

HOW DOES A MODERN FIELD ARTILLERY CANNON BATTALION  
OPERATE IN A DEGRADED, DENIED, AND DISRUPTED  
SPACE OPERATING ENVIRONMENT?

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MASTER OF MILITARY ART AND SCIENCE  
General Studies

by

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The opinions and conclusions expressed herein are those of the student author and do not necessarily represent the views of the U.S. Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

## ABSTRACT

HOW DOES A MODERN FIELD ARTILLERY CANNON BATTALION OPERATE IN A DEGRADED, DENIED, AND DISRUPTED SPACE OPERATING ENVIRONMENT?, by Major Lucas F. Leinberger, 109 pages.

The Russo-Ukrainian conflict began in 2014, and brought with it an emergence of electronic warfare unexpected by the world, and the US Army. In the following years, gaps in US Army capabilities also emerged. To address these gaps, documents such as Lessons Learned from the Russo-Ukrainian War, and the Russian New Generation Warfare Handbook began to appear. These two documents described what this thesis refers to as a Degraded, Denied, and Disrupted Space Operating Environment (D3SOE). While mentioned in military articles, the term was never defined, or incorporated in to Army doctrine. As a result, there was a delay in response by Army component branches, including the Field Artillery.

This thesis seeks to answer, “How does a modern field artillery battalion operate in a D3SOE?” To answer the question, the thesis begins by examining the current capabilities of a modern field artillery cannon battalion, the characteristic of a D3SOE, and how a D3SOE affects the Five Requirements for Accurate Fire (5RFAF). The thesis then analyzes three cases to determine how well current units and their capabilities meet the 5RFAF. The thesis concludes by answering the research question, and providing recommendations for capability developments in Doctrine, Training, and Materiel to enable a field artillery battalion to effectively meet the 5RFAF.

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## ACRONYMS

5RFAF	Five Requirements for Accurate Fire
AAR	After Action Review
ADFCS	Artillery Digital Fire Control System
AFATDS	Advanced Field Artillery Tactical Data System
ATP	Army Techniques Publication
CMD-P	Computer, Meteorological Data–Profiler
CR	Cavalry Regiment
CTC	Combat Training Center
D3SOE	Degraded, Denied, and Disrupted Space Operating Environment
DST	Digital Sustainment Training
EMP	Electromagnetic Pulse
EW	Electronic Warfare
FA	Field Artillery
FADOWP	Field Artillery Degraded Operations White Paper
FCoE	Fires Center of Excellence
FDC	Fire Direction Center
FM	Frequency Modulated
FSR	Field Service Representative
GBS	Global Broadcast System
GPS	Global Positioning System
IGrADS	Interactive Grid Analysis and Display System
IPADS-G	Improved Position and Azimuth Determining System- Global Positioning System



LLDR	Lightweight Laser Designator Rangefinder
MET	Meteorological
PACE	Primary, Alternate, Contingency, and Emergency
PDFCS	Paladin Digital Fire Control System
PFED	Pocket-sized Forward Entry Device
RTU	Rotational Training Unit
RUW	Russo-Ukrainian War
SBCT	Stryker Brigade Combat Teams
TC	Training Circular
T&EO	Training and Evaluation Outline
TTP	Tactics, Techniques, and Procedures
UAS	Unmanned Aerial Systems
US	United States
USAFAS	United States Army Field Artillery School

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## CHAPTER 1

### INTRODUCTION

The worst of all conditions in which a belligerent can find himself is to be utterly defenseless. Consequently, if you are to force the enemy, by making war on him, to do your bidding, you must either make him literally defenseless or at least put him in a position that makes this danger probable.<sup>1</sup>

— Carl von Clausewitz, *On War*

#### The Worst Case

Clausewitz's words invoke images of glory, success, and triumph in war. Nothing sounds sweeter than overwhelming an enemy to the point it renders him operationally and mentally defenseless. But what if your adversary possesses the ability to affect a friendly force in the same manner? The situation now becomes less appealing, and Clausewitz's thoughts become more relevant for modern military organizations and leaders. This is especially so during a time when emerging electronic and cyber warfare capabilities are capable of rendering a force defenseless.

In 2014, a Ukrainian separatist movement with alleged ties to Russia ousted Ukrainian President Viktor Yanukovich. In 2017, the RUW still rages on, and functions as a proxy war, demonstrating the shape of warfare in the near future.<sup>2</sup> Observations from the conflict included innovative tactics by both sides such as the use of unmanned aerial

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<sup>1</sup> Carl von Clausewitz, *On War*, ed. and trans. by Michael Howard and Peter Paret (Princeton, NJ: Princeton University Press, 1984), 77.

<sup>2</sup> Phillip Karber, "Draft of Lessons Learned from the Russo-Ukrainian War: Personal Observations" (Historical Lessons Learned Workshop, Sponsored by Johns Hopkins Applied Physics Laboratory and U.S. Army Capabilities Center (ARCIC), 2015), 10.

vehicles, and increasing lethality of indirect fires.<sup>3</sup> Additionally, an unconfirmed report from the cybersecurity firm CrowdStrike in December 2016 alleged the Russian hacking of Ukrainian artillery software that expedited the processing of targeting data and firing unit location. The report further alleged that the hacking provided Russian military forces with precise locations of Ukrainian artillery units, and the ability to mass fires on these units.<sup>4</sup> While the Ukrainian defense ministry publicly denied such hacking and effects on its artillery units, the possibility of such attacks is not far-fetched.<sup>5</sup> As alarming as these examples are, they are only a small sample of threat capabilities.

The current conflict between Russia and Ukraine presents a more powerful example of what a determined adversary can do with seemingly simple technology. According to the United States (US) Army Europe Commander, Lieutenant General Ben Hodges, Russia's use of electronic warfare (EW) and cyber techniques to destroy command and control networks by disrupting communication systems, radar tracking, and Global Positioning System (GPS) location services is "eye watering."<sup>6</sup> This type of

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<sup>3</sup> Karber, 11.

<sup>4</sup> Adam Meyers, "Danger Close: Fancy Bear Tracking of Ukrainian Field Artillery Units," Crowd Strike, December 22, 2016, accessed January 16, 2017, <https://www.crowdstrike.com/blog/danger-close-fancy-bear-tracking-ukrainian-field-artillery-units/>.

<sup>5</sup> Ukraine Ministry of Defense, "Information about the 'Loss of Armed Forces of Ukraine 80% Howitzer D-30' is not True," January 6, 2017, accessed January 16, 2017, <http://www.mil.gov.ua/news/2017/01/06/informacziya-po-vtrati-u-zs-ukraini-80-gaubicz-d-30%E2%80%9D-ne-vidpovidaє-dijsnosti/>.

<sup>6</sup> Joe Gould, "Electronic Warfare: What US Army Can Learn from Ukraine," *Defense News*, August 2, 2015, accessed January 13, 2017, <http://www.defensenews.com/story/defense/policy-budget/warfare/2015/08/02/us-army-ukraine-russia-electronic-warfare/30913397/>.

environment, where radio or satellite communications, positioning, and navigation do not properly function, is known as a Degraded, Denied, Disrupted Space Operating Environment (D3SOE).<sup>7</sup> Operations in this environment are much like that of the predicament described earlier by Clausewitz; a situation where military forces are utterly defenseless, or incapable of executing their mission.

### The Field Artillery

The mission of the Field Artillery (FA) is to destroy, defeat, or disrupt the enemy with integrated fires to enable maneuver commanders to dominate in Unified Land Operations.<sup>8</sup> Through this mission, a FA battalion contributes as a force multiplier by providing the ability to mass artillery fires on a target.

The importance of massing fires is not a new concept. In fact, military theorist Henri Jomini considered massing fires critical to overwhelming an enemy force.

It should be borne in mind that the chief office of all artillery in battles is to overwhelm the enemy's troops, and not to reply to their batteries. It is, nevertheless, often useful to fire at the batteries, in order to attract their fire. A third of the disposable artillery may be assigned this duty, but two-thirds at least should be directed against the infantry and cavalry of the enemy.<sup>9</sup>

In this passage, Jomini described the use of artillery to overwhelm what is essentially now known as a combined arms unit. A combined arms unit, such as a brigade combat

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<sup>7</sup> Brigadier General Kurt Story, "Protecting Space in a Contested and Congested Domain," *Army Space Journal* (Winter/Spring 2010): 8.

<sup>8</sup> Department of the Army, Army Doctrine Reference Publication (ADRP) 3-09, *Fires* (Washington, DC: Headquarters, Department of the Army, August 2012), 1-4.

<sup>9</sup> Baron de Jomini, *Summary of the Art of War* (reprint excerpts, US Command and General Staff School, 2016), 242.

team, typically consists of three maneuver battalions, and a field artillery battalion in addition to other sustainment or support units. As such, doctrine requires the combined arms unit to “mass the effects of overwhelming combat power against selected portions of the enemy force with a tempo and intensity that cannot be matched by the enemy.”<sup>10</sup> The modern FA battalion supports this concept with the help of previously mentioned radio or satellite capabilities that facilitate the synchronization of all available fires assets.

Interestingly, Jomini also mentioned using fires to attract enemy fires in response. According to Ukrainian artillery commanders fighting in Ukraine, this tactic was not only about destroying enemy artillery, but more so about disrupting the enemy’s ability to mass fire.<sup>11</sup> For example, a report from the Joint Multinational Readiness Center stated Russian military forces used mortar fires to prompt a response from enemy artillery units.<sup>12</sup> Their enemy’s counterfire then disclosed its location by firing when Russian target acquisition assets were already scanning in anticipation. As a result, the Russian military was able to respond with timely counterfire. Using field artillery this way arguably gave Russian forces a positional advantage over their adversary who did not wish to suffer a steady flow of strikes and salvos by continuing to conduct destructive

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<sup>10</sup> Department of the Army, Field Manual (FM) 3-90-1, *Offense and Defense Volume 1* (Washington, DC: Headquarters, Department of the Army, March 2013), 3-1.

<sup>11</sup> Karber, 19.

<sup>12</sup> Joint Multinational Training Group-Ukraine, *UKR Leadership Discussion on ATO Lessons Learned* (Yavoriv, Ukraine: IPSC, November 26, 2015), 9.

counterfire.<sup>13</sup> The following section explores other modern field artillery capabilities, and how they came to fruition.

### Emergence of Modern FA Capabilities

In the late 1980s and early 1990s, the US Army transitioned from Air Land Battle to Air Land Operations. This transition occurred as a result of the fall of the Warsaw Pact that in turn reduced expansive budgets designed to fund development during the Cold War.<sup>14</sup> Later, following Operation Desert Storm and another round of budgetary constraints, the Fires Center of Excellence (FCoE) identified a need to remain relevant as the Effects Based Operations concept began to take hold.<sup>15</sup> However, the conflict between a decreasing budget and the ability to support increasing capability requirements posed an issue. In response, the Army updated Air Land Operations doctrine that subsequently increased the use of joint force operations to support Army efforts.

Simultaneously, the Army FA component also developed technology that facilitated precision targeting to increase effects deeper on the battlefield, and reduced troop strength needed to win the close fight.<sup>16</sup> For example, the introduction of the M109A6 Paladin supported efforts for precision fires by possessing self-locating GPS

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<sup>13</sup> Karber, 20.

<sup>14</sup> Kirk Junker, “The Field Artillery in Combined Arms Maneuver and Wide Area Security Operations” (Master’s Thesis, US Army Command and General Staff College, Fort Leavenworth, KS, 2011), 13.

<sup>15</sup> Ibid.

<sup>16</sup> Ibid.

capabilities, a faster rate of fire, and improved survivability.<sup>17</sup> Eager to continue increasing capabilities, the FA developed Guided Multiple Launch Rocket System rockets, and the Army Tactical Missile System.<sup>18</sup> These rocket capabilities, in addition to enhanced cannon fire capabilities such as the Paladin, and the 155mm Excalibur GPS guided round solidified the transition of the FA from massing fires to precision strikes.

The FCoE's Air Land Operations modernization efforts in the late 1970s included two new counterbattery and target acquisition systems: the AN/TPQ-36 counter-mortar radar and the AN/TPQ-37 counterbattery radar. According to FA historian Boyd Dastrup's *The King of Battle, a Branch History of the U.S. Field Artillery*, both systems enhanced counterbattery operations compared to their predecessors with exceptional range and tracking abilities, which mitigated the potential superiority of enemy artillery and mortars. For example, the AN/TPQ-36 reportedly located enemy mortar batteries so quickly that friendly forces could deliver counterfire before the enemy mortars impacted their intended targets.<sup>19</sup> Over time, these systems underwent upgrades to further improve performance. At the same time, however, the addition of enhanced counterfire capabilities added to the growing importance of developing a means to synchronize these assets into a finely tuned fire support and delivery system.

The introduction of past or current digital command and control systems to coordinate and synchronize the use of these new capabilities in Air Land Operations is

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<sup>17</sup> Ibid., 14.

<sup>18</sup> Ibid., 16.

<sup>19</sup> Boyd Dastrup, *King of Battle, Branch History of the U.S. Army Field Artillery* (Fort Monroe VA: Office of the Command Historian, 1991), 293.



critical to understanding the impact of D3SOE on a modern FA battalion. The most prominent and recognizable capability to appear was the Force XXI Battle Command Brigade and Below system. This system facilitated mission command by providing situational awareness of troop locations on the battlefield, and provided a means of enhancing the flow of communication across the chain of command. Similarly, the FA identified a need for a system to control artillery operations. As a result, the FCoE developed the Tactical Fire Direction System in the 1970s, and later in 1990s the Advanced Field Artillery Tactical Data System (AFATDS). Among many capabilities, the AFATDS allowed a FA unit or Fires coordinator to synchronize fire support and maneuver plans, as well as automatically determining the most effective munition for attacking high payoff targets.<sup>20</sup>

For over 40 years, the US Army increased its ability to provide precision fires and counterfire through technological improvements in munitions and systems. These developments led to capabilities that are still in use such as the Paladin, Excalibur, Guided Multiple Launch Rocket System, and AFATDS. In fact, until recently the Q-36 and Q-37 radars were the primary counterfire systems for most brigade combat teams. All of these systems, and their successors, depend on the ability to transmit information over a digital radio communication system, or a satellite communication system. For these reasons, this research is exceedingly important for understanding what the future battlefield looks like for a FA battalion in a D3SOE.

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<sup>20</sup> Ibid., 310.

### Intent of Research

The purpose of this research was to address the effects of emerging threat capabilities found in a D3SOE, and to discern how a FA battalion operates in a D3SOE. This included assessing the FA battalion's ability to communicate, utilize positioning assets, and synchronize targeting systems. The research problem for this thesis was an absence of tactics, techniques, and procedures (TTPs) specifically designed to allow FA battalions to counter the threat of a D3SOE. This absence of guidance demonstrated a gap in professional literature, Army doctrine, and institutional learning. The existence of this gap was also directly acknowledged in the *Field Artillery 2017 Training Strategy*, which clearly states our Field Artillery units have challenges operating under degraded operating conditions.<sup>21</sup> This thesis filled this gap in scholarly literature by conducting a thorough analysis of case studies directly related to the previously defined research problem statement, and the supporting problem questions. Analysis produced answers to the problem, and provided a platform for future solutions research and capabilities development.

### The Research Question

How does a modern FA cannon battalion operate in a D3SOE? To answer this primary research question, the thesis considered other secondary research questions that aided in describing certain qualities of the problem. The supporting research questions are: How does a modern FA cannon battalion currently operate? What is a D3SOE, and

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<sup>21</sup> United States Army Field Artillery School (USAFAS), *The United States Army Field Artillery 2017 Training Strategy* (Fort Sill, OK: Headquarters, USAFAS, November 2016), 21.

what are its characteristics? What are the effects of a D3SOE on the Five Requirements for Accurate Fire (5RFAF)?

### Limitations and Delimitations

In conducting this thesis there were some limitations, and delimitations that applied to keep findings manageable. The limiting factors for this thesis included a limited knowledge base to call upon. Specifically, detailed information regarding the ongoing conflict between Russia and Ukraine was difficult to find in a professional format that is not classified. Army doctrine also limited research and analysis by not providing a clear definition for a D3SOE.

Delimiting factors for the thesis included isolating the research to considering the effects of a D3SOE on the 5RFAF. These requirements are the doctrinal foundation for how a FA battalion provides field artillery support. As such, analysis focused on how a D3SOE affects the 5RFAF. As a result, the research discerned the overall ability of a FA battalion to operate in a D3SOE, and developed recommendations based on these findings for how the FA battalion operates in a D3SOE.

This research also excluded electromagnetic pulse (EMP) weapons, and naturally occurring EMPs. An EMP denies the use of electronics in an affected area by rendering the hardware incapable of operating without an extensive number of repairs, or a total replacement of the affected device. This would require the affected force to refit with all new equipment. In comparison, a D3SOE might involve many different capabilities to impose a D3SOE on an opposing force. Furthermore, using EW as an example, the affected force may be able to troubleshoot effects in the D3SOE. Similarly, a D3SOE does not always result in the destruction an EMP inflicts upon electronic hardware. Given

these concepts, ruling out EMPs allowed research to focus on how the enemy combines multiple effects to degrade, deny, and disrupt the space operating environment versus simply using an EMP to disable all electronic devices.

Also, research concerning the impact of adversary unmanned aerial systems (UAS) on FA battalions was not part of this research. However, this did not delimit some research of adversary cyber and EW effects on friendly UAS capabilities. This allowed the research to include discussion of how a D3SOE may affect a force's ability to use UAS as sensors for target acquisition or observation. This also directly related to named areas of interest and target areas of interest, which are critical sources of targeting information for determining preplanned targets for FA battalions to attack.

A third delimitation for this research applied to the extent that the thesis described and explains technical details of various systems. This kept the classification and handling level of the thesis at Unclassified—For Official Use Only or lower. Also, this delimitation reduced the minutiae of interesting, but staggering technical details that did not serve a purpose in understanding the broader topic of how a FA battalion operates. Lastly, adherence to the aforementioned purposes allowed the author to present the thesis in an easy to read format accessible to United States Army professionals.

