Lessons Learned and Forgotten: Electronic Warfare in the United States Army

A Monograph

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2021

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
23 05 2019	MASTER'S MONOGRAPH	JUNE 20-MAY 21

4. TITLE AND SUBTITLE
Lessons Learned and Forgotten: Electronic Warfare in the United States Army

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
MAJ Philip T. Henke
US Army

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Command and General Staff College
ATTN: ATZL-SWD-GD
Fort Leavenworth, KS 66027-2301

8. PERFORMING ORG REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
ADVANCED MILITARY STUDIES PROGRAM

10. SPONSOR/MONITOR'S ACRONYM(S)
SAMS AMSP

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for Public Release; Distribution is Unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

Since World War Two, the US Army has tended to neglect its electronic warfare (EW) enterprise until the start of a conflict. Once in conflict, the US Army has rapidly developed equipment, organizations, and doctrine to meet the operational environment's demands. The speed and lethality of future combat against near-peer adversaries such as Russia and China may demand a US Army EW enterprise that is already manned, trained, and equipped at the start of the conflict. The gap in EW capabilities that have characterized the US Army in previous conflicts may lead to defeat during future conflicts if large-scale combat operations (LSCO) begin quickly.

This monograph focuses on the lessons that the US Army has learned and forgotten while employing EW during and following: World War Two, Vietnam, and Operations Desert Shield and Desert Storm. Closely examining EW during these three conflicts and the lessons learned may inform current EW equipment, organizations, and doctrine in the US Army.

15. SUBJECT TERMS
Electronic warfare, Large Scale Combat Operations, Electromagnetic Spectrum, Lessons Learned, World War Two, Vietnam, Operation Desert Shield, Operation Desert Storm, Operation Overlord, Operation Lam Son 719

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			Philip T. Henke
(U)	(U)	(U)	(U)	47	**19b. PHONE NUMBER** *(include area code)* 913 758-3300

Monograph Approval Page

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Monograph Title: Lessons Learned and Forgotten: Electronic Warfare in the United States Army

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Abstract

Lessons Learned and Forgotten: Electronic Warfare in the United States Army, by MAJ Philip T. Henke, 54 pages.

Since World War Two, the US Army has tended to neglect its electronic warfare (EW) enterprise until the start of a conflict. Once in conflict, the US Army has rapidly developed equipment, organizations, and doctrine to meet the operational environment's demands. The speed and lethality of future combat against near-peer adversaries such as Russia and China may demand a US Army EW enterprise that is already manned, trained, and equipped at the start of the conflict. The gap in EW capabilities that have characterized the US Army in previous conflicts may lead to defeat during future conflicts if large-scale combat operations (LSCO) begin quickly.

This monograph focuses on the lessons that the US Army has learned and forgotten while employing EW during and following: World War Two, Vietnam, and Operations Desert Shield and Desert Storm. Closely examining EW during these three conflicts and the lessons learned may inform current EW equipment, organizations, and doctrine in the US Army.

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Acknowledgements

Completing this monograph would not have been possible without the support of several individuals and organizations. I would like to thank Dr. Justin Kidd and COL Jason Alvis for their patience, guidance, and support throughout this process. I would also like to thank my older brother COL Glenn Henke for sparking my interest in the SAMS by inviting me to his AMSP graduation a few weeks before I left for officer candidate school over a decade ago. Thanks to Katie for wrangling the kids and the hounds and keeping them as quiet as you did while I worked in the "dungeon." Finally, a special thanks to my classmates in the "The B-Team" and the Technology and Doctrine Study Group. I am eternally grateful for your support and am glad that you got to see me every day.

Abbreviations

AAA	Anti-Aircraft Artillery
ARDF	Airborne Radio Direction Finding
ARVN	Army of the Republic of Vietnam
ASA	Army Security Agency
ASE	Aircraft Survivability Equipment
CEWI	Combat Electronic Warfare and Intelligence
EMS	Electromagnetic Spectrum
EW	Electronic Warfare
IADS	Integrated Air Defense System
INSCOM	Intelligence and Security Command
LSCO	Large-Scale Combat Operations
NVA	North Vietnamese Army
RAF	Royal Air Force (British)
RRL	Radio Research Laboratory
SAM	Surface-to-Air Missile
SIGINT	Signals Intelligence
TRADOC	Training and Doctrine Command
USAAF	United States Army Air Forces
VC	Viet Cong

Introduction

Background of the Study

Following the dissolution of the Soviet Union and the end of Operation Desert Storm in 1991, the US Army largely divested from training and equipping electronic warfare (EW) capabilities at all echelons.[1] Without the Soviet Union, the need to maintain formations and equipment that could conduct EW was a luxury that the US Army could not afford given reduced budgets and no clear near-peer threat. Since 1991, the US Army's ability to conduct EW during large-scale combat operations (LSCO) against a near-peer adversary atrophied to a point where it could no longer be considered a credible capability.[2] The lack of capability did not just manifest itself solely in material solutions but also in doctrine, organizations, and training.

Electronic warfare in the US Army remained dormant until 2006 when the need for trained EW personnel and equipment became apparent as radio-controlled improvised explosive devices demonstrated a significant threat to soldiers in Iraq and Afghanistan.[3] In 2009, the US Army officially established Functional Area 29, EW.[4] This new functional area trained and equipped officers, warrant officers, and non-commissioned officers to combat the improvised explosive threat.

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[1] Sydney Freedberg Jr., "Digital Arsenal: Army Inches Forward On Electronic Warfare," *Breaking Defense*, August 9, 2019, accessed August 25, 2020, https://breakingdefense.com/2019/08/army-inches-forward-on-electronic-warfare/.

[2] Laurie Buckhout, "Short History of US Army Electronic Warfare," *Leonardo DRS* (1st Quarter 2016), accessed December 21, 2020, https://www.leonardodrs.com/sitrep/q1-2016-the-invisible-fight/short-history-of-us-army-electronic-warfare/.

[3] Joint Improvised Explosive Device Defeat Organization, *Joint Improvised Explosive Device Defeat Organization Annual Report FY2009* (Washington, DC: Department of Defense, 2010), 5.

[4] Jamie Findlater, "Army Creates Electronic Warfare Career Field," *US Army*, February 6, 2009, accessed November 1, 2020, https://www.army.mil/article/16536/army_creates_electronic_warfare_career_field.

When the US Army shifted focus to multi-domain operations in 2018, a gap was identified in the ability to compete in the electromagnetic spectrum (EMS) and cyberspace.[5] Russia and China's rapid expansion of their EW enterprises threaten to significantly impact the US Army's ability to operate in the contested and congested EMS of future conflicts. A thorough examination of EW in previous conflicts is required to inform present-day capability requirements for the US Army against near-peer threats such as Russia and China.

Statement of the Problem

There is a literature gap that addresses lessons the US Army learned or failed to learn about integrating EW during previous conflicts and if understanding can inform the future force. Since World War Two, the US Army has tended to ignore integrating EW into its operations until faced with a crisis. When the crisis is over, EW has been neglected until it becomes evident that it is needed again. There has been little research examining what capabilities the US Army will need to compete in the EMS, informed by lessons learned during previous conflicts.

Purpose of the Study

The purpose of this study was to examine how the US Army has integrated EW capabilities during previous conflicts, what lessons it learned, and if those lessons apply to the future EW enterprise. This research examined US Army EW operations in World War Two, Vietnam, and Operations Desert Shield and Desert Storm. Second, the study focused on understanding how and why the US Army developed capabilities. Specific attention was paid to the period following the end of combat operations in Vietnam in 1973 to Operation Desert Shield in 1989. During this time, the US Army faced a challenge similar to today in developing EW capabilities for LSCO instead of counterinsurgency operations.

[5] US Department of the Army Training and Doctrine Command, TRADOC Pamphlet 525-3-1, *The U.S. Army in Multi-Domain Operations 2028* (Washington, DC: Government Publishing Office, 2018), v–vii.

While the US Army focused on counterinsurgency operations in Iraq and Afghanistan, current and potential adversaries were developing EW capabilities that support the full range of military operations. Electronic warfare within the US Army must be adequately manned, trained, and equipped to attack, support, and defend in the EMS. Ceding these capabilities to current and future adversaries poses a significant risk to the US Army.

Definition of Terms

Electronic Warfare: EW consists of the three subdivisions of electronic attack, electronic support, and electronic protection.[6] In the US Army, EW, cyberspace operations, and signals intelligence (SIGINT) are sometimes used interchangeably. This monograph used current US Army and Joint Forces doctrinal terms even when those terms were absent or defined differently in previous eras.

Electronic Attack: Electronic attack involves the use of electromagnetic energy, directed energy, or anti-radiation weapons to attack personnel, facilities, or equipment with the intent of degrading, neutralizing, or destroying enemy combat capability and is considered a form of fires.[7]

Electronic Protection: Electronic protection involves actions taken to protect personnel, facilities, and equipment from any effects of friendly or enemy use of the EMS that degrade, neutralize, or destroy friendly combat capability.[8]

Electronic Warfare Support: EW support involves actions taken to search for, intercept, identify, and locate or localize sources of intentional and unintentional radiated electromagnetic energy for the purpose of immediate threat recognition, targeting, planning, and conduct of future operations.[9]

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[6] US Department of Defense, Joint Staff, Joint Publication (JP) 3-13.1, *Electronic Warfare* (Washington, DC: Government Publishing Office, 2012), I–5.

[7] Ibid., GL-8.

[8] Ibid.

[9] Ibid., GL-9.

Electromagnetic Spectrum: The range of frequencies of electromagnetic radiation from zero to infinity. It is divided into 26 alphabetically designated bands.[10]

Research Questions

This study was guided by one primary and two secondary research questions. The primary question was: What lessons did the US Army learn in integrating EW capabilities during previous conflicts? Answering this question should help to inform how the Army views EW in peacetime and during war. If the US Army only addresses capability gaps when there is a crisis, it may show that they had discarded lessons learned in previous conflicts.

