THE JOINT TACTICAL AERIAL RESUPPLY VEHICLE IMPACT ON SUSTAINMENT OPERATIONS

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This study seeks to examine the implications associated with fielding an autonomous unmanned aerial system to provide sustainment functions at the tactical level. The lack of an organic sustainment platform that can keep pace with dismounted infantry Soldiers creates a capability gap for the IBCT. An additional gap currently exists between the various strategy documents outlining the roadmap for fielding autonomous technologies and the policies of the Department of Defense. Using a tactical scenario to employ an autonomous platform, this study evaluates the advantages and disadvantages of autonomous aerial resupply. The author argues that autonomous unmanned aerial systems provide enhanced mobility and adaptability to dismounted infantry rifle companies and allow for increased freedom of action. This study's implications serve to highlight the need for greater dialogue on the policies that govern the development and use of autonomous systems.

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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

THE JOINT TACTICAL AERIAL RESUPPLY VEHICLE IMPACT ON SUSTAINMENT OPERATIONS, by MAJ Lawrence M. Csaszar, 98 pages.

This study examines the implications associated with fielding an autonomous unmanned aerial system to provide sustainment functions at the tactical level. The lack of an organic sustainment platform that can keep pace with dismounted infantry soldiers creates a capability gap for the Infantry Brigade Combat Team. An additional gap currently exists between the various strategy documents outlining the roadmap for fielding autonomous technologies and the policies of the Department of Defense. Using a tactical scenario to employ an autonomous platform, this study evaluates the advantages and disadvantages of autonomous aerial resupply. The author argues that autonomous unmanned aerial systems provide enhanced mobility and adaptability to dismounted infantry rifle companies and allow for increased freedom of action. This study's implications serve to highlight the need for greater dialogue on the policies that govern the development and use of autonomous systems.

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ACRONYMS

AACUS	Autonomous Aerial Cargo/Utility System
AAR	Autonomous Aerial Resupply
ACIDS	Army Capabilities Integrations and Development System
AI	Artificial Intelligence
ARCIC	Army Capabilities Integration Center
ARDEC	Armament Research, Development and Engineering Command
AUAS	Autonomous Unmanned Aerial System
BSA	Brigade Support Area
BSB	Brigade Support Battalion
CBA	Capabilities Based Assessment
COE	Centers of Excellence
DAS	Defense Acquisition System
DOD	Department of Defense
DOTMLPF-P	Doctrine, Organization, Training, Materiel, Leadership & Education, Personnel, Facilities and Policy
EPW	Enemy Prisoner of War
FM	Field Manual
FSC	Forward Support Company
GCS	Ground Control Station
IBCT	Infantry Brigade Combat Team
ICD	Initial Capabilities Document
JTAARS	Joint Tactical Autonomous Aerial Resupply System
JTARV	Joint Tactical Autonomous Resupply Vehicle

LCLA	Low Cost, Low Altitude
MCOE	Maneuver Center of Excellence
MULE-T	Multifunctional Utility/Logistics and Equipment-Transport
OBJ	Objective
ORP	Objective Rally Points
PM	Program/Project/Product Manager
RAS	Robotics and Autonomous System
TRADOC	Training and Doctrine Command
UAS	Unmanned Aerial System
UGV	Unmanned Ground System

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CHAPTER 1

INTRODUCTION

> For as long as common foot soldiers have marched off to battle, they have carried the same basic load-around eighty to a hundred pounds of weapons, armor, rations, digging tools, uniforms, and whatever else their sergeant thinks they ought to have handy when push comes to shove, and all of it digging into their shoulders through overloaded pack straps. Roman legionaries carried eighty pounds of gear, and modern Rangers carry about the same or more. Both probably used similar profanity (although in different languages) to complain about it.
>
> ― Hans Halberstadt, *Battle Rattle: The Stuff a Soldier Carries*

Challenges of Tomorrow's Fight

U.S. Army Training and Doctrine Command (TRADOC) Pamphlet 525-3-1, *U.S. Army Operating Concept: Win in a Complex World, 2020-2040*, describes the threats that the United States faces in future conflicts as a blend of traditional, unconventional, and hybrid forces. The presence of both nation states and non-state actors, such as terrorist groups and insurgents, creates a need for flexible operations to counter a variety of enemy strengths.[1] The lessons from Desert Storm, Operation Iraqi Freedom, and Operation Enduring Freedom continue to shape adversary tactics and strategies to avoid U.S. strengths by marginalizing capabilities that previously provided an overmatch. Additionally, U.S. ground forces will operate in all types of terrain and weather conditions in increasingly complex environments where enemy forces may not clearly distinguish themselves from civilian populations. These civil considerations limit the

[1] Headquarters, Department of the Army (HQDA), TRADOC Pam 525-3-1, *The U.S. Army Operating Concept: Win in a Complex World, 2016-2028* (Fort Monroe, VA: U.S. Army Training and Doctrine Command, 2014), 10-12.

United States to using precision strike capabilities to prevent the erosion of legitimacy through collateral damage. Enemy forces will continue to become more sophisticated using technology to increase their lethality, information warfare, recruiting, and financing. By leveraging the internet and social media, disinformation and propaganda will create additional unrest and aid enemy forces. Enemy investments into Anti-Access, Area Denial technologies, such as long-range artillery and air defense systems, will limit U.S. involvement short of escalating conflicts. Extended ground lines of communication will offer opportunities to attack a critical requirement for U.S. forces: operational reach and sustainment.[2] To prevent the disruption of sustainment operations, and thus, combat operations, the Army will combine emerging technology with existing doctrine and organizations to create dilemmas for the enemy.[3] The U.S. Army Infantry Brigade Combat Team (IBCT) looks to overcome current challenges associated with providing sustainment for its forces.

Overview of the IBCT

The U.S. Army began its organizational transformation to design modular brigade combat teams as self-contained combined arms formations in 2006. The IBCT continues to fill the role that many Americans associate with the U.S. Army, namely, dismounted soldiers fighting in close contact with enemy forces. According to Field Manual (FM) 3-96, *Brigade Combat Team*, the uniqueness of the IBCT, compared to other brigade

[2] Joint Chiefs of Staff, Joint Publication1-02, *Department of Defense Dictionary of Military and Associated Terms* (Washington, DC: Government Printing Office, 2016), 176.

[3] HQDA, TRADOC Pam 525-3-1, 11-12.

combat team types, such as the Armored Brigade Combat Team and Stryker Brigade Combat Team, lies in its purpose as “an expeditionary, combined arms formation optimized for dismounted operations in complex terrain—a geographical area consisting of an urban center larger than a village and/or of two or more types of restrictive terrain or environmental conditions occupying the same space.”[4] Additionally, the IBCT’s Table of Organization and Equipment boasts the smallest Tooth-to-Tail Ratio,[5] which makes the IBCT the preferred brigade combat team formation type to perform early entry operations into contested areas characterized by austere conditions.

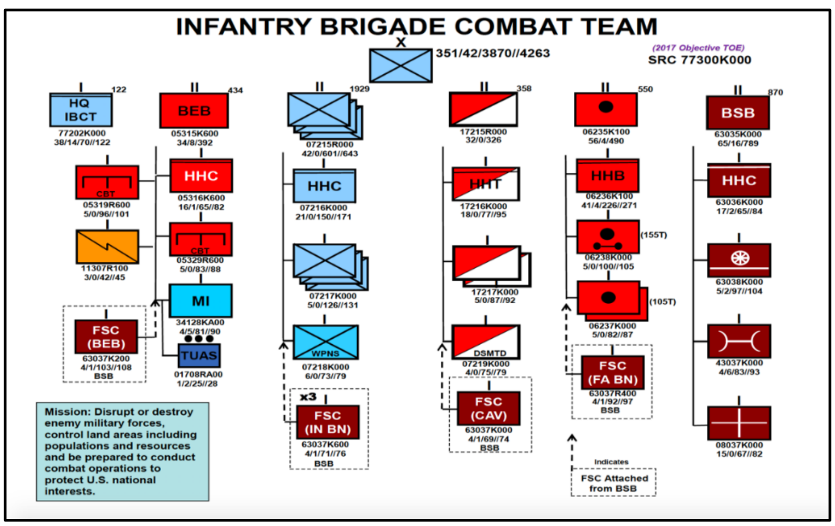

Figure 1. IBCT Task Organization

Source: Organizational Development Branch, Concepts Development Division, CDID, Maneuver Center of Excellence, Supplemental Manual 3-90, *Force Structure Reference Data, Brigade Combat Teams* (Ft. Benning, GA: Maneuver Center of Excellence, 2015), 9.

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[4] Headquarters, Department of the Army (HQDA), Field Manual (FM) 3-96, *Brigade Combat Team* (Washington, DC: Government Printing Office, 2015), 1-1.

[5] Spencer Beatty, *Beans to Bullets Logistics for Non-Logisticians* (Madison, AL: Mentor Enterprises, 2016), 5.

The preponderance of forces, and arguably the strength of the IBCT, resides in the three infantry battalions (see figure 1) tasked to close with the enemy by means of fire and maneuver. FM 3-21.20, *The Infantry Battalion* describes the infantry battalion as a rapidly deployable formation that sustained through limited support systems.[6] This description highlights the versatility afforded to infantry battalions by employing a limited number of vehicles.

Capability Gaps in the IBCT

Like other aspects of military doctrine, the IBCT's concept of sustainment does not always function as designed. Shortfalls in sustainment systems result in soldiers without the equipment needed to maintain momentum in combat operations. The restrictive terrain in which an IBCT normally finds itself operating disrupts and, in some cases, prevents ground based sustainment operations that support combat soldiers at the company level. This limitation degrades the operational reach of company, platoon and squad sized formations; moreover, company sized units lack the ability to sustain themselves, using organic assets, for more than seventy-two hours. The likelihood for combat operations to outpace sustainment operations further exacerbates the problem by creating justification, often masqueraded as risk-mitigation, for soldiers to carry excessively heavy combat loads of supplies on their backs. The modern-day IBCT soldier can expect to carry both an approach load and a fighting load in combat conditions (inclement weather, restrictive terrain, and an active enemy threat). Currently, the U.S.

[6] Headquarters, Department of the Army (HQDA), Field Manual (FM) 3-21.20, *The Infantry Battalion* (Washington, DC: Government Printing Office, 2006), 1-1.

Army FM for foot marches directs that a dismounted soldier should carry no more than forty-eight pounds as their fighting load and no more than seventy-two pounds as their approach load (which includes the fighting load) during combat operations to prevent physical exhaustion.[7] As evidenced in an extensive study conducted by the U.S. Army Center for Army Lessons Learned on light infantry forces in Operation Enduring Freedom, units habitually violate recommended weight limits with the average fighting load that many soldiers carry exceeding sixty pounds and approach march loads close to ninety-five pounds.[8] Carrying these substantial loads increases soldier exhaustion and decreases the ability of soldiers to perform their combat related tasks.[9] The Institute of Defense Analysis published evidence to support the relationship between soldier exhaustion and physical exertion in 2016 after testing approximately 700 soldiers over six months (see figure 2).

[7] Headquarters, Department of the Army (HQDA), Field Manual (FM) 21-18, *Foot Marches* (Washington, DC: Government Printing Office, 1990), 2-7.

[8] U.S. Army Center for Army Lessons Learned, *The Modern Warrior's Combat Load: Dismounted Operations in Afghanistan, April-May 2013* (Ft. Leavenworth, KS: U.S. Army Center for Army Lessons Learned, 2003), 17.

[9] Samuel Lyman Atwood Marshall, *The Soldier's Load and the Mobility of a Nation* (Quantico, VA: Marine Corps Association, 1980), 49.

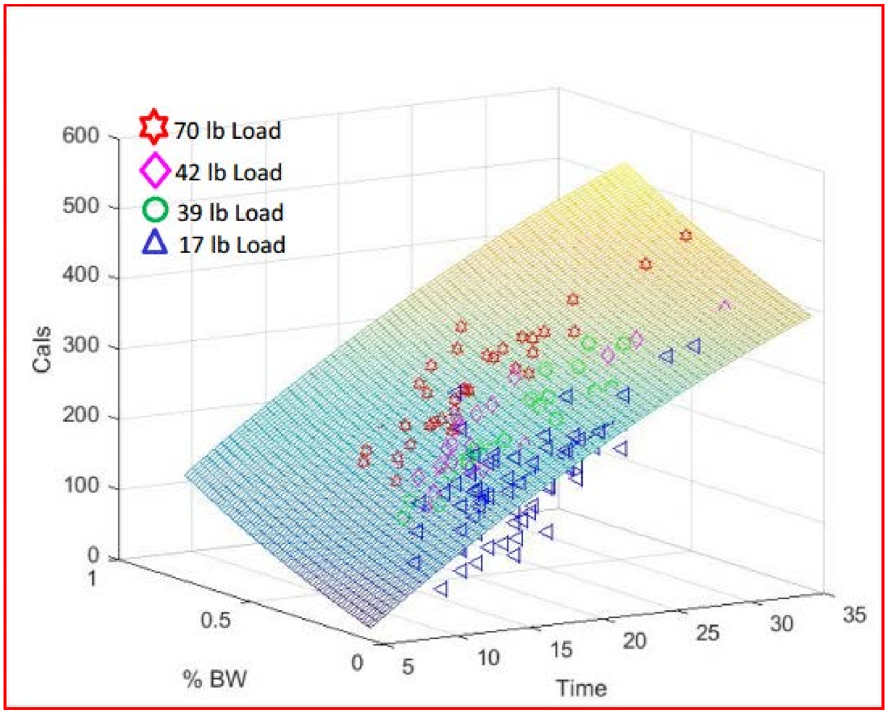

Figure 2. Impacts of Soldier Load on Energy

Source: Joint Advanced Warfighting Division, Institute for Defense Analysis, "Trade Space Left of the Requirement: A Prototype Tool to Provide Capability Planners a 'Common Squad Capabilities Picture'," (PowerPoint Presentation, Institute for Defense Analysis, Alexandria, VA, October 19, 2016), 13.