Lastly, this thesis provided conclusions and recommendations for only three components of the Army capabilities development process: Doctrine, Training, and Materiel. The delimitation allowed the author to maximize time available for research, and to focus on the areas deemed to be the most beneficial for answering the research question. Furthermore, conclusions based on these three factors will drive future

capabilities development in terms of organizational, leadership, personnel, and facility requirements.

### Summary

Ongoing conflict in Ukraine showcases the technological advancements of Russia, and potentially any adversaries observing the conflict seeking to advance their own military capabilities. The conflict is particularly critical for the US Army, and FA battalions seeking to identify vulnerabilities when confronting a modern, near peer adversary. From satellite disruption to digital communication denial, the application of these capabilities in the Russo-Ukrainian War (RUW) demonstrate that adversaries have the ability to significantly shape the operational environment to their advantage.

This thesis utilized a case study methodology to address the research problem that there are no TTPs specifically designed to allow FA battalions to counter the threat of a D3SOE. The primary research question was, “How does a modern FA cannon battalion operate in a D3SOE?” To answer this question, the thesis first used three supporting research questions to guide the review of literature in the following chapter. The supporting research questions are: How does a modern FA cannon battalion currently operate? What is a D3SOE, and what are its characteristics? What are the effects of a D3SOE on the Five Requirements for Accurate Fire (5RFAF)?

## CHAPTER 2

### LITERATURE REVIEW

Therefore, it is said that he who knows the enemy and knows himself will not be endangered in one hundred battles, that he who does not know the enemy but knows himself will lose one battle for each one he wins, and that he who knows neither the enemy nor himself will certainly be endangered in every battle.

— Sun Tzu, *The Art of War*

#### Know Yourself and Know Your Enemy

Using the above passage from *The Art of War* by Sun Tzu as inspiration, this chapter focuses on understanding the challenges a modern FA battalion faces when it operates in a D3SOE. To accomplish this, the review of literature used the previously mentioned supporting questions to guide research, and gain a better understanding of the problem. Doing so provided relevant material to better determine how a modern FA battalion operates in a D3SOE. This was a very relevant question for a force increasingly reliant on frequency modulated (FM) radio communication systems to attack or defend against potential near peer adversaries who demonstrate an ability to disrupt those same communication capabilities. To frame the problem, this research first reviewed applicable US Army FA doctrine to determine how a modern FA cannon battalion currently operates. The research then considered available material to understand the characteristics of a D3SOE. To “artillerize” the research, the review of literature sought examples of how a D3SOE affects the 5RFAF.

### How does a Modern FA Cannon Battalion Operate?

A discussion of how a modern FA battalion operates must include an understanding of the 5RFAF, previously known as the Five Requirements for Accurate Predicted Fire. Approaching the topic in this manner provided a basic understanding of what an FA battalion needs at a minimum to provide accurate fires. Such discussion also lent itself to understanding the implications of a D3SOE when assessing existing doctrine, training requirements, and materiel capabilities. The 5RFAF are: Accurate Target Location and Size, Accurate Firing Unit Location, Accurate Weapon and Ammunition Information, Accurate Meteorological (MET) Information, and Accurate Computational Procedures.<sup>22</sup> According to Field Manual 3-09: *Field Artillery Operations and Fire Support*, “To achieve accurate first-round fire for effect on a target, an artillery unit or other unit providing indirect fires must compensate for nonstandard conditions as completely as time and the tactical situation permit. If these requirements are met, the firing unit will be able to deliver accurate and timely fires.”<sup>23</sup>

The “predicted” aspect of these inherent requirements left FA doctrine when the United States Army Field Artillery School (USAFAS) established a working group to assess the five requirements and their application to modern precision capabilities. The working group determined that the availability and use of precision or near precision

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<sup>22</sup> Department of the Army, Field Manual (FM) 3-09, *Field Artillery Operations and Fire Support* (Washington, DC: Headquarters, Department of the Army, April 2014), 1-41.

<sup>23</sup> Ibid.

munitions meant artillerymen do not predict anything.<sup>24</sup> According to the USAFAS, “this requires a shift in ideology and culture to fully appreciate each of the elements of the Five Requirements in achieving accuracy or precision standards for all munitions.”<sup>25</sup>

### The Field Artillery Battalion

With the 5RFAF as a basic foundation, the FA battalion uses other available doctrine to support meeting the requirements, and to facilitate FA support operations. Documents such as official Army publications and manuals were necessary to define tactical terms, establish relevance of this thesis to capabilities development, and support discussions of topics such as how the FA battalion operates with doctrinal terminology. This section provided a review of doctrinal literature in order to better understand how a FA battalion currently operates. Exploring changes and development in doctrine also provided an understanding of how an FA battalion operated at a certain point in time. For example, how doctrine changed from 2014 to 2017, and what inspired the changes.

The FA battalion is part of a fires system that consists of four functions: fire support coordination, target acquisition, delivery of field artillery fires, and fire direction.<sup>26</sup> To perform these functions, the FA battalion provides sensor and observer capabilities, a fire direction center (FDC), and cannon or rocket artillery delivery systems. Field Manual 3-09: *Field Artillery Operations and Fire Support*, Army Doctrine

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<sup>24</sup> Capt Brock Lennon, “The Five Requirements for Accurate Fire in the 21st Century,” *Redleg Update* (February 2014): 3, accessed February 1, 2017, [http://sill-www.army.mil/USAFAS/redleg/archive/2014/FEB\\_2014.pdf](http://sill-www.army.mil/USAFAS/redleg/archive/2014/FEB_2014.pdf).

<sup>25</sup> Ibid.

<sup>26</sup> Department of the Army, FM 3-09, vi.



Reference Publication 3-09: *Fires*, and Army Doctrine Publication 3-09: *Fires* were important resources for understanding the Fires system. However, this research required the review of numerous other FA and Fires doctrine to better understand how each function performs its respective duties to achieve each of the 5RFAF.

### Accurate Target Location and Size

This research first reviewed literature pertaining to the first requirement for accurate fire: Accurate Target Location and Size. Army Techniques Publication (ATP) 3-09.30: *Techniques for Observed Fire* provided information to better understand the role of observers, and how they operate within the Fires system construct. Of note was the publication's discussion of the relationship between the observer, FDC, and artillery assets.

Fire support gunnery involves the coordinated efforts of the observer, fires cell, fire direction center (FDC), and firing elements each linked by an adequate communications and computer system. Team members must operate with a sense of urgency, continually strive to reduce the time required to execute an effective fire mission, and strive to achieve first round fire for effect (FFE). To achieve accurate first-round FFE on a target, an artillery unit must compensate for nonstandard conditions as completely as time and the tactical situation permit.<sup>27</sup>

An important take away from this excerpt was the importance placed on urgency and speed while discussing the necessity for stable communication links between each element of the system. According to the manual, observers play a critical role in how artillery systems provides fires.

The observer serves as the “eyes” of indirect fire systems. He detects and locates suitable targets within his area of observation. To ensure that the first requirement

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<sup>27</sup> Department of the Army, Army Techniques Publication (ATP) 3-09.30, *Techniques for Observed Fire* (Washington, DC: Headquarters, Department of the Army, August 2013), 1-1.

of accurate predicted fires is met, the observer must use the most accurate method of target location available. To attack a target the observer transmits a call for fire and when necessary, adjusts the fires onto the target.<sup>28</sup>

This excerpt provided the basic role of the observer. However, the inclusion of the first requirement for accurate fire added value to the manual's use in the research methodology that involved the 5RFAF. Adding to relevance, the manual stated, "The observer is solely responsible for the first requirement. Failure to provide accurate target location and size may require adjust fire missions resulting in increased ammunition expenditure, decreased effects on target, and an increased risk of detection by hostile TA assets."<sup>29</sup> The remainder of the manual described how the observer doctrinally accomplishes this important task.

Under normal conditions, doctrine asserted that accurate target location and size depends on the ability of an observer or sensor to provide target information to the FA battalion. Incorrect fire mission data results in a target location error. To mitigate errors in target direction and distance, ATP 3-09.30 provided guidance for both factors. The publication stated there are five methods for determining directions. These methods included precision measuring devices such as the Lightweight Laser Designator Rangefinder (LLDR), measuring from a reference point, using a compass, scaling from a map, and estimating.<sup>30</sup> Similarly, the publication addressed determining distance to target providing four methods that include a laser range finder, flash to bang (calculating

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<sup>28</sup> Ibid., 1-1.

<sup>29</sup> Ibid.

<sup>30</sup> Ibid., 3-3.

distance using equations based upon when the observer hears the round impact), estimation, and utilizing an observed fire fan (a graphic aid much like a protractor that can be placed on a map).<sup>31</sup>

Another digital device observers use is the Pocket-sized Forward Entry Device (PFED). The PFED is a device that observers may use to conduct a wide range of actions for precision targeting.<sup>32</sup> This device relies on GPS connectivity to acquire target or observer locations, and digital connectivity to transmit fire missions. ATP 3-09.30 recommends the use of digital communications as a primary means of transmission, and directed the use of voice communications only when digital systems are not functioning or if operational tempo makes the use of digital systems infeasible.<sup>33</sup>

#### Accurate Firing Unit Location

Much like an observer, an FA battalion must also accurately determine its own location. An FA battalion survey section is the primary means of meeting this requirement. However, the FA battalion may also use GPS enabled devices to provide position data. To understand both of these capabilities, this research also examined ATP 3-09.30.

Army Techniques Publication 3-09.30 provided relevant information for use in later analysis. For example, the manual discussed forward observer operations, and the

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<sup>31</sup> Ibid., 3-9.

<sup>32</sup> United States Army Field Artillery School (USAFAS), *U.S. Army Field Artillery Degraded Operations: White Paper* (Fort Sill, OK: Headquarters, USAFAS, October 2016), 9.

<sup>33</sup> Department of the Army, ATP 3-09.30, 4-1.

requirement for the FDC to receive observer team locations. Similarly, the FDC must obtain accurate firing unit locations using a set standard of accuracy and specific systems.

The components of accurate firing unit location are position, direction, and altitude. Accuracy standards of 7.0 meters horizontal circular error probable (CEP), 3.0 meters vertical probable error and no more than 0.6 mil azimuth probable error are considered the minimums for firing and target acquisition assets to achieve accurate unit location. The improved position and azimuth determining system (IPADS)—global positioning system and on-board navigation systems are the primary means to achieve these levels of accuracy. The fire direction center can also determine the grid location of each piece by using the reported direction, distance, and vertical angle for each piece from the aiming circle used to lay the battery.<sup>34</sup>

This excerpt from Field Manual 3-09 is important because it described how the FDC obtains accurate unit location using means other than a GPS. An aiming circle is a manual non-electronic artillery surveying device similar to a civilian survey theodolite. Howitzer batteries or platoons using the aiming circle are then able to emplace or lay the battery. The result of this manual process is an accurate unit location that the FDC applies to fire mission computations using accurate computational procedures.

A FA battalion's survey section uses the Improved Position and Azimuth Determining System- Global Positioning System (IPADS-G) to establish a common grid for all supported fire support assets. This allows the firing unit to then determine its position, direction, and altitude.<sup>35</sup> While the IPADS-G uses GPS to aid in expediting survey, the device does not require a GPS connection to provide survey.<sup>36</sup> Additionally,

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<sup>34</sup> Department of the Army, FM 3-09, 1-42.

<sup>35</sup> Ibid.

<sup>36</sup> United States Army Field Artillery School (USAFAS), *U.S. Army Field Artillery Degraded Operations*, 15.

ATP 3-09.2, *Survey* stated, “survey control should be obtained from other FA units operating in the area or may be established by using hasty survey techniques.”<sup>37</sup> This means survey operations for determining location were not hindered by a degraded environment.

According to ATP 3-09.30, the battalion FDC directs fire missions from the observer to a firing unit. “An FDC serves as the ‘brain’ of the system. It receives the call for fire from the observer and sends a fire order to the firing unit. An FDC has the capability to determine how to attack a target (tactical fire direction) as well as determining firing data and converting this data into fire commands (technical fire direction).”<sup>38</sup> This excerpt highlights the FDC’s responsibility to provide tactical and technical fire direction. It is my personal experience that tactical fire direction resides mostly with the battalion FDC, and technical fire direction with the battery FDCs. However, mission variables may require a battery FDC to perform tactical fire direction, and similarly the battalion FDC to perform some degree of technical fire direction. Regardless of structuring, the FDC relies on accurate unit location to provide firing data to the firing units.

According to ATP 3-09.50, *The Field Artillery Cannon Battery*, “communications between the howitzers and the FDC is a major concern with increased distances.”<sup>39</sup>

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<sup>37</sup> Department of the Army, Army Techniques Publication (ATP) 3-09.2, *Survey* (Washington, DC: Headquarters, Department of the Army, August 2013), 3-8.

<sup>38</sup> Department of the Army, ATP 3-09.30, 1-1 - 1-2.

<sup>39</sup> Department of the Army, Army Techniques Publication (ATP) 3-09.50, *The Field Artillery Cannon Battery* (Washington, DC: Headquarters, Department of the Army, May 2016), 10-3.

Although howitzers can self-locate using GPS or manual lay methods using an aiming circle, a loss of voice or digital connectivity hinders the ability of the gunline to send their location to the battalion FDC. A solution mentioned throughout ATP 3-09.50, is the use of communications wire between the FDC and gunline to reduce EW vulnerabilities.<sup>40</sup> However, the manual stated that with this security comes a tradeoff for mobility that may not always be acceptable when speed is critical.

Army Techniques Publication 3-09.23, *Field Artillery Cannon Battalion* also addresses radio communications problems by recommending the use of wire communications.<sup>41</sup> However, as ATP 3-09.50 stated, the use of wire reduces mobility, and may not always be available such as when transmitting survey data across a large area of operations. Furthermore, ATP 3-09.23, recommends using civilian telephone systems when available for unsecured communications.<sup>42</sup> This may be a useful tactic if referring to hard line telephone systems.

#### Accurate Weapon and Ammunition Information

Related to the second requirement for accurate fire is the FA battalion's need for accurate weapon and ammunition information. To achieve this accuracy, Training Circular (TC) 3-09.8, *Field Artillery Gunnery* specified howitzer piece status, or an update of howitzer location, ammunition round count, and propellant temperature

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<sup>40</sup> Ibid., 11-11.

<sup>41</sup> Department of the Army, Army Techniques Publication (ATP) 3-09.23, *Field Artillery Cannon Battalion* (Washington, DC: Headquarters, Department of the Army, September 2015), 6-13.

<sup>42</sup> Ibid.

throughout the publication's step procedures for artillery gunnery tasks.<sup>43</sup> According to TC 3-09.81, *Field Artillery Manual Gunnery*, the accuracy and validity of this information is important for the battery FDCs as they compute fire mission data to solve what is referred to as the gunnery problem.<sup>44</sup> The results of solving the gunnery problem are weapons and ammunition settings that allow the firing unit to achieve the desired effects.<sup>45</sup>

An FA cannon battalion usually consists of three company sized firing units or "batteries." These batteries each have two platoons of three howitzers each.<sup>46</sup> This amounts to an FA battalion possessing a total of 18 howitzers. There are three main types of howitzers currently in use by United States Army FA units; the M109A6 "Paladin" self-propelled, 155mm howitzer; the M777 towed, 155mm howitzer; and the M119A3 towed, 105mm howitzer. The M109A6 and M777 preceded the M119A3 in using integrated GPS enabled devices for unit locations. These devices are the Paladin Digital Fire Control System (PDFCS) for the Paladin, and the Artillery Digital Fire Control System (ADFCS) for the M777. The PDFCS and ADFCS also facilitate a battery or platoon in meeting the 5RFAF by transmitting information to the FDC using a digital

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<sup>43</sup> Department of the Army, Training Circular (TC) 3-09.8, *Field Artillery Gunnery* (Washington, DC: Headquarters, Department of the Army, November 2013), 4-33.

<sup>44</sup> *Ibid.*, 1-1.

<sup>45</sup> *Ibid.*

<sup>46</sup> Department of the Army, Army Techniques Publication (ATP) 3-09.70, *Paladin Operations* (Washington, DC: Headquarters, Department of the Army, September 2015), 1-1.

radio system. Such information, referred to as piece status, includes updated propellant temperature, ammunition quantities, ammunition lots, calibrated muzzle velocity variations, and the aforementioned unit location. Additionally, the PDFCS and ADFCS receive fire mission data from the platoon FDC.

Army Techniques Publication 3-09.70: *Paladin Operations* discussed cannon battery operations in moderate depth. For research purposes, the following excerpt was useful in understanding the basic cannon battery operations concept, and how the FA battalion provides tactical control.

The cannon battery conducts operations through decentralized execution based upon mission orders. Battery leaders exercise initiative to accomplish the mission within the commander's guidance. The capability of the cannon battery is enhanced through the flexibility and survivability of the platoon-based organization. The platoon fire direction centers are equipped with the Advanced Field Artillery Tactical Data System (AFATDS) computer as the primary digital interface between the battalion command post and the howitzers.<sup>47</sup>

The AFATDS interface between a battalion FDC and subordinate FDCs also allows the battalion FDC to transmit MET updates. This facilitates accurate MET data, the fourth component of the 5RFAF.

#### Accurate Meteorological Information

Accurate meteorological data, or MET, is vital to a FA battalion's ability to provide first round fire for effect on a target. MET data comes from a device called a Profiler.

Two versions of the Profiler currently exist; the Meteorological Measuring Set–Profiler in use by Army units and the Computer, Meteorological Data–Profiler (CMD-P) in use by both Army and Marine Corps. Both systems rely on the Meteorological Model Fifth Generation to provide gridded meteorological data

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<sup>47</sup> Ibid.



that in turn are used to generate meteorological messages for the field artillery. Profiler measures and transmits meteorological conditions to indirect fire direction centers, such as wind direction, temperature, pressure and humidity, rate of precipitation, visibility, cloud height and cloud ceiling.<sup>48</sup>

This information, found in Field Manual 3-09, was complex but important to the research because it provides a common understanding of what MET is, and why it is important to achieving accurate fires.