Two secondary questions supported this study: How has the US Army employed EW during combat operations in previous conflicts? How did the doctrine, organizations, and materiel change in the US Army to effectively compete in the EMS against previous adversaries? Secondary research questions address the historical employment and development of EW and may help understand what is needed in the US Army in the future.

A thorough examination of every aspect of EW by every actor during World War Two, Vietnam, and Operations Desert Shield and Desert Storm is beyond this monograph's scope. For World War Two, EW's contributions to Operation Overlord were the primary research effort. For Vietnam, the research focused on North Vietnamese air defense and US Army efforts to geolocate North Vietnamese Army (NVA) and Viet Cong (VC) radio transmissions from fixed-wing propeller-driven aircraft. Finally, this study examined the US Army's efforts to procure, repair, install, and train rotary-wing pilots and aircrew on defensive electronic attack countermeasures and jamming during Operations Desert Shield and Desert Storm. This study frequently examined US Army SIGINT operations during these conflicts due to their similarities to EW support.

[10] US Joint Staff, JP 3-13.1 (2012), GL-7.

This monograph has six sections. Section one is the introduction and covered the background, purpose, significance, and organization of the study. Section two is the literature review, which examined the historical sources and doctrine covering EW during conflicts and peacetime in the US Army from World War Two to Operation Desert Storm. Section three covered the methodology used to analyze historical sources and doctrine. Section four covered the case studies. Section five presented findings and analysis that answered the research questions. Section six concluded the study and provided recommendations for future research.

Literature Review

This section will review what has been written how the US Army, US Air Force, and Allied forces employed EW during previous conflicts. Concurrently, it will examine what has been written about the US Army's adaptations to doctrine, organizational structures, and materiel development during and between those conflicts.

World War Two

At the start of World War Two, EW development focused on the air and sea domains in reaction to the Battle of Britain and the bombing of Pearl Harbor. During the interwar years, military radio and radar technology development had stalled in the United States because of a lack of a perceived threat. Dr. Alfred Price argues that rising German military power led to the rapid development of a wide variety of radars and jammers in Europe and Great Britain.[11] The key system for Great Britain would be the shore-based radar network and its command-and-control links to ground-based fighters. Designed to give early warning and direction finding to the Royal Air Force Fighter Command, these radars would be the first line of electronic defense in Great Britain's fight against the German Luftwaffe.[12] The Battle of Great Britain was the opening

[11] Alfred Price, *The History of US Electronic Warfare, Volume I: The Years of Innovation-Beginnings to 1946* (Arlington, VA: The Association of Old Crows, 1984), 9.

[12] Tony Devereux, *Messenger Gods of Battle: Radio, Radar, Sonar, the Story of Electronics in War* (Washington, DC: Brassey's, 1991), 77.

salvo in an EW campaign that intensified with the United States' entry into the war following the Japanese attack on Pearl Harbor.

The National Defense Research Committee established the organization responsible for the research and design of EW technology in the United States during World War Two on January 1, 1942.[13] Originally known as the Radar Counter-Measure Laboratory, it was renamed the Radio Research Laboratory (RRL) for secrecy. In a letter to Dr. Frederick E. Terman (Director of the RRL), Dr. Karl T. Compton of the National Defense Research Committee lays out the director's responsibilities, purpose, importance, and the "ultra-secret character" of the project.[14] The importance of the establishment of the RRL cannot be overstated. Virtually every single jammer, receiver, and countermeasure of importance made for the US Army and US Navy during World War Two were developed by the RRL.[15]

For US Army ground forces, the radio intelligence signal company was the organization in World War Two that demonstrated the most potential for EW support. This organization was responsible for intercepting enemy radio transmissions, finding enemy radio stations, and intercepting and finding unauthorized radio stations.[16] The operating platoons consisted of a control section, intercept section, and position finding section. The 1940 version of Signal Corps Field Manual 11-20 does not mention radio countermeasures or jamming, only direction finding and interception.[17] The lack of purpose-built ground-to-ground jamming systems and the desire to locate and listen rather than jam help explain this absence. Once Germany and Japan

[13] Price, *The History of US Electronic Warfare, Volume I*, 269.

[14] Ibid., 270–71.

[15] Ibid., 272–73.

[16] War Department, Signal Corps Field Manual (FM) 11-20, *Organizations and Operations in the Corps, Army, Theater of Operations, and GHQ* (Washington, DC: Government Printing Office, 1940), 43–49.

[17] Ibid., 114-117.

surrendered, EW in the US Army became an afterthought due to the lack of a near-peer adversary and the entire force's contraction.

Post-World War Two to Vietnam

Following World War Two, the development of EW doctrine and equipment in the US military came to a virtual standstill. The RRL closed in December 1945 and passed off all remaining projects to the Naval Research Laboratory, the Army Air Force's Aircraft Radio Laboratory, and the Army's Evans Signals Laboratory.[18] The US Air Force's establishment in 1947 as an independent branch forced Army Signal Corps personnel on assignment to the Army Air Force to choose between the two services, leaving the newly established branch with virtually no EW personnel.[19]

The most significant development in US EW following World War Two was the establishment of the Army Security Agency (ASA) on September 15, 1945.[20] The ASA would become directly responsible for EW in 1955, removing most subdisciplines from the Signal Branch.[21] This decade marked a confusing relationship with the Signal Corps that demonstrated several problems. First, the Signal Corps was still responsible for managing electronic intelligence techniques and countermeasures, acquiring equipment for the ASA, and maintaining an EW development laboratory.[22] Second, Signal Corps personnel would be doctrinally responsible for electronic attacks but could only jam if they could ensure that the ASA was not conducting collection operations on those frequencies. Further complicating the issue was that

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[18] Daniel Kuehl, *The Radar Eye Blinded: The USAF and Electronic Warfare* (Wright-Patterson AFB, OH: Air Force Institute of Technology, 1992), 50.

[19] Ibid., 48–49.

[20] Michael Bigelow, "A Short History of Army Intelligence," *Military Intelligence Bulletin* 38, no. 3 (Washington, DC: U.S. Army Intelligence and Security Command, 2012), 49.

[21] John Finnegan and Romana Danysh, *Military Intelligence* (Washington, DC: Center of Military History, United States Army, 1998), 193.

[22] Alfred Price, *The History of US Electronic Warfare, Volume II: The Renaissance Years, 1946 to 1964* (Arlington, VA: The Association of Old Crows, 1989), 11.

Signal Corps personnel did not have the security clearances to determine if the frequencies had even been cleared for jamming.[23] Finally, as argued by SGT Richard "Dick" Deeds who moved from the Signal Corps to the ASA, "to the preponderance of Signal Corps officers and NCOs, jamming was anathema. It was like giving the sheep responsibility for raising the wolf cub!"[24]

When the United States committed forces to the Korean War in June of 1950, the US military's EW enterprise was not prepared. The US military had done very little in the interwar years to improve EW capabilities due to the absence of a perceived threat. All of the equipment used for high-frequency radio direction-finding during the Korean War by the US Army was the same that was in use in 1945.[25] Virtually all this equipment was in poor shape due to neglect and lack of training. Radio direction-finding and SIGINT operations in the land domain during the Korean War were limited due to terrain, technology, the static nature of most of the conflict, and the threat itself. There are no recorded attempts to jam radar or communications by the US Army during the Korean War using an electronic attack.[26]

For the US Air Force and US Navy, the Korean War gave them their first combat exposure to Soviet-made aircraft, equipment, and tactics.[27] For the US Army, the Korean War was the first test of the newly established ASA in combat. In *History of US Electronic Warfare,* Price argues that for EW, the Korean War was "like a catalyst in a chemical reaction–it sparked off some major advances, but none of them had any effect on the conflict itself."[28] Based on the lessons learned throughout the conflict, the US Army would move all EW under the ASA in

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[23] Price, *The History of US Electronic Warfare, Volume II*, 12.

[24] Ibid.

[25] David Hatch and Robert Benson, "The Korean War: The SIGINT Background," National Security Agency Central Security Service, accessed December 28, 2020, https://www.nsa.gov/about/cryptologic-heritage/historical-figures-publications/publications/korean-war/koreanwar-sigint-bkg/.

[26] Price, *The History of US Electronic Warfare, Volume II*, 110.

[27] Walter Boyne, "Air Force Aircraft of the Korean War," *Air Force Magazine*, January 7, 2000, accessed December 28, 2020, https://www.airforcemag.com/article/0700korea/.

[28] Price, *The History of US Electronic Warfare, Volume II*, 110.

1956. Intended to solve the challenges of integrating EW into operations, the issues with having an intelligence organization responsible for all aspects of EW became apparent during and following the Vietnam War.

Defensive Electronic Attack During Vietnam

The Vietnam War ushered in a period of rapid expansion of EW in the US military. Throughout the war, the US Air Force faced an advanced integrated air defense system (IADS) while bombing targets in North Vietnam. The US Army faced the dual challenges of finding enemy radio signals in Vietnam's unforgiving terrain and later in the war, protecting their rotary and fixed-wing aircraft from radar-guided air defense weapons.

In the recently declassified monograph, "Electronic Countermeasures in the Air War Against North Vietnam 1965-1973," Bernard C. Nalty argues that the critical event that signaled the beginning of EW within the air domain in Vietnam was the downing of Leopard 02 on July 24, 1965, by a Russian-made SA-2 "Guideline."[29] Leopard 02 was an F-4C Phantom that was a part of a four-ship flight protecting other aircraft bombing targets in North Vietnam. The radar-guided SA-2 missile exploded directly below the aircraft causing severe damage that killed the co-pilot and forced the pilot to eject.[30] The SA-2 forced the US Air Force to change its tactics, create new organizations, and develop EW technology to protect aircraft.

