operations revealed the essential activities, capabilities and TTPs of successful protection for global strike platforms in order to forecast probable effective AEA solutions for future operations.

Vietnam and the 1991 Gulf War AEA

> *In preparing for battle, I have always found that plans are useless but planning is indispensable.*
>
> Dwight D. Eisenhower

The process of planning is most important in considering the opportunities and challenges and ways to meet them. Airborne electronic attack is dynamic by nature and requires agility and maximized flexibility to counter ever-changing enemy modifications. Additionally, no adversary will remain static and once engaged in a fight and the DOD should anticipate adversary capabilities and tactics would then shift more quickly. Since the North Vietnamese of the 1960s, our enemies have demonstrated their continued adaptability in overcoming DOD jamming techniques. Any planned mission, weapon, or TTP will likewise require maximum adaptability to maintain effectiveness for the duration of the air war.

The key attributes of AEA success during the Vietnam air campaign were those intended to deny, degrade, and disrupt enemy defenses. Both the air and naval components of the DOD employed outdated aircraft to meet the demands of protecting strike assets. Electronic Warfare Officers, flying onboard these dedicated jamming platforms, frequently modified TTPs in response to North Vietnamese counter-moves. For example, spot jamming, barrage jamming, and chaff techniques evolved as the intelligent North Vietnamese enemy presented AEA new challenges to achieving an effective jam-to-signal ratio. Enemy defenses eventually forced AEA platforms further way from friendly strike routes, creating a distance gap for effective jamming.

Power output will always function as a restrictive feature of radar jamming. No single platform can jam all required systems simultaneously at all locations. The power required to deny, degrade, and disrupt receivers of target-tracking and fire-control radars in the target area legitimized the requirement for self-protection pods as the strike force approached their targets. This multi-layered conceptual approach transferred forward to the Gulf War of the 1990s in order to ensure aircrew and aircraft survivability against an Iraqi Integrated Air Defense.

EF-111s Ravens with speed and range and EA-6Bs with power jamming transmitters covered strike assets proceeding to and from their targets. Specified and sequenced timing and TTPs also proved key enabling AEA dynamics for strike forces. AEA platforms supported initial attacks, responded to mobile and target area threats, and supporting roving bands of SAM killers. AEA assets standing off at safe distances also provided an additional layer of protection for radar-eluding stealth aircraft. The jamming effects on Iraqi radarscopes complicated the detection of the LO aircraft as it raised the noise-floor above the return of the LO aircraft.

The overwhelming air superiority gained early in the Gulf War and the resultant absence of an air-to-air threat permitted coalition strike forces to exploit the benefits of dedicated escort jamming. Escort jamming, in close proximity to both the targeted enemy radar receiver and the protected strike platform provided one of the most effective defenses.[54] DOD's effective employment of AEA during the Gulf War led to aggregate aircraft losses dramatically lower than those seen in previous wars and, perhaps most remarkably, even lower than DOD training accident rates.[55] However, the solid performance of AEA assets during Vietnam and the Gulf War does not mean the DOD should leave well enough alone.

An observed DOD AEA trend includes producing as few and minimum quality AEA assets as possible to fill the minimal capacity requirement in order to meet high demands. For example, the antiquated, and dangerously over-weight Vietnam EB-66 jammer workhorse required three maintenance man-hours for every hour of flight time. An eight-year gap then followed the retirement of the EB-66 and the delivery of its intended replacement, the EF-111. The USAF subsequently retired the EF-111, with no replacement, depending on the USN as the sole repository of AEA expertise in the DOD. Meanwhile, the Navy's EA-6B Prowler, still operational today, first flew operational sorties over Vietnam in 1972 using the same ALQ-99 jamming pod as today's EA-18G Growler. This sluggish DOD approach to AEA upgrades, both in quality and quantity, limits AEA flexibility in a seemingly inverse relationship to the rapidly evolving threat to global strike operations. This strategic methodology has shaped the context of DOD's current capability.

[54] Gershanoff, "EC in the Gulf War," 40.

[55] Werrell, *Archie to SAM: A Short Operational History of Ground-Based Air Defense*, 228.