The July 2015 edition of the *Field Artillery Lessons Learned Primer* offers a doctrinal approach to receiving MET when the CMD-P is inoperable. The study assessed National Training Center (NTC) rotations, and asked the rotational training units (RTU), “What would the FDC do if the Profiler became inoperable?”<sup>49</sup> The solution, for most RTUs, was to use forecasted MET provided by the Air Force’s Interactive Grid Analysis and Display System (IGrADS).<sup>50</sup> The article’s author, Karl Wendel, says the IGrADS lacks an official comparison study with the Profiler, and therefore using IGrADS as a backup is doctrinally incorrect.<sup>51</sup> Wendel goes on to recommend some doctrinal solutions.

According to doctrine, which Wendel referred to, one alternative method to acquire MET data is referred to as a ballistic MET message. A ballistic MET message is

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<sup>48</sup> Department of the Army, FM 3-09, 1-43.

<sup>49</sup> Karl Wendel, *FA Lessons Learned Primer: Met: IGrADS vs Profiler* (Fort Sill, OK: Field Artillery Lessons Learned, Fires Center of Excellence, July 2015), 1.

<sup>50</sup> Ibid.

<sup>51</sup> Ibid.

an older form of MET message used when manually calculating meteorological data.<sup>52</sup> Interestingly, TC 3-09.81 acknowledged, in practice, this is a lost means of acquiring MET, and a computer MET message is the only way to derive ballistic MET data.<sup>53</sup> However, the manual, and other doctrinal publications maintained the procedures necessary to execute the process.

A FA battalion may also compensate for a failure to achieve accurate MET data by conducting a registration. The registration provides corrections for cumulative effects of nonstandard conditions to include MET.<sup>54</sup> The corrections or adjustments in a registration are then included in calculations for concurrent MET. However, even this option was questionable as it requires voice or digital communication with an observer or a radar to identify the point of impact, make subsequent adjustments, and report the information to the FDC. Additionally, a registration in a combat environment potentially exposes the firing unit to enemy target acquisition systems.<sup>55</sup>

#### Accurate Computational Procedures

Doctrinal facilitation of achieving accurate computational procedures was the final area of literature review studying how a FA battalion currently operates. In actuality, all of the other 5RFAF contribute to this requirement, and determine its achievement to a certain degree. TC 3-09.81 was very clear on the importance of this

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<sup>52</sup> Department of the Army, TC 3-09.81, 11-11.

<sup>53</sup> Ibid.

<sup>54</sup> Ibid., 10-1.

<sup>55</sup> Ibid., 10-2.

requirement for an FA battalion achieving accurate fire: “The computation of firing data must be accurate. Manual and automated techniques are designed to achieve accurate and timely delivery of fire. The balance between accuracy, speed, and the other requirements discussed in this chapter should be included in the computational procedures.”<sup>56</sup> In other words, doctrine supports both manual and automated means of computation. In regards to the AFATDS, the primary means of computing technical firing data,<sup>57</sup> doctrine provided sufficient instruction on using the system to calculate firing data. Doctrine also provided guidance for backup means for calculating fire mission data including the use of a handheld technical fire direction system such as the CENTAUR.<sup>58</sup> Either automated system is also capable of computing fire mission data without a GPS or network connection by way of the operator manual inputting the required data.<sup>59</sup>

The AFATDS plays an important role in achieving accurate computational procedures. As mentioned, the AFATDS is an interface between several different nodes at different echelons. However, the system is a digital platform for achieving the fifth requirement for accurate fire. According to Field Manual 3-09.50, a FDC team can achieve accurate computational procedures without a digital platform. The AFATDS simply replicates the fire mission computation process in a digital platform. This expedites the process in some ways. However, the manual does specify the need for the

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<sup>56</sup> Ibid., 1-3.

<sup>57</sup> Ibid., A-5.

<sup>58</sup> Ibid.

<sup>59</sup> United States Army Field Artillery School (USAFAS), *U.S. Army Field Artillery Degraded Operations*, 21-22.

FDC to continue conducting safety checks and to maintain the AFATDS database to ensure sustained accuracy.<sup>60</sup> The manual emphasized the importance of AFATDS database management and accurate computational data.

The capabilities of the howitzers' computers generate a substantial increase in information management requirements for the FDC. Accurate and timely information management is a necessity. The Advanced Field Artillery Tactical Data System (AFATDS) software is designed to replicate the decision process that a leader would go through to determine whether a target is appropriate for engagement. However, the recommendation will only be appropriate if commander's guidance is properly input.<sup>61</sup>

In short, the AFATDS must receive accurate information to successfully achieve accurate computational data, and produce an accurate firing solution. This includes information manually entered by an FDC AFATDS operator, and information sent via radio or satellite from a unit such as ammunition data. The manual also provided options for conducting degraded operations to mitigate inaccuracies due to degraded communications.

Another alternative doctrine provides for calculating fire missions is manual computations. In fact, the following excerpt specified the need to maintain this perishable skill, and described it as a backup to the previously mentioned automated systems.

The ability to perform manual fire direction must be maintained, should a need to transition to manual fire direction techniques occur at any time. Each FDC should maintain at least one firing chart with the appropriate fire direction equipment and manuals to support all manual cannon gunnery operations. The firing charts should serve as an emergency backup for AFATDS and CENTAUR.<sup>62</sup>

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<sup>60</sup> Department of the Army, ATP 3-09.50, 2-5.

<sup>61</sup> Ibid., 2-4.

<sup>62</sup> Department of the Army, TC 3-09.81, A-5.

Any of the aforementioned options for computing firing data are acceptable. As stated automated computations are the doctrinally prescribed primary means, and manual procedures are a required backup. However, available doctrine did not address how the operator receives data for manual input in the AFATDS. Similarly, doctrine did not address how to acquire data for computations in AFATDS if voice or digital communications are inoperable. This is important to consider when analyzing current capabilities to identify gaps in a FA battalion's ability to achieve accurate computational procedures in a D3SOE.

#### What is a D3SOE and what are its Characteristics?

The second research question seeks to provide an understanding of a D3SOE. To answer this question, the research first attempted to find a doctrinal definition for the term D3SOE. However, as mentioned in chapter 1, Army doctrine does not provide a definition for a D3SOE. One non-doctrinal source, the *U.S. Army Field Artillery Degraded Operations White Paper* (FADOWP) dated 2016, confirmed this fact stating that neither the Army Doctrine Reference Publication 1-02 or Joint Publication 1-02, nor any FA publications offer a definition for the term.<sup>63</sup> However, ATP 3-09.70 *Paladin Operations* provided the following concerning degraded conditions:

A degraded condition indicates a subsystem is not 100% functional. Though a degraded condition exists, certain degraded subsystems will not interfere with howitzer operation or impede mission effectiveness. However, it is important to

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<sup>63</sup> United States Army Field Artillery School (USAFAS), *U.S. Army Field Artillery Degraded Operations*, 6.

know which subsystem is degraded. Knowing which failure to compensate for or correct will allow the howitzer section to continue the mission.<sup>64</sup>

In other words, a degraded environment exists when a system or its subsystem is improperly functioning, and results in limited or zero ability to use the respective system.

A review of ADRP 1-02 also found no available definition of “deny.” However, it defined denial operations, and denied area. The latter term included a Department of Defense definition describing a denied area as, “an area under enemy or unfriendly control in which friendly forces cannot expect to operate successfully within existing operational constraints and force capability.”<sup>65</sup> This definition is important because it described how something being denied affects a unit’s ability to operate. As a result, this provided a better understanding of what a denied environment is, and allowed the research to differentiate between the degraded and disrupted components of a D3SOE.

Disrupted, the final “D” of D3SOE, was not specifically defined in existing FA doctrine. However, Army doctrine defined the term “disrupt” in the previously mentioned ADRP 1-02.

1. A tactical mission task in which a commander integrates direct and indirect fires, terrain, and obstacles to upset an enemy’s formation or tempo, interrupt his timetable, or cause enemy forces to commit prematurely or attack in piecemeal fashion. 2. An obstacle effect that focuses fire planning and obstacle effort to cause the enemy to break up his formation and tempo, interrupt his timetable, commit breaching assets prematurely, and attack in a piecemeal effort.<sup>66</sup>

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<sup>64</sup> Department of the Army, ATP 3-09.70, 5-1.

<sup>65</sup> Department of the Army, Army Doctrine Reference Publication (ADRP) 1-02, *Terms and Military Symbols* (Washington, DC: Headquarters, Department of the Army, December 2015), 1-27.

<sup>66</sup> *Ibid.*, 1-30.

This definition provided a way to differentiate a disrupted environment in contrast to degraded or denied environments. Specifically, it categorized the term as a task or obstacle effect, and based its purpose on an ability to affect the enemy's condition based on formation, timetables, tempo, or otherwise force the enemy to change his plan to some degree.

The *Merriam-Webster's* definition of disrupt provided a similar description. While less military related, this research considered the definition to ensure objectivity and well-rounded methods for defining a D3SOE. The first definition provided the meaning of, "to break apart: rupture," or "to throw into disorder." The second meaning was, "to interrupt the normal course or unity of." <sup>67</sup> Given the context of an FA digital system, this definition suggested a system or its subsystems under disrupted conditions might still function but are disordered or sporadic. Such disruptions might be due to attacks on a communication network or a particular aspect of a system such as AFATDS software or the fire support coordination measures recorded in the database.

This final definition combined with the two previous elements of a D3SOE provided a better understanding of how a D3SOE affects a FA battalion in general terms. A synthesis of these definitions also provided a definition to use in conducting this research. Thus, the definition of a D3SOE for this research was: An operational environment in which an adversary uses synchronized capabilities to concurrently degrade, deny, and disrupt the space operating environment in order to gain a positional advantage or to desynchronize the friendly force's ability to provide massed or precision

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<sup>67</sup> Merriam Webster, "Disrupt," accessed April 26, 2017, <https://www.merriam-webster.com/dictionary/disrupt>.

fires in support of combined arms maneuver or wide area security. This definition enhanced the review of literature for the third research question by ensuring resources provided information relevant to understanding how a D3SOE affects the 5RFAF. Additionally, defining the term contributed to a framework for understanding the basic characteristics of a D3SOE, and how it affects a FA battalion when analyzing case studies later in chapter 4.

#### What are the effects of a D3SOE on the Five Requirements for Accurate Fire?

The third and final supporting research question sought to determine how a D3SOE affects the 5RFAF. To accomplish this, the review of literature returned to available doctrine to find areas that might provide guidance to address the conditions of a D3SOE as determined and defined by the previous section. Additionally, this section considered the 5RFAF as outlined in the first section of this chapter to maintain relevance to overall primary research question. As a result, the literature review provided a foundation of knowledge to facilitate answering the question of how a D3SOE affects a FA Battalion.

As mentioned, Army and FA doctrine did not specifically address a D3SOE. However, doctrine provided some clues as to how a D3SOE affects the 5RFAF. Beginning with Accurate Target Location and Size, doctrine described the role of the observer. For the most part, doctrine provided excellent guidance for how observers acquire targets in degraded conditions utilizing only a map, compass, and binoculars. TC 3-09.8 emphasized the role of the observer, and the importance of accurate target location.



Accurate target location is critical to creating first round effects on targets. The use of position locating systems, mensuration tools, and laser rangefinders/designators operating from known locations are critical to accurately locating targets and creating first round fire for effect. When these capabilities are not available and the observer is operating in a degraded mode, the observer must rely on thorough terrain map study to accurately locate targets. Frequently in these degraded situations, the observer is unable to accurately locate targets and must correct errors in target location by adjusting fires onto a target, thereby forfeiting surprise and minimizing effects on target.<sup>68</sup>

Several of the position locating tools listed in this excerpt require the use of a GPS device to accurately locate a target. This meant observers must self-locate their own position on a map before conducting a call for fire based on direction and distance from their position. This method worked well for standard targets, but precision targeting required precise grids to meet precision requirements. Furthermore, a thorough research of older FA doctrine, including Field Manual 6-30: *Tactics, Techniques, and Procedures for Observed Fire*, did not find a solution for how to transmit any fire missions or target locations if a D3SOE denies communications.

In regards to Accurate Firing Unit Location, doctrine provided several descriptions of how firing units may self-locate in degraded situations. There was some mention of positioning capabilities in an older doctrinal publication, Field Manual 6-50: *Tactics, Techniques, and Procedures for the Field Artillery Cannon Battery*.

Unfortunately, it simply covered the effects of different terrain on a unit's ability to self-locate using a map. Of note was the manual's recommendation for the survey section to provide survey data using the IPADS-G.

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<sup>68</sup> Department of the Army, TC 3-09.8, 3-1.

The IPADS-G is a self-contained system used to determine accurate position, elevation, and azimuth.<sup>69</sup> Modern artillery battalions use the IPADS-G to determine survey data for the firing batteries, and for counterfire fire finder radar positioning. Modern FA units are also capable of using their organic GPS systems to provide positioning data for cannon batteries, individual howitzers, and counterfire radars. However, doctrine did not provide any options to GPS other than using survey control points as previously described to achieve accurate unit location. Furthermore, doctrine did not provide guidance for how to transmit unit location from the gunline to the FA battalion FDC in a D3SOE scenario where communications are inoperable, and wire communications are unavailable.

The review of literature found the same results when researching doctrine's approach to achieving accurate weapon and ammunition information. This was based on previous discussions concerning piece status. Because piece status includes piece location, the same challenges in transmitting that information apply to transmitting weapon and ammunition information that is also included in the piece status update.

The first section of this chapter addressed the 5RFAF, and consequently identified an issue in achieving accurate MET information. In review, doctrine suggested that if radio communication is not available, the FA battalion must compensate for a failure to achieve accurate MET data by conducting a ballistic MET, conducting a registration, or by requesting MET from a nearby adjacent unit. These options surely face challenges in a D3SOE where transmitting MET, or registration missions may be impossible.

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<sup>69</sup> United States Army Field Artillery School (USAFAS), *U.S. Army Field Artillery Degraded Operations*, 15.

A study of FA doctrine provided some guidance for conducting fire missions to achieve accurate computational procedures in degraded conditions. In Field Manual 3-09 dated April 2014, doctrine simply stated, for “firing units without an on-board technical computation capability, or operating in a degraded mode, the fire direction center (FDC) transmits firing data to the firing unit as fire commands.”<sup>70</sup> This meant the FDC must compute fire missions manually without using the AFATDS, and transmit the fire commands to the gun line over the battalion or battery voice frequency radio net. The manual did not give guidance on how to transmit the fire mission if radio communications are degraded. However, there was an emphasis on rehearsing fire missions both voice and digital along the entire data link, and under the same digital or voice communication conditions anticipated during operations.<sup>71</sup>

Current training guidance from the USAFAS also addressed the need for training degraded operations. In the USAFAS *Field Artillery 2017 Training Strategy*, guidance for targeting includes adhering to a 80-10-10 standard for training time allotment; 80 percent of available time should focus on using digital precision devices to achieve CAT 1 or 2 coordinates; 10 percent of the time units should train with digital systems in a degraded capacity; 10 percent of the time units train with fully degraded back up methods.<sup>72</sup>

Degraded operations at the platoon and section level are perishable skills. It is imperative that commanders allocated sufficient time and resources for unit

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<sup>70</sup> Department of the Army, FM 3-09, 1-45.

<sup>71</sup> Ibid., 1-46.

<sup>72</sup> United States Army Field Artillery School (USAFAS), *The United States Army Field Artillery 2017 Training Strategy*, 28.

leaders to institute training programs that enable their units to exercise operations in degraded modes. TC 3-09.8 provides guidance on degraded operations, both dry and live fire, as per the commander's discretion. Units must be able to shoot-move-communicate under degraded/manual operations as part of the Artillery tables in less than optimal, conditions.<sup>73</sup>

Following this guidance, TC 3-09.8: *Field Artillery Gunnery* dated June 2016 provided guidance on conducting field artillery gunnery in degraded conditions. According to the manual, firing incidents resulting from degraded communications during Paladin live fire operations can be prevented by secondary independent checks.<sup>74</sup> The general theme for guidance throughout the manual emphasized units must train and receive assessment on their qualification to conduct degraded fire missions using manual computation, and voice radio transmissions for relaying the fire missions to the gun line.<sup>75</sup> However, there was no mention of how to conduct fire missions when radio communications are not possible.

### Summary

In summary, this chapter discussed multiple sources of literature to address each of the supporting research questions. Each section successfully answered its respective research question, and provided the answer as a summary of the review of related literature. The findings of this chapter set the conditions for understanding what to look for later in chapter 4 when analyzing the case studies to determine how a FA battalion

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<sup>73</sup> Ibid., 29.

<sup>74</sup> Department of the Army, TC 3-09.8, 2-8.

<sup>75</sup> Ibid., 1-1.

operates in a D3SOE. Most importantly, the synthesis of literature from all three areas provided a thorough and sufficient base for continuing the research.

## CHAPTER 3

### METHODOLOGY

[A military leader] must put together a perspective in which he will evaluate the phenomena of war. [He] needs a working hypothesis. Of course, not every military leader will take the trouble or have the opportunity to think about the nature of a future war. Strategic mediocrity perhaps prefers to proceed from stereotypes and recipes. Reality will be a cruel disappointment for such a poor excuse for a leader; the theory of strategic art cannot have him in mind.

— Aleksandr A. Svechin, *Strategy*

#### Research Approach

This chapter explains the methodology used to research and answer the thesis question of how does a modern FA cannon battalion operate in a D3SOE. The chapter begins with a discussion of the thesis background and related research. After the background, subsequent sections include an explanation of how the methodology addresses secondary research questions, and a reflection on the strengths or weaknesses of the methodology.

#### Thesis Background and Methodology

In the context of this study, a D3SOE represents future war for the US military. In the interest of focusing the research, this thesis sought to assess how a modern FA cannon battalion operates in a D3SOE. This included researching and developing a determination of existing capability gaps that might prevent a unit from achieving mission success. To organize the research, the thesis used a qualitative collective case study research methodology (see figure 1) to address the primary and secondary research questions.