During the Vietnam War, US Army rotary-wing aircraft did not face significant radar-guided air defense weapons until 1971 during Operation Lam Son 719.[31] During this operation, three divisions of South Vietnamese soldiers, supported by US Army helicopters from the 101st Airborne Division, conducted offensive operations in Laos to disrupt the flow of supplies to the

[29] Bernard Nalty, "Electronic Countermeasures in the Air War Against North Vietnam 1965-1973" (Monograph, Office of Air Force History, Headquarters, USAF, 1977), 1.

[30] Ibid.

[31] Price, *The History of US Electronic Warfare, Volume I*, 178–179.

NVA from the Ho Chi Minh Trail.[32] The difference between US Army helicopter losses and US Air Force fixed-wing losses during Lam Son 719 suggests that the US Army was unprepared to conduct operations while fighting a sophisticated IADS with experienced operators.[33]

Electronic Warfare Support in Vietnam

Electronic warfare support and SIGINT operations conducted by the ASA in Vietnam started on May 31, 1961, when the 400th ASA Special Operations Unit (provisional) arrived at Tan Son Nhut Air Base.[34] Using the cover name, "3rd Radio Research Unit" (3d RRU), they began conducting SIGINT and radio direction-finding under OPLAN 7-61, named "Whitebirch."[35] OPLAN 7-61 was meant to increase the US direction-finding and SIGINT in South Vietnam, focusing primarily on insurgent forces operating in the south.

In the declassified history of SIGINT in Vietnam, *Spartans in the Darkness*, Robert Haynock discusses the tensions between the NSA and the ASA. The ASA believed that the intelligence value of intercepting and listening to NVA and VC radio communications was, for the most part, not worth the effort. They argued that the best tactic was to conduct direction-finding on NVA and VC radio signals, geolocate the emission source, and then pass that information to the Army of the Republic of Vietnam (ARVN), who could then target the emitter and nearby enemy forces for destruction.[36]

Post-Vietnam to Operations Desert Shield and Desert Storm

Following the Vietnam War, intelligence and EW in the US Army changed dramatically. These changes began when GEN Frederick Weygand commissioned the Intelligence

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[32] Nguyen Duy Hin, *Lam Son 719* (Washington, DC: U.S. Army Center of Military History, 1979), 45–47.

[33] Ibid., 128.

[34] Robert Hanyok, *Spartans in Darkness: American SIGINT and the Indochina War, 1945-1975, VI: The NSA Period: 1952-Present* (Fort Meade, MD: Center for Cryptologic History, 2002), 123.

[35] Ibid.

[36] Ibid., 124.

Organization and Stationing Study in 1974.[37] Headed by MG James Ursano, this panel examined the US Army's intelligence and EW programs. In the final report, the ASA was judged particularly harshly. According to the panel, "the ASA pattern of organization had actually impeded the development of an efficient mechanism for carrying out intelligence and electronic warfare." The report also critiqued the secrecy under which the ASA operated, stating "compartmented secrecy had artificially kept signals intelligence out of the general intelligence flow and had largely excluded the rest of the Army from involvement in the vital electronic warfare field."[38]

Based on the report's recommendations, the Army established the US Army Intelligence and Security Command (INSCOM) in January 1977 by redesignating the ASA and moving several other intelligence organizations to the new command.[39] For US Army EW, the establishment of INSCOM was just as important as the establishment of the ASA had been in 1945. INSCOM and US Army Training and Doctrine Command (TRADOC) would spearhead the establishment of Combat Electronic Warfare and Intelligence (CEWI) brigades, battalions, and companies that would house EW in the US Army until 2004.[40] These new organizations had dedicated units for jamming, EW support, SIGINT, and aerial-based electronic intelligence.

The establishment of the CEWI brigades, battalions, and companies led to a flurry of doctrine development for the new organization's employment as part of the AirLand Battle concept of warfare. In the early 1980s, the Army released a series of field manuals for EW, The new CEWI battalions and companies to replace the interim doctrine and training publications developed shortly after the ASA's deactivation. Army FM 32-20 *Electronic Warfare,* FM 34-10 *Military Intelligence Battalion (CEWI),* and FM 34-11 *Ground Surveillance Company, Military*

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[37] Finnegan, *Military Intelligence,* 170–71.

[38] Ibid.

[39] Ibid., 174.

[40] Ibid., 180.

Intelligence BN (CEWI) were released soon after TRADOC Pamphlet 525-5 *The Airland Battle and Corps 86.* These new CEWI field manuals codified the EW operational concepts from TRADOC Pamphlet 525-5 and informed the 1982 edition of FM 100-5 *Operations,* which described how the Army would enable its operational concept of AirLand Battle.[41] From the early 1980s until the start of Operation Desert Shield, CEWI doctrine continued to evolve. By the beginning of Operation Desert Shield, most CEWI field manuals and training publications were on their second or third version.

Purpose-built EW equipment was required For the CEWI units to be successful. To equip the new units, the US Army fielded several systems that could conduct EW support and electronic attacks. As early as 1979, the 522nd CEWI Battalion (Provisional) of the 2nd Armored Division fielded the AN/TRQ-37 Tacfix, the AN/TLQ-17 Traffic Jam, the TRR-20 multi-channel receiver, and the MLQ-24 radar interceptor.[42] Over the next decade, this equipment would be upgraded or replaced with more sophisticated systems. By the beginning of the Gulf War, the US Army had already equipped CEWI units with upgraded versions of the AN/TLQ-17 Traffic Jam, AN/TSQ-114A Trailblazer, AN/MLQ-34 Tacjam, and AN/ALQ-151 Quick Fix.[43] The creation of CEWI units, doctrine, and new equipment enabled the US Army's EW enterprise to conduct all three subdisciplines of EW for the first time in its history.

This section reviewed what has been written about EW and how it was employed and developed by the US military and Allied forces during previous conflicts. Concurrently, it examined what has been written about the US Army's adaptations to doctrine, organizational structures, and materiel development during and between those conflicts. The following section presents the methodology used during this study.

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[41] US Department of the Army, Field Manual (FM) 100-5, *Operations* (Washington, DC: Government Printing Office, 1982).

[42] Bigelow, "A Short History of Army Intelligence," 48.

[43] US Department of the Army, Field Manual (FM) 34-80, *Brigade and Battalion Intelligence and Electronic Warfare Operations* (Washington, DC: United States Government Printing Office, 1986), 2–40.

Methodology

This study used a qualitative research approach. A structured and focused comparison method was used to examine and understand how the US Army has integrated EW during combat operations, what lessons it has learned, and how those lessons may apply to the EW enterprise against future adversaries. This study used this method because "The method and logic of structured, focused comparison is simple and straightforward."[44] This research aimed to understand how the US Army has integrated EW capabilities during previous conflicts, what lessons it learned, and if those lessons apply to the future.

Primary and secondary sources were used when researching this study. The majority of primary sources used came from the Ike Skelton Combined Arms Research Library's online archives at Fort Leavenworth. Primary sources consisted of official reports, first-hand accounts, press releases, interviews, technical manuals, autobiographies, and US Army field manuals and doctrine. Secondary sources consisted primarily of historical studies of EW during World War Two, specifically Operation Overlord, the Vietnam War, and Operations Desert Shield and Desert Storm.

The historical case studies chosen examined one or more of the subdisciplines of EW. Each case study provided clear examples of one or more EW subdisciplines used by the US Army or its allies during combat operations. The first case study examined EW contributions to Operation Overlord during World War Two. The second examined what role EW support played during the Vietnam War. The third case study focused on defensive electronic attacks by US Army Aviation during Operations Desert Shield and Desert Storm. In addition, this study examined developments made in EW during the interwar periods to understand the lessons learned between conflicts.

[44] Alexander L. George and Andrew Bennett, *Case Studies and Theory Development in the Social Sciences* (Cambridge, MA: MIT Press, 2005), 68.

Operation Overlord provided an example of the planning, resourcing, integration, and execution of all three EW subdisciplines during a single operation. Operation Overlord is a unique example of a massive joint operation that successfully used lessons learned earlier in the war to attack, support, and defend allied forces, while also contributing to the deception plan.

Research into EW during Vietnam served two purposes for this study. The primary objective was to investigate how the US Army conducted EW support from fixed-wing, propeller-driven aircraft to enable maneuver forces. The secondary purpose was to understand North Vietnam's formidable IADS. This IADS was a testbed for some of the same Russian equipment and tactics that US and Allied pilots faced during Operations Desert Shield and Desert Storm.

The study of Operations Desert Shield and Desert Storm focused on how the US Army quickly acquired, installed, repaired, and utilized defensive electronic attack equipment and tactics in its fleet of rotary-wing aircraft against a sophisticated Iraqi IADS. In addition to examining EW equipment employed by US Army Aviation, this study traced the US Army Aviation doctrine progression between the Vietnam War and Operation Desert Shield.

This study used three standardized questions to provide structure and focus to the case studies. As stated by Alexander George and Andrew Bennett, "The importance of formulating a set of standardized, general questions to ask of each case will be of value only if those questions are grounded in–and adequately reflect–the theoretical perspective and research objectives of the study."[45]

1. How had the US Army employed EW earlier in this conflict?
2. How did doctrine or organizations change to incorporate lessons learned during this period?
3. What advances were made to materiel and equipment during this period?

[45] George, *Case Studies and Theory Development in the Social Sciences*, 71.

Answering the three questions for each case study should answer the two secondary research questions and meet the research objectives. Using three standardized questions for each case study should enable cross-analysis between conflicts and show trends and reoccurring EW employment patterns, development, and lessons learned.