The correlation between the increase in calories burned and weight carried suggests that the Army's efforts to solve IBCT sustainment challenges by having soldiers carry more supplies may actually increase the consumption of food and water; thus, requiring resupply sooner than if soldiers carried lighter loads.

Although the easiest option for increasing the IBCT soldier's maneuverability on the battlefield seems to be lightening the load that the soldiers carry—this has proven difficult due to increasing requirements placed on the individual soldier.[10] Military leaders address the problem at their level by means of direct influence over what their soldiers carry. Tactical leaders have had to learn how to instill load discipline back into their mission planning. This process normally involves a deliberate cost-benefit analysis where the leader considers whether the piece of equipment impacts the chances of success on an operation.[11] This trade-off lies at the core of IBCT sustainment challenges. To operate effectively, infantry soldiers require speed and mobility. However, mobility comes at the price of diminished endurance for extended operations and adaptability to respond to unplanned situations. Recent examples of this problem include the inability of coalition forces to regularly provide sustainment support to Chosen Company, 2-503PIR at Combat Outposts Ranch House and Bella in 2007 and 2008, respectively. According to a case-study published by the Combat Studies Institute Press on the battle of Wanat "to support Ranch House, the battalion had to rely on external resources they did not directly control such as aviation assets to quickly resupply or provide a quick reaction force (QRF)."[12] The inability to resupply soldiers at Command Outposts Ranch House and Bella led to a decision to abandon the command outposts and hastily establish a new base in the town of Wanat in July 2008. As a platoon attempted to establish their fighting

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[10] Soldier Requirements Division, Capabilities Development and Integration Division, U.S. Army Maneuver Center of Excellence, "Soldier's Load" (PowerPoint Presentation, U.S. Army Maneuver Center of Excellence, Ft. Benning, GA, 2016), 5.

[11] Hans Halberstadt, *Battle Rattle: The Stuff a Soldier Carries* (St. Paul, MN: Zenith Press, 2006), 30.

[12] The Staff of the U.S. Army Combat Studies Institute, *Wanat, Combat Action in Afghanistan* (Ft. Leavenworth, KS: Combat Institute Press, 2010), 43-44.

positions at the new base, the contracted Afghan support failed to arrive with heavy equipment and supplies leaving the soldiers dangerously vulnerable to an attack. The events that took place on July 13, 2008 in Wanat, Afghanistan and the resulting thirty-six casualties (including nine soldiers killed) serve as a pointed example of tactical sustainment challenges and their effects on combat operations. Because of incidents like Wanat, and many other historic situations where sustainment operations failed to adequately support the war-fighter, leaders and soldiers increasingly stockpile supplies and carry more equipment than necessary to prevent coming up short. The results of a 2016 survey conducted by the Maneuver Center of Excellence (MCOE) Capabilities Development and Integration Directorate confirm this trend and highlight a minimal level of confidence in the responsiveness of sustainment services that are not organic to dismounted forces.[13] Although the U.S. Army continues to leverage the benefits of the technological advancements to gain efficiencies in sustainment and maintain an overmatch against adversaries, the issue of balancing rapid maneuver against operational endurance and adaptability continues to result in overloaded soldiers. Simply put, today's soldier faces the same problem as what Colonel Samuel Lyman Atwood Marshall described in 1950 when he stated, "it is conspicuous that what the machine has failed to do right up to the present moment is decrease by a single pound the weight the individual

[13] When surveyed, only 22 percent of dismounted infantry soldiers responded that they feel confident in the current resupply system to provide equipment/supplies on time. Test and Analysis Office, Capabilities Integration Directorate, U.S. Army Maneuver Center of Excellence (MCOE), "NCOA Assured Resupply Survey" (PowerPoint Presentation, U.S. Army Maneuver Center of Excellence, Ft. Benning, GA, June 16, 2016), 28.

has to carry in war. He is still as heavily burdened as the Soldier of 1000 years B.C."[14] Because the primary means for distributing supplies to soldiers in the IBCT remains ground-based vehicles, the brigade lacks the ability to rapidly maneuver and sustain units in locations where ground-based vehicles cannot travel.

A Possible Solution

In response to the identified capability gap that exists in the IBCT, the U.S. Army's Combined Arms Sustainment Command, Sustainment Center of Excellence, and MCOE began a collaborative effort in 2016 to define the requirements for a capability that improves the effectiveness of dismounted operations by optimizing sustainment and reducing the soldier's load. System performance benchmarks from a 2016 MCOE Capabilities Development and Integration Directorate study helped to define the characteristics of an emerging concept called assured resupply. This concept involves a reliable, responsive platform that carries forward supplies needed by dismounted forces and provides emergency resupply capability to lighten the load that each soldier carries. Currently, the missing piece in the concept of assured resupply remains the development of a rugged and versatile platform that provides dismounted forces with an off-load capability. To produce a physical platform, an Autonomous Unmanned Aerial System (AUAS), the U.S. Army Research Laboratory began development of the Joint Tactical Aerial Resupply Vehicle (JTARV) in 2014 to provide Autonomous Aerial Resupply (AAR). To expedite fielding of the JTARV, the U.S. Army Research Laboratory selected a commercially produced platform, Malloy Aeronautics P-300 Hoverbike (see figure 3),

[14] Marshall, 5.

from which to start development. In 2016, Research, Development and Engineering Command tasked the Armament Research, Development and Engineering Command (ARDEC) to provide a workable AUAS prototype to demonstrate an AAR capability at the Army Warfighting Assessment 18.1 in the fall of 2017.

Figure 3. U.S. Army JTARV

Source: Malloy Aeronautics, "Hoverbike," accessed February 12, 2017, http://www.hover-bike.com/#_invest.

Primary Research Question

Will employment of the JTARV increase the effectiveness of IBCT rifle companies?

Secondary Research Questions

To address the primary research question, examination of the following secondary research questions provides refined granularity on a variety of issues involving the U.S. Army's efforts to field the JTARV:

1. Does the JTARV reduce the soldier's load and unit sustainment requirements?
2. Does the JTARV provide an assured resupply capability in restrictive terrain environments?
3. What are the vulnerabilities of autonomous systems?
4. What major organization considerations must be accounted for before fielding the JTARV in an IBCT?

Assumptions

Technological advancements in lightweight materials will not provide the joint force with significant weight reductions in combat loads in the near and mid-term (2017-2030). The political risks associated with U.S. casualties, in the absence of an existential threat to the United States, will continue the trend of placing ever-increasing importance in protecting soldiers by requiring the wear of body armor, ballistic helmets, protective outer and under garments, and additional safety equipment. Future wars will occur in complex, dynamic environments where belligerents seek to produce numerous challenges to the joint force simultaneously; thus, the importance of flexibility and multi-mission capabilities will require the expedient deployment of a variety of combat loads. The U.S. Army will avoid creating new positions in IBCT rifle companies dedicated to the operation of AUAS to maintain required personnel numbers on the Table of Organizational Equipment. The U.S. Army will continue to need dismounted forces capable of operating in areas inaccessible to motorized and armored formations in the conduct of Unified Land Operations.

Definition of Key Terms

Assured Resupply: A concept centered around an accurate and timely sustainment platform that deliver required supplies when needed. Assured resupply provides a responsive, user focused capability that allows leaders to off-load supplies to preserve soldier performance without sacrificing flexibility to respond to contingencies.[15]

Autonomous: A term used to describe a system that does not require human control. Many levels of autonomy exist: tethered systems, wireless systems, semi-autonomous systems, and fully autonomous systems. Autonomy of machines depends on sophisticated software, including Artificial Intelligence (AI), and hardware to enable self-location within the operational environment and navigation to a pre-designated location.[16]

Artificial Intelligence: Describes the means for a computer system to mimic human functions such as conducting analysis and critical thinking to solve problems. The development of AI remains one of the keys to fielding autonomous robotic systems.[17]

Classes of Supply: The ten, Department of Defense (DOD) categories used to identify supplies: I. Rations; II. Clothing, individual equipment; III. Petroleum, oils, and

[15] MCOE, "NCOA Assured Resupply Survey," 4.

[16] Maneuver, Aviation, and Soldier Division, Army Capabilities Integration Center (ARCIC), *The US Army Robotics and Autonomous Systems Strategy* (Ft. Eustis, VA: U.S. Army Training and Doctrine Command, March 2017), 3.

[17] Ibid.

lubricants; IV. Construction materials; V. Ammunition; VI. Personal demand items; VII. Major end items, including tanks, helicopters, and radios; VIII. Medical; IX. Repair parts; and X. Nonstandard items to support nonmilitary programs such as agriculture and economic development.[18]

Common Controller: A single, common software suite designed to control the vast array of manned/un-manned systems being fielded.[19]

Common Data Link: A signal used to connect an Unmanned Aerial System (UAS) to a Ground Control Station (GCS) for the purpose of transmitting and receiving data necessary to control UAS while in flight.

Distribution-Based Logistics: A sustainment system that replaces the previous method of maintaining stockpiles at echelon with a more responsive, precise method of distribution. This concept relies on units providing accurate on hand quantities of supplies and forecasted requirements to develop a Logistical Common Operating Picture. The Logistical Common Operating Picture allows for higher level sustainment commands to identify needs, rapidly deliver supplies, and provide accurate status updates on the location and expected arrival of the supplies.[20]

Electronic Warfare: Military action involving the use of electromagnetic and directed energy to control the electromagnetic spectrum or to attack the enemy. EW

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[18] Headquarters, Department of the Army (HQDA), Army Doctrine Reference Publication 1-02, *Terms and Military Symbols* (Washington, DC: Government Printing Office, 2016), 1-16.

[19] ARCIC, *The US Army Robotics and Autonomous Systems Strategy,* 4.

[20] HQDA, FM 3-21.20, 10-41.

consists of three divisions: Electronic Attack, Electronic Protection, and Electronic Warfare Support.[21]

Off-loading: The reduction of a soldier's physical and cognitive load by removing equipment and/or requirements.

Restrictive Terrain: Terrain that does not support vehicular movement to natural or man-made obstacles. Limits cross-country traffic ability to air and dismounted movement only. Includes swamps, jungles, forests, mountains, and densely populated urban areas.

Soldier's Load: The physical (aggregate component weight of equipment carried during an operation) and cognitive (both relevant and extraneous information during an operation) burdens that a soldier contends with. The physical load includes both a fighting load and an approach march load.[22]

Unmanned Aircraft System: A system designed and equipped to conduct unmanned flight operations in support of a variety of roles.[23]

Limitations

This study analyzed data obtained through open-source, unclassified means. Due to the in-progress status of many of the technologies involved in the study as well as

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[21] Joint Chiefs of Staff, Joint Publication (JP) 1-0, *Doctrine for the Armed Forces of the United States* (Washington, DC: Government Printing Office, 2013), 137.

[22] HQDA, FM 21-18, 2-7.

[23] Department of Defense (DOD), *Unmanned Systems Integration Roadmap, FY2013-2038* (Washington, DC: U.S. Department of Defense, 2012), 15, accessed November 5, 2016, https://www.defense.gov/Portals/1/Documents/pubs/DOD-USRM-2013.pdf.

private, commercial parties concerned with intellectual property rights, some specifications, testing parameters and experiment data were not available for review. This study does not disclose any sensitive or classified information. This study considers the operational environment of the near and mid-term as described in TRADOC Pamphlet 525-3-1, *The U.S. Army Operating Concept: Win in a Complex World, 2020-2040,* TRADOC's *The US Army Robotics and Autonomous Systems Strategy,* and the Department of Defense *Unmanned Systems Integration Roadmap, FY2013-2038,* to determine the feasibility of the JTARV program. All conclusions and recommendations were based on a current, common understanding of the U.S. Army's force management process.

Scope and Delimitations

This study does not involve any human subject research, or surveys. This study only seeks to determine whether the JTARV serves as a suitable mitigation strategy for a specific capability gap facing rifle companies in the IBCT. Although JTARV fielding may include other brigade combat team formations, this study only considers the effects on the IBCT. Additionally, this study does not analyze other non-materiel solutions to address IBCT's capability gaps. Several ground-based, semi-autonomous, and autonomous systems already exist and remain involved in testing and evaluation by the U.S. Army. This study does not include all current proposed materiel solutions. The JTARV remains just one of twenty-eight proposals that make up the Joint Capability Technology Demonstration for the Joint Tactical Autonomous Aerial Resupply System (JTAARS). This study does not evaluate all proposals for the JTAARS.

Significance of Study

This study evaluates emerging technology and concepts against known capability gaps that exist in the IBCT. To develop a robust third-offset strategy, the U.S. military will need to leverage technology in novel ways to provide options to senior leaders. The JTARV presents a novel idea, but its utility ultimately depends on its employment, if it becomes a program of record at all, to determine if it affords U.S. forces any advantage. By analyzing the JTARV's strengths and weaknesses this study seeks to inform military professionals on the considerations involved with employment of AUAS.

Summary

The preceding chapter provided background information on the U.S. Army's future wars concept, the IBCT's organizational design, the limitations and challenges posed by real-world operations, and the efforts to develop solutions to these problems. The primary research question and secondary research questions were introduced along with definitions of key terms, assumptions, limitations, and delimitations. The next chapter, literature review, presents the reader with an overview of what others have written about the topic of AUAS and provides further details on the study's topic.