Current AEA Capabilities

Given the that context of today's electro-magnetic spectrum has developed considerably since Vietnam and the Gulf War, the DOD cannot assume future unfettered access to denied areas defended by advanced adversaries. At best, AEA assets can provide transitory coverage for strike platforms during key windows of vulnerability against an enemy seeking to limit their freedom of action in the region. Budgetary restrictions, an over-dependence on stealth technology, and a pivot towards stand-in jamming to offset the requirement for a core component jammer have further limited DOD's adaptive capability towards advanced threats.[56]

Budget pressures during 1990s led to both the retirement of the EF-111 escort jammer and the aborting of subsequent efforts to convert B-52 bombers into core component jammers. The prevailing wisdom concluded that a higher cost-effectiveness could be brought about by investing in stealth technology rather than upgrading fourth-generation, non-stealth platforms.[57] The justification followed that investments in stealth were the preferred over vulnerable fourth-generation 'aluminum' assets which would only be shot down during the opening volleys with an advanced adversary.

The exclusive dependency on stealth platform seems to carry the idea that one platform can do it all. Conversely, recent operational exercises invalidated the theory that stealth assets can successfully attack heavily defended targets 'alone and unafraid'. Stealth, however, does not obviate the need for AEA jamming capability. Rapid advances in IADS technology has made it easier for adversaries to share information, scattered amongst multiple sensors working in parallel, to

---

[56] A core component jammer performs a standoff jamming role and maintains the ability to detect and perform battle management functions for reactive jamming.

[57] Sydney Freedberg "Will Stealth Survive as Sensors Improve? F-35, Jammers at Stake," *www.defense.aol.com*, http://defense.aol.com/2012/11/27/will-stealth-survive-as-sensors-improve-f-35-jammers-at-stake/ (accessed March 6, 2013).

piece together a picture clear enough to engage stealth platforms.[58] Granted, stealth aircraft with Active Electronically Scanned Array radar provide significant capability against future threats; however, considering stealth characteristics alone fall short in making any aircraft 'invisible' to an advanced IADS, classical components of AEA remain vital to global strike operations.

At first glance existing core component jammers such as the EA-18G seem fit to handle advanced threats to strike operations, but only at a superficial level. Studies found the Growler's external ALQ-99 legacy-jamming pod degraded its internal AESA radar performance. Additional findings determined the aircraft's two-man crew would likely have difficultly managing the workload of the traditional four-man EA-6B crew in a highly contested environment. Furthermore, AEA specialists do not expect to field the Next Generation Jammer, the intended to replacement for the antique ALQ-99 for the EA-18G, until 2018. To compound the problem, plans to field mid-band, low-band, and high-band frequency capabilities occur in incremental block dates with the last update not occurring until 2024. This analysis implies probable coverage gaps against advanced threats over the next decade.

To offset these capability gaps, the DOD intends to shift towards a stand-in jamming capability in order to disrupt enemy firing solutions of anti-aircraft weapons. The expendable Miniature Air Launched Decoy-Jammer (MALD-J), with its ability jam adversary radar screens from close range, may resolve some of the likely AEA deficiencies. The DOD is clearly emphasizing force resiliency by transitioning to unmanned systems. However, upon closer examination, purchased orders of 2,400 non-retrievable jamming decoys may not be enough to contest advanced threats in future conflicts.

---

[58] Sydney Freedberg "Will Stealth Survive as Sensors Improve? F-35, Jammers at Stake," *www.defense.aol.com*, http://defense.aol.com/2012/11/27/will-stealth-survive-as-sensors-improve-f-35-jammers-at-stake/ (accessed March 6, 2013).

Although the weapon is expendable, MALD-J's 45-minute flight time may not provide enough duration to cover global strike operations in an area protected by advanced defensive systems. By way of comparison, during the Gulf War 36 EF-111s and 39 EA-6Bs flew average mission durations of roughly three hours during 2,735 combat missions with only one noncombat loss in 43 days.[59]

The quantity of MALD-Js required for a future conflict will depend on the scale and duration of the operation and the tactics planners chose to employ. If historical precedent is an indicator of DOD's approach to AEA, specialists may find shortages in MALD-J stockpiles when operating in a future advanced threat environment. If low observable and stand-in technologies do not completely negate the requirement for AEA escort and standoff jammers, and AEA assets remain high-demand/low-density capability, a different approach to electronic warfare may be in order.