Case Studies

Operation Overlord

The size of the allied invasion force, the complexity of the operation, and the consequences for failure made Operation Overlord the largest and most critical amphibious operation of World War Two.[46] The seaborne and airborne invasions that marked the operation's beginning were preceded by significant shaping operations and a complex deception plan. Using lessons learned from the allied air campaign in Europe and previous amphibious operations, allied planners successfully integrated all three subdisciplines of EW into Operation Overlord. Electronic warfare contributions to Operation Overlord are virtually impossible to quantify but contributed to mission success. This case study focused primarily on the integration of electronic attack and EW support during Operation Overlord and the supporting deception plans.

When planning for Operation Overlord late in 1943, the allied EW enterprise's goals began with the assumption that the Luftwaffe would not be able to mount an effective air campaign to counter the invasion, giving the allies air superiority over the landing sites.[47] With the assumption of air superiority, the allies focused their EW efforts on achieving four aims: preventing early warnings of surface and air forces, preventing radar-controlled coastal fires, supporting airborne operations, and delaying enemy reserve forces movement through military

[46] Mary Barbier, *D-Day Deception: Operation Fortitude and the Normandy Invasion* (Westport, CT: Praeger Security International, 2007), Kindle, chap. 1.

[47] Price, *The History of US Electronic Warfare, Volume I*, 116.

deception.[48] These four aims became the plan of action that successfully integrated all three EW subdisciplines into Operation Overlord.

Locating and destroying radars on the coasts of France and Belgium was paramount to prevent early warning of surface vessels and aircraft to increase the likelihood that the Allied deception plan would work.[49] Before D-Day, the 6th of June 1944, British and American electronic reconnaissance aircraft and bombers flew countless missions to locate and destroy the estimated ninety-two radar sites that would be able to provide early warning of an approaching invasion force.[50] Regardless of how effective the allied air campaign was in destroying the German coastal radars, a massive jamming operation was still planned to blind and deceive whatever remained on D-Day.[51]

The electronic attacks designed to blind German coastal radars in France and Belgium started the night before the landings and came from both the air and the sea. As the Allied air armada formed over England, British and American EW aircraft began the electronic barrage by blinding enemy search radars with Mandrel spot jammers set to low-frequencies.[52] At H-7, at least 420 ship-based jammers of different powers created a wall of electronic interference that screened the entire invasion fleet.[53] As Allied ships moved within the German artillery range, the ships changed their jammers' frequencies to blind German artillery radars, reducing their surface-to-surface fires' accuracy.[54] Once the seaborne assaults commenced, the Allied armada turned off their shipborne jammers and shifted EW support and attack duties to specially trained EW

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[48] Price, *The History of US Electronic Warfare, Volume I*, 116.

[49] George Thompson and Dixie Harris, *The Signal Corps: The Outcome (Mid-1943 Through 1945)* (Washington, DC: Center of Military History, United States Army, 1991), 98.

[50] Price, *The History of US Electronic Warfare, Volume I*, 116–17.

[51] Thompson, *The Signal Corps*, 99.

[52] Ibid.

[53] Ibid.

[54] Ibid.

personnel.[55] These teams searched the EMS for German radars and conducted electronic attacks that were designed to not interfere with Allied air-defense radars protecting the fleet and the troops onshore.[56]

The allied deception plan for Operation Overlord consisted of multiple long-running operations with the primary objective to convince the Germans that the Allied invasion was going to take place at Pas-de-Calais and not in Normandy.[57] In the Allied deception plan, the role of EW was to create an electronic signature indicating a vast fleet of ships and aircraft approaching Pas-de-Calais.[58] To make the electronic signature for the fake air armada, Dr. Robert Cockburn, an EW expert from the Telecommunications Research Establishment, planned on having a small number of aircraft drop large amounts of radar chaff (known as "rope") in a portion of the airspace that German radar monitored.[59] The rope would give the impression that many aircraft were attempting to jam early warning radars and radar-laid air defense guns, a technique used countless times over Europe by the 8th Air Force.[60] The hope was that this large and fake Allied air armada, called Operation Taxable, would trigger the Germans to commit or delay their reserve's movement to Pas-de-Calais, buying time for the allies to establish a foothold on the Normandy beaches.

The second part of the EW deception, Operation Glimmer, occurred on the sea the night before D-Day. Cockburn procured a total of eighteen small ships, each equipped with a "Moonshine" radar repeater and a twenty-nine-foot balloon, known as a "Filbert," which created an airborne radio-echo in German radars.[61] In addition, smoke generators and megaphones

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[55] Thompson, *The Signal Corps*, 99.

[56] Ibid.

[57] Barbier, *D-Day Deception*, chap. 4.

[58] Ibid.

[59] Ibid.

[60] Price, *The History of US Electronic Warfare, Volume I*, 125-126.

[61] Barbier, *D-Day Deception*, chap. 4.

broadcasting sounds of large ships anchoring added additional credence to the Operation Glimmer story.[62] These combined effects created an electronic, audio, and visual signature that resembled a combined air and naval force approaching Pas-de-Calais.

Operations Glimmer and Taxable attempted to convince the Germans that an invasion force was approaching Pas-de-Calais during Operation Overlord. Based on the Luftwaffe high command's telephone messages, it was highly likely they believed some portion of the deception story that Operation Glimmer was attempting to sell.[63] Although Allied aircrews performed Operation Taxable correctly, it appears that it was not noticed by the Germans, given that there are no mentions of it in German dispatches on June 5th or 6th.[64]

During Operation Overlord, EW operations achieved most of the goals that the Allies set out when the planning began in early 1943. The combined EW support and strike operations in the months leading up to the invasion reduced German operational radars from ninety-two to sixteen.[65] Jamming operations from the air and sea resulted in only one German radar monitoring the entire allied air and sea armada approach.[66] German forces also directed some of their limited Luftwaffe assets to investigate the area where Operation Taxable operations were occurring.[67] Operation Overlord confirmed the importance of EW to the allies and validated many of the tactics and equipment.

Question one: How had the US Army employed EW earlier in the conflict?

Before Operation Overlord, the United States Army Air Forces (USAAF) had focused their EW efforts towards finding and countering German early-warning radars and radar-laid anti-

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[62] Barbier, *D-Day Deception*, chap. 4.

[63] Ibid., chap. 8.

[64] Price, *The History of US Electronic Warfare, Volume I*, 129.

[65] Ibid., 125–26.

[66] Ibid., 128.

[67] Thompson, *The Signal Corps*, 100.

aircraft guns. In early 1943, modified B-24D Liberator bombers, equipped with electronic reconnaissance equipment, flew a series of test missions over the Aleutian Islands chain in Alaska that succeeded in locating Japanese early-warning radars.[68] These modified aircraft designed for electronic reconnaissance were designated as "ferrets" and became an essential element of USAAF and British Royal Air Force (RAF) EW support operations for the remainder of the war.[69]

Knowing the location of enemy early-warning radar and radar-laid anti-aircraft guns did not make them less dangerous if they could not be avoided, jammed, or destroyed. As the allies moved to a bombing campaign over Europe and Germany, additional EW countermeasures, tactics, and organizations were needed to keep aircraft and aircrew safe from Germany's integrated air defenses. To counter the German air defenses, the USAAF and RAF relied on radar jamming and blinding techniques utilizing aluminum foil bunches known as chaff, window, or rope.[70] Virtually none of the EW technology or tactics used by the USAAF or RAF during World War Two were available at the beginning of the war.[71] The tactics and technology that made these three countermeasures effective developed throughout the war by trial and error.

In the land domain, the US Army was almost entirely divested from radio jamming.[72] The primary reason that the Allies did not prioritize the development of ground-to-ground radio jamming during World War Two is due to the effectiveness of Allied intelligence services decryption of radio transmissions.[73] Communications jamming was rarely permitted except in exceptional circumstances, despite having the necessary equipment. One such instance was in

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[68] Price, *The History of US Electronic Warfare, Volume I*, 52–55.

[69] Ibid.

[70] Thompson, *The Signal Corps*, 307–8.

[71] Price, *The History of US Electronic Warfare, Volume I*, 11.

[72] Thompson, *The Signal Corps*, 301.

[73] Price, *The History of US Electronic Warfare, Volume I*, 118.

December of 1944 during the Battle of the Bulge when three American B-24s using a Jackal radio jammer flew over German formations to jam tank communications.[74] There is very little evidence showing Allied forces ever purposely conducted ground-to-ground radio jamming in any theater during World War Two.

The US Army was heavily active in EW support throughout World War Two, especially radio direction finding. War Department, Field Manual 11-35, *Signal Corps Intelligence,* clearly delineates subordinate units' responsibilities within the Army Signal Corps regarding radio direction finding and SIGINT.[75] Electronic warfare support operations in World War Two closely resembled what the US had done during World War One. Signal Corps personnel remained responsible for the technical aspects of geolocation of radio signals, and Intelligence personnel remained accountable for the translation, analysis, and dissemination of information related to SIGINT.[76]

Question two: How did doctrine or organizations change following this period to incorporate lessons learned?

The majority of changes to EW doctrine and organizations did not occur until immediately after World War Two. The most notable change that occurred directly after Operation Overlord was within the air domain. In the USAAF, the most significant change was to organizations and was forced by adding an EW crewmember to the B-24 bomber.[77] On land, the vast majority of US Army forces received their first exposure to combat and used EW doctrine and organizations developed earlier in the war or before the war even started.[78] This combat

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[74] Price, *The History of US Electronic Warfare, Volume I,* 118.

[75] War Department, Field Manual (FM) 11-35, *Signal Corps Intelligence* (Washington, DC: Government Printing Office, 1942), 4–6.

[76] Lori Tagg, "Tactical Signals Intelligence Originates in World War I," US Army, June 25, 2017, accessed November 10, 2020, https://www.army.mil/article/191282/tactical_signals_intelligence_originates_in_world_war_i.

[77] Price, *The History of US Electronic Warfare, Volume I,* 165.

[78] War Department, FM 11-35, *Signal Corps Intelligence,* 5–8.

resulted in doctrinal and organizational changes to the US Army's ground-based EW enterprise, but they were not enacted until after the war.