CHAPTER 2

LITERATURE REVIEW

This study intends to answer the primary research question: will employment of the JTARV improve the effectiveness of IBCT rifle companies? The following literature review supports the resolution of the primary and secondary research questions by providing the reader with an overview of current trends related to the integration of autonomous systems and combat sustainment. Though still a relatively nascent concept, a fair amount of literature applies to AUAS technologies and how they might provide sustainment functions on the battlefield. This chapter contains five sub-topics: IBCT sustainment, Army capabilities development, attempted solutions, autonomy on the battlefield, and autonomous resupply.

IBCT Sustainment

According to FM 3-96, *Brigade Combat Team*, IBCT infantry battalions consist of five companies (see figure 4): one headquarters and headquarters company, three rifle companies, and one weapons company.[24] The headquarters and headquarters company provides war-fighting function support to the battalion to enable the rifle companies to accomplish their missions through enabler support, synchronization of friendly forces, and most importantly, sustainment. Of note, the infantry battalion task organization does not include the Forward Support Company (FSC), previously shown as attached from the Brigade Support Battalion (BSB). The FSC serves as the link between the infantry

[24] Headquarters, Department of the Army (HQDA), Field Manual (FM) 3-96, *Brigade Combat Team* (Washington, DC: Government Printing Office, 2015), 1-2.

battalion and the BSB, provides distribution-based logistics support to keep soldiers sustained, and ensures that the battalion can maintain momentum (see figure 4).

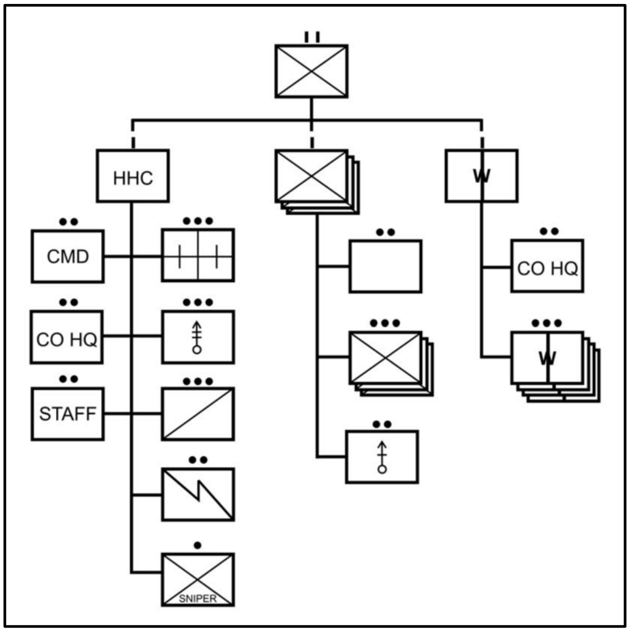

Figure 4. IBCT Infantry Battalion Task Organization

Source: Headquarters, Department of the Army, Field Manual 3-21.20, *The Infantry Battalion* (Washington, DC: Government Printing Office, 2006), 1-3.

Currently, Army doctrine outlines a multi-echeloned approach to sustaining an infantry battalion in the IBCT using trains. Groupings of personnel, vehicles, and equipment create trains and serve as the basic tactical sustainment organization. The first sustainment echelon resides at the company level and consists of the company trains. The company first sergeant manages the employment of one M1078 Truck Cargo: Light Medium Tactical Vehicle and one 400-gallon water trailer. This minimal capability set provides some freedom of maneuver for the rifle company by limiting the amount vehicles that the company must plan for. However, the single cargo truck also limits the number of nodes that the company can support at one time. The second sustainment echelon resides at the battalion level and consists of the FSC's distribution platoon's vehicles, split between the battalion's combat trains and field trains. The battalion positions the combat trains after considering Mission, Environment, Terrian, time, Troops, Civilians and determining how best to provide responsive sustainment to the companies. The field trains can co-locate with the Brigade Support Area (BSA) and includes those assets not located in the combat trains. The FSC supports supply distribution and replenishment of the rifle companies by transporting supplies from the BSA to a Logistics Release Point. The third sustainment echelon is located with the BSB in the BSA and consists of the BSB distribution company's vehicles (see figure 5).[25]

[25] Organizational Development Branch, Concepts Development Division, CDID, Maneuver Center of Excellence, Supplemental Manual 3-90, *Force Structure Reference Data, Brigade Combat Teams* (Ft. Benning, GA: Maneuver Center of Excellence, 2015), 51.

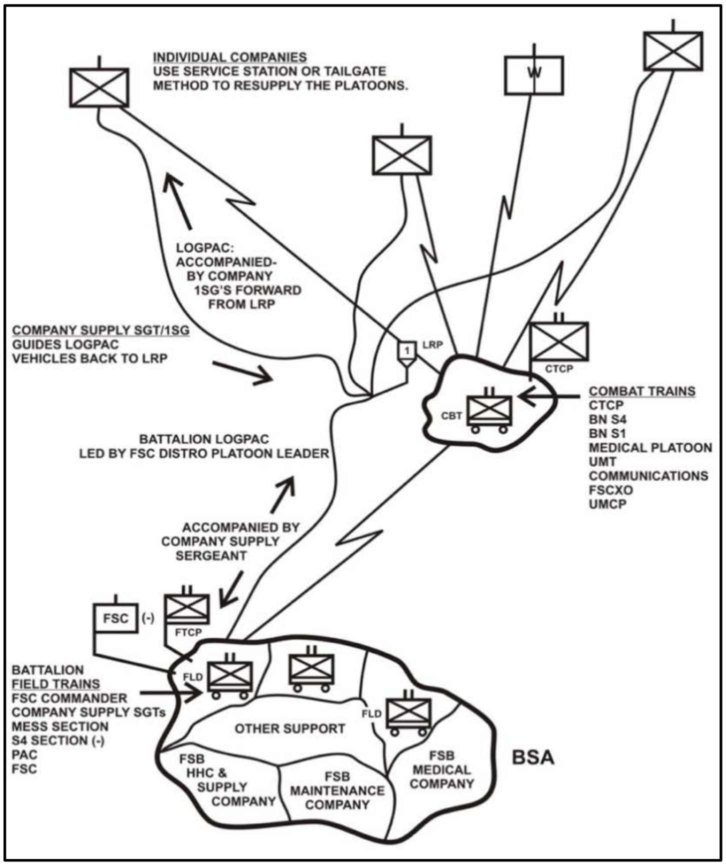

Figure 5. Echeloned Concept of Sustainment

Source: Headquarters, Department of the Army, Field Manual 3-21.20, *The Infantry Battalion* (Washington, DC: Government Printing Office, 2006), 10-45.

The Brigade Support Operations Officer manages these assets as a part of the overall sustainment of the IBCT. The variables of Mission, Enemy, Terrain, Time, Troops available and Civilian considerations determine the best mix of distribution assets from BSB and the FSC. The SPO, and the various sustainment planners assigned to the BSB, determine the right balance of logistics to support the BSB commander's intent. This concept of sustainment allows the IBCT to sustain infantry battalions using only organic equipment, but relies exclusively on ground-based vehicles and the establishment, and protection of ground lines of communication to support delivery of supplies from the BSA to the combat trains, and ultimately, the individual company trains. The reliance on a ground-based concept of sustainment creates a major limiting factor in the adaptability and endurance of the IBCT, absent external, non-organic sustainment support.

Army Capability Development

The simplicity of the Army Force Management purpose statement, to provide trained and ready units to combatant commands, stands in stark contrast with the tremendous complexity of the Force Management process and all that it encompasses. This section does not intend to cover all aspects and intricacies of the Force Management but instead provides an overview of the key stakeholders, processes, and outputs. Instead, this section facilitates a common understanding on the development of forces and capabilities while highlighting how the primary and secondary research questions contribute to the greater body of knowledge on IBCT sustainment. The Army Capabilities Integration and Development System (ACIDS) generates Army-specific Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, Facilities, and Policy (DOTMLPF-P) solutions against capability gaps derived from strategic planning documents. The Deputy Chief-of-Staff, G-3/5/7 (Operations, Plans, Training) leads ACIDS and manages the Army Requirements Oversight Council. The Army Requirements Oversight Council provides advice to the Army G-3 (Operations) and Vice Chief-of-Staff of the Army on the status of capabilities, proposals for rapid fielding of capabilities, and strategies for addressing capability gaps identified in ACIDS. ACIDS supports a CBA that evaluates future joint and Army warfighting concepts, with consideration to likely terrain and enemy characteristics, to identify gaps and recommend solutions. Nested within joint and national military strategy, ACIDS begins with the development of Army strategic guidance by the Army Staff. The Army Staff produce the Army Concept Framework, which includes *The U.S. Army Capstone Concept*, *The U.S. Army Operating Concept: Win in a Complex World, 2020-2040,* and the Army Functional Concepts.

These documents serve to describe what U.S. forces will face and how they will operate during the nation's future wars. They also provide a conceptual framework that enables a CBA, through the execution of a Functional Area Analysis, resulting in a crosswalk of strategy to concepts to tasks. These tasks outline what the Army needs to do to succeed and provide input for the next step of the CBA, the Functional Needs Analysis. During the Functional Needs Analysis step of CBA, analysis of required capabilities (needs) determines where the current Army force lacks the ability to accomplish a task within the DOTMLPF-P framework. TRADOC's subordinate command, the U.S. Army Capabilities Integration Center (ARCIC), documents shortfalls as capability gaps and serves as the proponent for management of all capability documents. TRADOC exists to design, acquire, build, and improve the Army by developing proposed solutions in the form of concepts. As of 2017, ARCIC's list of Army Warfighting Challenges highlights the sustainment challenges of the IBCT and its impact on conducting joint combined arms maneuver: "the Infantry Brigade Combat Team (IBCT) lacks the ability to move to decisively close with and destroy enemy under restrictive terrains such as mountains, littorals, jungles, subterranean and urban areas because of excessive physical burdens imposed by organic material systems."[26] Relying on organic sustainment distribution assets and comprised mostly of foot-mobile soldiers, the infantry battalions of the IBCT must determine how their soldiers will carry all the necessary equipment for an extended operation. To overcome this limitation and enable the IBCT to provide more responsive sustainment services to soldiers, a myriad of other DOD organizations work with TRADOC and ARCIC to transform concepts into requirements which ultimately generate solutions across the DOTMLPF-P framework.

During the final step of the CBA, the Functional Solution Analysis, ARCIC, the Army Centers of Excellence (COE) and the Research, Development and Engineering Command solve capability gaps by conducting experimentation, simulations, testing, and analysis to create DOTMLPF-P requirements. An Initial Capabilities Document (ICD) captures these requirements and outlines in broad terms, a capability that requires research, development, and fielding. The ICD documents both non-materiel and materiel solution approaches to address a specific capability gap identified in the CBA. In the absence of a non-materiel solution, the ICD should also include recommendations for the type of materiel approach required to support the needed capability. The Army Requirements Oversight Council validates ICDs to ensure that all non-materiel solutions were adequately considered in an analysis-of-alternatives before the document serves as the entry point into the Defense Acquisition System (DAS) as the Materiel Development Decision.

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[26] Army Capabilities Integration Center, "Army Warfighting Challenges," U.S. Army, updated April 1, 2017, accessed November 5, 2016, http://www.arcic.army.mil/ Initiatives/ArmyWarfightingChallenges.

The DAS consists of several steps, stakeholders, organizations, and oversight committees, but it fundamentally exists to field a materiel solution to U.S. forces requiring a capability. The DAS connects concepts, broad ideas about how the force should fight, with tangible, materiel solutions to enable the force to operate in accordance with a concept. The Assistant Secretary of the Army (Acquisition, Logistics, and Technology) serves as the Army Acquisition Executive and acts as the senior representative of the Secretary of the Army for all army procurement in the DAS. The Army Acquisition Executive appoints a Headquarters, Department of the Army System Coordinator to serve as the linkage between the Program/Project/Product Manager (PM) and Headquarters, Department of the Army. The PM bears responsibility to manage the acquisition of a specific program along the DAS program model after the approval of a Capabilities Development Document.

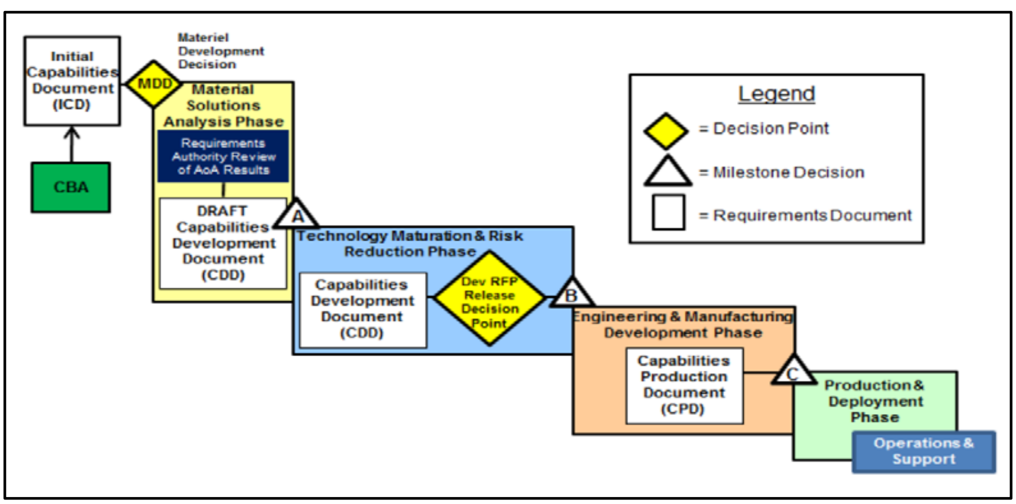

Figure 6. CBA and the Defense Acquisition System Phases/Milestones

Source: AcqNotes, "JCIDS Process: Capabilities Based Assessment," accessed November 19, 2016, http://www.acqnotes.com/acqnote/acquisitions/capabilities-based-assessment-cba.