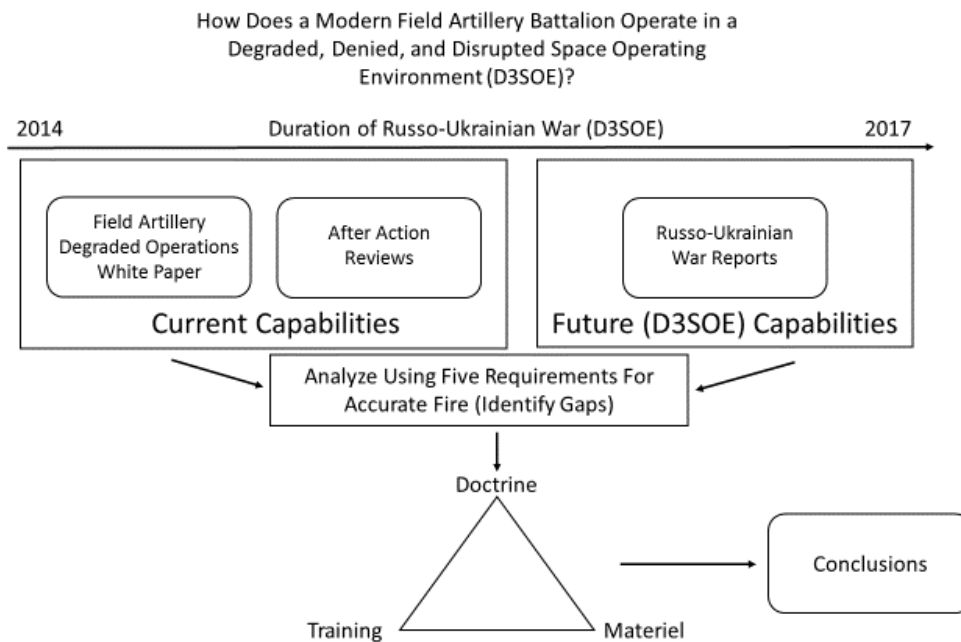


Figure 1. Thesis Methodology

Source: Created by author.

As a case study methodology, research involved an initial exploration of doctrine to determine how modern FA cannon battalions currently operate. Next, the review searched through doctrine to determine what a D3SOE is, and what its characteristics are. Finally, the literature review examined doctrine to determine how a D3SOE affects the FA battalion's ability to meet the 5RFAF.

The fourth chapter analyzed cases using the 5RFAF as a lens. This allowed the analysis to determine in some cases how well the case supported the 5RFAF, or where cases demonstrated a failure in one or more of the 5RFAF. The cases used for analysis were the *U.S. Army Field Artillery Degraded Operations White Paper (FADOWP)*, Combat Training Centers (CTC) and Home Station Training: Firing Incident Reports and

After Action Reviews (AAR), and reports from the RUW. These three cases represented theoretical, training, and combat contexts, respectively, for D3SOE during the period of 2014 to 2017 to facilitate cross case analysis for trends. The research then presented the results of the analysis according to a 5RFAF assessment rubric (see figure 2). The rubric served as a means of graphically depicting the success of the 5RFAF in a D3SOE.

Case 5RFAF	FA Degraded Operations White Paper	CTC and Home Station AARs/ Reports	Reports from RUW
Accurate Target Location and Size			
Accurate Firing Unit Location			
Accurate Weapon and Ammunition Information			
Accurate Meteorological Information			
Accurate Computational Procedures			

Figure 2. Five Requirements for Accurate Fire and Capability Assessment Rubric

*Source:* Created by author.

The process continued by synthesizing the information to determine whether current capabilities help a FA battalion meet the 5RFAF in a D3SOE situation. Based upon the analysis, the fifth chapter of this paper provided conclusions on how a FA



battalion operates in a D3SOE. These conclusions also provided recommendations for doctrine, training, and materiel capabilities to enhance a FA battalion's ability to meet the 5RFAF according to the findings of the analysis in chapter 4. Final thoughts of the paper concluded with recommendations for future research in areas that deserve further exploration to fill other gaps in knowledge identified during the course of research.

### Data and Information Collection

The methodology for this thesis required a thorough review of literature beginning with a review of modern FA cannon battalion operations as described in doctrine. Then doctrine assisted with gaining a base of knowledge in understanding what a D3SOE is, and its characteristics. AARs from Army CTCs and home station training exercises were also critical as they provide insight as to how CTCs incorporated D3SOE characteristics in to simulated training, and the responses of the RTUs. Assessments or reports from the RUW were the third source considered for review in order to assess how peer or near-peer forces fight and operate in a D3SOE. Together, these three areas of research literature built a common understanding for the methodology to expound upon.

Additional sources, such as white papers and findings from formal studies were also considered relevant to the review of literature. Some of these particular sources were not considered official doctrine, or the official views of the US Army or the FA branch. However, these analytical documents provide a deeper understanding of their respective topics. Collectively, all of the aforementioned sources combined for use in applying the methodology for conducting analysis and developing conclusions later in the thesis. As a case study based methodology, the collection of information in this study did not involve any direct engagement with living persons.

Again, the research methodology directed a review of doctrinal literature relevant to current FA battalion operations, and associated capabilities. While a lengthy process, the review of doctrine was critical to the success of the methodology framework. Furthermore, understanding doctrine facilitated understanding of the other research areas by defining key FA and D3SOE related terms. An example of this was the use of doctrine to understand how a unit operates before researching how a unit actually operates based on AARs. Ultimately, a doctrinal foundation contributed to a more professional approach to the research.

The review of AARs and lessons learned was the next area of focus for research. This involved finding and filtering many documents to identify the documents most relevant to the research. The goal was to find AARs that included a detailed description of CTCs simulating D3SOEs, issues faced by RTUs in the simulations, and the lessons learned by both sides from the incident. Other reports considered and used in the research were firing incident reports. These incidents occurred either at CTCs, or during the RTUs home station training. All materials in this area contributed to understanding how units operate in training in contrast to what doctrine prescribed.

The final area of research focused on the RUW and the two main forces operating in the conflict. Russia and Ukraine both possess D3SOE capabilities. This makes the RUW a fantastic example or proxy for assessing how well a unit operates in a D3SOE. Literature pertaining to the RUW was therefore beneficial to the methodology by providing real world combat experiences of peer or near-peer forces for comparing and contrasting with the knowledge gleaned from doctrine and AARs. Most importantly,

using the RUW as a proxy war allowed the research to identify how a D3SOE affects the 5RFAF, and subsequently determine gaps in capabilities.

The current and historical information found in doctrine, AARs, and RUW studies or reports provided sufficient data to understand the operating picture of a modern FA battalion in a D3SOE. Existing doctrine did not provide solutions to every issue a D3SOE presents. Training at CTCs and home station events reflected a mixed picture of units operating by doctrine, and overcoming their shortfall by improvisation alone. Also, CTCs are not yet fully implementing a D3SOE for units to better test doctrine and TTPs. This initial impression emphasized the importance of this thesis, and the benefit of focusing on a particular organizational echelon of the fires warfighting function.

### Questions

The primary research question was how does a modern FA cannon battalion operate in a Degraded, Denied, Disrupted Space Operations Environment (D3SOE)? To answer this question, the thesis considered secondary research questions that seek to uncover the foundations of the issue.

The first supporting question was how does a modern FA cannon battalion currently operate? Answering this question involved a review of current doctrine, and the history of how doctrine evolved to its current state. Also, a study of CTC AARs and similar sources were available to expand the answer to this question. Developing the answer to this question was critical for understanding the limitations of current capabilities when comparing them to those in use in a D3SOE such as the RUW.

The second question was, what is a D3SOE, and what are its characteristics? Answering this question required defining a D3SOE, and determining its major

characteristics. The term itself did not exist in doctrine. As a result, finding a definition required some extrapolation by the researcher through a process of defining the terms “degraded,” “denied,” and “disrupted” individually. The rest of identifying the characteristics of a D3SOE required a synthesis of current doctrine, training observations, and combat reports pertaining to the elements of a D3SOE.

The final question was, what are the effects of a D3SOE on the Five Requirements for Accurate Fire (5RFAF)? To answer this question, the research considered the 5RFAF in D3SOE as defined by the previous review of literature. Using doctrine, the review of literature returned to available doctrine, and sought to identify where doctrine addresses a D3SOE. This review found areas in literature that provided guidance to address how the conditions of a D3SOE affect the 5RFAF. These findings contributed to the primary research question by providing more detail on just how a FA battalion operates in a D3SOE using a detailed approach provided by the 5RFAF.

### Summary

In summary, this chapter discussed the guiding principles of the research methodology for this thesis. Also, the chapter identified the three cases for the research: emergent doctrine, AARs, and reports from or about the RUW. The discussion of research literature section then led to a walkthrough of how the methodology seeks to address the primary and secondary research questions. This final section of the chapter focused on explaining how the secondary questions relate to and support answers for the primary research question. Chapter 4 will provide the results of the case analysis.

## CHAPTER 4

### ANALYSIS

Most people, in fact, will not take the trouble in finding out the truth, but are much more inclined to accept the first story they hear.

— Thucydides, *History of the Peloponnesian War*

#### Introduction

This chapter analyzed available literature and reports in order to determine how a modern FA cannon battalion operates in a D3SOE. Beginning with an emergent doctrine case, the analysis assessed the FADOWP's proposed solutions, and the document's ability to facilitate achieving the 5RFAF. Analysis continued with an assessment of current CTC AARs, firing incident reports, and home station training AARs to assess how well FA battalions currently meet the 5RFAF in training situations exhibiting one or more elements of a D3SOE within a US training context as a case. Finally, this chapter analyzed reports from the RUW to determine how well either side of the conflict met the 5RFAF given a D3SOE as a case of combat employment. The findings of this analysis linked relevance to a field artillery battalion by considering the 5RFAF throughout the chapter, and provided information to develop answers to the primary research question during conclusions in chapter 5.

#### Field Artillery Degraded Operations White Paper

In 2016, the USFAS published the FADOWP. White Papers are not a doctrinal document, but usually contain doctrine as a foundation to gain relevance. As a result, these documents are sometimes viewed as an approved method, or solution to a problem

until an official update to doctrine occurs. According to Colonel Stephen Maranian, Chief of the Field Artillery, the FADOWP's intent was, "to spark thought on how to plan for and train to continue to maintain firing capability even when all of our digital capabilities are not fully functional."<sup>76</sup> However, Maranian added that it is up to commanders to determine the degree of degraded conditions to train their units in based on anticipated future missions.<sup>77</sup> The white paper itself is based upon what he describes as, "the inevitability that we may be temporarily degraded but at the same time we must continue to deliver effective fires."<sup>78</sup>

Upon examination, the FADOWP provided little mention of a denied environment outside of acknowledging, "systems sometimes fail or capabilities can be denied."<sup>79</sup> Further study of the paper found a discussion on the loss of Precision Navigation and Timing, or what the paper refers to as a GPS denied environment. Within the discussion, is the phrase "persistent disruption" that refers to a prolonged absence of GPS service.<sup>80</sup> This phrase is critical for understanding what denied might mean for any digital capability the FA battalion uses to achieve the 5RFAF.

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<sup>76</sup> United States Army Field Artillery School (USAFAS), *U.S. Army Field Artillery Degraded Operations*, 3.

<sup>77</sup> Ibid.

<sup>78</sup> Ibid.

<sup>79</sup> Ibid.

<sup>80</sup> Ibid., 7.

## Accurate Target Location and Size

Analysis began with an assessment of how well the FADOWP assists a FA battalion in meeting the first requirement for accurate fire in a D3SOE. Accurate target location and size depends on the ability of an observer or sensor to provide target information to the FA battalion. Incorrect fire mission data thus results in a target location error. According to the FADOWP, target location error results from errors in observer self-location, direction of target from the observer, and the range or distance to the target.<sup>81</sup>

To mitigate target location error in a degraded environment, the FADOWP also provided guidance by referencing Appendix A of ATP 3-09.30, *Techniques for Observed Fire* for self-location techniques using a LLDR. For observer location, the white paper stated, “In absence of a GPS signal the device can be oriented with the celestial compass, the digital magnetic compass (DMC) and by performing a laser resection and map spot off the PFED’s PFI information providing very accurate positioning information.”<sup>82</sup> Referencing chapter 2 discussions on methods of determining direction, the white paper also suggested, but did not state, all five methods remain valid in a degraded environment, including the LLDR.

This guidance successfully identified a way to continue using the LLDR in a GPS degraded environment, and in a D3SOE where GPS may be completely denied. Of note, was the fact that ATP 3-09.30, did not specifically state this guidance for degraded

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<sup>81</sup> Ibid., 9.

<sup>82</sup> Ibid.

operations, nor a step procedure for doing so. Also of concern was the FADOWP's lack of discussion on a primary, alternate, contingency, and emergency (PACE) plan for a true D3SOE, and only provided the previously discussed doctrinal recommendations that in this context only apply to a degraded environment.

In addition to the LLDR, the FADOWP discussed how the PFED can conduct self-location using "a laser resection and map spot off the PFED's PFI information proving very accurate positioning information."<sup>83</sup> Once again, however, the white paper referenced ATP 3-09.30 for this procedure. Upon inspection, ATP 3-09.30 did not specifically include this guidance, or a description of how to execute the required tasks with a PFED. Also, similar to the LLDR, the FADOWP did not discuss the PFED's ability to transmit precision targeting information. For example, the document referenced ATP 3-09.30, declaring digital communications as the primary means for transmitting fire commands.<sup>84</sup> This guidance supported the use of digital systems to increase precision and timely fires in an uncontested environment, but it does not address what to do in a D3SOE where digital and voice communications might be unavailable to the observer.

In summary, the FADOWP sufficiently addressed how an observer acquires an accurate target location. It also clearly conveyed the ability of an observer to continue using the LLDR to acquire distance and direction in a degraded environment. Although not specified, the same appears true for a denied or disrupted environment as the LLDR does not need any communications connectivity to perform this function. The same is

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<sup>83</sup> Ibid., 9.

<sup>84</sup> Ibid., 7.



true for the PFED's ability to provide self-location capabilities for the observer.

However, the FADOWP does not address the ability of the observer to transmit a call for fire when digital and voice methods are not available. As a result, the document's facilitation of the first requirement for accurate fire is questionable.

### Accurate Firing Unit Location

Previous review of literature determined the FA battalion's survey section to be of critical importance for achieving accurate unit location. The FADOWP similarly stated the importance of survey, but emphasized the use of digital and automated systems to acquire survey data. Accordingly, the white paper recommended using a GPS enabled howitzer internal navigation unit (INU) as the primary means of determining firing unit location both when the unit is occupied, and when it receives a mission while moving between position areas for artillery (PAA), also referred to as a "hip shoot."<sup>85</sup> The FADOWP continued by listing the use of an IPADS-G survey data enabled INU, a non-GPS or IPADS-G enabled INU, and manual survey as the alternative, contingency, and emergency methods respectively.<sup>86</sup> Upon inspection of current Paladin, M777, and M119A3 units' Modified Table of Organization and Equipment (MTOE) on the "Force Management System Web Site" (FMSWEB), the aiming circle was included on the list, and validates manual survey as an option.<sup>87</sup>

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<sup>85</sup> Ibid., 15.

<sup>86</sup> Ibid.

<sup>87</sup> United States Army Force Management Support Agency, "Force Management System Web Site," January 4, 2017, accessed May 15, 2017, <https://fmsweb.fms.army.mil/unprotected/splash/welcome.aspx>.

The previous options worked well for acquiring survey in a degraded environment, but did not address the dissemination of survey data or unit location in a D3SOE. For example, ATP 3-09.2 states, “data can be stored and rapidly transmitted by using digital systems such as an Advanced Field Artillery Tactical Data System.”<sup>88</sup> The FADOWP did not provide recommendations on how the FA battalion may enable this process, and transmit firing unit locations when communications experience denied or disrupted environments. This is a problem because data transmission using the AFATDS requires a digital connection. Data may be sent verbally via radio or telephone, although it is not a preferred method given the difficulty in describing particular aspects of survey data.<sup>89</sup>

The FADOWP succeeded in providing solutions to allow a survey section to acquire accurate unit location. Albeit, the solutions were based on doctrine already discussed in the review of literature for how a FA battalion normally operates. The was also true for the white paper’s mention of the gunline using existing doctrinal manual lay procedures to occupy a PAA. However, this was not an effective solution for units conducting a “hip shoot” when a D3SOE potentially prevents them from quickly acquiring their location between PAAs. Additionally, the dissemination of survey data, and updated unit location from the gunline are not reliable due to the effects of a D3SOE on radio frequencies. While the radio capability is a materiel problem, a lack of doctrinal guidance for alternative means of communicating accurate unit location in a D3SOE

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<sup>88</sup> Department of the Army, ATP 3-09.2, 3-14.

<sup>89</sup> Ibid.

demonstrates a potential doctrinal shortfall as well. For this reason, analysis concluded that the FADOWP does not adequately support accurate unit location.

### Accurate Weapon and Ammunition Information

Previous review of literature identified the use of digital systems such as the PDFCS or ADFCS as the primary means to transmit information such as piece status from individual howitzers to a FDC. The FADOWP provided little discussion on how a degraded environment may affect a FA battalion's ability to use these PDFCS or ADFCS to achieve accurate weapon and ammunition information. In fact, the document stated that the information, or piece status, "is not usually affected by degraded operations."<sup>90</sup> Furthermore, the only other guidance provided is the impact of a degraded environment on precision guided munitions (PGM), and the possibility of using alternative munitions if operating in a GPS denied environment.<sup>91</sup> This information is good, but does not address the impact of degraded communications on transmitting or receiving piece status.

The overall brevity of discussion in the FADOWP on how degraded communications affect accurate weapon and ammunition information is an area of concern. Obviously, a howitzer crew can obtain the required information to update their piece status in a D3SOE. This is because communication issues in a D3SOE do not affect the ability of tools such as a thermometer, or crew members counting rounds to acquire their respective data. Similarly, the crew can still input data in their ADFCS or PDFCS.