The air domain in Europe remained highly contested after the invasion. Between January and July of 1944, combat losses to the German IADS increased dramatically as the Allies began bombing more heavily defended targets in Germany.[79] Because of the increased risk and counteractions of the Luftwaffe, the allies started installing EW systems into a far greater percentage of their bomber fleet. From July 1944 to January 1945, the number of allied bombers with the AN/APT-2 "Carpet" jammers installed rose from 196 to 3,967; 507 of which required an additional crewmember to operate.[80] This requirement forced the USAAF to develop organization, training, and manning solutions to meet the increased demand for new crewmembers.

Question three: What advances were made to materiel and equipment during or following this period?

Before World War Two began, the US military recognized that if radar and radio could see aircraft and ships and provide wireless communications over vast distances, someone would develop countermeasures to prevent their use.[81] At the start of World War Two, the United States military had minimal ability to conduct the three subdisciplines of EW in the land and air domain. For the United States and its Allies, countering German and Japanese radar and radios while protecting their own sparked a technology revolution. The two types of technologies that advanced the most during World War Two were radar jammers and expendable countermeasures.

In the air and sea domain, the jammers that were most important during World War Two for the US and its Allies were the AN/APT-1 "Dina," AN/APQ-9 "Carpet," AN/APQ-2 "Rug,"

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[79] Price, *The History of US Electronic Warfare, Volume I*, 105.

[80] Ibid., 168.

[81] Devereux, *Messenger Gods of Battle*, 75–78.

and the AN/APT-3 "Mandrel."[82] These systems had been put into production by RRL starting in 1943 and were designed to counter all known and expected German and Japanese radars.[83] By the end of the war, 55,495 of these units had been produced and installed in USAAF and Allied bombers, with an additional 1,550 shipborne versions built and installed into allied ships.[84]

In the land domain, the AN/MRQ-1/2, the AN/MRT-1 "Cigar" radio jammers, and the AN/CRT-2 and PRT-1 expandable jammers were listed in the inventories of US Army Signal Corps equipment.[85] Of these three, the AN/MRT-1 stands out due to its size; it was purpose-built for radio jamming and was not a modification of existing radios like the AN/MRQ-1/2.[86] The AN/MRT-1 was a massive, 50-kilowatt transmitter with a two-hundred-mile range designed to jam airborne radio communications.[87] It was not needed during Operation Overlord due to a lack of German fighter resistance but was later modified to disrupt radio frequencies that were thought to control the German V2 rockets.[88] While not used in combat during World War Two, large radio jammers like the AN/MRT-1 showed that jamming radio signals from long distances was possible and had potential military value.

The RRL began experiments on the efficacy of using expandable countermeasures, known as "chaff" and "Window," to disrupt radars in 1943.[89] The concept for their use was to have aircraft drop large quantities of thin foil when they flew within range of a radar. This metal foil reflected radar waves from the ground and bounced them in different directions, effectively

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[82] Thompson, *The Signal Corps*, 312.

[83] Price, *The History of US Electronic Warfare, Volume I*, 60–62.

[84] Ibid., 272–73.

[85] Thompson, *The Signal Corps*, 656.

[86] Ibid.

[87] Ibid.

[88] Price, *The History of US Electronic Warfare, Volume I*, 180.

[89] Ibid., 31–32.

blinding the radar operator's scope and disrupting radar-guided air defense guns.[90] By the end of the war, the United States and Great Britain had produced 30,000 tons of chaff, Window, and Rope, costing $39 million.[91]

Vietnam

Following the Korean War, the United States once again found itself fighting a war in Asia against a determined enemy, in rugged terrain, and with a military that was not well prepared. The US Army had done very little to develop their EW enterprise following the Korean War, and the US Air Force and US Navy had focused their efforts on protecting aircraft and ships. During Vietnam, much like World War Two, the US Army quickly developed new EW equipment, trained operators, and linked everything to provide valuable capabilities. With the establishment of the US Air Force in 1947 as an independent service, and given the nature of counterinsurgency warfare in Vietnam, US Army EW did not play as prominent a role as it had during World War Two. However, ASA operations and Lam Son 719 significantly impacted the EW enterprise in the US Army throughout Vietnam until the start of Operation Desert Shield.

For the US Army, EW during Vietnam centered on the ASA's actions and its conduct of SIGINT and EW support operations. For the US Air Force and Navy, EW focused almost entirely on protecting aircraft from the North Vietnamese IADS. United States Army aviation also faced numerous air-defense weapons throughout the war but was not exposed to the full breadth of the North Vietnamese IADS until 1971, while supporting Operation Lam Son 719.[92]

During Vietnam, conducting EW support operations from the ground proved untenable due to the terrain. Less than a year after the 3d RRU arrived in Vietnam, it started developing

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[90] Doug Richardson, *An Illustrated Guide to the Techniques and Equipment of Electronic Warfare* (New York: Arco, 1985), 84.

[91] Price, *The History of US Electronic Warfare, Volume I*, 251.

[92] John Tolson, "Vietnam Studies," *Airmobility 1961-1971* (Washington, DC: Department of the Army, 1973), 245–46.

systems and tactics that could conduct airborne radio direction-finding (ARDF).[93] By installing ground-based direction-finding equipment in US Army fixed and rotary-wing aircraft, the ASA overcame Vietnam's terrain challenges. Over time, most ASA units in Vietnam were integrated into US Army divisions and brigades and provided them with valuable intelligence that could not be obtained by other means.[94] The ASA's organizational changes and equipment developed during Vietnam became a lasting component of the US Army EW and intelligence enterprises.

When the 3rd RRU arrived in Vietnam in 1961, their initial plan was to utilize current ground-based radio direction-finding technology to geolocate the radio signals used by the VC.[95] Once the ASA identified and geolocated the VC signals, their location was passed to South Vietnamese units to conduct a ground operation to destroy the emitter and enemy.[96] Several problems emerged early during operations that made this approach untenable. Vietnam's terrain and weather were ill-suited for ground-based direction finding and made operations from a fixed-site location ineffective. In addition, the current generation of ASA equipment could not conduct effective direction-finding from fixed ground sites, which limited the amount of targetable information provided to the ARVN.[97] Terrain and technology limitations forced ASA soldiers to operate direction-finding equipment in the field where the danger of enemy attack was significantly greater. The first ASA casualty occurred in 1961, when Specialist 4, James T. Davis, was returning from a direction-finding mission with a contingent of ARVN soldiers, and the VC ambushed his convoy.[98] The death of Specialist 4 Davis made clear to the ASA that their current direction-finding methods were not only ineffective but becoming increasingly dangerous.

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[93] Hanyok, *Spartans in Darkness*, 129.

[94] Finnegan, *Military Intelligence*, 148.

[95] Hanyok, *Spartans in Darkness*, 125.

[96] Ibid.

[97] Ibid., 125–28.

[98] Hanyok, *Spartans in Darkness*, 127.

Airborne radio direction-finding in Vietnam came about as a necessity to solve the problems that ground-based direction-finding made apparent early in the war.[99] In the fall of 1961, the ASA attempted to develop technology that would increase the number of radio transmissions they could intercept and direction-find from the abysmal 5 percent rate achieved at that point in the war.[100] While some improvements to direction-finding technology occurred during the interwar period, little of it translated well to an airborne platform.[101] The best available system, the AN/ARD-15 Direction Finding Set, was selected and modified for testing in both helicopters and fixed-wing propeller-driven aircraft.[102]

The AN/ARD-15, when paired with the UH 6-A Beaver, proved to be the most viable candidate for a combat environment.[103] Following a trial-and-error period, the aircraft, now designated the L-20, began flying ARDF missions on March 22, 1962, and in four weeks located six VC headquarters.[104] By the end of 1962, the ASA had flown 162 missions and located 23 transmitters tied to 16 enemy headquarters.[105] The ASA had overcome the terrain and technological limitations by developing new technology and shifting from ground-based direction-finding to airborne direction-finding. Despite overcoming these significant challenges, the joint ASA and ARVN operation's weakness became apparent early in 1963.[106]

The ASA mission was reexamined after the success of the L-20 and ARDF. The ARDF had proved helpful in locating VC emitters in South Vietnam and the ASA wanted to capitalize

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[99] Ibid., 120–23.

[100] Ibid., 129.

[101] Price, *The History Of US Electronic Warfare, Volume II*, 270–71.

[102] Hanyok, *Spartans in Darkness*, 130.

[103] Ibid., 131.

[104] Ibid.

[105] Ibid., 133.

[106] Ibid., 135.

on this and focus almost entirely on providing tactical intelligence to ARVN ground forces.[107] This transition was not without friction as the National Security Agency still believed that the ASA should focus on SIGINT operations with operational and strategic implications rather than radio direction-finding at the tactical echelon.[108] The ASA provided relatively accurate locations of VC emitters in South Vietnam, but conducting ground operations to destroy them fell to the ARVN at this stage of the war. One of the biggest failures that demonstrated joint ASA and ARVN operational weakness occurred on January 2, 1963, in Ap Bac village, located in Dinh Toung province.[109]

Before the Ap Bac village operation, ASA direction-finding teams located a transmitter belonging to a 120-person company of VC operating near the village.[110] A 2,500 strong ARVN force from the 7th Infantry Division moved into the village in armored personnel carriers supported by US combat aircraft and helicopters.[111] During the battle, the ARVN suffered more than 200 casualties; while 5 US helicopters were shot down trying to evacuate casualties and fly-in reinforcements, killing 3 US military advisors and aircrew and wounding 7 more.[112] Only three VC bodies were found, another dozen were believed to have been removed during the VC withdrawal.[113]

Throughout 1963, the ARVN conducted at least fifteen other operations based on ASA ARDF intelligence.[114] Information into how successful these operations were is mixed, South

[107] Hanyok, *Spartans in Darkness*, 134.