The DAS consists of five phases: materiel solution analysis, technology maturation and risk reduction, engineering and manufacturing development, production and deployment, and operations and support (see figure 6). During the first two phases, Key Performance Parameters and Key System Attributes are developed and used to obtain an approved acquisition strategy for the product. Once approved, the project completes Milestone A. The PM also seeks to reduce the risks and costs associated with the production or procurement of a working prototype to support phase three of the DAS. To enter the Engineering and Manufacturing Development phase, a product must complete Milestone B by demonstrating a minimum of Technology Readiness Level 6 (prototype demonstration in a relevant environment) and obtain an approved Development Request for Proposal. The Engineering and Manufacturing Development phase supports the development and testing of a product to ensure that it meets the operational requirements identified in the ICD, as well as the Key Performance Parameters and Key System Attributes. The success of this phase will determine whether the product proceeds into phase four, completing Milestone C, and begins initial production and deployment. From this point, the PM oversees low-rate and full-rate production efforts as the newly developed materiel solution begins fielding to designated units.

The Army's laboratories within the Research, Development and Engineering Command develop new technologies while the COEs experiment to develop concepts and requirements, using Science and Technology objectives, to decide whether to invest in a proposal, discard it, or experiment further. The Army Science and Technology strategy seeks to maintain technological superiority by providing operational solutions for capability requirements. Other key organizations that support this strategy include the various research, development, and engineering centers; industry and academia. Through basic research, applied research, and advanced technology development, Science and Technology activities facilitate technology demonstrations to inform ARCIC and the Army COEs on the Technology Readiness Levels of developing operational solutions. Concept and materiel development do not always occur sequentially. An on-going research project that currently does not fit into the Army Warfighting Challenges may become a priority after the introduction of new doctrine and capability gaps.

Attempted Solutions

One of the more recent solutions fielded by the U.S. Army includes a family of Unmanned Ground Vehicles (UGV) known as the Multifunctional Utility/Logistics and Equipment-Transport (MULE-T) and the Squad Maneuver Equipment Transport. UGVs lighten the load that a dismounted soldier carries by serving as an off-load platform that can move with the formation. Although the DOD cancelled the MULE-T program (as a part of the Future Combat Systems program) in 2011, it served as the subject for studies on the use of an autonomous vehicle specifically designed to provide increased mobility and operational reach. Studies on the MULE-T suggested targets for future systems of 950 pounds of payload and a 100-kilometer operational range.[27] The Squad Maneuver Equipment Transport shares many similarities to the MULE-T as a UGV, and therefore suffers from the same limitations. Ground based systems often create the need for a

[27] John A. McLaughlin, “The Soldier's Load and the Multifunctional Utility/Logistics and Equipment-Transport” (Thesis, U.S. Army Command and General Staff College, Ft. Leavenworth, KS, 2010), 79-80.

soldier to accompany the platform to steer it clear of obstacles and ensure that it does not become immobilized or disabled. These issues may cause soldiers to lose focus on the mission and instead worry about the platform.

The U.S. Army is a land-focused force and therefore places emphasis on movement of supplies and equipment with ground-based systems. This type of thinking increases the amount of combat logistics patrols on the road to keep soldiers supplied and thus places lives at risk. A significant portion of U.S. casualties in Iraq and Afghanistan involve soldiers conducting and supporting combat logistics patrols. To overcome the risks and problems associated with UGVs and ground-based logistics, Army planners also considered non-materiel solutions such as updating doctrine to augment sustainment assets organic to the IBCT with both rotary and fixed-wing platforms to reach locations inaccessible by ground. The concept of Low Cost, Low Altitude (LCLA) resupply operations proved invaluable during combat operations in the rugged terrain of eastern Afghanistan. The idea of using a plane to deliver supplies to soldiers, however, is not necessarily new. For years, the U.S. Air Force has provided high velocity container delivery system drops. However, the LCLA system sought to provide smaller, unit-configured re-supply bundles on target, typically within twenty meters of the target drop point. LCLA provides bundles that range in weight from 250 to 560 pounds and its limiting factor in range depends on the airframe used to deliver the bundle, usually a C-23 Sherpa, Casa 212, UH-60 Blackhawk, or CH-47 Chinook. However, the LCLA resupply concept's many successes in Afghanistan fails to solve the issues of responsiveness and removing soldiers from harm's way to resupply units. Additionally, due to limiting factors like weather conditions, elevation, availability of assets and mission requirements, rotary and fixed wing assets may not be available to provide consistent sustainment to IBCT companies and platoons. To address these shortfalls, the U.S. Army decided to combine the capabilities of the UGVs and the LCLA concept to create an AUAS capable of delivering supplies to soldiers.

Autonomy on the Battlefield

An important distinction in the discussion of AUAS concerns the difference between unmanned and autonomous systems, their strengths and weaknesses, and the implications for fielding either type of system. Unmanned systems refer to systems that have no human operator aboard the platform to physically control and direct its actions. An unmanned system operates during a mission by means of a data set that includes various parameters and allows the unmanned system to execute the mission as designed. However, an autonomous system can perform advanced operations without the direct input of a human operator due to the system's ability to sense, process, consider, decide, and interact with the environment. As noted in other studies, a common language within the DOD is still required to adequately describe the various characteristics of AUAS.[28] A need for common terminology also exists with regards to the level of a system's autonomy. In 2004, a North Atlantic Treaty Organization working group codified a description of autonomy levels to establish a common understanding of capabilities associated with each level of autonomy (see table 1).

[28] Jaysen Yochim, "The Vulnerabilities of Unmanned Aircraft System Common Data Links to Electronic Attack" (Thesis, U.S. Army Command and General Staff College, Ft. Leavenworth, KS, 2010), 79.

Table 1. NATO Autonomy Levels		
Autonomy Level	Title	Description of Capabilities
Level 1	Remotely-controlled system	System reactions and behavior depend on operator input
Level 2	Automated system	Reactions and behavior depend on fixed built-in functionality (preprogrammed)
Level 3	Autonomous non-learning system	Behavior depends upon fixed built-in functionality or upon a fixed set of rules that dictate system behavior (goal-directed reaction and behavior)
Level 4	Autonomous learning system with the ability to modify rules defining behaviors	Behavior depends upon a set of rules that can be modified for continuously improving goal directed reactions and behaviors within an overarching set of inviolate rules/behaviors

Source: Created by author based on information from Marco Protti and Ricardo Barzan, "UAV Autonomy–Which level is desirable?–Which level is acceptable?" North Atlantic Treaty Organization, Brussels, Belgium, 2007, accessed February 22, 2016, http://www.dtic.mil/get-tr-doc/pdf?AD=ADA478669, 12-7.

The level 1 systems familiar to most people, such as MQ-1 Predator and RQ-11 drones, require a link between the system and a human operator to provide flight control, mission parameters, as well as take-off and landing guidance. This technology gained an incredible amount of attention and popularity by military officials for its ability to remove humans from having to perform dull, dangerous, dirty work. These early systems provided advantages to military leaders by reducing risks for service members, providing options through operational endurance, flexibility to re-task in support of multiple missions, and a cost savings over traditional means to perform similar tasks.[29]

The DOD *Unmanned Systems Integration Roadmap, 2013-2038*, published in 2013, articulates the U.S. military's vision and strategy for the development and fielding of unmanned systems over a 25-year timeframe. Although the roadmap describes UAS as primarily an Information Collection asset, the increasing interest towards unmanned systems indicates that both the U.S. Congress and the DOD favor expanding the roles of UAS. Level 1 UAS, however, possess numerous vulnerabilities that create risks to mission accomplishment. A common data link provides instructions to the system and therefore requires that the system always remain within line-of-sight of either the GCS or a relay. Any latency in the data transmission rate, due to loss in signal strength, electro-magnetic activity, or an electronic attack could result in the GCS losing control of the UAS. Concerns over the widespread proliferation of advanced computing technologies across the developing world and the relative ease to field passive jamming devices resulted in increasing the layers of security of UAS.[30] Furthermore, the act of removing the human pilot from the system also significantly limits the amount of situational awareness that the system operator, now located in a GCS, has about the airspace. For example, an operator cannot avoid collision with another aircraft if the only information

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[29] William Martel, *The Technological Arsenal: Emerging Defense Capabilities* (Washington, DC: Smithsonian Institute Press, 2001), 185.

[30] Kris Osborn, "Cybersecurity Experts Tell Congress Weapons Need Better Security," Defense Systems, March 2, 2017, accessed March 15, 2017, https://defensesystems.com/articles/2017/03/02/cybrerpanel.aspx; Wilson Wong, *Emerging Military Technologies: A Guide to the Issues* (Santa Barbara, CA: Praeger, 2013), 106.

available consists of what the system's camera records along with the system's location and flight data. The United States is not the only country that has invested heavily in UAS and therefore it stands to reason that enemy UAS could potentially seek out and destroy friendly UAS in future wars. The Defense Advances Research Projects Agency budgeted $11 million for the Peregrine UAV Killer in 2006 to operate in an over-watch position, maintain a minimal signature, identify an enemy UAS, and then fly into it to destroy it.[31] Not only would the virtual tether between the GCS and the UAS need to be severed to support this concept, the unpredictability of this type of drone versus drone battle would require an autonomous, thinking platform capable of sensing and reacting. These requirements and concerns over level 1 UAS disadvantages serve to support the development of increased autonomy. Current Army UAS only have a basic level of autonomy, due to technological limitations, and require some level of operator involvement. This creates an operator-to-system ratio of 1:1. Future autonomy capabilities seek to improve this ratio by reducing the number of soldiers required to operate and supervise the activities of an AUAS.[32]

The potential impacts of artificial intelligence advancing to a point where decision-making no longer requires human input raise significant questions on how to ensure that autonomous systems operate within their designed parameters. This issue encompasses more than just an engineering problem and calls into question the suitability

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[31] Peter W. Singer and William Hughes, *Wired for War: The Robotics Revolution and Conflict in the 21st Century* (Ashland, OR: Blackstone Audio, 2010), 120.

[32] Science, Technology, Research, and Accelerated Capabilities Division, Army Capabilities Integration Center, *The Warfighter's Science and Technology Needs* (Ft. Eustis, VA: U.S. Army Training and Doctrine Command, September 21, 2016), 3.

of current laws and policies to address this new frontier of technology. Another issue of autonomy centers on the machine language itself. If humans, who cannot clearly articulate decision-making, create the software that enables AI and AUAS then the machine will likely struggle to replicate human decision-making abilities.[33] This issue calls into question the ability for autonomous software to ever advance to a point where an AUAS could demonstrate initiative and take necessary action. Additionally, computer systems do not understand context and therefore blindly follow orders without consideration of all the factors involved in individual situations. Removing the human from the decision-loop creates an opportunity for things to go awry when conditions become dynamic and complex.[34] To address concerns over autonomy in future defense systems, the House of Representatives Armed Services Committee held a hearing in 2015 with leading military autonomy experts. The committee addressed the panel with concerns over the lack of understanding across the government regarding the potential game-changing capabilities that autonomous systems promise and posited several important points:

1. How do we distinguish between degrees of complexity of autonomous systems?
2. Who is ultimately responsible for the actions of an autonomous system? How should autonomous systems be integrated into manned formations?

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[33] Martel, 231.

[34] Wong, 93-94; Singer and Hughes, 123.

3. What are the risks of employing autonomous systems?[35]

The Army's representative, Dr. Jonathan Bornstein spoke of the on-going efforts to ensure that its forthcoming autonomous systems doctrine considered and provided answers to these questions. Additionally, he spoke to the committee of the need to continue funding the development of autonomous technologies, especially learning software, to take the systems from "tool to teammate."[36] To emphasize this point, Dr. Bornstein highlighted the difference between civilian and military autonomous technology applications. The self-driving cars and package delivery drones developed by Google and Amazon, respectively, operate in an environment based on an established structure with rules and order. For instance, a self-driving car operating on a highway is bound by a set of traffic laws and norms that do not change very often. The rules of operation and physical terrain in a dynamic environment like a battlefield are less stable and require systems that can sense and respond to their surroundings.

The 2017 U.S. Army Robotics and Autonomous Systems (RAS) describe how the Army plans to integrate emerging technologies into future organizations to ensure that the United States maintains a relative advantage over enemies. The RAS highlights the possibility for autonomous systems to lighten the soldiers' load, both physical and

[35] U.S. Congress, House, Armed Services Committee, *Hearing to Receive Testimony in Review of Advancing the Science and Acceptance of Autonomy for Future Defense Systems* (Washington, DC: Government Printing Office, 2015), 3.