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<sup>90</sup> United States Army Field Artillery School (USAFAS), *U.S. Army Field Artillery Degraded Operations*, 19.

<sup>91</sup> Ibid.

However, the howitzer crew's ability to transmit their updated piece status is not so simple if radios are not properly functioning. To mitigate this issue in a degraded environment, the FADOWP recommended the use of wire, and cited ATP 3-09.50's guidance which this thesis discussed in the review of literature.<sup>92</sup> However, a search of FMSWEB yielded no inclusion of radio communication wires or cable on the unit MTOEs for Paladin, M777, or composite howitzer battalions.<sup>93</sup> As a former battery commander from 2012-2014, radio communication wire was a common property book item. The removal of this item from the MTOE contradicted guidance in the FADOWP, and in doctrine.

#### Accurate Meteorological Information

As previously stated, the FA battalion uses the CMD-P to acquire meteorological data in order to meet this requirement for accurate fire. The FADOWP addressed MET, and the CMD-P stating the CMD-P utilizes a local area network within the FA battalion tactical operations center (TOC) to acquire MET data, and interface with the FDC AFATDS.<sup>94</sup> When this process fails, the FADOWP recommended acquiring MET using data from another nearby unit. Doing so, however, requires radio communication with an adjacent unit or individual to input the MET message.<sup>95</sup> In addition to using an adjacent

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<sup>92</sup> Ibid, 24.

<sup>93</sup> United States Army Force Management Support Agency, "Force Management System Web Site."

<sup>94</sup> United States Army Field Artillery School (USAFAS), *U.S. Army Field Artillery Degraded Operations*, 20.

<sup>95</sup> Ibid.

unit's MET, the FADOWP recommended using ballistic MET, and in an emergency to conduct a registration.<sup>96</sup> However, a D3SOE hinders the FA battalion's ability to update MET using a registration because of the communication platforms used to coordinate with an observer.

Given this analysis, the FADOWP sufficiently described how to acquire MET in a degraded operating environment. However, it did not provide guidance for a unit operating in a D3SOE where acquiring MET using the CMD-P, or attempting to receive MET via voice radio communications from another unit are not dependable due to instances of connectivity denial. Even the option of registration, though clearly articulated, needs further doctrinal guidance to be effective when communications do not properly function. In summary, the FADOWP provided alternatives for acquiring MET when a CMD-P is not properly functioning. However, these alternatives, such as a registration, may expose the FA battalion to enemy detection. Subsequently, some alternatives are not guaranteed in a D3SOE. Furthermore, as with the previous requirements, the transmission of MET data to subordinate firing batteries operating in a D3SOE is also an issue for concern. As a result, the FADOWP did not provide an adequate solution for acquiring MET in a D3SOE.

#### Accurate Computational Procedures

The FADOWP briefly discussed options for achieving accurate computational procedures in a degraded environment. Recommendations mainly focused on using stand-alone backup systems that could compute data without a network connection.

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<sup>96</sup> Ibid.

However, the white paper stated this method relies on the operator to input accurate data instead of receiving it via digital communications.<sup>97</sup> The document also recommended using the CENTAUR, but recognized the same requirement for operator input of data.<sup>98</sup> Analysis showed that inputting data is not the problem, but the ability of the operator to receive the data. Manual computations were listed as an emergency method to achieve accurate computational procedures, but again this requires the receipt of fire mission data to actually compute firing data.

Further research of the FADOWP's recommendations for using manual gunnery techniques identified another issue. Based on a search of the FMSWEB, the Fiscal Year 2018 MTOE did not include all equipment necessary for a FA battalion to conduct manual computations.<sup>99</sup> This search included one Paladin artillery battalion, one M777 howitzer battalion, and a M777/ M119A3 composite battalion. The list of missing equipment, which were the artillery fire control plotting sets, and indirect fire plotting boards, was the same across all three battalions. In my experience, this equipment was part of the battalion FDC and battery FDC assigned equipment.

### Summary

This section analyzed the FA Degraded Operations Whitepaper using the 5RFAF to determine how well it prepares a FA battalion to meet the 5RFAF in a D3SOE. The

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<sup>97</sup> Ibid., 21.

<sup>98</sup> Ibid.

<sup>99</sup> United States Army Force Management Support Agency, "Force Management System Web Site."

white paper demonstrated how the FCoE attempted to address degraded operations. In this context, the white paper succeeded, and did an outstanding job of identifying the fundamental skills necessary for a FA battalion to successfully operate degraded. However, as a “Degraded Operations White Paper,” the document only addressed one aspect, degraded, of a D3SOE. Overall, the white paper lacked recommendations or solutions to overcome situations specific to a D3SOE, such as the denial of communications, rather than simple degradation. While the FADOWP recommended useful TTPs, such as using wires to establish radio communications within the firing battery during degraded operations, it failed to acknowledge the absence of the radio wires on unit MTOEs. Additionally, the FADOWP included recommendations, such as manual computations, that depend on equipment not currently listed in the FA battalion’s property book such as indirect fire plotting boards, and artillery fire control plotting sets.

Combat Training Centers and Home Station Training:  
Firing Incident Reports and After Action Reviews

Following the release of the FADOWP, the USAFAS released another publication, *The United States Army Field Artillery 2017 Training Strategy*. This strategy underscored the importance of the FA to support maneuver commanders in a D3SOE saying, “The emergence of the disrupted, degraded, denied space operational environment (D3SOE) problem set will require maneuver commanders to rely more heavily on their organic surface-to-surface fires.”<sup>100</sup> The acknowledgement of a D3SOE, gave reason to consider the current ability of FA battalions to meet the 5RFAF while

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<sup>100</sup> United States Army Field Artillery School (USAFAS), *United States Army Field Artillery 2017 Training Strategy*, 8.

facing a D3SOE in training. However, at the time of research there were not any reports available which cited a D3SOE training environment to study as a case. As a result, this research assessed available reports and AARs as cases, focusing on failures of units to meet the 5RFAF.

The AARs considered for this analysis were those of 1-2 and 2-2 Stryker Brigade Combat Teams (SBCT). The AARs chronicle the experience of both SBCTs during their NTC rotations in 2016, and provided information useful for determining how well the 5RFAF were met in training. Other reports included the experiences of firing units supporting the 82nd Airborne Division, and various other units either conducting either home station training, or RTUs conducting training at the NTC. As mentioned, these reports did not provide D3SOE specific examples. Instead, they provided instances of communications or positioning problems that resemble the effects of a D3SOE identified in chapter 2.

This section of the analysis assessed reports from CTC rotations, home station AARs, and firing incident reports ranging from 2014 to 2016 in order to determine how well units met the 5RFAF. Doing so allowed the research to assess not only unit achievement of the 5RFAF, but to determine if performance improved after 2014 when the idea of a D3SOE became more common in professional discussions. Accordingly, this section considered reports that contained information relevant to the 5RFAF, but where the incident was not necessarily the result of a D3SOE.

#### Accurate Target Location and Size

Relevant firing incident reports are critical to understanding the cause of firing incidents, and how to prevent them in the future. Similarly, firing incidents assisted this



analysis by providing instances when a unit did not meet one or more of the 5RFAF. In some instances, the firing incidents were the result of a communications related issue, and afforded an opportunity to better assess how well a unit achieved the 5RFAF. In fact, the first case this analysis examined was this type of firing incident.

During a Brigade Live Fire Exercise, conducted by the 82nd Airborne Division in 2015, a firing unit lost digital communications.<sup>101</sup> This prompted the unit to utilize voice frequencies to receive a call fire.<sup>102</sup> Meanwhile, the fire mission stayed in the AFATDS mission queue until after the fire mission when digital communications came back online, causing the battalion FDC to receive the same fire mission in AFATDS.<sup>103</sup> Unaware of the duplicate fire mission, partly due to a human error in not noticing the duplicate target number, the unit FDC fired the mission again. Subsequently, the unit issued a “Check Fire” to investigate the error.<sup>104</sup> This example demonstrated the confusion a loss of communications creates within a firing unit, and the potential ability to stop artillery fires for a time to determine the error.

Another report used for analysis of accurate target location and size was the AAR for NTC Rotation 16-03. In the report, 2-2 SBCT identified communications between the

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<sup>101</sup> John Folland, “FCoE Voluntary DIVARTY Data Call E-Mail,” US Army Fires Center of Excellence, 2015.

<sup>102</sup> Ibid.

<sup>103</sup> Ibid.

<sup>104</sup> Ibid.

brigade fires cell and the fires battalion as an issue of concern.<sup>105</sup> While not an example of a call for fire, coordination of fire missions between echelons is critical to ensuring timely and accurate fires. Problems in communications likely resulted from issues related to radio retransmission operations also addressed in the AAR.<sup>106</sup> Nevertheless, maintaining communications proved to be a challenge that forced the brigade to rely on contingency and emergency communication systems to continue their mission.

To mitigate communications issues, the brigade identified the need for a clearly defined and prescriptive communications plan spanning from the brigade to battalion level.<sup>107</sup> The major take away from this study was 2-2 SBCT's recognition of a need to maintain communications in order to provide detailed integration and rehearsals across the fires system. Also, their establishment of a common communications plan that included a PACE plan for communication mirrors guidance in the FADOWP published about two months after this AAR.

A final AAR used to analyze the first requirement for accurate fire was from another RTU, 1-2 SBCT, and its actions in training during NTC Rotation 16-06. 1-2 SBCT visited the NTC approximately three months after 2-2 SBCT, and exhibited some of the same issues concerning communications. For example, the AAR cited difficulties communicating on a common platform to coordinate brigade controlled fires. This

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<sup>105</sup> MAJ Michael Taylor, "SBCT S-3. 2-2 SBCT NTC 16-03 AAR to FORSCOM" (Headquarters, 2nd Stryker Brigade Combat Team, Joint Base Lewis-McChord, WA, August 23, 2016), 2.

<sup>106</sup> Ibid.

<sup>107</sup> Ibid.

deficiency subsequently constrained their ability to link sensors such as observers, to shooters or the firing battery.<sup>108</sup> Further review of the AAR revealed a discussion on a need for improved EW training support at the NTC. 1-2 SBCT identified this need after identifying a shortage of Observer Coach/ Trainer (OC/T) support for EW that resulted in minimal forcing functions for the brigade to exercise or integrate EW assets in their operations. Their recommendations included improved battalion level maneuver training incorporating a contested Electromagnetic Spectrum.<sup>109</sup> This realization may be the result of the brigade's rare ability to identify FM communication "jamming" by the enemy.<sup>110</sup> This AAR is important because it demonstrated how 1-2 SBCT failed to consistently achieve accurate target location and size due to issues with communication equipment.

Additionally, 1-2 SBCT appeared to not take 2-2 SBCT's lessons learned in to consideration for their NTC rotation. However, this may not have been intentional. For example, 1-2 SBCT's rotation was in May 2016, and published the AAR within a month of redeployment. In contrast, 2-2 SBCT trained at NTC in January to February of 2016, and published its AAR in August 2016. Analysis concluded that communications difficulties hindering the ability of observers in both brigades were the result of two factors. First, the delay in AAR publication from 2-2 SBCT. This subsequently led to the

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<sup>108</sup> MAJ Keith Benedict, "1-2 Stryker Brigade Combat Team National Training Center Rotation 16-06 After Action Review to US Forces Command" (Headquarters, 1st Stryker Brigade Combat Team, Joint Base Lewis-McChord, WA, June 24, 2016), 2.

<sup>109</sup> *Ibid.*, 11.

<sup>110</sup> *Ibid.*, 2.

second factor: training shortfalls during 1-2 SBCT home station exercises that presumably did not benefit from the experience of 2-2 SBCT.

#### Accurate Firing Unit Location

Another firing incident occurred, at Joint Base Lewis-McChord, in November 2015 as a result of an error in firing unit location. Specifically, the error occurred when a howitzer's Defense Advanced GPS Receiver did not properly acquire satellites.<sup>111</sup> Human error contributed as well in the FDC where personnel failed to use required redundant checks to notice the discrepancy in piece location prior to firing. As a result, a 155mm high explosive round impacted 2000 meters from the intended target.<sup>112</sup> This particular example was important because it highlighted a failure to achieve accurate unit location as the result of a malfunctioning positioning device, and low competency in fire direction core competencies in the FDC.

Another unit that experienced competency issues related to unit location was the 2nd Cavalry Regiment's (CR) Fires Squadron. According to a 2014 post combat report, the 2CR SBCT Fires Squadron could not resolve inaccurate cannon piece status. Although the unit did not experience an error in unit location, their errors in piece status made the report concerning for potential issues where piece status results in an inaccurate unit location. Unable to resolve the issue themselves, the squadron requested Field Service Representative (FSR) assistance that also yielded no solution. This was a similar to the experience of the aforementioned 1-2 SBCT and 2-2 SBCT who also possessed

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<sup>111</sup> Folland.

<sup>112</sup> Ibid.

minimal internal ability to overcome digital connectivity issues. Analysis showed the unit also turned to degraded operations TTPs; using voice commands and manual piece status updates. However, as the previous section discovered, training only for degraded operations does not render a solution for accurate unit firing unit location in a D3SOE where an enemy can deny the transmission of unit location or survey data.

### Accurate Weapon and Ammunition Information

An article in the *Field Artillery Lessons Learned Primer*, written by Karl Wendel in January 2015, revealed a trend relating to accurate weapon and ammunition information. Specifically, the issue at hand was the use of “Black Keys,” a form of communications security used by the M777 and M109A6 Paladin for employing PGMs such as the Excalibur 155mm round.<sup>113</sup> In short, these keys are loaded in to the Platform Integration Kit, facilitate fire mission processing, and enable features such as loading firing data on munitions by the Enhanced Portable Inductive Artillery Fuze Setter.<sup>114</sup> Wendel stated this is a simple but detailed process.<sup>115</sup> However, his research showed a deficiency among gun crews employing the Excalibur or other PGMs, as well as among the 25 series Military Occupational Series in obtaining and using the “Black Keys.”<sup>116</sup> One particular error he mentioned as a result of gun crew deficiencies was the inability to

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<sup>113</sup> Karl Wendel, *FA Lessons Learned Primer: Current Trend: Black Keys* (Fort Sill, OK: Fires Center of Excellence, January 2015), 2.

<sup>114</sup> Ibid.

<sup>115</sup> Ibid.

<sup>116</sup> Ibid.

solve an issue known as a “Ghost Key.”<sup>117</sup> This error involved how many days the “Black Keys” remain active. When the error occurred, it created a malfunction in setting, or in some instances the round flew to the ballistic impact point.<sup>118</sup> These deficiencies, Wendel said, are easily corrected if units utilize available training teams to help train their gun crews.<sup>119</sup> The study was important as it demonstrated how a disruption such as inaccurate “Black Keys” in digital systems affects the ability to achieve accurate ammunition and weapon information.

The previous analysis of the 2CR SBCT Fires Squadron also contained information on how the unit performed in achieving accurate weapon and ammunition information. As mentioned, the 2CR fires squadron failed to update cannon piece status digitally.<sup>120</sup> This implied the unit failed to relay ammunition data to include the quantity of ammunition and propellant by type on hand, as well as propellant temperature. Additionally, a howitzer piece status includes other weapon information such as muzzle velocity information, which the FDC uses to calculate muzzle velocity variation, or the change in velocity of each round fired over time.

The 2CR Fires Squadron’s weapon and ammunition information was inaccurate or unavailable due to errors in handling a loss of AFATDS capabilities.<sup>121</sup> Of note, was

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<sup>117</sup> Ibid.

<sup>118</sup> Ibid.

<sup>119</sup> Ibid.

<sup>120</sup> James Bishop, *2CR SBCT Post Combat Lessons Learned* (Fort Sill, OK: Fires Center of Excellence, May 2014), 1.

<sup>121</sup> Ibid.

the unit's inability to resolve the issue internally. Furthermore, their FSR support could not resolve the AFATDS issues either, and the unit turned to degraded operations methods, including voice radio transmissions, in order to continue delivering fires.<sup>122</sup> However, given the nature of a D3SOE, the unit's reliance on voice communications and manually inputting data does not guarantee an ability to provide fires. The experience of the 2CR Fires Squadron, and the article are important because they demonstrated fairly recent shortfalls in unit abilities to properly manage weapon and ammunition information. For this reason, analysis concluded that units possess only a moderate ability to achieve accurate weapon and ammunition information in a D3SOE where communications might fail, and digital system denial is a potential threat.

#### Accurate Meteorological Information

The next incident for analysis, which did not result in an actual firing incident, occurred at the NTC in Fort Irwin, California. In this case, digital connectivity issues were again a major contributor to the problem. There were major learning points that the unit, 1st Battalion, 21st FA Regiment, used to improve upon following their rotation. The problem centered around acquiring MET data for maintaining accuracy in fire mission processing. The unit cited issues integrating their newly fielded CMD-P that replaced a previous profiler system.<sup>123</sup>

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<sup>122</sup> Ibid.

<sup>123</sup> Ruth Edwards, 1LT, *Achieving Accurate Meteorological Procedures at the National Training Center* (Headquarters, 1-21 FA Battalion, NTC Rotation 13-08), 1.

Somehow, the unit was not fielded a Global Broadcast System (GBS) antenna prior to their NTC rotation, and left the CMD-P without a means to acquire MET data.<sup>124</sup> This forced the unit to rely on wireless hotspots to download the necessary files from IGrADS both in cantonment, and in the field training environment.<sup>125</sup> Further complicating the situation was the degree of separation in the field between the TOC and firing batteries that limited their ability to transmit the MET message over FM radios.<sup>126</sup> Additionally, the unit could not use doctrinal methods, such as nearby units, to acquire MET data because there were no other FA units in the exercise.

This report demonstrated how a unit failed to achieve accurate MET using doctrinally approved means such as the GBS. While the unit displayed initiative, the use of IGrADS is not a doctrinal approved solution. Also, the unit's inability to transmit MET across further distances implied the unit would likely not be able to receive MET from nearby units anyway. Furthermore, the battalion's use of non-doctrinal methods demonstrated an expectation of uncontested access to internet sources as an alternate means of acquiring MET. As a result, analysis showed that the unit did not effectively achieve accurate MET information in a situation possessing the characteristics of a D3SOE.