[108] Ibid.

[109] Ibid., 135.

[110] Ibid.

[111] Ibid.

[112] Ibid.

[113] Ibid.

[114] Hanyok, *Spartans in Darkness*, 137.

Vietnam reported success while US military advisors reported mediocre results.[115] At the end of 1963, a political upheaval within South Vietnam curtailed ARVN and ASA joint operations in favor of ASA and NSA operations supporting the Central Intelligence Agency and their intelligence operations in North Vietnam.[116]

Starting in 1965, the ASA responded to the massive increase in US ground troops in Vietnam by deploying detachments, companies, and battalions in a direct support role to US Army brigades and divisions.[117] Between 1965 and 1968, at least twenty-two ASA elements were deployed to Vietnam, with twelve arriving between June 1965 and 1966 alone. These deployments included an entire battalion of ADRF aviation.[118] When US Army divisions or brigades were conducting operations, the direct support ASA unit would deploy mobile teams to support operations.[119] Using ground-based fixed and mobile direction-finding sites in conjunction with ARDF, the ASA provided tactical intelligence directly to US Army ground units.[120]

Despite robust direct support to US Army ground units, weaknesses in the overall SIGINT and direction-finding efforts in Vietnam became apparent in 1967.[121] One of the main issues with SIGINT and direction-finding in Vietnam was that no single agency managed all information for the Military Assistance Command Vietnam, which led to an incomplete picture of the EMS.[122] This lack of coordination within the US intelligence and EW communities was not restricted to just SIGINT and direction-finding, but also EW in the aviation community.

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[115] Ibid.

[116] Ibid., 151.

[117] Ibid., 291.

[118] Ibid.

[119] Ibid., 290.

[120] Ibid.

[121] Ibid., 298.

[122] Hanyok, *Spartans in Darkness*, 298.

The purpose of the South Vietnamese operation Lam Son 719 was to seize a North Vietnamese supply depot near Tchepone, Laos, and disrupt the flow of supplies from the Ho Chi Minh Trail into South Vietnam through Laos and Cambodia.[123] During Lam Son 719, most rotary-wing aviation support for the ARVN was furnished by US forces, with the 101st Airborne Division providing the bulk of the support for the duration of the operation.[124] By the end of Lam Son 719, the US Army had lost 92 helicopters, suffered 102 dead, 215 wounded, and 53 crewmembers were missing in action.[125] NVA forces, equipped with large numbers of air defense guns and new shoulder-fired surface-to-air missiles (SAM), inflicted losses that forced US Army Aviation leaders to examine their tactics, munitions, survivability, and EW equipment.

The NVA force that US Army helicopter pilots faced in Laos during Lam Son 719 was completely different than anything it faced in the war to that point. During previous operations in Vietnam and Cambodia, most NVA and VC forces were light infantry, with 7.62-mm and 12.7-mm machine guns used to defend against helicopters.[126] During Lam Son 719 in Laos, US helicopters had their first encounters with NVA tanks and 23-mm, 37-mm, and 57-mm air-defense guns, some of which were radar-guided.[127] In addition to the air-defense guns, the NVA employed Russian-made, shoulder-fired SA-7 "Grail" infrared SAMs.[128]

Without even rudimentary EW countermeasures or radar warning receivers, US Army pilots had no way of knowing if infrared or radar-guided weapons were engaging them.[129] The lack of EW equipment in US Army helicopters during Lam Son 719 forced an examination and

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[123] Duy Hin, *Lam Son 719*, v.

[124] Ibid., 175–76.

[125] Ibid., 128.

[126] Tolson, *Airmobility 1961-1971*, 245.

[127] Ibid.

[128] Alfred Price, *The History of US Electronic Warfare, Volume III: Rolling Thunder Through Allied Force, 1964 to 2000* (Arlington, VA: The Association of Old Crows, 2000), 179.

[129] Price, *The History of US Electronic Warfare, Volume III*, 179.

debate on helicopter survivability during high-intensity conflicts against a near-peer adversary.[130] These examinations and discussions, and the solutions that came from them continued until the end of Vietnam, through the interwar period, and to Desert Shield.

Question one: How had the US Army employed EW earlier in the conflict?

Signal's intelligence and radio direction-finding operations conducted by the ASA began almost immediately after arriving in 1961 and lasted until 1973.[131] From the beginning of the Vietnam War, US Army EW focused almost entirely on radio direction-finding operations conducted by the ASA to support ground forces. The ASA quickly recognized the value in radio-direction finding, both in supporting SIGINT operations and as a way to provide actionable intelligence to ground units rapidly. The ASA did not conduct electronic attacks against the VC or NVA throughout the war because they did not see its value compared to the potential intelligence gained by interception.

The US Air Force and Navy used EW equipment and tactics to protect aircraft from the North Vietnamese IADS since 1965. US Army rotary aviation entered Lam Son 719 with no EW equipment to defend their helicopters and little experience fighting against an enemy with advanced air defense systems. It was not until after Lam Son 719 that US Army Aviation began to develop EW technology to counter radar and infrared-guided air defense missiles and guns.[132] Lam Son 719 forced US Army Aviation to consider the full range of guided and unguided air defense weapons that could be employed against helicopters.

Question Two: How did doctrine or organizations change to incorporate lessons learned during this period?

The most significant changes within the ASA during Vietnam were the organizational changes that occurred beginning in 1965. As the US Army presence grew in Vietnam, structure

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[130] Tolson, *Airmobility 1961-1971*, 252.

[131] Hanyok, *Spartans in Darkness*, vi – ix.

[132] Price, *The History of US Electronic Warfare, Volume III*, 180.

was needed to provide divisions, brigades, and battalions with SIGINT and radio direct-finding support. This structure would also need to determine a way to centrally manage the limited ARDF support in Vietnam. The resulting organizational structure employed by the ASA from 1965 onward was the result of two factors. The first, and most obvious factor was the massive increase in US Army ground units that began in 1965.[133] The second factor was the problems identified while supporting ARVN ground forces from 1961 to 1965 with ARDF.

The escalation of US involvement in Vietnam between 1965 and 1967 resulted in a dramatic increase in the number of troops in the country. Troop counts at the end of 1965 reached 184,000, and by 1967 had reached almost 500,000.[134] The ASA followed a similar growth trajectory between June of 1965 to July of 1968.[135] Vietnam became the ASA's main effort, with approximately 5,000 of the total 30,000 ASA forces deployed to Vietnam from 1965 to 1973.[136] To better support ground combat operations, the ASA changed the structure of direct support units assigned to the divisions, brigades, and battalions.[137] In most cases, an ASA company would be assigned to a division, and the company would provide detachments to support the brigades and regiments.[138]

The design of ASA detachments provided flexibility to ground forces and a touchpoint for ASA planes that may be flying ARDF missions in support of the unit.[139] Each company carried a mix of vehicle-mounted and man-portable signal intercept and radio direction-finding equipment customizable to support field operations lasting several weeks.[140] Company-sized

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[133] Hanyok, *Spartans in Darkness*, 285.

[134] Ibid.

[135] Ibid., 291.

[136] Finnegan, *Military Intelligence*, 147.

[137] Hanyok, *Spartans in Darkness*, 289.

[138] Ibid.

[139] Hanyok, *Spartans in Darkness*, 289

[140] Ibid., 289–90.

direct support units generally operated four semi-fixed sites from a base camp and have one available for mobile operations. In comparison, independent detachments maintained two fixed sites and one mobile team.[141] Organizational changes to direct support unit employment also helped solve some of the weaknesses seen during ASA operations with the ARVN before 1965. Having ASA members embedded with ground forces enabled them to pass on information to commanders quickly.

Question 3: What advances were made to materiel and equipment during or following this period?

Advances in EW technology in the US Army during and immediately following Vietnam were primarily to radio direction-finding equipment and aircraft. These developments increased the ASA's ability to perform these missions, but major leaps in SIGINT and EW support technology did not occur until after Vietnam.[142] Compared to the pace of EW technology development in the US Air Force and Navy, EW technology in Army aviation developed much slower during and after Vietnam, significant expansion of EW systems designed to protect US Army rotary-wing aviation did not happen until after the war.

When the ASA began to commit forces to Vietnam in 1961, their direction-finding equipment (AN/PRD-1 and AN/TRD-4) was from the 1950s and ill-suited for operations on anything but flat terrain without vegetation.[143] Two civilian experts, Herb Hovey and Harold Jaffe spent a month in Vietnam gathering information and then returned to the US to begin testing potential AN/PRD-1 replacements.[144] The recently developed AN/ARD-15 proved to be the best system, but to overcome the terrain in Vietnam meant that it would need to be airborne.[145] After

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[141] Ibid., 290.

[142] Price, *The History of US Electronic Warfare, Volume III*, 282.

[143] Price, *The History Of US Electronic Warfare, Volume II*, 270.

[144] Ibid.

[145] Hanyok, *Spartans in Darkness*, 130.

testing both rotary and fixed-wing aircraft, the U-6A "Beaver" emerged as the best platform to carry the new system.[146] By configuring the U-6A with two dipole antennas on the wings, the AN/ARD-15 could essentially turn the plane itself into a direction-finding antenna, overcoming the terrain and weather in Vietnam.[147] Through the rest of the war, the ASA continued to develop and improve the AN/ARD-15, its components, and the aircraft that carried it.