[36] U.S. Congress, House, Armed Services Committee, *Hearing to Receive Testimony in Review of Advancing the Science and Acceptance of Autonomy for Future Defense Systems*, 8.

cognitive, resulting in improved speed, mobility, stamina, and effectiveness.[37] The strategy clearly states that there exists a direct correlation between heavy loads carried by soldiers and their ability to maintain momentum and combat effectiveness. Thus, the effort to lighten the soldier's physical load remains a priority in the near-term, 2016-2020, but currently only includes discussion about UGVs. The strategy also discusses the possibility of sustaining the force with increased supply distribution and an emphasis on augmenting current systems to gain efficiencies. Army leaders acknowledge the high costs, in terms of time and resources, required to sustain forces with current logistics distribution doctrine and organization. As soldiers operate further from established bases with sustainment capabilities, the difficulty of resupply operations grows. This leaves soldiers vulnerable and tied to their ground-based lines of communication for supplies. AUAS capabilities provide additional options to logistics planners and tactical commanders to ensure the delivery of materials when and where required. AUAS could drastically reduce delivery times, increase responsiveness through on-demand delivery and minimize risk to soldiers by reducing the demand for ground convoys and associated security.[38]

An improved sustainment capability also enables soldiers to operate in small, dispersed units to negate enemy strengths such as long-range fires. The increasing complexity of sustaining units spread across the battlefield requires updating the methods for distribution operations. Autonomous resupply enables dispersion amongst small units,

[37] ARCIC, *The US Army Robotics and Autonomous Systems Strategy*, 1.

[38] MuShawn D. Smith, "Technologies to Sustain the Army of 2025 and Beyond," U.S. Army, accessed October 15, 2016, https://www.army.mil/article/132473.

which affords commanders additional flexibility to create multiple dilemmas for enemy forces. Future concepts envision autonomous resupply improving unit endurance and enabling continuous operations for up to seven days. AUAS will function as scouts, load carriers, resupply platforms, and communication nodes using easily maintainable and repairable sensors. Ultimately, future concepts foresee autonomous systems that operate with a high degree of autonomy and execute tasks without soldier intervention.[39] The RAS prioritizes the effort to increase supply distribution capabilities with AUAS in the far-term, 2031-2040.

The RAS acknowledges that achievement of capability objectives depends on the maturation of technology related to autonomy, AI, and common control. The development of advanced AI will allow for greater levels of autonomy in AUAS and further reduce the amount of human interactions required to successfully employ AUAS. A common controller contributes to further reductions in weight requirements and allows a single user to control multiple platforms. One of the problems with developing new technologies involves consideration of the bigger picture when addressing issues. Soldiers receive new capabilities as individual systems that were developed by independent teams. Usually these new systems lack interoperability with other equipment that soldiers already carry, thereby increasing their load.[40] The multitude of publications and statements on the role of autonomy in future combat systems serve to answer

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[39] Headquarters, Department of the Army, TRADOC Pam 525-3-6, *The U.S. Army Functional Concept for Movement and Maneuver* (Ft. Eustis, VA: U.S. Army Training and Doctrine Command, 2017), 30.

[40] Joint Advanced Warfighting Division, Institute for Defense Analysis, “Trade Space Left of the Requirement,” 2.

secondary research questions; specifically, what are the vulnerabilities and threats associated with autonomous systems and what DOTMLPF-P considerations must be accounted for before fielding the JTARV. The remaining portion of the literature review focuses on sources that provide details on the primary research question as well as questions about the JTARV platform and the JTAARS concept.

Autonomous Resupply

In 2009, the U.S. Marine Corps began to actively seek a solution from industry that could provide an unmanned aerial system for the purposes of providing resupply to Marines in remote locations in Afghanistan. Responding to Marine Corps needs, Lockheed-Martin provided a system by transforming a manned helicopter, the K-1200 K-MAX, into an optionally or unmanned platform and began operational trials in Afghanistan less than a year later. From 2011 to 2013, the K-MAX flew thousands of unmanned missions and delivered more than 4.5 million pounds of cargo, keeping a significant number of Marines out of harm's way.[41]

The three-year experiment also highlighted a need for greater autonomy to correct mid-flight issues. In 2014, a K-MAX helicopter flying an unmanned mission experienced strong tail winds and crashed before Lockheed Martin contractors, who were operating the helicopter remotely, could regain control and stabilize the helicopter.[42]

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[41] Dan Lamothe, "Robotic Helicopter Completes Afghanistan Mission, Back in U.S.," *The Washington Post,* July 25, 2014, accessed February 25, 2017, https://www.washingtonpost.com/news/checkpoint/wp/2014/07/25/robotic-helicopter-completes-afghanistan-mission-back-in-u-s/?utm_term=.4597d0a0a383.

[42] Dan Lamothe, "Why Pilots Couldn't Stop a Marine Corps Drone Helicopter from Crashing," *The Washington Post,* August 7, 2014, accessed February 25, 2017,

Figure 7. Lockheed Martin K-MAX

Source: Lockheed Martin, "K-MAX," accessed January 13, 2017, http://www.lockheed martin.com/us/products/kmax.html.

Lockheed Martin continues to increase the versatility of the K-MAX (see figure 7) by working to integrate the Office of Naval Research Autonomous Aerial Cargo/Utility System (AACUS). In 2014, researchers at the Office of Naval Research successfully demonstrated two autonomous helicopter flights using the AACUS program and highlighted the systems' ability to avoid obstacles, select an optimal route, land as close to soldiers as possible, and return to base without a GCS to control its actions.[43]

https://www.washingtonpost.com/news/checkpoint/wp/2014/08/07/exclusive-why-pilots-couldnt-stop-a-marine-corps-drone-helicopter-from-crashing/?utm_term=.804e4eb804ac.

[43] David Smalley, "Robocopter: New Technology Brings New Capabilities to the Marine Corps," U.S. Navy, April 5, 2014, accessed November 24, 2016, http://www.navy.mil/submit/display.asp?story_id=80104.

Figure 8. Boeing H-6U Unmanned Helicopter

Source: Boeing, "Unmanned Little Bird H-6U," accessed February 15, 2017, http://www.boeing.com/defense/unmanned-little-bird-h-6u/.

Aurora Flight Sciences also fielded an unmanned helicopter, Boeing's H-6U, to demonstrate the operational capabilities of their platform with AACUS (see figure 8). Although both platforms provide a basic AAR capability, they require existent helicopter platforms, and therefore entail similar maintenance, services, and costs as manned helicopters. These requirements effectively prevent these platforms from becoming an organic asset to smaller maneuver units (companies and platoons). Thus, the Marine Corps and the Army Combined Arms Sustainment Command established a joint effort to develop a concept that included a range of options to provide an AAR capability. These concepts focused on platforms maintained and employed at the small unit level. This concept, referred to as JTAARS describes how AUAS could support AAR in small units.

Acknowledging the need for units to operate dispersed across austere terrain, JTAARS provides supply distribution capabilities using organic assets. JTAARS acknowledges the limitations of UAS to carry heavy loads and the linkage between increases in complexity, rules, policy, maintenance, costs of UAS and platform size, and lift capacity. Therefore, JTAARS seeks to employ a family of AUAS platforms to augment current supply distribution capabilities. Platforms would integrate into units at the echelon where a need for their capabilities exists (see figure 9).

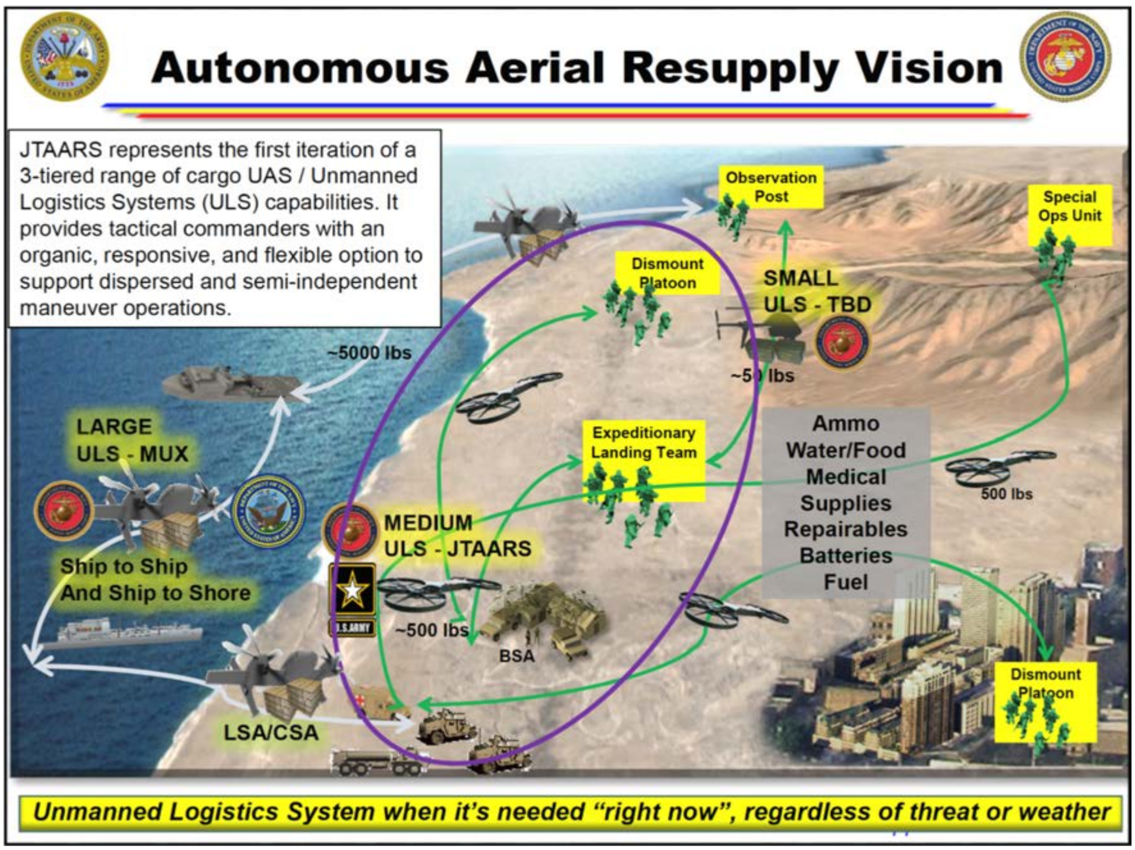

Figure 9. AAR Vision

Source: U.S. Army Combined Arms Sustainment Command, "Joint Tactical Autonomous Aerial Resupply System: Requirements IPT" (PowerPoint Presentation, U.S. Army Combined Arms Sustainment Command, Ft. Lee, VA, October 27, 2016), 7.

A heavy lift AUAS platform could, for example, augment brigade or battalion ground-based distribution assets to provide flexibility and options on how to resupply company command posts. To provide this capability in all-weather/all-terrain environments, the JTAARS requires AUAS that are ruggedized and capable of surviving both direct fire and cyber/electronic attacks. Key concept assumptions: the personnel required to operate the AUAS will come from within the brigade combat team, AUAS will deliver supplies to platoon size or smaller units located in restrictive terrain, and AUAS will maintain some form of contact with a GCS to allow for dynamic re-tasking.

The JTAARS focuses on a medium sized AUAS platform with the following Key Performance Paramaters and Key System Attributes: 600-pound payload weight, 130-kilometer operational radius, two-hour endurance, 130 kilometers per hour speed, and ten gallons per hour fuel consumption rate.[44] These parameters guide in the development of an AUAS platform, which can help achieve the following goals:

1. Flexibility—provide additional options for maneuver units.
2. Lighten the Load—increase war-fighter endurance and effectiveness by reducing the amount of weight they carry.
3. Velocity—increase the responsiveness of supply distribution and provide assured resupply capability.
4. Optimize—increase the level of autonomy and decrease the need for human controllers.
5. Visibility—provide a means to track the location and status of AUAS.

[44] DOD, *Unmanned Systems Integration Roadmap*, 106.

To conduct a typical mission, a planning cell reviews the upcoming day's sorties and tasks an AUAS platform to fly at a specified time carrying a resupply package prepared by distribution personnel. The AUAS platform departs the distribution hub once authorized and flies approximately 200 feet Above Ground Level along a designated path. If the AUAS platform detects a better route, it informs the platform operator and provides location updates. Upon reaching its destination, the AUAS notifies the ground unit (a soldier tasked to receive the platform) and either lands or comes to a hover to release its cargo. If the AUAS platform lands, it senses when its cargo has been removed and allows the soldiers to load any supplies, and possibly personnel, for retrograde. The platform then continues to complete tasks in a similar fashion and returns to the distribution center for reset.

In 2016, the JTARV, P-300 Hoverbike, program became one of two platforms in the Tactical Resupply UAS Competitive. The other component of Tactical Resupply UAS Competitive includes an additional platform known as the SkyFalcon. These two technical approaches provide a shared capability and employ the same autonomous flight software. The U.S. Army's ARDEC serves as the technical manager for the JTARV and works with the manufacturer, Malloy Aeronautics, to integrate technology packages such as the Office of Naval Research AACUS as the on-board, autonomous navigation platform and Net Warrior integration for tactical control of the system. ARDEC aims to provide an AUAS platform organic to a rifle company that any soldier, with minimal training, can use. Modularity and the ability to accept different cargo packages remain important goals for the project. As do minimizing size and costs while still providing sufficient capability to provide precise assured resupply. Malloy Aeronautics promotes the characteristics of the current generation JTARV as: 300-pound payload (supplies or personnel), 10,000-foot operating ceiling, sixty miles per hour operating speed, the size of a small car, electric rotor motors that can be augmented with an on-board generator to provide an extended operating range, and autonomous capabilities. The JTARV can fly from point to point without a human controller or GCS, and future versions of the JTARV will feature additional sensors and software to allow the vehicle to sense and avoid obstacles in its environment.[45] Projected capabilities of the JTARV within the next three years include a range of seventy miles, a run-time of ninety minutes, a payload capacity of up to 1,000 pounds, and a response time of thirty minutes.[46] ARDEC continues experimentation with additional system capabilities packages that allow the JTARV to blow a hole through walls and operate in areas without landing pads.[47]

Analysis of Literature Review

Current doctrine provides a framework for the employment of autonomous systems by describing the ways in which future conflicts will be fought. This framework serves as the basis for development of technologies to provide an AAR capability using AUAS. Fielding autonomous systems on the battlefield requires further debate regarding the legal and policy issues. Concerns over autonomous systems capable of learning will become more frequent as concepts and technologies become mature. The United States

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[45] Malloy Aeronautics, "Hoverbike."