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<sup>124</sup> Ibid.

<sup>125</sup> Ibid.

<sup>126</sup> Ibid.



## Accurate Computational Procedures

Concerning accurate computational procedures, the 2CR Fires Squadron reported several issues involving the AFATDS including PGM or near precision fuzes, false fire commands, cannon piece status, and system lock ups while trying to update MET.<sup>127</sup> The Fires Squadron called upon FSRs to inspect the faults, but they were unable to resolve the issue. This prompted the unit to establish TTPs similar to the aforementioned doctrine for degraded operations such as using voice commands to send fire missions, and manually updating piece status.<sup>128</sup> This report was relevant because it demonstrated how a unit can fail to meet the requirement for accurate computational procedures when it loses AFATDS functionality.

## Summary

This section analyzed CTC AARs, home station AARs, and firing incident reports using the 5RFAF to determine how well units met the 5RFAF based upon unit performance in training. Discussion included performance of units, and some of the trends identified during research. Analysis determined units have an overall moderate level of success in achieving some of the 5RFAF. Trouble areas included achieving accurate MET and accurate computational procedures in a D3SOE. Also, analysis of this case found a trend among units in regards to maintaining communication system proficiency under normal conditions. Furthermore, units displayed a trend worth noting

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<sup>127</sup> Bishop, 1.

<sup>128</sup> Ibid.

later in this thesis' conclusions: a lack of internal ability to resolve digital system issues that causes a dependency on FSR support.

Further analysis revealed potential competency issues among howitzer sections to provide accurate weapon and ammunition information. For example, the *Field Artillery Lessons Learned Primer* suggested that howitzer sections were deficient in employing PGMs such as the Excalibur due to the improper use of "Black Keys." The article continued by asserting the need for units to request external training teams to provide remedial training on PGM firing procedures. While a good source for assistance, remedial training teams were not always available in non-combat environments, let alone in combat.

The previously mentioned 82nd Airborne Division FA unit's computational problems resulted in a duplicate fire mission that led to a "Check Fire" of firing until completing an investigation. This was another example of how a disruption in communications can affect core competencies, or basic FA battalion operations in a D3SOE. Furthermore, the human error involved in all of the examples alluded to a potential shortfall in digital sustainment training (DST).

While an assumption, it is my personal opinion as a former OC/T that both of the aforementioned units' training plans did not incorporate effective DST. When planned properly, DST allows a unit to test all communication and positioning devices in the fires system.

Digital sustainment training must include all aspects of the Fires mission command system of systems to include the FDC, weapon systems, and fire support elements at each echelon. Successful programs are allocated time through the unit

training system. It should be addressed in the annual and quarterly training guidance, Quarterly Training Briefs, training schedules and discussed in detail at the battery training meetings.<sup>129</sup>

The approach to training described in this excerpt ensures digital system proficiency, and readiness. Additionally, this method allows units to identify issues in areas such as ammunition allocations, and computing firing solutions for complex missions.

The potential shortfall in DST or FA technical rehearsals for howitzer crews, FDC crews, and the entire fires system was troubling because it corresponded with how a FA battalion prepares for and executes FA table qualifications that are a prerequisite for a unit to provide accurate fires in support of the maneuver commander. Furthermore, applying the same logic as with accurate target location, a unit that struggles to gain proficiency in core competencies in an uncontested space operating environment may fail entirely in a D3SOE where an adversary's effects achieve more than a degradation of communications. As a result, units were not as prepared to meet all of the 5RFAF in training under normal conditions, let alone a D3SOE scenario.

#### Reports from the Front: Russo-Ukrainian War

The final area of focus for research literature was the RUW. Specifically, literature pertaining to the use of D3SOE capabilities by Russian and Ukrainian military forces involved in the conflict. This conflict functions as what is known as a proxy war.

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<sup>129</sup> United States Army Field Artillery School (USAFAS), *United States Army Field Artillery 2017 Training Strategy*, 28.

A proxy war allows observers to identify lessons learned, and return to their respective organizations to glean information that suggests new ways of fighting, or reveal the impact of new technology in war.<sup>130</sup> Therefore, this analysis of the RUW sought to assess how well both sides of the conflict met the 5RFAF. One of the added benefits of this analysis included an opportunity to assess capabilities in the conflict that presented a new way of fighting.

According to the Asymmetric Warfare Group's (AWG) *Russian New Generation Warfare Handbook (RNGWH)*, the Russian concept of fighting in the RUW consists of delivering devastating indirect fires, while maintaining standoff partially through the use of EW assets.<sup>131</sup> This was a direct response to the US and North Atlantic Treaty Organization approach to warfare that requires communication and synchronization to be most effective. Russia's ability to affect these elements of success rests in what their military refers to as a Radio Electronic Battery (REB). This unit exists to degrade or deny (note not to disrupt) communications at the tactical and operational level.<sup>132</sup> Notably, the Russians possess multiple platforms to counter US communications capabilities such as FM, Satellite Communications (SATCOM), cellular, and GPS.<sup>133</sup> Furthermore, Russian EW operations in Eastern Ukraine proved devastating for Ukrainian radio

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<sup>130</sup> Karber, 5.

<sup>131</sup> Asymmetric Warfare Group, *Russian New Generation Warfare Handbook*, Version 2 (Fort Meade, MD: Asymmetric Warfare Group, January 2017), 12.

<sup>132</sup> *Ibid.*, 17.

<sup>133</sup> *Ibid.*

communications, and also demonstrated Russian ability to produce false GPS signals.<sup>134</sup> This information was relevant as it shows a current capability relating to two of the “D’s,” degraded and denied, in D3SOE.

Also of note in the *RNGWH* was the Russian ability to perform direction finding using Ukrainian electromagnetic signals.<sup>135</sup> This capability ultimately facilitates the massing of indirect fires on the source of the signals. For example, a Ukrainian army unit became the victim of accurate Russian artillery fire while broadcasting a radio message. Adding to the disaster, the same unit received text messages on their cell phones asking how they liked the artillery.<sup>136</sup> The *RNGWH* also addresses the Russian communication network that supports and coordinates these EW operations. The network was reportedly similar to US capabilities by integrating GPS and tactical radios. However, the disturbing part was the mention of how Russia’s EW platforms are designed to allow their own radio and communication networks to function while simultaneously denying Ukrainian capabilities that mirror those of US systems.<sup>137</sup> A review of findings such as these in the *RNGWH* provided a very thorough analysis of how a D3SOE affected all warfighting functions.

According to other reports, a potential solution to communication shortfalls was the use of high frequency (HF) Harris radios that possess complex encryption

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<sup>134</sup> Ibid.

<sup>135</sup> Ibid., 18.

<sup>136</sup> Ibid.

<sup>137</sup> Ibid.

capabilities. In fact, the Ukrainian military requested Harris radios, and received an incrementally funded foreign military sales contract approval in September 2015.<sup>138</sup> Despite this success, research indicated the Harris' higher operating frequency gave away Ukrainian positions.<sup>139</sup>

Another key piece of literature for understanding the D3SOE present in the RUW was the previously mentioned "Lessons Learned from the Russo-Ukrainian War," by Dr. Phillip Karber. This document provided on the ground observations by Karber who visited Ukraine to conduct research from March 2014 to June 2015.<sup>140</sup> This document, much like the RNGWH, provided an extensive amount of information pertaining to all of the warfighting functions. Of note for FA battalions and the Fires system were Karber's observations on both Ukrainian and Russian use of counterfire radars. Specifically, he discussed the Russian ability to accurately locate Ukrainian radar systems, such as the AN/TPQ-35 (Q-35) provided by the US in 2015, by detecting the radar system's scanning signals.<sup>141</sup>

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<sup>138</sup> Department of Defense, "Contracts: Press Operations, Release No. CR-184-15," September 25, 2015, accessed April 4, 2017, <https://www.defense.gov/News/Contracts/Contract-View/Article/620608>.

<sup>139</sup> Thomas Gibbons-Neff, "'We Don't Have the Gear': How the Pentagon is Struggling with Electronic Warfare," *The Washington Post*, February 9, 2016, accessed April 4, 2017, [https://www.washingtonpost.com/news/checkpoint/wp/2016/02/09/we-dont-have-the-gear-how-the-pentagon-is-struggling-with-electronic-warfare/?utm\\_term=.cc038fac8ebf](https://www.washingtonpost.com/news/checkpoint/wp/2016/02/09/we-dont-have-the-gear-how-the-pentagon-is-struggling-with-electronic-warfare/?utm_term=.cc038fac8ebf).

<sup>140</sup> Karber, 3.

<sup>141</sup> Ibid., 20.

In his report, Karber also provided very specific details on UASs operating in the RUW. Among these details, he highlighted some of the countermeasures observed to disrupt their ability to operate. For example, the Russians employed a self-propelled EW vehicle equipped with a targetable jammer that disrupts GPS signals, causing targeted Ukrainian UASs to crash.<sup>142</sup> It is important to note that Karber also specified Ukrainian UAS were only used for reconnaissance, and not for any type of strike on Russian targets.<sup>143</sup> The “Karber Report” was a critical document for understanding how a modern near peer or peer uses EW to affect communication systems. More importantly, Karber’s personal observations helped explain the second and third order effects of a D3SOE on the Fires system including observer platforms such as the Q-35, and UASs that provide reconnaissance for intelligence collection plans in support of targeting efforts.

A similar report by Karber and Lieutenant Colonel Joshua Thibeault, titled “Russia’s New-Generation Warfare” served as a companion article to Karber’s “Lessons Learned.” In the article, the authors discussed similar topics to the “Lessons Learned.” However, some discussions in the article provided clarification and insight to points made by Karber’s work. The article also provided a listing of the four primary roles of Russian EW that are denying communications, defeating unmanned aerial systems, defeating artillery and mortars, and targeting command and control nodes. Karber and

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<sup>142</sup> Ibid., 14.

<sup>143</sup> Ibid., 13.

Thibeault provided examples of how each EW role affects specific systems such as the Force XXI Battle Command Brigade and Below, radios, and cellular phones.<sup>144</sup>

#### Accurate Target Location and Size

Analysis of the RUW showed a wide use of artillery assets by both sides. This included the use of observers on the ground, and UAS systems for fire direction. According to Karber's publication, "Lessons Learned," the Russian military utilized a variety of EW assets to successfully hinder observer operations. In particular, the Russians were fully capable of interfering with Ukrainian Q-35 and UAS targeting operations. This included a Russian ability to accurately detect Ukrainian counterfire radars, and subsequently massing fires on the radar location. Furthermore, earlier findings determined a Russian ability to adversely affect UAS communication and positioning capabilities. Additionally, the RUW presented itself as an environment where observer communication reliability ranges from degraded, denied, or disrupted.

Conversely, analysis showed a trend of increasingly deceptive camouflage techniques, and discipline in the use of electronic devices. In particular, Ukrainian army units implemented a "dirty snow" paint scheme to camouflage their troops and equipment.<sup>145</sup> The use of such methods and other counter-observation techniques was also a recommendation in a *Small Wars Journal* assessment of Russian capabilities.

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<sup>144</sup> Phillip Karber and Joshua Thibeault, "Russia's New-Generation Warfare," Association of the United State Army, May 20, 2016, accessed January 31, 2017, <https://www.ausa.org/articles/russia%E2%80%99s-new-generation-warfare>.

<sup>145</sup> Joint Multinational Training Group-Ukraine, 3.



Static formations, large command posts, and exposed sustainment nodes are primary targets in hybrid environments and are likely to be high on the enemy's target list. Likewise, tactical formations must continually relocate and reposition, to include command posts and sustainment nodes to disrupt combined identification and targeting by UAS, long-range fires, and air assets. These positions must maintain the smallest possible signature, they must maintain maximum dispersion, they must employ camouflage, and they must maintain local security when static.<sup>146</sup>

Analysis of this recommendation determined that observation of targets in a D3SOE is more difficult than in past conflicts. This was mostly due to a need for military units to reduce visual observation by UAS, and to reduce their electromagnetic presence as well. Compounding the issue was the aforementioned ability of adversaries to hinder communications using EW capabilities similar to those of Russian military forces.

For these reasons, and the aforementioned instances of Russian forces using radio transmissions to locate Ukrainian positions, accurate target location in a D3SOE is very difficult. Additionally, the observer or asset trying to avoid detection while operating faces equal difficulty in mission success. As a result, a FA battalion in a D3SOE such as the RUW is likely to experience a large degree of difficulty acquiring or receiving target information.

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<sup>146</sup> Amos Fox and Andrew Rossow, "Assessing Russian Hybrid Warfare: A Successful Tool for Limited War," *Small Wars Journal* (August 8, 2016): 5.

## Accurate Firing Unit Location

In this research, there were no FA specific RUW examples available to study. However, analysis of communication and positioning capabilities used in the RUW allowed the research to determine the likely effects of a D3SOE on a FA battalion's ability to achieve accurate firing unit location. Given the previous background information on the RUW, the analysis determined that Russian EW capabilities pose the same difficulties for achieving accurate unit location as those experienced by observers and observation assets.

One example closely related the issue of unit location was the aforementioned situation where Ukrainian units receiving artillery fire soon after sending a radio transmission. Applying this example to a FA battalion means using FM radio transmissions to send location information is extremely risky in a D3SOE. Further complicating the situation is the implied need for survivability moves following a radio transmission. This creates a chaotic environment where the FA battalion remains in constant motion to avoid enemy detection.

Analysis also considered the case of Russian forces targeting the Ukrainian military's tactical and operational communications capabilities. Capabilities of concern to achieving accurate firing unit location include FM radio, and GPS. As noted, Russian capabilities are designed to deny such capabilities that in many ways mirror those in use by US FA battalions. In doing so, Russian forces retained freedom of communication while simultaneously denying the same for their adversaries. Analysis of these factors determined that a D3SOE further compounds problems for a FA battalion to achieve

accurate unit location by disrupting transmission of unit locations, and limiting the use of positional devices to acquire locations.

As mentioned, Russian forces in the RUW are capable of denying GPS signals. However, there was also evidence in research showing an ability to transmit false GPS signals. These are both capabilities of Russian REBs, and give Russian forces the ability to degrade, deny, or disrupt Ukrainian FA capabilities. As a result, forces operating in these conditions might turn to degraded operations procedures, such as using an aiming circle, to acquire firing unit location.

Analysis of these examples concluded that a firing unit in a D3SOE may be able to acquire accurate firing unit location by using degraded techniques. However, based upon the findings of chapter 2, this process requires functions such as survey to acquire the most accurate self-location. Additionally, degraded operations as defined in the FADOWP still required voice radio transmissions to send piece status to the FDC. This means a continued vulnerability for enemy detection of friendly electromagnetic activities. Therefore, the ability of a FA battalion to achieve accurate firing unit location in a D3SOE is moderate to low depending on the extent of enemy EW operations.

#### Accurate Weapon and Ammunition Information

There were also no available reports of Ukrainian FA units attempting to achieve accurate weapon and ammunition information. However, available reports showed that Ukrainian units attempting to transmit any kind of information experienced difficulties. Previously cited challenges in RUW ranged from no digital connectivity, to intermittent voice communications, or no communications at all. Thus, analysis determined the same

issues affect a FA battalion as described in this thesis when attempting to transmit or receive weapon and ammunition information in a D3SOE.

Final analysis determined that a D3SOE moderately limits a FA battalion's ability to achieve accurate weapon and ammunition information. How greatly a D3SOE affects this requirement for accurate fire depended on what adversary EW capability the FA battalion encounters. This is due mostly to the aforementioned threat of adversaries with EW targeting capabilities similar to those of Russia. Especially troubling was the ability of near peers to quickly target the unit with effective, massed artillery fires. In other words, the disruption included not only the tangible threat of communication or positioning device failures, but also intangible the threat of imminent enemy artillery fires that caused the unit to limit its use of radio systems.

#### Accurate Meteorological Information

Analysis of the RUW resulted in limited results concerning a FA battalion's ability to achieved accurate MET information. However, there was some information worth mentioning. For example, Russian denial of Ukrainian communications including voice and digital radio, GPS, and satellite systems. Given the CMD-P's use of the GBS to acquire MET data, analysis suggested a D3SOE would at a minimum degrade or disrupt the system's ability to properly function. For this reason, current conditions in the RUW make achieving accurate MET information very difficult for a FA Battalion.

#### Accurate Computational Procedures

Research found no specific reports of FA units in the RUW attempting to achieve accurate computational procedures. This does not mean, however, there were no lessons

to learn from the conflict on this topic. All previous requirements for accurate fire had a low to moderate level of success in the RUW. Each of the shortfalls resulted from a communications issue identified during analysis. Given this fact, a FA battalion in a D3SOE has a low to moderate chance of achieving accurate computational procedures because it may receive inaccurate information such as piece status or MET. Furthermore, even if the unit receives all required accurate information, the FA battalion will have difficulty sending the fire mission for execution unless using a wire radio connection.

### Summary

This section analyzed reports from the RUW to assess how a real world D3SOE affected a peer or near-peer force's ability to meet the 5RFAF. An examination of the RUW D3SOE identified where gaps exist in meeting the 5RFAF. Areas of greatest concern were the ability to achieve accurate target location and size, accurate weapon and ammunition information, and accurate MET information. These functions suffered the most in the RUW due to limitations on communication systems, and positioning devices. Overall, a FA battalion operating in the RUW did not effectively meet all of the 5RFAF.

### Findings

Applying the research methodology facilitates conclusions, and recommendations for capabilities development in chapter 5. Figure 3 below displays the results of the analysis in a graphic form. For simplicity, the diagram uses a color scheme to specify how effective a FA battalion was at meeting the 5RFAF in each of the cases. Red denotes minimally effective or ineffective, amber denotes moderately effective, and green denotes

effective. Again, this is a synthesis of the analysis conducted using the FADOWP, CTC, and Home Station training AARs or firing incident reports, and reports from the RUW.