Anticipated AEA Future

The DOD's current AEA strategy will likely fail if it becomes dependent solely on stealth and stand-in jamming strategy. "The costs of EMS-dependent technology development, coupled with the required speed of development, transcend its resources and capabilities."[60] To accomplish the key mission activities of deny, degrade, disrupt the DOD should invest in areas of technological differentiation and adaptive commercial assets to secure advantages over advanced future threats.[61]

To deny or degrade enemy systems, future assets must carry the power output capable of overwhelming enemy defensive radar receivers.

---

[59] Eliot A. Cohen, Survey Gulf War Air Power, and Force United States. Department of the Air, *Gulf War Air Power Survey* (Washington, D.C.: Office of the Secretary of the Air Force, 1993), Vol 4, 96.

[60] J.D. McCreary, *Gaining the Economic and Security Advantage for the 21st Century: A Strategy Framework for Electromagnetic Spectrum Control*, (Lackland AFB, TX: Electronic Warfare Directorate Joint Information Operations Warfare Center United States Strategic Command, 2010), 45.

[61] LCDR J.D. McCreary, *Gaining the Economic and Security Advantage for the 21st Century: A Strategy Framework for Electromagnetic Spectrum Control*, (Lackland AFB, TX: Electronic Warfare Directorate Joint Information Operations Warfare Center United States Strategic Command, 2010), 45.

Additionally, a future weapon must be capable of responding to unknown threats dynamically changing locations in-flight. The essential AEA activity of disruption also requires responsive timing in order to defeat the enemy engagement by disrupting the kill-chain timing sequence. This activity has historically required human interface to adapt to the counter moves of a thinking enemy.

Remotely Piloted Aircraft (RPA) or space-based EA offer some alternative approaches for AEA. RPAs generally have extended loiter times and could service multiple strikes. However, concerns regarding priority to other mission areas rather than AEA, bulky jammer payload size, jamming interference with the command and control signal, and relative limited flexibility may hinder a move towards RPA based AEA for some time. Additionally, the current model of RPA has limited maneuverability, which may also limit the platforms survivability against advanced future threats. The DOD might also consider a persistent space based-EA capability, yet the probability of development in this area is low due to the exorbitant cost of space-based systems, especially considering the current context of significant DOD spending cuts.

Another possible alternative, the Counter-electronics High Power Microwave Advanced Missile Project (CHAMP) missile, may ostensibly transform the face of AEA from deny, degrade, disrupt to include *destroy*. CHAMP reportedly delivers a precision electromagnetic pulse-type effect against enemy electronics and computer systems supporting their advanced threats. However, similar to concerns surrounding RPAs, CHAMP must demonstrate the capability to navigate through enemy territory while receiving in-flight updates in order to target/destroy critical enemy circuits. More importantly, perhaps only a stealth version of CHAMP would survive operations inside an enemy's area-denied environment. Otherwise, CHAMP's high-powered microwave beam would require exceptionally powerful range and precision directionality to target specific enemy systems. While future AEA alternatives such as CHAMP may eventually mature into realistic solutions, in the short term, plausible solutions will instead likely involve integrated AEA TTPs such as the Electromagnetic Battle Manager (EMBM) concept discussed in chapter three.

Implications for AEA in the Future

DOD's best anticipatory posture includes a flexible, rapidly adaptive, and resilient AEA force. Nevertheless, budget austerity raises several questions for a future, smaller force. Such a DOD force may find it difficult for sister services to draw on each other's capabilities for specified missions such as global strike. The DOD's sole core component jammers, EA-18G and EA-6B may receive tasking for dedicated surface fleet defense leaving global strike operations wanting for support.

Furthermore, as mentioned in chapter two, rather than investing an indigenous AEA support asset after the retirement of the EF-111, the USAF opted to maintain a cadre of qualified EWOs who fly on the Navy-owned EA-18Gs. The USN planned to retire their 120 four-seat EA-6Bs in 2012, yet they extended the EA-6B service life through 2016. Eventually this will mean fewer seats for USAF electronic warfare officers through the joint program, implying even less influence to shift dedicated AEA aircraft for global strike purposes.[62]

The case studies of Vietnam and the Gulf War imply a key take-away for DOD service allocation: quantity and variety of AEA platforms matter. During both the Vietnam and Gulf War, maintenance crews drew heavily on non-deployed assets for parts during these major contingencies. If wartime requirements call for the wholesale deployment of a smaller force, it will be difficult to maintain mission-capable rates like those seen in the past. Instead of depending on USN assets for

---

[62] John Tirpak, "Electronic Warfare Meets Austerity," www.airforcemag.com, http://www.airforcemag.com/MagazineArchive/Pages/2010/January%202010/0110electronic.aspx (accessed April 5, 2013).

global strike operations, perhaps the USAF should invest in an indigenous AEA dedicated jamming platform.