[46] Geoff Fein, "Express Delivery: US Army Targets UAS-Based Tactical Force Resupply," *IHS Jane's International Defence Review* 54, no. 5 (February 2017): 38.

[47] Ibid., 40.

risks missing a window of opportunity to take advantage of its hegemonic position over a new capability if it fails to resolve these issues. The soldier on ground, carrying his combat load remains constant in the face of new technology developments. Numerous studies and papers discuss the detrimental effects of over-loading soldiers and the impact of sustainment challenges on soldier's load. Due to the emerging state of AUAS technology and the on-going testing and evaluation efforts of the DOD, a significant amount of literature on the performance of AUAS does not exist. However, field tests and operational deployments of optionally manned platforms provide a proof of concept that a UAS in a sustainment role can contribute to increasing the effectiveness of combat units. Most available literature focuses on concepts and capabilities needed to fight and win future wars. Without a robust body of knowledge on the AUAS role in tactical formations, leaders may not identify weaknesses in the concepts of operations or the proposed platforms. This thesis intends to contribute to the available literature on AAR with AUAS by analyzing whether JTARV addresses sustainment challenges and enhances the effectiveness and fighting ability of soldiers at the company level. The methodology for accomplishing this analysis is explained in detail in the following chapter.

CHAPTER 3

RESEARCH DESIGN

Introduction

This chapter provides the reader with an overview of the research methodology used to answer the primary research questions: will employment of the JTARV increase the effectiveness of IBCT rifle companies? The research methodology also answers the following secondary research questions:

1. Does the JTARV reduce the soldier's load and unit sustainment requirements?
2. Does the JTARV provide an assured resupply capability in restrictive terrain?
3. What are the vulnerabilities of autonomous systems?
4. What major organization considerations must be accounted for before fielding the JTARV in an IBCT?

Methodology

To develop an appropriate research methodology, this study applies an approach similar to the one used by General William DePuy while he commanded the Combined Arms Center at Fort Leavenworth, Kansas. General Depuy started with a concept and then applied it to a scenario that included specific terrain, weather, and enemy activity to test the concept using current doctrine and organization. This approach produced an outcome that allowed the Army to determine what improvement a new materiel solution provided and demonstrated compatibility with other Army equipment.[48]

For the primary research methodology, this study uses a qualitative literature review to test a proposed theory by means of modeling. The study's theory proposes that by employing the JTARV in an IBCT rifle company, the company can perform its mission more effectively. Figure 10 illustrates the methodology employed by this study. Beginning with the information presented in chapter 1, a primary research question and secondary research questions were developed, focusing on whether the employment of the JTARV can improve IBCT rifle company effectiveness. To answer the research questions, a qualitative literature review was conducted to understand the on-going nature of AUAS strategy, doctrine, research, and development. This literature review resulted in a broader understanding of how the JTARV platform fit into the JTAARS and what capabilities were needed to support the concept of AUAS performing AAR.

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[48] Paul H. Herbert, Leavenworth Papers No. 16, *Deciding What has to be Done: General William E. Depuy and the 1976 Edition of FM 100-5, Operations* (Ft. Leavenworth, KS: Combat Studies Institute, 1988), 28-29.

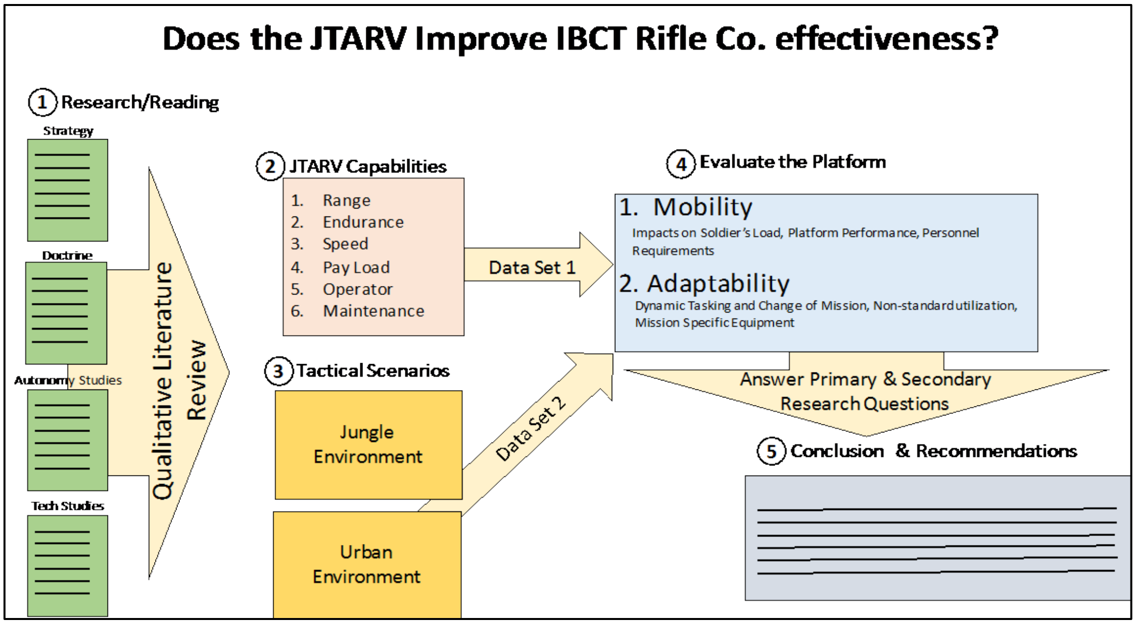

Figure 10. Research Methodology

Source: Created by author.

Further research into the JTARV yielded information on the platform's capabilities and serves to inform the analysis in chapter 4. The JTARV's performance characteristics and its current limitations will be considered during an IBCT rifle company patrol involving two separate, distinct types of restrictive terrain. The scenario used for this study is explained in detail later in this chapter. To determine whether the JTARV improves the effectiveness of the rifle company, this study selected and grouped evaluation criteria under two categories: mobility and adaptability. The benchmarks for each of these criteria is explained in detail later in this chapter. The study records the JTARV's impact on each criterion separately and assigns a score based on whether the JTARV improves effectiveness (+1) or degrades effectiveness (-1). The total scores from each criterion provide an overall score for both factors and informs the study's recommendations and conclusions in chapter 5.

Data

To answer the primary and secondary research questions, this study used two sets of data. The first data set consists of an analysis of literary works presented in the previous chapter. These primary and secondary sources provided details on the critical factors of the capability needs assessment gaps facing the IBCT, autonomy's role on the battlefield, concepts on how to employ autonomous systems, and the JTARV. Each COE annually compiles a list of capability needs assessment gaps and ranks them in terms of operational risk. The gap descriptions include a background of the problem and identified solutions that may address the gaps. The gaps are also grouped by period: when the technologies may become available (near, mid, far). The capability needs assessment gap information served to describe a list of desired capabilities needed to address the IBCT's inability to operate effectively in restrictive terrain due to excessive loads and degraded sustainment capabilities. Additionally, AUAS and JTARV research and development documents were considered to obtain the current and projected system capabilities. Analysis of these desired requirements and capabilities shaped the tactical scenario and evaluation criteria. After executing the scenario, the JTARV was evaluated against selected criteria and scored. The individual scores of each criterion and the total aggregate scores form the second data set. These two data sets answer the primary and secondary research questions.

Scenario

The following tactical scenario provides the context needed to generate the second source of data in this study. A rifle company (A Company) deploys to the country of Sol Island in the South Pacific as part of a combined joint task force. Approximately two weeks ago, Sava Island forces conducted an internationally condemned illegal annexation of Sol Island following the government of Sol Island's decision to join a regional trade alliance. Sol Island is characterized by restrictive and severely restrictive jungle terrain consisting of rolling hills covered in thick trees, plants, and brush. To the north, along the coastline of Sol Island, lies the capital city, Lambella, a large urban area containing major government institutions. As a capital of a developing country, Lambella consists of high-rise buildings, industrial areas, open markets, and slums. Enemy forces operating on Sol Island consist of both regular and irregular forces. Regular forces from neighboring Sava Island, possess the ability to conduct battalion sized attacks, including electronic warfare attacks, against the government of Sol Island using former Warsaw Pact style vehicles, weapons, and equipment. Multiple groups of disenfranchised and under-represented local farmers from Sol Island support Sava Island and comprise the irregular forces in the scenario. Although lightly armed, the irregular forces are almost indistinguishable from the civilian population and possess a superior understanding of both the human and physical terrain. Alpha Company's task-organization includes three rifle platoons, each with three rifle squads and one weapons squad, a sixty-millimeter mortar section and a company headquarters section. Additionally, the company's Modified Table of Organization and Equiment includes two JTARV platforms maintained by the company supply team (92Y30 Supply Sergeant and 92Y10 Supply

Specialist) in the company headquarters section. Each rifle platoon has a 11B30 Squad Leader trained on JTARV operations, controlling its landing and take-off, and properly loading and unloading the platform. For the scenario, the company deploys out of its current location at a combat outpost and conducts tactical movement toward its objective, approximately twelve kilometers away to the southwest (see figure 11). The company commander expects the operation to clear Objective (OBJ) Eagle to last approximately twenty-four hours but prepares to conduct follow-on operations if needed. Upon departing from the company's battle position, 2nd Platoon establishes a blocking position approximately one kilometer to the north of OBJ Eagle to prevent enemy forces from withdrawing from the objective. 3rd Platoon, along with the company mortar section, establishes a support by fire position approximately 800 meters to the east of OBJ Eagle to suppress enemy forces. Once 2nd and 3rd Platoons report their conditions being met, 1st Platoon moves along its assigned axis of advance and clears OBJ Eagle.

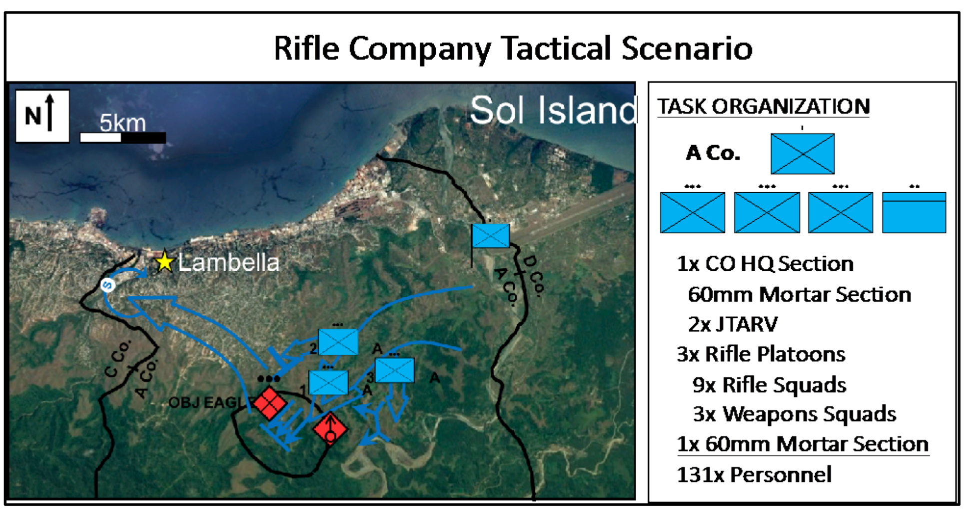

Figure 11. Tactical Scenario Overview

Source: Created by author.

After clearing the objective of enemy fighters, the company commander receives a new order to move to and secure the prime minister's compound in Lambella, ten kilometers to the northwest. A combination of Sava Island and rebel forces totaling approximately one hundred fighters plans to attack the compound. Collateral damage concerns limit the use of artillery and attack aviation. The company has already been away from its outpost for over twenty-four hours, conducting difficult and tiring movement while completing an attack on an enemy position. Now, it must consolidate forces, plan, prepare, move, and conduct a hasty defense in an urban environment.

Although the scenario used for this study omits many factors that contribute to the success or failure of an infantry operation, it outlines a complex situation that would strain contemporary sustainment systems to the detriment of combat units. This scenario assists with evaluating the JTARV's effects on an IBCT rifle company. This evaluation is enabled by focusing on a tactical problem and applying how the JTARV might perform given the known capabilities of the platform. The following section explains what factors were considered and evaluated from the execution of the scenario to determine the effects of the JTARV.