Shortly after the end of Vietnam, the US Army invested in new aircraft and systems to conduct airborne radio direction-finding, electronic intelligence, and SIGINT. The most significant addition was the Guardrail V system that the US Army purchased in 1978.[148] This purchase included three Guardrail V systems and twenty-one RU-21H aircraft.[149] The Guardrail Common Sensor was initially developed in 1971 and designed to conduct ARDF, SIGINT, and electronic intelligence in direct support to US Army corps.[150] One of this system's key features is that the equipment is operated remotely through the ground-based Integrated Processing Facility.[151] The Guardrail Common Sensor provides a near real-time multidiscipline intelligence airborne collection capability to the US Army that was still in service at the start of Desert Shield.[152]

The most effective EW countermeasure for helicopters developed immediately following Vietnam was the AN/APR-39 threat warning receiver.[153] This system warned helicopter pilots when they were being targeted or engaged by radar or infrared-guided systems and was used

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[146] Ibid.

[147] Ibid.

[148] Price, *The History of US Electronic Warfare, Volume III*, 282.

[149] Ibid.

[150] United States Army Acquisition Support Center, "Guardrail Common Sensor (GRCS)," USAASC, January 1, 2021, accessed February 28, 2021, https://asc.army.mil/web/portfolio-item/guardrail-common-sensor-grcs/.

[151] Martin Streetly, ed., *Jane's Radar and Electronic Warfare Systems: 2011-2012*, 23rd ed. (Alexandria, VA: Jane's Information Group, 2011), 374–82.

[152] Streetly, *Jane's Radar and Electronic Warfare Systems*, 374-382.

[153] Ibid., 245.

extensively during Operations Desert Shield and Desert Storm.[154] Other EW countermeasures were developed in the decade following Vietnam, but the AN/APR-39 is the EW system directly linked to lessons learned during Vietnam and Lam Son 719.[155]

Operations Desert Shield and Desert Storm

When Saddam Hussein invaded his neighbor, Kuwait on August 2, 1990, he triggered a chain of events that lead to the destruction of a large part of his military and the retreat of his forces from Kuwait in less than a year.[156] The Iraqi military, despite recent combat experience, was ill-prepared to fight the US-led Coalition. Utilizing advanced technology, superbly trained troops, and doctrine developed to fight a similar foe, the Coalition soundly defeated the Iraqi military following a forty-two-day combined air and ground campaign.[157] During Operations Desert Shield and Desert Storm, EW was critical to mission success and was integrated in a way not seen in the US military since Operation Overlord. This case study focuses on the EW countermeasures that protected US Army Aviation throughout the conflict, and the potential disaster avoided following years of neglect and apathy of those countermeasures.

During Operation Desert Shield and Operation Desert Storm, coalition air forces faced a complex Iraqi IADS with combat experience against a regional adversary. The Iraqi military fielded ten different SAMs and air defense guns ranging from 23mm to 85mm.[158] Despite the density of Iraqi air defense weapons and the number of sorties and missions flown by the US-led Coalition, the air losses were low. The US Air Force and Navy lost seventeen aircraft to radar and

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[154] Ibid., 525–27.

[155] Price, *The History of US Electronic Warfare, Volume III*, 244–45.

[156] Allan Reed Millett and Peter Maslowski, *For the Common Defense: A Military History of the United States of America from the Revolutionary War through Today*, rev. and updated (New York: Free Press, 2012), 593–94.

[157] Ibid.

[158] Alfred Price, *War in the Fourth Dimension: US Electronic Warfare, from the Vietnam War to the Present* (Mechanicsburg, PA: Stackpole, 2001), 212.

infrared-guided SAMs and anti-aircraft artillery (AAA).[159] US Army Aviation losses were also minimal, with only four helicopters lost to ground fire.[160] In the land domain, the US Army successfully employed their CEWI units in combat for the first time and again saw ARDF and SIGINT's effectiveness in direct support of ground combat operations.[161] Operation Desert Shield and Operation Desert Storm showcased the EW doctrine, organization, and materiel changes and improvements that the US Army made following Vietnam.

At the start of Operation Desert Shield, US Army Aviation was unprepared to deal with the threat posed by Iraqi infrared and radar-guided air defense missiles and guns. US Army Colonel Tom Reinkober, Program Manager for Aircraft Survivability Equipment (ASE) at the time, rated Army aviation a two out of ten when it came to their knowledge of EW.[162] Army aviation units were not training with or maintaining the protection systems that kept them safe. In addition, the Army aviation community seemed to be ignoring the ADA threat detailed in their doctrine.

The Iraqi military's preponderance of air defense systems during Operations Desert Shield and Desert Storm was Russian designed and built, with many still in service throughout the world today.[163] The fact that US Army Aviation had been preparing almost exclusively to fight Russian equipment and doctrine since 1973 makes the lapse in EW training and maintenance of equipment even more curious. The Israeli experience during the Yom Kippur War in 1973, and the Lebanon War in 1982, provided examples of the capabilities of Russian-made

[159] Ibid., 212.

[160] Ibid.

[161] Finnegan, *Military Intelligence*, 188-189.

[162] Price, *War in the Fourth Dimension*, 150–52.

[163] US Department of the Army, Field Manual (FM) 1-101, *Aircraft Battlefield Countermeasures and Survivability* (Washington, DC: Government Printing Office, 1982), 2-4 – 2-5.

equipment against a US ally.[164] US Army Aviation should have been prepared to fight against the less capable version of an enemy they had been preparing to fight since 1973.

If the US Army Aviation community had entered Operation Desert Shield with inferior equipment and flawed doctrine, losses to Iraqi radar and infrared-guided air defense guns and missiles would have been understandable. At the start of Desert Shield, this was not the case. Army rotary-wing aircraft were some of the most advanced and survivable in the world and had advanced EW countermeasures effective against known threats.[165] The 1990 version of US Army FM 1-101 *Aircraft Battlefield Countermeasures and Survivability* provided information on almost every air defense system that US Army aviators faced during Operations Desert Shield and Desert Storm.[166] This information did not appear for the first time in 1990. The 1982 version of FM-101 also detailed information on enemy ADA systems and tactics that closely mirrored what the Iraqi Army employed during Operations Desert Shield and Desert Storm.[167] In addition to the information on enemy threats and tactics, both field manuals reference the EW countermeasures installed in the aircraft that were still in service at the start of Operation Desert Shield.[168] Unfortunately, this equipment had not been maintained or utilized frequently in training and had fallen into disrepair by the beginning of Operation Desert Shield.

The state of EW systems and US Army aircrew training at the start of Operation Desert Shield was abysmal. As described by Colonel Reinkober, "Very few Colonels really took EW to heart. That's something that they didn't train for. They didn't use their jammers, they didn't use their radar warning receivers. Most of them thought those things were a pain in the butt to have in

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[164] Devereux, *Messenger Gods of Battle*, 266, 287.

[165] US Department of the Army, Field Manual (FM), 1-101, *Aviation Battlefield Survivability* (Washington, DC: Government Printing Office, 1990), 1-9 – 1-11.

[166] US Army, FM 1-101, *Aircraft Battlefield Countermeasures and Survivability* (1982), 2-7 – 2-11.

[167] Ibid., 2-1 – 2-12.

[168] Ibid.

the aircraft."[169] Because most EW systems had fallen into disrepair, Colonel Reinkober and his fifty-person team had to rapidly acquire replacement parts and then install them before the ground war started.[170] The majority of these installations had to be conducted in Saudi Arabia because units were packing up equipment and aircraft stateside for movement overseas.[171]

Despite the challenges that US Army Aviation faced with their EW equipment and training before the start of Desert Storm, they quickly corrected the deficiencies and accomplished their mission.[172] During Operations Desert Shield and Desert Storm, the US Army employed 274 AH-64 Apaches, which flew 652 operational flights over 83 missions.[173] They destroyed an estimated 278 tanks, 500 light and armored vehicles, and over 100 artillery pieces during these missions.[174] During these missions, only one AH-64 was lost to ground fire.[175] A Russian-built, shoulder-fired, infrared-guided SA-14 Gremlin SAM is credited with shooting down the sole AH-64 that was lost.[176] This particular AH-64 did not have the ALQ-144A(V) installed, despite Colonel Reinkober and the ASE team's best efforts.[177]

Throughout the war, EW equipment and aircrew tactics defeated all but one of the seventeen radar or infrared-guided missiles fired at US Army helicopters during eight engagements.[178] These missile engagements did not include the unknown number of occasions

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[169] Price, *War in the Fourth Dimension*, 215.

[170] Ibid., 217.

[171] Ibid.

[172] Richard Davis, *Operation Desert Storm: Apache Helicopter Was Considered Effective in Combat, but Reliability Problems Persist* (Washington, DC: United States General Accounting Office, 1992), 2-3, https://www.gao.gov/products/nsiad-92-146.

[173] Ibid., 3–4.

[174] Ibid., 3.

[175] Ibid.

[176] Price, *War in the Fourth Dimension*, 220-221.

[177] Ibid.

[178] Ibid.

where the SAM or AAA could not lock-on the aircraft due to jamming by EW equipment.[179] The ZSU-23-4 air defense gun and other formidable AAA systems used during Lam Son 719 and the closing chapters of Vietnam did not down any US Army helicopters during Operations Desert Shield or Desert Storm.[180]

Question One: How had the US Army employed EW earlier in the conflict?

Before starting the air campaign, the US Army EW enterprise focused on deploying to the theater, installing and repairing EW systems in rotary and fixed-wing aircraft, and providing intelligence from ARDF. The most challenging operation was installing and repairing the EW systems that protected US Army rotary-wing aviation from Iraqi radar and infrared-guided missiles and guns.

Due to neglect and apathy, a herculean effort by a small team of officers and technicians from the US Army ASE program was needed to ensure that US Army Aviation flew into combat during Operation Desert Storm with the systems to protect them. Through various creative methods and a lot of hard work, the US Army ASE team repaired and installed EW equipment in 1,058 rotary and fixed-wing aircraft and trained aircrews and pilots on their use before the start of Operation Desert Storm.[181] This team was also able to install the new ALQ-144A active infrared countermeasure system, which was not even in production at the beginning of Operation Desert Shield, in two-thirds of the Army's AH-64 Apaches and OH-58 Kiowas before the ground war started.[182]

In addition to installing and repairing EW equipment in rotary and fixed-wing aviation, US Army EW provided ARDF support through their CEWI aerial exploitation units. The US Army asset that contributed the most EW and SIGINT support before the air and ground

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[179] Ibid.