Nevertheless, well-planned and executed TTPs can overcome certain technological and financial challenges. The 2002 AEA Analysis of Alternatives study determined no "individual or mix of transformational technologies, systems, or military concepts of operations [sic] would warrant the elimination of a complete and comprehensive AEA capability from the current United States Air Superiority arsenal."[63] Unfortunately, the DOD recently opted for the less expensive AEA Family of Systems over the more robust System of Systems (SoS) mentioned in chapter two. DOD's skimping, restrained command and control options amongst AEA platforms, consequently inhibiting synergy. Were the DOD to reorient towards the SoS approach and also add fused integration with cyberpower, DOD's capability to protect global strike assets in a highly-contested advanced threat environment would substantially improve. The danger for DOD is while enemy IADS communications architecture has increased exponentially, inversely, budget decisions have undercut much-needed AEA communications upgrades.

If disruption and denial of the enemy remain critical elements of AEA, DOD should ensure a coherent EW management plan to mitigate fog and friction of electronic warfare. Stove-piped planning and execution leads to an inability to maneuver in the battlespace, putting global strike operations, and lives, at risk.[64]

The issue is not simply technology, but also tactics. While the emerging Electromagnetic Battle Manager (EMBM) model is in its infancy, it shows promise in coordinating integrated TTPs across the DOD. Similarly, the DOD must consider how to integrate any of these

---

[63] Department of Defense, Airborne Electronic Attack Analysis of Alternatives (AEA AoA), Unclassified Synopsis (Washington, DC: Department of Defense, June 2002), 1.

[64] Briefing. Joint Electronic Warfare Center. Subject: Electromagnetic Battle Management, 3 November 2012.

proposed changes in terms of Doctrine, Organization, Training, Material, Leadership, Personnel, and Facilities.

The arrival of radar in the 1940s challenged Julio Douhet's theory that the "bomber will always get through" after establishing command of the air.[65] Douhet mischaracterized future anti-aircraft defenses with extensive ranges, which can protect territory from the offensive air attack.[66] AEA assets necessarily continue to counter-challenge adversary defenses. The degree to which strike assets achieved air superiority in Vietnam and the Gulf War reflects to large extent on the victories and advantages achieved through Airborne Electronic Attack. Most importantly, there is the danger the DOD may foolishly venture into battle as a sharp, double-edged sword, yet neglect to bring its shield.

---

[65] Giulio Douhet, *The Command of the Air* (Washington, D.C.: Office of Air Force History, 1983), 9.
[66] Douhet, *The Command of the Air*, 112.

BIBLIOGRAPHY

Academic Papers

Dobbs, William F. "Reclaiming Lost Ground: The Future of Electronic Warfare in the USAF." Maxwell AFB, AL: School of Advanced Air and Space Studies, June 2008.

Feaga, Keith P. "The USAF Capabilities Based CONOPS Construct." Ft. Belvoir: Defense Technical Information Center, May 2004.

Houser, Jonathan P. "From Prowlers to UAVs: A Bridge Too Far for Airborne Electronic Warfare?" Naval War College, May 2002.

Parker, Brandon D. *Caught in a Jam: The US Air Force's Electronic Attack Conundrum*. Maxwell AFB, AL: Air Command and Staff College, April 2008.

Rentfrow, James C. "Electronic Combat Support for an Expeditionary Air Force: The Lessons of History." Maxwell AFB, AL: Air Command and Staff College, April 2000.

Schendzielos, Kurt M. "Electronic Combat in Space: Examining the Legality of Fielding a Space-Based Disruptive Electromagnetic Jamming System." Fort Leavenworth, KS: Army Command General Staff College, June 2007.