Evaluation Criteria Standards

This section provides a detailed explanation of each factor and its corresponding evaluation criteria. The key determinant in developing evaluation criteria for this study centered on how the JTARV might help forces execute operations in accordance with the U.S. Army's operating concept for future wars in the years 2020-2040. To properly evaluate a potential future materiel solution like the JTARV, this study considered the concepts outlined in TRADOC PAM 525-3-1, *The U.S. Army Operating Concept, Win in* *a Complex World, 2020-2040.* The document outlines a total of eight tenets that apply to how future Army forces operate.[49] From this list, two tenets were selected as over-arching factors for evaluating the JTARV: mobility and adaptability. These factors were selected because of their impact on planning and executing operations at the tactical level. Additionally, both factors help friendly forces achieve the relative advantage needed to seize, retain, and exploit the initiative. The first factor, mobility, considers how the JTARV helps dismounted forces "gain positions of relative advantage, conduct high tempo operations, and concentrate combat power against decisive points while operating dispersed across wide areas."[50] An IBCT rifle company does not possess a fleet of vehicles for movement and maneuver; thus, it must move its personnel by foot and carry its own equipment on back. Therefore, the single greatest factor affecting the mobility of a rifle company remains the load carried by individual soldiers. The evaluation criteria used to assess the JTARV's effect on the mobility of the rifle company include impacts on soldier's load, platform performance, and personnel requirements. The impacts on soldier's load criterion considers the effects on soldier performance when carrying heavy loads, the speed of travel, the distance of travel and ability to traverse restrictive terrain. The platform performance criterion evaluates the JTARV's current characteristics, including visual and audible signatures, as well as terrain and weather considerations, to determine whether the JTARV can keep up with the formation that it supports or if technical limitations prevent its employment under certain conditions. Additionally, this

[49] HQDA, TRADOC Pam 525-3-1, 20.

[50] Ibid., 22.

study weighs the risks associated with the employment of the JTARV against both regular and irregular forces. Using a planning factor of 2xJTARV per rifle company, this study evaluates the JTARV's impacts based on a carrying capacity of 600 lbs. per platform. Additional medium-AUAS characteristics for the JTARV include: 130 kilometer operational radius, two-hour endurance, 130 kilometers per hour top speed, and ten gallons per hour fuel consumption rate. Each JTARV can carry its load either in boxes loaded alongside the platform's skids, with each side accommodating approximately ten cubic feet, or from a releasable hoist located under the center of the JTARV. The personnel requirements criterion analyzes the human interactions needed to load, launch, operate, communicate, land, secure, unload, recover, and maintain the JTARV.

The second factor, adaptability, considers how the JTARV supports dismounted forces responding to unexpected changes or requirements while maintaining tempo. Often, the dynamic nature of the modern battlefield presents unanticipated issues and strains units and leaders to quickly adjust to meet new needs. Transitions and changes of mission create increased risk to soldiers due to the uncertainty associated with these periods of time. The evaluation criteria used to assess the JTARV's impact on the adaptability of the rifle company include dynamic tasking and change of mission, non-standard utilization, and mission specific equipment. The first criterion, dynamic tasking and change of mission, considers the ability for ground forces to provide new information to the JTARV while in flight to their location. This criterion uses the current network architecture model of the IBCT rifle company to push data to the JTARV by means of line-of-site radio systems. Additional consideration of JTARV's operational range helps to understand limitations to supporting unexpected requirements. The next criterion, non-standard utilization, considers other ways that the JTARV might provide additional capabilities to the IBCT rifle company. Adaptability requires leaders to think critically and creatively to identify opportunities where taking prudent risk and performing the unexpected affords an advantage.[51] The criterion of mission specific equipment looks at the JTARV's impacts on the leadership responsibility to determine what equipment must be carried to conduct an operation. This mission specific equipment (equipment carried in addition to soldier's approach march and fighting loads) usually includes some equipment required for contingency operations. Leaders balance the need to keep combat loads to a minimum with the requirement to handle unexpected challenges. The result of this equation normally means extra gear and extra weight carried by soldiers.

Advantages and Disadvantages of Methodology

The scenario design provides a realistic, albeit simplistic, background to conceptualize the requirements of the IBCT rifle company and how the JTARV might support those requirements. The main advantage of this methodology includes the use of future force requirements, as outlined by TRADOC, to develop evaluation factors and criteria. This study provides a theoretical test of the effectiveness of the JTARV in the absence of trial-based data and uses data sets built upon identified capability gaps, known system attributes, and doctrinally correct scenarios. In addition, the use of multiple criteria within each factor provides a holistic evaluation of the JTARV and serves to strengthen the validity of the conclusions and recommendations.

[51] HQDA, TRADOC Pam 525-3-1, 21.

There are, however, inherit disadvantages to the methodology. The first disadvantage concerns the limited amount of detail in the scenario and the absence of intangible variables that play a role in the success or failure of an operation. The methodology also cannot consider technological developments that have yet to occur; thus, only current characteristics and performance data of the JTARV are considered within a contemporary model of how the IBCT rifle company operates. While this study may find that the JTARV does improve the effectiveness of the IBCT rifle company, the implementation of AUAS may not be feasible due to several other considerations.

CHAPTER 4

ANALYSIS

Introduction

This chapter answers the primary and secondary research questions by analyzing two evaluation factors, through the execution of a tactical scenario. The primary research question asks: will employment of the JTARV increase the effectiveness of IBCT rifle companies? The secondary research questions ask:

1. Does the JTARV reduce the Soldier's load and unit sustainment requirements?
2. Does the JTARV provide an assured resupply capability in restrictive terrain?
3. What are the vulnerabilities of autonomous systems?
4. What major organization considerations must be accounted for before fielding the JTARV in an IBCT?

The first section of this chapter, scenario execution, reviews the company's performance and its tactical employment of the JTARV. Observations from the scenario support the next section, findings, to provide justification for rating the JTARV's impacts on the effectiveness of the company. Ratings for each criterion, defined in the previous chapter, serve to answer the primary and secondary research questions. The final section, summary of findings, concludes the study's analysis.

Scenario Execution

The company commander begins the mission to clear OBJ Eagle by performing Troop Leading Procedures. While developing a tentative plan, the company commander and first sergeant, consider the mission, enemy, terrain, time available, and the status of their troops. These factors help determine the appropriate level of protective equipment posture and the packing list for soldiers. The company maintains two JTARVs available for resupply operations and plans to resupply each platoon every twelve hours. Additionally, emergency resupply is available should a platoon require it. Based on these capabilities, each soldier's packing list is limited to a minimum combat load. With enemy contact not expected until the platoons move to an area within 1,500 meters of the object, the soldiers do not wear ballistic plates in their body armor during the approach march. Instead, the commander plans for the JTARVs to deliver the platoons' protective equipment at Objective Rally Points (ORPs). An ORP serves as a location where the unit plans to halt and prepare men, weapons, and equipment for the objective. Normally, the ORP remains out of range of sight, sound, and small arms fire.[52]

Strict enforcement of packing lists and equipment load out results in an average fighting load of forty-eight pounds. This reduced weight provides additional options for the commander when planning the company's movement routes and direction of the attack now that soldiers are not as encumbered by burdensome loads. As a part of the mission planning, the company supply team prepares the JTARVs to support the company. The supply team updates the JTARVs' data sets with new mission parameters including weather and light data, objectives, routes, rally points, danger areas, and communication frequencies. Because of the dense vegetation in the area of operations, supplies are loaded on the JTARVs' cargo hook for airdrop negating the need for landing

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[52] U.S. Army Infantry School, SH 21-76, *Ranger Handbook* (Ft. Benning, GA: Ranger Training Brigade, U.S. Army Infantry School, 2011), 7-4.

zones. Each platoon sergeant constructs speed bundles for emergency resupply in case their platoon engages in a significant firefight with enemy forces (see table 2 and table 3).

Table 2. Rifle Platoon Speed Bundle Contents and Weight

Item	Quantity	Weight	Notes
M4 Magazines with ammunition	124 magazines	170.5 lbs.	Provides each soldier armed with a M4 rifle (x31) with 120 rounds.
M249 Ammunition	24 cases	81.6 lbs.	Provides each M249 gunner (x6) with 400 rounds.
M240B Ammunition	10 cases	120 lbs.	Provides each M240B gunner (x2) with 2000 rounds.
40mm Grenades	120 grenades	60 lbs.	Provides each M320 grenadier (x6) with 20 rounds.
AT-4	3 rockets	43.5 lbs.	Provides 3 anti-tank weapon systems.
Water	20 gallons	160 lbs.	Provides 2 qt. of drinking water for each Soldier (x39).
Total Weight		635.6 lbs.	

Source: Created by author using data from U.S. Army Center for Army Lessons Learned. *The Modern Warrior's Combat Load: Dismounted Operations in Afghanistan, April-May 2013* (Ft. Leavenworth, KS: U.S. Army Center for Army Lessons Learned, 2003), 107-111.

Table 3. Headquarters Platoon Speed Bundle Contents and Weight

Item	Quantity	Weight	Notes
M4 Magazines with ammunition	48 magazines	66 lbs.	Provides each soldier armed with a M4 rifle (x12) with 120 rounds.
Water	7 gallons	56 lbs.	Provides 2 qt. of drinking water for each Soldier (x14).
60mm Mortar Ammunition	30 rounds	150 lbs.	Provides each mortar team with 15 rounds.
Battery BA 5590	6 batteries	13.5 lbs.	Provides batteries for company headquarters section's radios.
Total Weight		285.5 lbs.	

Source: Created by author using data from U.S. Army Center for Army Lessons Learned. *The Modern Warrior's Combat Load: Dismounted Operations in Afghanistan, April-May 2013* (Ft. Leavenworth, KS: U.S. Army Center for Army Lessons Learned, 2003), 107-111.

After completing the plan and rehearsals, the company begins movement in a file using the travelling movement technique (see figure 12). Despite the difficulties associated with movement in limited visibility, the company makes good time due to light loads and completes an eleven-kilometer movement in six hours.[53]

[53] Rate of march planning factor is normally 1.6 kilometers per hour in difficult terrain at night. HQDA, FM 21-18, 3-9.

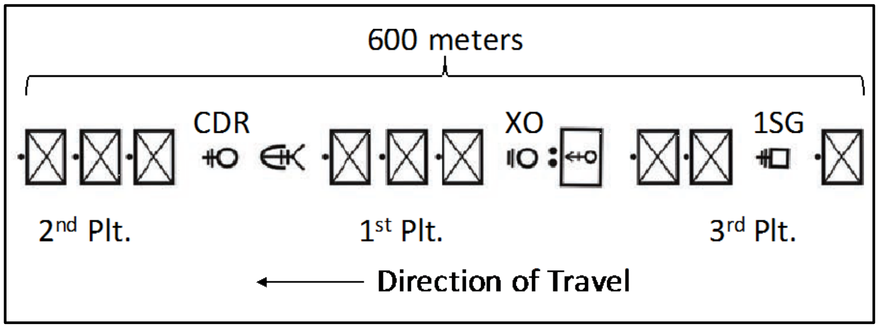

Figure 12. Company Movement Formation

Source: Headquarters, Department of the Army, Field Manual 3-21.10, *The Infantry Rifle Company Collective Task Publication* (Washington, DC: Government Printing Office, July 2006), 3-10.

Once the company arrives at its ORP, the JTARVs take off with fifty-five pairs of Enhanced Small Arms Protective Inserts ballistic armor plates, each pair weighing eleven pounds, on each platform. The JTARVs travel to the ORP within seven minutes and avoid visual detection by flying within five meters of the treetop canopy. While en route to the ORP, one of the JTARVs detects infrared signatures in an area consistent with the location of OBJ Eagle; thus, confirming intelligence reports regarding activity at that location. The commander's radio-telephone operator receives this information via a secure data link and aids the commander in pin-pointing the objective location. At the ORP, the JTARVs receive final coordinates from a squad leader, jettison their loads, and return to the company outpost.

After making final preparations for actions on the objective, the platoons depart the ORP, 2nd Platoon establishes a blocking position, 3rd Platoon, along with the company mortar section, establish a support-by-fire position, and 1st Platoon and the company commander move to an assault position near the objective area. After 2nd

Platoon and 3rd Platoon report their positions as established, the company commander orders 3rd Platoon to initiate the attack with mortars and machine gun fire. 1st Platoon moves toward the objective area and assaults through the objective area as suppressive fires shift in advance of 1st Platoon's movement and eventually halt. The platoon executes its mission with violence of action since it carries only mission essential equipment. 1st Platoon discovers a wounded Enemy Prisoner of War (EPW) while consolidating forces and establishing a hasty defense on the objective area. Upon searching the EPW, soldiers discover numerous documents that may be of intelligence value to higher headquarters. The EPW receives medical attention from the platoon medic and is secured to prevent his escape.

The platoon leader orders his platoon to clear an area, ten meters by ten meters, to allow a JTARV to land. The platoon sergeant provides a report of requested resupply items for the company supply sergeant and a JTARV moves to the 1st Platoon location with ammunition, water, food, and medical supplies. The soldiers blind-fold the EPW, secure him in a folding-litter, and attach him to the JTARV for movement back to the battalion detainee holding area for tactical questioning. Meanwhile, the additional JTARV makes trips to 2nd and 3rd Platoons' locations providing responsive resupply on a distributed battlefield where the company's organic, ground-based vehicles would find it difficult to reach. Due to the JTARVs autonomous flight capabilities, nearby enemy forces equipped with electronic warfare systems fail to take over the platform while in flight. With OBJ Eagle cleared of enemy forces, the platoons move back to the ORP and take up a defensive perimeter as the company commander issues updates to his platoon leaders.

Based on the information that the EPW provides to the battalion intelligence section, the battalion operations officer alerts the company commander about an impending attack against the prime minister's compound in Sol Island's capitol city Lambella, ten kilometers to the northwest. The company receives a new order to rapidly relocate to Lambella and prepare a hasty defense around the prime minister's compound. Despite having operated for nearly eighteen continuous hours, the company moves easily to the capital city unburdened by heavy approach march loads. During the company's movement, the JTARVs remain at the company outpost where the company's supply team performs operator-level maintenance, tops off the fuel, and updates data sets to prepare for upcoming operations. The company first sergeant notifies the supply team that upon arrival at the new objective the company (137 soldiers) will require a resupply of Meals Ready to Eat and water. In addition, to adequately defend against an attack, the commander requests an M41 Improved Target Acquisition System to provide long-range target identification, anti-tank weapons, and barrier materials consisting of pickets, concertina wire, and a picket pounder.