[180] Ibid.

[181] Price, *War in the Fourth Dimension*, 217.

[182] Ibid., 220-221.

campaign were the three battalions of Guardrail V aircraft deployed.[183] Flying almost continuously from early January until February 23rd, Guardrail provided a clear picture of the disposition and composition of Iraqi forces.[184]

Question Two: How did doctrine or organizations change to incorporate lessons learned during this period?

Operation Desert Storm confirmed that doctrine and EW equipment developed to defeat radar and infrared-guided ADA missiles and guns worked in combat for US Army Aviation. The two biggest lessons that they learned were the importance of maintaining EW equipment and training to fight in an environment with simulated radar and infrared-guided ADA systems.

Without the incredible efforts of Colonel Reinkober and his small team of officers and engineers, repairs and installation of EW equipment would not have been completed before the air campaign began. Lacking these systems and training on employing them would have likely led to a significant increase in aircraft losses. The one AH-64 that was lost did not have the most advanced version of the ALQ-144A installed and could not counter the SA-14 missile that shot it down. Operation Desert Shield and Operation Desert Storm confirmed that lessons learned from previous conflicts were correct and that the doctrine and equipment which resulted from them were helpful in combat.

Question Three: What advances were made to materiel and equipment during this period?

Advances in US Army EW equipment during this period focused on equipment that enabled EW support and electronic attacks. The ASE in rotary and fixed-wing aircraft had continued following Vietnam through Operations Desert Shield and Desert Storm. By the start of Operation Desert Storm, the ASE outlined in Army Field Manual 1-101, *Aviation Battlefield Survivability*, was installed in most US Army aircraft.[185] In the land domain, CEWI units

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[183] Finnegan, *Military Intelligence*, 188-189.

[184] Ibid.

[185] US Army, Field Manual (FM), 1-101, *Aviation Battlefield Survivability* (1990), 96–99.

deployed to Saudi Arabia with the most current versions of the equipment outlined in Army Field Manual 34-10, *Division Intelligence and Electronic Warfare Operations.*[186] Operation Desert Shield and Operation Desert Storm would be the first combat test of most of the EW equipment that the US Army had developed from the end of the Vietnam War.

Electronic warfare equipment in US Army rotary and fixed-wing aviation at the start of Operation Desert Shield consisted of a mix of nine different systems.[187] All but one of these systems were designed to protect aircraft. The lone exception not meant for protection was the AN/ALQ-151 Quick Fix installed in EH-60 helicopters to conduct ARDF, intercept, and jamming.[188] The most notable improvement to EW technology for rotary-wing aviation leading up to Operation Desert Storm was the AN/ALQ-144A.[189] Defense manufacturer BAE Systems designed the AN/ALQ-144A to counter the next generation of shoulder-fired infrared SAMs, specifically the SA-14.[190] This system went into production at the start of Operation Desert Shield, and updated versions are still in service in 2021 in most US Army rotary-wing aircraft.[191]

This section of the study examined three case studies and how the US Army integrated EW into operations during that conflict. Case studies focused primarily on one EW subdiscipline, its impact during the conflict, and the lessons learned during and after the conflict. The following section will present the findings and analysis from the case studies.

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[186] US Department of the Army, Field Manual (FM) 34-10, *Military Intelligence Battalion (Combat Electronic Warfare Intelligence) (Division)* (Washington, DC: Government Printing Office, 1982).

[187] Price, *War in the Fourth Dimension*, 216.

[188] Ibid.

[189] Ibid.

[190] Streetly, *Jane's Radar and Electronic Warfare Systems*, 603.

[191] Ibid.

Findings and Analysis

This study's primary research question was, What lessons did the US Army learn in integrating EW capabilities during previous conflicts? This study has shown that there are three primary lessons that the US Army learned in earlier conflicts. The first lesson was that offensive and defensive electronic attacks and EW support worked during the conflicts examined. The second is EW capabilities will atrophy between conflicts if they are not maintained. The final lesson is that the US Army may unnecessarily lose personnel and equipment at the beginning of its next conflict if historical trends in managing its EW enterprise are maintained.

Operation Overlord, ASA radio direction-finding operations in Vietnam, and rotary-wing aviation operations in Desert Shield and Desert Storm demonstrate that electronic attack and EW support create success during combat operations. During Operation Overlord, the United States and Great Britain integrated EW attack and support capabilities that protected aircraft and ships, located German radars, and contributed to the allied deception plan. During Vietnam, the ASA developed novel solutions to overcome terrain, weather, and the enemy to provide radio direction-finding support to ARVN and US Army ground forces. Finally, during Operations Desert Shield and Desert Storm, US Army Aviation was able to overcome years of apathy and neglect to its EW equipment and training to counter the threat posed by the Iraqi IADS using defensive electronic attacks and disposable countermeasures. These three conflicts demonstrate that when EW capabilities and equipment are resourced, put in the hands of trained operators, and integrated into operations, they have contributed to mission success.

The second lesson that the US Army learned regarding EW is the difficulties in rapidly building EW capabilities if neglected between conflicts. During World War Two, Vietnam, and Operations Desert Shield and Desert Storm, the US Army entered into the conflict with varying levels of EW capabilities. Most of the time, EW was given little attention during the interwar years because there was no perceived need or because it was not prioritized. All three case studies

showed that if a gap in capabilities exists, there will be increased risks to soldiers, equipment, and mission success.

During World War Two, a gap existed at the beginning of the conflict between what EW could do and what it needed to do in the US Army. The primary shortfall manifested itself in the skies over Europe as allied fighters and bombers fought through the German IADS to strike strategic targets. These gaps were not due to neglect in the US Army but because EW had never been used to the same degree in previous conflicts. The lessons learned by the USAAF and RAF during the air campaign were applied during Operation Overlord in the air, sea, and land domains. The equipment and tactics developed to protect aircraft from radar-aided AAA could also protect ships and contribute to military deception. The integration of all three subdisciplines of EW into Operation Overlord contributed to the allied landings, reduced casualties, and caused confusion in the German high command.

During Vietnam, the US Army found itself ill-prepared to conduct the type of EW needed given the enemy and the terrain. The US Army likely missed the opportunity to apply some of the lessons that the US Air Force and US Navy had learned flying against North Vietnam's IADS. The ASA recognized that their method of conducting ARDF was not suitable for Vietnam and promptly took action to fix the problem. Some of these lessons should have been learned during the Korean War when radio direction-finding was ineffective primarily due to terrain and equipment limitations.

It is reasonable to argue that US Army Aviation losses during Operation Lam Son 719 could have been reduced. There would likely have been fewer aircraft and personnel losses if US Army helicopters had been equipped with EW equipment that warned pilots that they were being targeted or engaged by radar and infrared-guided weapons ADA. US Army EW and aviation should have learned lessons from the US Air Force and Navy experience since 1965 when the SA-2 was introduced. Given the development of EW doctrine, organizations, and equipment in

the US Army following Vietnam, it appears that lessons learned by the ASA and US Army Aviation were not forgotten and led to changes immediately following the war.

At the start of Operation Desert Shield, US Army Aviation was not prepared to counter the Iraqi IADS due to neglect and apathy of EW training and equipment. Thankfully, the US Army had devoted significant resources to developing technology and doctrine capable of countering all known and projected air defense threats following Vietnam. The rapid repairs to US Army Aviation EW systems rendered the Iraqi air defense largely ineffective and reduced casualties and aircraft losses. Although it is now viewed as a success story, it is highly likely that US Army Aviation losses would have increased if they had to immediately begin combat operations upon arrival. The buildup of combat power during Desert Shield gave US Army Aviation the time needed to correct oversights in maintenance and training of EW equipment and tactics.

During all three conflicts that this study examined, challenges emerged that tested the US Army's EW enterprise's capabilities. Each time, the US Army was eventually able to match its capabilities to meet those challenges. These improvements have usually come from painful lessons learned during combat operations. This study has shown that the US Army's record of adapting its EW enterprise during combat based on lessons learned has been consistently good. It has also demonstrated that its history of remembering these lessons and applying them during the next conflict is mixed.

Conclusion

This study's focus was understanding what lessons the US Army learned or failed to learn about integrating EW during previous conflicts and how that understanding can inform the future force. This study's findings have shown two trends in prioritization and development of EW since World War Two in the US Army. The first trend is that the US Army has not

consistently prioritized EW until there was a compelling need or crisis. The second trend is that the US Army rapidly improved its doctrine, organizations, and equipment when the need arises.

With the likely lethality of future conflict, the US Army may not have the time to recover from initial mistakes or gaps in its EW enterprise and still accomplish its mission. If historical trends are repeated, the US Army will enter into a conflict with some EW capability gaps; still, it would also develop capabilities to close those gaps rapidly. How fast the US Army can identify those gaps and how quickly it can close them will determine whether EW contributes to mission success. With the US Army focusing on preparing for LSCO against Russia and China, there will likely be fewer gaps at the start of a conflict than in previous eras where there was a lack of a clear threat.

Two areas within this topic deserve further research. The first is how can the US Army protect itself from electronic attacks? The second is how to best delineate joint EW into subdisciplines of electronic attack, EW support, and electronic protection? The first question requires an understanding of the capabilities that potential future adversaries currently have and are developing, and what the US Army needs to counter those threats. A great deal has been written about defensive electronic attacks and how they can protect aircraft and ships. Little has been written that examines EW's electronic protection subdiscipline and how it impacts ground operations. Answering the second question and developing a possible alternative framework may help EW obtain wider acceptance within the US Army and eliminate confusion due to counterintuitive definitions such as "defensive electronic attack."

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