Van Nederveen, Gilles. "Sparks Over Vietnam: The EB-66 and the Early Struggle of Tactical Electronic Warfare." Maxwell AFB, AL: College of Aerospace Doctrine, Research and Education, December 2000.

Articles

Axe, David, and Colin Clark. "New Air Force Missile Turns Out Lights with Raytheon Microwave Tech," Aol Defense, 23 October 2012. http://defense.aol.com/2012/10/23/new-air-force-missile-turns-out-lights-with-raytheon-microwave-t/ (accessed March 19, 2013).

Canan, James W. "Electronic (Warfare in Desert) Storm." *Air Force Magazine* 74, no. 6 (June 1991): 26. http://www.armedforces-int.com/news/usaf-flight-trials-for-mald-j-decoy-jammer.html (accessed 5 March, 2013).

Dudley, Richard. "Australian Growler Crews Have a Heavy Workload Ahead," *Defense-Update.com*, 7 September 2012. http://defense-update.com/20120907_ausi_growlers.html (accessed March 5, 2013).

Elder, Robert J., and Association of Old Crows. *21st century Electronic Warfare*. Alexandria, VA.: Association of Old Crows, 2010.

Fiddian, Paul. "USAF Flight Trials for MALD-J Decoy Jammer." *Armed Forces International News*, 25 September 2012.

Franklin, Robert C. "First person … Singular." *Journal of Electronic Defense* 27, no. 7 (July 2004): 74.

Freedberg, Sydney. "Navy Bets On 'Baby Steps' to Improve Electronic Warfare; F-35 Jamming Not Enough," *Aol Defense*, 6 December 2012. http://defense.aol.com/2012/12/06/navy-bets-on-baby-steps-to-improve-electronic-warfare-f-35-ja/ (accessed March 2, 2013).

Freedberg, Sydney. "Will Stealth Survive as Sensors Improve? F-35, Jammers at Stake," Aol Defense, 27 November, 2012. http://defense.aol.com/2012/11/27/will-stealth-survive-as-sensors-improve-f-35-jammers-at-stake/ (accessed March 6, 2013).

Fulghum, David. "Leave Them Sitting in Silence, in the Dark," Aviation Week, 2 March 2009. http://www.aviationweek.com/Blogs.aspx?plckBlogId=blog:27ec4a53-dcc8-42d0-bd3a-01329aef79a7&plckPostId=Blog:27ec4a53-dcc8-42d0-bd3a-01329aef79a7Post:347da0db-c427-4928-85ff-da01662523fe (accessed March 18, 2013).

Gershanoff, Hal. "EC in the Gulf War." *Journal of Electronic Defense* 14, no. 5 (1991): 37-48.

Nordwall, Bruce D. "Electronic Warfare Played a Greater Role In Desert Storm Than Any Conflict." *Aviation Week and Space Technology* 134, no. 16 (April 1991): 68-69.

Northrop Grumman Corporation. "AESA Radar: Revolutionary Capabilities for Multiple Missions." http://www.es.northropgrumman.com/ASD/combat/AESA.html (accessed January 22, 2013).

Northrop Grumman Corporation. "AN/APG-80 F-16 AESA Radar." http://www.northropgrumman.com/Capabilities/ANAPG80AESARadar/Pages/default.aspx (accessed February 13, 2013).

Shephard News Team. "Sea Air Space 2011: USN Spells Out Future for Airborne Electronic Attack", Shephard Media, 12 April 2011. http://www.shephardmedia.com/news/uv-online/sea-air-space-2011-usn-spells-out-future/ (accessed March 13, 2013).

Streetly, Martin. "Battle of the Airwaves (Electronic Warfare)." *Janes Defense Weekly* 15, no. 6 (February 1991): 186.

Tirpak, John. "Electronic Warfare Meets Austerity," AirForce-Magazine.com, January 2010. http://www.airforcemag.com/MagazineArchive/Pages/2010/January%202010/0110electronic.aspx (accessed April 5, 2013).

Tirpak, John. "Seeking Growler Backseat, No Buff SOJ," *AirForce-Magazine.com*. October 20, 2009. http://www.airforcemag.com/DRArchive/Pages/2009/October%2

02009/October%2021%202009/SeekingGrowlerBackseat,NoBUFFSOJ.aspx (accessed January 18, 2013).