Case 5RFAF	FA Degraded Operations White Paper	CTC and Home Station AARs/ Reports	Reports from RUW
<b>Accurate Target Location and Size</b>	<ul style="list-style-type: none"> <li>- Observers Can Self Locate Using Degraded Procedures</li> <li>- Can Acquire Target Using Degraded Procedures</li> <li>- PACE Doesn't Always Work in D3SOE, Limits on Ability to Transmit CFF</li> </ul>	<ul style="list-style-type: none"> <li>- Units Unable to Transmit CFF</li> <li>- Unable to Coordinate Fires</li> <li>- Forces Use of Contingency and Emergency PACE systems</li> <li>- Limited Sensor to Shooter Link</li> </ul>	<ul style="list-style-type: none"> <li>- Limited Target Acquisition and UAS Assets Due to Denial or Falsified GPS Data</li> <li>- Limited Observer Ability to Transmit Due to Threat of Russian EM Detection, and Targeting</li> <li>- Russians Able to Communicate While Jamming (Sending Very Accurate Fire Missions)</li> </ul>
<b>Accurate Firing Unit Location</b>	<ul style="list-style-type: none"> <li>- IPADS Survey Accurate Without GPS</li> <li>- Survey PACE Relies on INU, A D3SOE Hinders This Process</li> <li>- Transmitting Unit Location Not Always Possible in D3SOE</li> </ul>	<ul style="list-style-type: none"> <li>- IPADS Works Effectively</li> <li>- DAGR/ GPS Loss Results in Large TLE</li> <li>- Forced Manual Computation and Voice Transmissions to Unit Location</li> <li>- Highlighted Need for Improved DST, and D3SOE Training</li> </ul>	<ul style="list-style-type: none"> <li>- Russian EW Capability Threatened GPS Use</li> <li>- Russian EM Denial Limits Ability to Transmit Locations</li> <li>- Transmission Risks Detection and Targeting</li> </ul>
<b>Accurate Weapon and Ammunition Information</b>	<ul style="list-style-type: none"> <li>- Gunline Can Acquire Weapon and Ammunition Data</li> <li>- D3SOE Limits Transmission of Data to FDCs</li> </ul>	<ul style="list-style-type: none"> <li>- PGMs Don't Work Without Accurate Digital Data/ GPS</li> <li>- No Communications Resulted in No Updated Piece Status</li> <li>- Highlighted Dependency on FSRs</li> </ul>	<ul style="list-style-type: none"> <li>- Denial of Digital and Voice Communications</li> <li>- EM Detection and Targeting Forces Units to Limit Transmission of Weapon and Ammunition Data</li> <li>- Wire Communications a Solution</li> </ul>
<b>Accurate Meteorological Information</b>	<ul style="list-style-type: none"> <li>- Limited Ability to Acquire MET in D3SOE</li> <li>- Connectivity Denial Renders Unit Unable to Transmit MET to FDCs</li> <li>- Cannot Communicate with Adjacent Units for MET Data</li> <li>- Cannot Conduct Registration, D3SOE Limits Communication with Observers</li> </ul>	<ul style="list-style-type: none"> <li>- CMD-P Inoperable Without Connectivity</li> <li>- Units Dependent on IGrADS (Requires Internet, and Not an Approved Solution)</li> <li>- Poor PACE Results in No Ability to Acquire Adjacent Unit MET if Present</li> <li>- Highlighted Dependency on FSRs</li> </ul>	<ul style="list-style-type: none"> <li>- Limited MET options in a D3SOE</li> <li>- CMD-P Most Likely Would Not Be Able to Acquire MET</li> <li>- Transmission of MET Limited by EM Denial and Targeting</li> </ul>
<b>Accurate Computational Procedures</b>	<ul style="list-style-type: none"> <li>- Stand Alone Systems Can Compute</li> <li>- Receiving Accurate Data Limited</li> <li>- Manual Computations Also Require Data</li> <li>- PACE Does Not Support Requirement in a D3SOE</li> </ul>	<ul style="list-style-type: none"> <li>- Loss of AFATDS Resulted in Inaccurate Computations</li> <li>- Units Forced to Manually Input Computational Data, and Send Voice Missions</li> <li>- Units Forced to Use Voice to Send Fire Mission</li> </ul>	<ul style="list-style-type: none"> <li>- Potential for False Data (Positional Data)</li> <li>- Denial of Communications Results in No Data to Compute, and Inability to Transmit Fire Mission</li> </ul>

Figure 3. Results of Research Analysis using the 5RFAF

Source: Created by author.

Finding No. 1: Accurate target location and size are dependent on FM communications. Current solutions in the FADOWP, and Army units in training were ineffective in their ability to facilitate the requirement for accurate target location and size. Similarly, actors such as the Ukrainians were limited by a denied environment, while the Russians maintained the ability to concurrently transmit very accurate target location and size. However, analysis of the RUW found improvements in camouflage,

and electromagnetic discipline that made acquiring targets more difficult as the conflict progressed. This resulted in an overall rating of minimal effectiveness in achieving accurate target location and size in all three cases.

Also, all three cases of analysis suggested that while observers might be able to determine an accurate target location and size using manual and mechanical means, there is no doctrine covering how to transmit that information to the FDC when FM communications are not possible. This suggests a potential materiel shortfall in the US Army when a peer competitor possess FM or HF denial capabilities. Training for units suffers as a result of the absence of D3SOE specific doctrine either in field manuals or in Training Evaluation and Outlines (T&EO). The absence of proven D3SOE resistant materiel systems further exacerbates the training shortfall as units do not have the equipment needed to train according to T&EOs, or gain proficiency in transmitting target location and size uncontested in a D3SOE.

Finding No. 2: Accurate unit location depends on FM communications. The FADOWP provided an effective means of acquiring survey data using the IPADS-G, and manual survey techniques found in doctrine. However, the FADOWP did not provide any means, doctrinal or non-doctrinal, to allow transmission of unit location or survey data when FM communications are denied. Similarly, CTC AARs showed that units can effectively acquire accurate unit location using GPS, or manual survey techniques. However, communication system failures in training suggested that units lack guidance in doctrine to overcome this problem, and to drive training that prepares units for the loss of FM radio communications. The overall rating for both cases was moderately effective

because units could achieve accurate unit location, and only lacked the ability to transmit the data.

In the RUW, similar issues with GPS, and radio communication appeared in reports. This provided analysis the determination that units in a RUW scenario were limited in their ability to transmit unit locations based on manual survey due to either a denied environment, or the deterrence of Russian electromagnetic targeting. These factors resulted in a D3SOE rendering units ineffective in acquiring accurate unit location due to a gap in materiel capabilities such as radios that allow transmission of information without detection. Additionally, Russian materiel capabilities included systems that transmit false GPS data. This is another significant materiel gap for an FA battalion to overcome.

Finding No. 3: Accurate weapon and ammunition information are dependent on FM communications. Despite a strength across all three cases in acquiring weapon and ammunition information, units ultimately faced difficulty transmitting the data when communications became degraded, or failed altogether. In the RUW, not only were communications jammed, but Ukrainian units feared Russian electromagnetic targeting, and the accurate artillery rocket strikes that followed. This threat, combined with communication denial, equated to an overall rating of minimally effective in all three cases. The same doctrine, training, and materiel gaps identified in the previous findings concerning communications apply to this requirement. An additional materiel gap, radio communication wires, was also identified in the analysis of the FADOWP. This FADOWP recommends the use of these wires in degraded operations, but they are not found on currently approved unit MTOEs.



Finding No. 4: Accurate MET information depends on digital connectivity provided by a GBS, and FM communications. This requirement was severely limited across all three cases. As with the previous findings, doctrine did not provide a means to overcome communication shortfalls that hindered the CMD-P's ability to acquire MET in conditions other than a degraded environment. This is because the doctrinal alternatives to using the CMD-P all required communication capabilities to either acquire MET from another unit, or to conduct a registration using observers to report adjustments to the FDC. In a D3SOE, these methods faced highly contested and denied environments. This was especially true in the RUW case, where the trend in jamming as a threat continued, as well as Russian electromagnetic targeting capabilities. As a result, all three cases received a minimally effective rating for accurate MET information. In addition to the gap in doctrine, the previously identified gaps in training, and materiel apply to this requirement.

Finding No. 5: Accurate computational procedures are dependent on FM systems to acquire data for computations. This all-encompassing requirement was moderately effective in the FADOWP recommendations, and as exhibited by units in training. This is based mostly on the ability of units to continue firing despite degradation, disruption, and denial of communication or positional systems. However, this achievement was not the result of the unit's ability to troubleshoot system failures. Instead, analysis showed a dependence on FSRs to overcome problems with systems such as the AFATDS, or connectivity between multiple systems. As a result, analysis found this dependence to be a gap in training capabilities.

In the case of the FADOWP, the document offered alternative methods found in doctrine to compute data digitally using stand-alone systems, or manual gunnery procedures. Similarly, units in training duplicated these methods, exemplifying a success in training capabilities to ensure units understood all available computational procedures. However, both cases were not completely effective due to the effects of a D3SOE on the transmission of data used in computations. An example of this was in the RUW, where the Russians not only denied GPS, but falsified GPS signals, causing positional data to be inaccurate. In other words, a firing unit might not be denied, but it could be using false grid coordinates for targets.

As a result, the RUW produced an ineffective rating. Doctrine, training, and materiel gaps addressing both communication and position locating requirements from previous findings remain valid in this finding. Additionally, a materiel gap was identified in the analysis of the FADOWP. This gap was the absence of required equipment, which enables the FDC to compute fire missions using the recommended manual procedures, in currently approved MTOEs.

### Chapter Summary

This chapter analyzed three types of available literature using the methodology described in chapter 3. The analysis of the FADOWP provided a robust assessment of how current doctrinal and non-doctrinal procedures are applied to address degraded operations. The common trend for this section was a lack of guidance specifically addressing a D3SOE, and how to overcome communication or positional system challenges. Instead, the paper focused only on degraded operations, and did not discuss a disrupted or denied environment.

In analyzing AARs and firing incidents, the trend of communication and positional system challenges continued. As a result, units experienced problems conducting basic communication requirements. Analysis determined this issue alone makes achieving the 5RFAF especially difficult for FA battalions unprepared for a D3SOE. Furthermore, there appears to be little threat of a D3SOE at the CTCs given the AARs used in this research. This is a concern considering the emphasis current army leaders such as the FORSCOM Commander, General Robert Abrams, place on the ability to, “project power across multiple domains in a degraded, denied, and disrupted electromagnetic spectrum and space operating environment.”<sup>147</sup>

The analysis of the final case, the RUW, there was a continuation of the trend in how communication interference negatively affects the 5RFAF. Also, limited literature made research of some of the 5RFAF difficult to assess. For example, there were no recorded examples from the RUW concerning the receipt of MET data, or the computation of firing data. However, this does not make the analysis less useful, and the analysis of these particular requirements for accurate fire solidified the importance of communication systems in a FA battalion. Finally, the analysis found a gap in training that appears to stem from a lack of emphasis in current doctrine to drive unit level training plans prior to STXs, CTC rotations, or deployments.

The analysis culminated with five findings, each of them relating to one of the 5RFAF. These findings help describe what a FA battalion needs to succeed in a D3SOE.

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<sup>147</sup> Department of the Army, *FORSCOM Command Training Guidance: Fiscal Year 2018* (Fort Bragg, NC: Headquarters, United States Army Forces Command, March 24, 2017), 6.

These needs propose Army capability developments in doctrine, training, and materiel components to ensure units achieve the 5RFAF in a D3SOE. Chapter 5 further addresses these findings to answer the primary research question, and to provide recommendations that may close the gap between current performance and future requirements.

## CHAPTER 5

### CONCLUSION

Thanks to my reading, I have never been caught flat-footed by any situation, never at a loss for how any problem has been addressed (successfully or unsuccessfully) before. It doesn't give me all the answers, but it lights what is often a dark path ahead.

— General James Mattis, *Personal Letter*

The purpose of this thesis was to determine how a modern FA cannon battalion operates in a D3SOE. This question accompanied the research problem that there are no TTPs specifically designed to allow a FA battalion to counter the threat of a D3SOE. To effectively address the question and problem, the literature review provided a common understanding of how a FA cannon battalion operates in an uncontested environment, what the characteristics of a D3SOE are, and how a D3SOE affects the 5RFAF. The analysis then continued the research methodology by focusing on three main cases: the FADOWP, CTC and Home Station Training: Firing Incident Reports and After Action Reviews, and available literature concerning the RUW. As a result, the analysis provided a rating of effectiveness in meeting the 5RFAF for each case. The analysis concluded with cross case analysis findings corresponding to each of the 5RFAF, and identified gaps in current capabilities.

This chapter provides further discussion of the findings in chapter 4, and expands upon the capability gaps identified in the analysis. The discussion of existing capability gaps includes recommendations on how to close the gaps to better meet the needs of a FA battalion in a D3SOE. Additionally, this chapter provides recommendations for future research to address areas this thesis did not include as part of the research process. Lastly,

the chapter concludes with a way ahead for how a modern FA cannon battalion operates in a D3SOE.

### Conclusions

The chapter 4 analysis provided a very robust list of concerns for a FA battalion operating in a D3SOE. However, the subsequent list of findings organized the issues using the 5RFAF to clearly articulate capability gaps. These gaps were then categorized as doctrinal, training, or materiel capabilities. This section discusses the capability gaps, and what they mean in regards to how a modern FA cannon battalion operates in a D3SOE.

### Doctrine

Overall, there is a lack of guidance in Field Artillery doctrine, and non-doctrinal publications such as the FADOWP, for how to effectively operate in a D3SOE. The absence of an overarching Army doctrinal definition, and operational guidance for a D3SOE is a source of this shortfall in FA doctrine. As for the gaps in FA doctrine, it is a matter of updating doctrine more than it is creating a new concept. For example, existing doctrine does suggest using radio communication wire to enable radio communications within a firing battery. However, doctrine presents the capability as an option for overcoming degraded conditions, which are the result of non-D3SOE effects, instead of as a procedure vital to the survival of a firing unit, or battalion TOC operating in a D3SOE. Similarly, doctrine discourages the use of wires by placing emphasis on the limitations wire communications pose to maneuverability, rather than on the benefits to survivability. As a result, modern FA units tend to favor wireless communications, and

neglect wire connectivity procedures for radio transmissions between the FDC, and gunline.

The gap in communications doctrine appears in all five findings from analysis in chapter 4, and reduces the ability of a FA battalion to meet the 5RFAF. For certain, observers can determine a target location and size. Likewise, the gunline can still find its unit location, and prepare a piece status that includes weapon and ammunition information. When MET is available, units can prepare a MET message. There are even doctrinal ways to compute fire missions if a system becomes corrupted with bad data.

Despite these successes in doctrine, each of the 5RFAF begins to diminish in effectiveness depending on the type of condition affecting communications in a D3SOE.

### Training

Given the gap in doctrine, it is no surprise that a gap exists in training. In fact, findings suggest a correlation between doctrine and training capability gaps concerning communication and positional system failures. However, the gap is not necessarily a new one. As the analysis described, FA battalions struggle to maintain proficiency in their digital and analog core competencies. For example, the inability to establish connectivity between the FA battalion and the brigade fires cell during CTC rotations was not the result of an equipment failure alone. Instead, the deficiencies were also the result of inadequate unit training that did not ensure core competencies proficiency prior to the CTC rotation.

Whether at a CTC, or during home station training, analysis found shortfalls in how units train to proficiency on their equipment. This includes findings that suggest a lack of effective DST to mitigate common issues, or equipment malfunctions that occur

even without the influence of a D3SOE. Additionally, analysis identified a lack of D3SOE implementation at CTCs and home station training. This particular training shortfall may be the result of inadequate resources to simulate a D3SOE.

The final training gap identified in analysis is the dependence on FSRs to resolve technical problems. Analysis suggests that a D3SOE is unsuitable for FSR support to be effective. This is mostly due to units needing solutions while being actively engaged with the enemy. If a FA battalion loses connectivity, it does not have time to wait for an FSR to arrive, or the ability to leave the battlefield to resolve the problem. The more troubling aspect of this gap relates to the previous discussion on DST. Some units lack expertise within their organization to overcome simple technical problems without FSR support. DST helps to mitigate this problem, and potentially the need for FSRs if soldiers are adequately trained.

### Materiel

In similarity to doctrine and training, a materiel gap exists in each of the 5RFAF across all three cases. The predominant gap is a reliable communication system to transmit and receive: target location and size, unit location, weapon and ammunition information, a MET message or registration data, and fire mission computation data. In all three cases, the 5RFAF were susceptible to a D3SOE when conditions changed from degraded, and approached a denied environment.

Research suggests the gap exists for two reasons; current capabilities function ineffectively in a D3SOE, and units are not being issued existing equipment that might enable communications. Previously mentioned, the analysis shows an absence of wire radio communication cables on unit MTOEs. This older capability disappeared as



wireless connectivity improved across the Army. As a result, FA battalions lack the necessary equipment to implement doctrine that describes a potential way to overcome a D3SOE.

Another critical materiel gap is the CMD-P's inability, discussed in Finding No. 4, to acquire MET data in a D3SOE. Similarly, existing alternatives, which include receiving MET from an adjacent unit, are not feasible in a D3SOE due to potentially ineffective FM radio communications. Even the unapproved IGrADS alternative is not an option if an adversary denies internet connectivity.

The GPS functionality, mentioned in Finding No. 1 and No. 2, is another materiel gap. Current doctrine prefers the use of a GPS device coupled with digital capabilities such as the INU, and PDFCS. However, the potential for GPS jamming, or the transmission of false GPS data reduces the efficiency these systems were intended to provide.

The final materiel gap corresponds with accurate computational procedures. Analysis suggests a disconnect between the doctrinal guidance provided to FA battalions, and the equipment provided to them to execute doctrine. In this case, doctrine specifies the use of indirect fire plotting boards, and artillery fire control plotting sets to compute fire missions manually. Neither of these items are currently listed on approved MTOEs for the Army's howitzer cannon battalions.