Trimble, Stephen. “Us Air Force Cancels Sam-Jamming EB-52 for Second Time,” *Flightglobal*, 3 March 2009. http://www.flightglobal.com/news/articles/us-air-force-cancels-sam-jamming-eb-52-for-second-time-323298/ (accessed March 6, 2013).

Books

Grant, Rebecca. *The Radar Game.* Arlington, VA.: IRIS Independent Research, 2010.

Nalty, Bernard C. *Tactics and Techniques of Electronic Warfare: Electronic Countermeasures in the Air War Against North Vietnam 1965 - 1973*: Office of Air Force History, 1977.

Werrell, Kenneth P. *Archie to SAM: A Short Operational History of Ground-Based Air Defense.* Maxwell Air Force Base, AL: Air University Press, 2005.

Briefings/Memos/Messages

Gilmore, J. Michael, 2011 Association of Old Crows AEA Symposium Slides: Key Issues with Airborne Electronic Attack (AEA) Test and Evaluation.

Goure, Daniel. “Man-Made Disasters: The Impacts and Implications of Sequestration and a Year-Long Continuing Resolution” (Webinar, Sponsor: Association of Old Crows).

Henry, Larry Major General. Briefing. Subject: Electronic Combat in Desert Shield/Desert Storm, 8 September, 2000.

Kistler, Jay. Briefing. NDIA 8th Annual Disruptive Technologies Conference. Subject: Electronic Warfare / Electronic Protection Science and Technology Steering Council, 8 November 2011.

McCreary, LCDR J.D. Gaining the Economic and Security Advantage for the 21st Century: A Strategy Framework for Electromagnetic Spectrum Control, (Lackland AFB, TX: Electronic Warfare Directorate Joint Information Operations Warfare Center United States Strategic Command, 2010), 45.

Government Documents

Department of Defense, Airborne Electronic Attack Analysis of Alternatives (AEA AoA), Unclassified Synopsis (Washington, DC: Department of Defense, June 2002).

House Armed Services Committee, *The Posture of the US Pacific Command and the US Strategic Command, 2013*, 113th Cong., 1st sess., 2013, 1.

Joint Publication 3-13.1. "Doctrine Update for JP 3-13.1." *Information Operations* (2012).

System Development and Demonstration RDT&E Project Justification. EW Development. MALD-J, May 2009.

Mullen, Michael G., and Staff United States. Joint Chiefs of. *The National Military Strategy of the United States of America, 2011: Redefining America's Military Leadership*. Washington, D.C.: Joint Chiefs of Staff], 2011.

NSAM 273, 26 November 1963, National Security Files, National Security Action Memorandums, Johnson Library, Boxes 1-9, 1.

US Senate. *Hearing to Consider the Nominations of General James E. Cartwright, USMC, for Reappointment to the Grade of General and Reappointment as the Vice Chairman of the Joint Chiefs of Staff; and Admiral Robert F. Willard, USN, for Reappointment to the Grade of Admiral and to be Commander, United States Pacific Command.* 111th Cong., 1st sess., 2009.

White House. 2010. National Security Strategy. Washington, DC: White House. http://www.whitehouse.gov/sites/default/files/rss_viewer/national_security_strategy.pdf.

Reports

Bolkcom, Christopher, and Service Library of Congress. Congressional Research. "Electronic warfare EA-6B aircraft modernization and related issues for Congress." Congressional Research Service, Library of Congress, http://opencrs.com/document/RL30639.

Sullivan, Michael J., Bruce Fairbairn, Christopher R. Durbin, Laura Greifner, James Kim, Scott Purdy, Sylvia Schatz, Brian Smith, and Roxanna Sun. "Airborne Electronic Attack: Achieving Mission Objectives Depends on Overcoming Acquisition Challenges." 2012.

Department of the Air Force, *Fiscal Year 2013 Air Force Posture Statement*, 28 February 2012.

United States Air Force. Pacific Air Forces. Directorate of Tactical Evaluation, CHECO Division. *Tactical Electronic Warfare Operations in SEA, 1962-1968: Special Report.* Edited by Robert M. Burch. S.l.1969.Cohen, Eliot A., Survey Gulf War Air Power, and Force United States. Department of the Air. *Gulf War Air Power Survey*. Washington, D.C.: Office of the Secretary of the Air Force, 1993.