#### How does a Modern FA Battalion Operate in a D3SOE?

Based on the research analysis, a modern FA cannon battalion operating in a D3SOE does so with minimal to moderate success. The most significant problem facing the FA battalion in a D3SOE is the lack of thorough discussion and guidance in doctrine

on the topic. This shortfall includes the absence of a doctrinally approved definition for a D3SOE. The second problem for a FA battalion in a D3SOE, is the likelihood of not achieving one, or even all of the 5RFAF at any time. According to the analysis, failures in FM radio communications have the ability to affect all of the 5RFAF. In addition to communication problems, some of the 5RFAF face challenges in acquiring information, such as positional data from a GPS, or MET data from a GBS internet connection. The possibility of multiple effects ranging from degraded to denied make the D3SOE a complex problem for a FA battalion to overcome while attempting to achieve all of the 5RFAF.

### Recommendations

#### Recommendations for Capabilities Development

As a complex problem, a D3SOE requires more than one solution for the FA battalion to achieve success. For example, a denied GBS signal requires a materiel capability solution to first overcome the signal denial, doctrine to provide guidance on using the capability, and training to ensure units effectively use the new capability. This thesis recommends the following capability developments to better prepare a FA cannon battalion to operate in a D3SOE.

#### Doctrine

Recommendation No. 1: The Army Combined Arms Doctrine Directorate (CADD) needs to develop guidance for, and define a D3SOE. This definition must be all inclusive of the conditions found in a D3SOE, and dissuade readers from believing a D3SOE means degraded conditions. Guidance must similarly present a D3SOE as a

complex problem that requires proficiency of core competencies, and adaptability in the application of those competencies when encountering a D3SOE. This provides a shared understanding of a D3SOE across the Army, and within each of the proponent doctrine directorates. As a result, FA doctrine will better address the impacts of a D3SOE, and provide guidance to FA battalions that improves their ability to execute their mission. Lastly, the resulting doctrinal publications must be available for any military professional seeking to improve their training. Otherwise, the lack of understanding discussed in this research will continue.

Recommendation No. 2: Update FA doctrine by incorporating the characteristics of a D3SOE. Doctrine, such as field manuals or T&EOs, must adapt to the conditions a D3SOE implies for communication systems. This means reassessing what current PACE plans recommend. As the FADOWP shows, current FA doctrine and T&EOs include degraded techniques for radio communications. However, doctrine needs to be validated with existing capabilities to ensure the TTPs, and T&EOs remain effective. An example of this is the aforementioned radio communication cables currently absent from unit MTOEs. Additionally, consideration of how a D3SOE affects the use of camouflage, and requires electromagnetic spectrum discipline is critical to effective TTPs and T&EOs. Current doctrine provides guidance to begin addressing this aspect of a D3SOE, but requires updating to incorporate current TTPs observed in the RUW. Lastly, doctrine must quickly adapt to ensure FA battalions properly implement any new materiel capabilities to effectively meet all of the 5RFAF in a D3SOE.

Recommendation No. 3: Update doctrine to address position location in a D3SOE. In addition to communications gaps, doctrine must adapt to how a D3SOE

affects position location devices such as the Defense Advanced GPS Receiver. This means updating current doctrine to determine if a better PACE plan for acquiring position data exists. For example, the FADOWP offers a solution for observers trying to self-locate in a GPS degraded environment. However, this particular guidance needs to be articulated in doctrine as step procedures that are available to all readers. Lastly, doctrine must address any new positional capabilities as they emerge to ensure proficiency across the Army.

### Training

Recommendation No. 4: Enforce proficiency of FA core competencies. Analysis shows a common trend of deficiency in core competencies among some FA battalions. By addressing this issue head on, FA leaders will mitigate the possibility of failure under normal, non-D3SOE conditions. This ensures all soldiers are proficient in their tasks, and armed with sufficient knowledge to adapt to the complex problems a D3SOE presents to a FA battalion.

Recommendation No. 5: Train FA battalions to become self-dependent for correcting technical issues. This recommendation is just as important as the previous for a unit preparing to operate in a D3SOE. Findings show a deficiency in some FA battalion abilities to maintain communication system connectivity. Regularly conducting DST mitigates this deficiency when it forces units to do more than ensure systems can power on. Effective DST must test the unit's ability to establish connectivity, and successfully synchronize efforts across the fires system. Equipment operability then becomes an associated benefit of DST instead of the focus of training. Furthermore, as units improve

they will gain the ability to troubleshoot technical problems without relying on FSR support.

Recommendation No. 6: Conduct realistic D3SOE training. To successfully overcome a D3SOE, FA battalions must train for all D3SOE conditions. This does not mean every training event should only be a denied environment scenario. Instead, as an example, the training might integrate degraded radio communication conditions with an intermittent presence of denied positional data. Training this way should also follow a crawl, walk, run approach. For example, the FA battalion might conduct DST in an uncontested environment to build core competencies, and increase implementation of D3SOE conditions in subsequent DST events. The goal of this training should be to challenge soldiers in an environment that requires a combination of core competencies or skills to successfully conduct a fire mission.

#### Materiel

Requirement No. 7: Improve or replace existing FM and HF radios. As stated, a D3SOE requires new materiel capabilities to regain freedom of communication in a D3SOE. This means the development of a new FM radios, or upgrading of existing systems. The same applies to the HF Harris radio that provides excellent encryption capabilities, but quickly discloses friendly locations to an EW equipped enemy as cited in the RUW case study. This capability increases a FA battalion's ability to maintain wireless radio connectivity unless severe denial conditions exist.

Requirement No. 8: Improve or replace existing positional devices. This materiel capability ensures FA battalions retain the ability to independently acquire both accurate target location and size, and accurate unit location in a D3SOE without an over

dependence on survey teams to provide positional data. Subsequently, this increases the acquisition of positional data, and facilitates more accurate computational procedures.

Recommendation No. 9: Improve CMD-P operability. This recommendation involves a holistic review of the CMD-P, and how it acquires data. Accomplishing CMD-P connectivity in a D3SOE may require the Army to develop a replacement, or upgrade to the GBS in order to allow the CMD-P to acquire MET in a D3SOE. Alternatively, developers should consider past means of acquiring MET, and determine their applicability to overcoming a D3SOE. The final solution must be a device, or system that can acquire MET uncontested in a D3SOE.

Recommendation No. 10: Reassess FA battalion MTOEs. Existing MTOEs do not support doctrinal guidance for degraded operations, and therefore do not support a piece of the D3SOE problem. This recommendation involves reinstating indirect fire plotting boards, and artillery fire control plotting sets to achieve accurate computational procedures. Also, FA battalion MTOEs need to include radio communication wires and cables. This facilitates radio communications, and improves the ability of a FA battalion to achieve all of the 5RFAF when a D3SOE creates a denied wireless radio environment.

#### Recommendations for Future Research

There are two areas related to this topic that deserve further research. The first area is how a D3SOE affects the rest of the fires system above the battalion level. This thesis only discussed the effects of a D3SOE on a battalion, its subordinate units, and observers. However, these are only a portion of the fires system. Specific topics to consider include the effects of a D3SOE on the brigade fires cell, and the division artillery (DIVARTY). Additionally, based on the complexity and importance of joint

operations, further research on how a D3SOE effects the ability to effectively synchronize joint fires is an important topic.

The second recommendation for research pertains to technology. This thesis intentionally delimited using more than basic details on technology to avoid classification issues. However, a study without such restrictions may glean slightly different results. For example, there may be more devices affected by a D3SOE than discussed in this thesis. Conversely, some devices such as the Harris radio, or the CMD-P may not be as ill-suited for a D3SOE as analysis determined. Additionally, further research may find a way for GPS devices to remain operable in a D3SOE.

### The Way Ahead

The purpose of this thesis and its findings is not to convey a scenario of impossibility for a FA battalion. Instead, it exists as a starting point for all FA professionals seeking to better understand how a D3SOE affects their ability to destroy, defeat, or disrupt the enemy with integrated fires. Improving the FA battalion's ability to conduct these tasks requires serious consideration of the preceding review of literature, analysis, and recommendations.

Also, at the Army level, the main emphasis needs to be on codifying what a D3SOE is, and what it means for the Army as a whole. This includes standardizing and defining the term while addressing each of the "D's" holistically, and incorporating the term in to existing Army doctrine. If Army doctrine properly addresses the challenges of a D3SOE, then FA doctrine will improve and adjust accordingly.

The inclusion of proxy wars in the thesis introduction is not an accident or coincidence. Instead, the discussion is intended to convey the importance of proxy wars

for developing capabilities that overcome an emerging threat. Much like the Yom Kippur War in 1973 functioned as a proxy war for those observing the conflict, the conflict between Russia and Ukraine also provides valuable observations of a D3SOE. The US Army and the FA community must use these observations to develop capabilities suitable for a D3SOE, and to maintain the FA battalion's ability to dominate any adversary.

Also, leaders must use the observations from the RUW, and the findings of this thesis to determine the second and third order effects of a D3SOE on their operations. For example, the analysis identified a problem with communications reliability for units operating in a D3SOE. This issue may mean more than one might think. Perhaps an observer or observer platform cannot transmit targeting information. If it can, then does using a radio give away the observer or firing unit location? Similarly, does the FDC give away the firing unit's location by transmitting firing data to the gunline? Apply all aspects of a D3SOE, such as denied GPS capability, and now the problem becomes exponentially worse.

Certainly, new or improved capabilities are necessary for success, and take time to develop. However, a modern FA cannon battalion needs to look no further than FA core competencies to achieve immediate success. Efforts such as the FADOWP are an example of existing resources to facilitate core competency proficiency. Increasing proficiency in areas such as degraded operations mitigates the possibility of avoidable errors due to a lack of proficiency in core competencies under any conditions, including those of a D3SOE. As new capabilities arrive, the FA battalion must adapt, and master the new competencies to further mitigate errors.



Leaders must think critically and creatively when applying the findings of this thesis. A D3SOE is a complex environment, and requires more than a one answer solution. The content of this thesis is a first step to overcoming a D3SOE, and provides FA leaders a basic understanding of how a D3SOE affects their operations. It is up to those same leaders to use this knowledge to their advantage. This ultimately ensures the FA battalion has the capabilities it needs to effectively operate in a D3SOE.

## BIBLIOGRAPHY

- Assymetric Warfare Group. *Russian New Generation Warfare Handbook, Version 2*. Fort Meade, MD: Assymetric Warfare Group, January 2017.
- Benedict, Keith, MAJ. "1-2 Stryker Brigade Combat Team National Training Center Rotation 16-06 After Action Review to US Forces Command." Headquarters, 1st Stryker Brigade Combat Team, Joint Base Lewis-McChord, WA, June 24, 2016.
- Bishop, James, SSG. *2CR SBCT Post Combat Lessons Learned*. Fort Sill, OK: Fires Center of Excellence, May 2014.
- Clausewitz, Carl von. *On War*. Edited and Translated by Michael Howard and Peter Paret. Princeton, NJ: Princeton University Press, 1984.
- Dastrup, Boyd. *King of Battle, Branch History of the U.S. Army Field Artillery*. Fort Monroe VA: Office of the Command Historian, 1991.
- Department of Defense. "Contracts: Press Operations, Release No. CR-184-15." September 25, 2015. Accessed April 4, 2017. <https://www.defense.gov/News/Contracts/Contract-View/Article/620608>.
- Department of the Army. Army Doctrine Reference Publication (ADRP) 1-02, *Terms and Military Symbols*. Washington, DC: Headquarters, Department of the Army, December 2015.
- . Army Doctrine Reference Publication (ADRP) 3-09, *Fires*. Washington, DC: Government Printing Office, August 2012.
- . Army Techniques Publication (ATP) 3-09.2, *Survey*. Washington, DC: Headquarters, Department of the Army, August 2013.
- . Army Techniques Publication (ATP) 3-09.23, *Field Artillery Cannon Battalion*. Washington, DC: Headquarters, Department of the Army, September 2015.
- . Army Techniques Publication (ATP) 3-09.30, *Techniques for Observed Fire*. Washington, DC: Headquarters, Department of the Army, August 2013.
- . Army Techniques Publication (ATP) 3-09.50, *The Field Artillery Cannon Battery*. Washington, DC: Headquarters, Department of the Army, May 2016.
- . Army Techniques Publication (ATP) 3-09.70, *Paladin Operations*. Washington, DC: Headquarters, Department of the Army, September 2015.
- . Field Manual (FM) 3-09, *Field Artillery Operations and Support*. Washington, DC: Government Printing Office, April 2014.

- . Field Manual (FM) 3-90-1, *Offense and Defense Volume 1*. Washington, DC: Government Printing Office, March 2013.
- . *FORSCOM Command Training Guidance: Fiscal Year 2018*. Fort Bragg, NC: Headquarters, United States Army Forces Command, March 2017.
- . Training Circular (TC) 3-09.8, *Field Artillery Gunnery*. Washington, DC: Headquarters, Department of the Army, November 2013.
- . Training Circular (TC) 3-09.81, *Field Artillery Manual Cannon Gunnery*. Washington, DC: Government Printing Office, April 2016.
- Edwards, Ruth, 1LT. *Achieving Accurate Meteorological Procedures at the National Training Center*. Headquarters, 1-21 FA Battalion, NTC Rotation 13-08.
- Folland, John. “FCoE Voluntary DIVARTY Data Call E-Mail.” US Army Fires Center of Excellence, 2015.
- Fox, Amos, and Andrew Rossow. “Assessing Russian Hybrid Warfare: A Successful Tool for Limited War.” *Small Wars Journal*, August 8, 2016.
- Gibbons-Neff, Thomas. “‘We Don’t Have the Gear’: How the Pentagon is Struggling with Electronic Warfare.” *The Washington Post*, February 9, 2016. Accessed April 4, 2017. [https://www.washingtonpost.com/news/checkpoint/wp/2016/02/09/we-dont-have-the-gear-how-the-pentagon-is-struggling-with-electronic-warfare/?utm\\_term=.cc038fac8ebf](https://www.washingtonpost.com/news/checkpoint/wp/2016/02/09/we-dont-have-the-gear-how-the-pentagon-is-struggling-with-electronic-warfare/?utm_term=.cc038fac8ebf).
- Gould, Joe. “Electronic Warfare: What US Army Can Learn From Ukraine.” *Defense News*, August 2, 2015. Accessed January 13, 2017. <http://www.defensenews.com/story/defense/policy-budget/warfare/2015/08/02/us-army-ukraine-russia-electronic-warfare/30913397/>.
- Joint Multinational Training Group-Ukraine. *UKR Leadership Discussion on ATO Lessons Learned*. Yavoriv, Ukraine: IPSC, November 26, 2015.
- Jomini, Baron de. *Summary of the Art of War*. Reprint excerpts, US Command and General Staff School, 2016. From Baron de Jomini, *Summary of the Art of War or a New Analytical Compend of the Principal Combinations of Strategy, of Grand Tactics and of Military Policy*. New York: G. P. Putnam and Co., 1854.
- Junker, Kirk J., USA. “The Field Artillery in Combined Arms Maneuver and Wide Area Security Operations.” Master’s Thesis, Command and General Staff College, Fort Leavenworth, KS, 2011.

- Karber, Phillip A., Dr. "Draft of Lessons Learned from the Russo-Ukrainian War: Personal Observations." Historical Lessons Learned Workshop sponsored by Johns Hopkins Applied Physics Laboratory and U.S. Army Capabilities Center (ARCIC), 2015.
- Karber, Phillip, and Joshua Thibeault. "Russia's New-Generation Warfare," Association of the United State Army, May 20, 2016. Accessed January 31, 2017. <https://www.ausa.org/articles/russia%E2%80%99s-new-generation-warfare>.
- Lennon, Brock, Capt. "The Five Requirements for Accurate Fire in the 21st Century." *Redleg Update* (February 2014): 3-4. Accessed February 1, 2017. [http://sill-www.army.mil/USAFAS/redleg/archive/2014/FEB\\_2014.pdf](http://sill-www.army.mil/USAFAS/redleg/archive/2014/FEB_2014.pdf).
- Merriam Webster. "Disrupt." Accessed April 26, 2017. <https://www.merriam-webster.com/dictionary/disrupt>.
- Meyers, Adam. "Danger Close: Fancy Bear Tracking of Ukrainian Field Artillery Units." Crowd Strike, December 22, 2016. Accessed January 16, 2017. <https://www.crowdstrike.com/blog/danger-close-fancy-bear-tracking-ukrainian-field-artillery-units/>.
- Story, Kurt S., Brigadier General. "Protecting Space in a Contested and Congested Domain." *Army Space Journal* (Winter/Spring 2010): 8.
- Taylor, Michael, MAJ. "SBCT S-3. 2-2 SBCT NTC 16-03 AAR to FORSCOM." Headquarters, 2nd Stryker Brigade Combat Team, Joint Base Lewis-McChord, WA, August 23, 2016.
- Ukraine Ministry of Defense. "Information about the 'Loss of Armed Forces of Ukraine Howitzer D-30' is not True." January 6, 2017. Accessed January 16, 2017. <http://www.mil.gov.ua/news/2017/01/06/informacziya-po-vtrati-u-zs-ukraini-80-gaubicz-d-30%E2%80%9D-ne-vidpovidae-dijsnosti/>.
- United States Army Field Artillery School (USAFAS). *The United States Army Field Artillery 2017 Training Strategy*. Fort Sill, OK: Headquarters, USAFAS, November 2016.
- . *U.S. Army Field Artillery Degraded Operations: White Paper*. Fort Sill, OK: Headquarters, USAFAS, October 2016.
- United States Army Force Management Support Agency. "Force Management System Web Site." January 4, 2017. Accessed May 15, 2017. <https://fmsweb.fms.army.mil/unprotected/splash/welcome.aspx>.
- Wendel, Karl S. *FA Lessons Learned Primer: Current Trend: Black Keys*. Fort Sill, OK: Fires Center of Excellence, January 2015.

———. *FA Lessons Learned Primer: Met: IGrADS vs Profiler*. Fort Sill, OK: Fires Center of Excellence, July 2015.