Table 4. Rifle Company Resupply Request			
Item	Quantity	Weight	Notes
M41 ITAS	1 system	256 lbs.	Does not include missile.
M136 AT4	9 rockets	130.5 lbs.	Provides 1 rocket per rifle squad.
Pickets	160 pickets	1,584 lbs.	For 300m triple strand obstacle.
Concertina Wire	59 spools	3,304 lbs.	For 300m triple strand obstacle.
Barbed Wire	3 reels	274.5 lbs.	For 300m triple strand obstacle.
MRE	22 boxes	506 lbs.	Provides 2 meals per soldier.
Water	130 gallons	1,040 lbs.	Provides 4 qt. per soldier.
Total Weight		7,095 lbs.	

Source: Created by author using data from Headquarters, Department of the Army, Field Manual 3-22-34, *TOW Weapon System* (Washington, DC: Government Printing Office, 2003), 1-3; Headquarters, Department of the Army, Technical Manual 3-34.85, *Engineer Field Data* (Washington, DC: Government Printing Office, 2013), 6-1.

Given the weight and size of the requested supplies (see table 4) and the proximity of the new objective to improved road surfaces, the supply team loads the JTARVs into a trailer attached to the company Light Medium Tactical Vehicle, moves to the combat trains, secures the required supplies, and drives to the new objective area. Once at the prime minister’s compound, the company begins priorities of work to establish engagement areas with integrated obstacles. The JTARVs are unloaded and configured to hoist the Improved Target Acquisition System to the top of five-story building where it provides superior observation along numerous roads in the city. The JTARVs send Full-Motion Video feed to assist the commander with identification of likely avenues of approach that the enemy may use to attack the compound. Lastly, the JTARVs provide an overt deterrence capability by signaling the presence of U.S. forces at the compound and a commitment to defend. This concludes the tactical scenario for the purposes of this study.

Findings

The preceding scenario provides a framework to demonstrate how the JTARV operates during a tactical operation. This vignette provides the basis for analyzing each of the criteria defined in the previous chapter and serves to answer the primary and secondary research questions.

Mobility

This study determines that the JTARV has the potential to reduce the soldier's load. The JTARVs carry 635.5 pounds for a rifle platoon resupply and 285.5 pounds for the headquarters platoon resupply during the scenario. Carrying these weights, divided amongst the soldiers of the platoons, saves each soldier an average of 16.3 pounds and 23.8 pounds, respectively. Removing the average of these two amounts, approximately twenty pounds, from the average approach march load in table 5 results in a carried weight of eighty-one pounds; within nine pounds of recommended approach march loads.[54]

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[54] HQDA, FM 21-18, 2-7.

Table 5. Average Load Data by Duty Position

Position in Unit	Fighting Load	FL % Body Wgt	Approach March Load	AML % Body Wgt	Emerg Approach March Load	EAML % Body Wgt
Rifleman	63.00	35.90%	95.67	54.72%	127.34	71.41%
M203 Grenadier	71.44	40.95%	104.88	60.25%	136.64	77.25%
Automatic Rifleman	79.08	44.74%	110.75	62.71%	140.36	79.56%
Antitank Specialist	67.66	37.57%	99.04	55.02%	130.20	79.65%
Rifle Team Leader	63.32	35.61%	93.78	52.43%	130.27	80.65%
Rifle Squad Leader	62.43	34.90%	94.98	52.59%	128.35	73.62%
Forward Observer	57.94	33.00%	91.40	52.12%	128.56	76.59%
Forward Observer RTO	60.13	35.37%	87.07	51.42%	119.13	74.94%
Weapons Squad Leader	62.66	34.02%	99.58	54.37%	132.15	69.19%
M240B Gunner	81.38	44.46%	113.36	62.21%	132.96	68.92%
M240B Asst Gunner	69.94	38.21%	120.96	66.11%	147.82	80.08%
M240B Ammo Bearer	68.76	36.59%	117.06	62.19%	144.03	78.46%
Rifle Platoon Sergeant	60.66	31.53%	89.96	46.35%	119.16	62.67%
Rifle Platoon Leader	62.36	34.02%	93.04	50.33%	117.62	65.44%
Platoon Medic	54.53	31.08%	91.72	51.58%	117.95	69.88%
Radio/Telephone Operator	64.98	35.60%	98.38	54.08%	no data avail	no data avail
Mortar Section Leader	58.31	30.59%	109.99	57.34%	149.30	90.49%
Mortar Squad Leader	60.98	37.89%	127.24	78.26%	142.30	96.80%
60mm Mortar Gunner	63.79	38.06%	108.76	64.22%	143.20	88.14%
60mm Mortar Assistant Gunner	55.34	31.93%	122.16	70.28%	no data avail	no data avail
60mm Mortar Ammo Bearer	53.13	30.14%	101.13	60.59%	no data avail	no data avail
Rifle Company Commo Chief	68.13	38.16%	109.69	61.67%	no data avail	no data avail
Fire Support Officer	54.11	27.32%	93.08	46.81%	no data avail	no data avail
Fire Support NCO	52.10	31.92%	90.08	55.22%	143.30	98.83%
Sapper Engineer	59.02	33.05%	95.70	53.50%	132.08	77.92%
Company Executive Officer	60.50	34.03%	93.65	52.81%	no data avail	no data avail
Company First Sergeant	62.88	33.69%	90.42	48.11%	126.00	86.30%
Company RTO	64.70	35.65%	98.09	54.27%	130.00	72.13%
RifleCompany Commander	66.10	37.08%	96.41	53.77%	111.20	70.83%
AVERAGE ACROSS REGIMENT	**63.08**	**35.27%**	**101.31**	**56.74%**	**131.74**	**77.82%**

Source: U.S. Army Center for Army Lessons Learned, *The Modern Warrior's Combat Load: Dismounted Operations in Afghanistan, April-May 2013* (Ft. Leavenworth, KS: U.S. Army Center for Army Lessons Learned, 2003), 113.

By off-loading the weight of water, food, batteries, extra ammunition, and mission specific equipment, the JTARV enables the soldier to carry less weight. For example, removing four quarts of water (eight pounds), two Meals Ready to Eat (3.8 pounds), four BB-521 batteries for a Multi-Band Inter/Intra Team Radio (3.2 pounds), and four full magazines of 5.56-millimeter ammunition (5.5 pounds) reduces 20.5 pounds from a soldier's load. Communication with the JTARV does, however, require a controller or radio system to provide mission updates to the platform. This controller likely requires additional equipment, including batteries, and all of this adds weight to the soldier's load. However, the overall change in weight remains beneficial despite the addition of another piece of kit for soldiers to carry.

The next criterion, platform performance, answers additional secondary research questions. This study determines that the JTARV does provide an assured resupply capability in restrictive terrain. Overall, the JTARV performs well in jungle and urban terrain types because it operates above the obstacles that make these types of terrain restrictive. The range, speed, and operational endurance of the JTARV does not have any effect on platform's ability to provide resupply to the rifle company. In fact, the movement speed of the rifle company serves as the main factor in determining the JTARV's rate of employment. By using a hoist to support releasable loads, the JTARV also eliminates the need for establishing a suitable landing zone to provide resupply. One drawback to this method of delivery, however, is that the supported unit may need to secure netting or other load handling equipment in the absence of newer, smarter material packaging developments.

The study identifies the JTARV's greatest vulnerability as the possibility for enemy forces to take over control of the JTARV. This concern is assuaged by the fact that the JTARV operates largely independent of a human controller. The JTARV's autonomy largely negates any opportunity for an unauthorized user to take control of the platform while in flight. Moreover, technology demonstrations have proven that precision locating can be accomplished without the aid of the Global Positioning System.[55] Hence,

[55] Patrick Tucker, "Army Testing Robo-Parachutes That Don't Need GPS," *Defense One*, January 14, 2016, accessed March 2, 2017, http://www.defenseone.com/technology/2016/01/army-testing-robo-parachutes-dont-need-gps/125151/.

this reduces the risk to mission of operating an AUAS in a Global Positioning System degraded or denied environment even further. The risk of losing a JTARV to enemy fire raises questions on the required actions of a unit. The JTARV needs to remain an expendable platform so as not to generate additional recovery operations; unless the payload includes sensitive items that warrant recovery. At the size of a small car, the JTARV creates a conspicuous presence on the battlefield and its four rotors generate a unique sound that carries several hundred meters. Although the JTARV lacks stealth, its purpose and intended use do not require it to remain out of sight and sound. Realistically, the JTARV should only move forward to a location after it has been secured by ground forces. There may be opportunities to use the visible presence of the JTARV as a deterrent similar to the persistent surveillance platforms in Afghanistan.[56] As an autonomous system, the JTARV operates in weather conditions considered too risky for manned aircraft operations. Of concern, high winds may prevent the system from achieving stability during flight, especially if a large load is slung underneath the platform, and limited visibility from fog or haze may affect Forward Looking Infrared cameras used for obstacle avoidance.

Personnel requirements associated with the employment of the JTARV highlight the major organization changes that must be accounted for before fielding the platform in an IBCT. In the scenario, the company supply team load and launch the JTARVs from the company train's location once they receive a request for resupply. The JTARVs

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[56] Graham Bowley, "Spy Balloons Become Part of the Afghanistan Landscape, Stirring Unease," *New York Times*, May 12, 2012, accessed March 2, 2017, http://www.nytimes.com/2012/05/13/world/asia/in-afghanistan-spy-balloons-now-part-of-landscape.html.

operate under a coordinating altitude, and therefore the company only needs to request permission to launch the JTARVs from the Battalion Fires and Effects Coordination Cell. With an autonomous flight capability, the JTARV does not require a trained operator to manage the platform while it moves to its destination. However, once it arrives at its destination, it requires a trained soldier to provide landing coordination information. The JTARV's sensor package identifies the best location for a landing to occur; however, there remains some type of requirement to receive approval for landing from the ground element. Maintenance of the JTARV generates an additional requirement for training of personnel. These requirements warrant a minimal update to the rifle company MTOE including a special identifier for a soldier trained in AUAS employment and maintenance.

Overall, the JTARV yielded positive results in the mobility factor during execution of the scenario. The company moved further and faster thanks to lighter combat loads and a steady resupply of Class I. The JTARV's performance failed to highlight any significant vulnerabilities besides the limitations that currently effect manned rotary-wing assets. Only minimal changes were identified to the existing infantry company Table of Organization and Equipment to provide the required knowledge and skills to operate and maintain the JTARV.

Table 6. Mobility Evaluation Matrix		
Criterion	Improves (+1)	Degrades (-1)
Impacts on Soldier's Load	• Off-loading provides significant weight savings. • Approach march loads are no longer required. • Rifle company's movement speed and operational endurance improved. • Ability to retrograde personnel and equipment.	• Requirement to carry controller. • Requires leaders to accept more risk.
Platform Performance	• Speed, range, and endurance keep pace with dismounted soldiers. • Minimal requirement for data link and Global Positioning System. • Hoist allows loads to be released without landing the JTARV. • Reduced impacts from weather conditions.	• Easily detectable by non-sophisticated means. • May require units to secure crash sites.
Personnel Requirements	• Similar requirements as other means of sustainment. • Additional identifier to provide appropriate skill set to company.	
Total Score	10	-4

Source: Created by author.

Adaptability

During the operation to clear OBJ Eagle, Alpha Company receives a new order to secure the prime minister's compound. Normally, extending an operation's timeline generates significant requirements for logisticians to update concepts of support and coordinate for supplies, movement assets, and additional personnel. The dynamic nature of modern combat operations requires a sustainment system that is equally nimble and responsive. The first criteria, dynamic tasking and change of mission, considers the ability for the JTARV to support dismounted forces required to alter their plan. The

JTARV's ability to change delivery locations or cancel requests simply by providing instructions to the platform supports unit flexibility. The ease with which this change occurs provides an advantage over other, external methods of conducting resupply. AAR increases the responsiveness of sustainment and provides end-user logistics support more quickly than traditional ground-based resupply. The JTARV also supports in-stride resupply, which enables units to begin movement before completing the plan, especially the concept of sustainment. In a dynamic environment, dispersing sustainment operations by way of numerous AUAS providing AAR creates multiple dilemmas for enemy forces. The operational endurance of the JTARV does however limit its loiter time, unlike a manned ground-based platform, increasing the risk of responsive, on-call sustainment operations.

Non-standard utilization examines possible uses for the JTARV besides delivering supplies. The JTARV's primary purpose provides unmanned sustainment support for forward deployed small units. Nonetheless, the JTARV supports several non-standard uses outside of providing sustainment such as non-standard casualty evacuation; retrograding equipment no longer needed, items of intelligence value and EPWs; or providing an information collection function. The JTARV could even serve in an offensive role with the addition of a weapons platform or by simply delivering up to 600 pounds of explosives to an enemy's location. Many of these non-standard roles require no additional equipment packages to be added to the JTARV; therefore, the JTARV contributes to military deception by presenting dilemmas for enemy forces trying to determine its role. The temptation to create additional uses for the JTARV raises concerns over leaders sacrificing sustainment to perform other functions and costs associated with applique features may designate the JTARV as non-expendable.

The final adaptability factor criterion, mission specific equipment, evaluates the JTARV's impacts on the leadership responsibility to determine what equipment must be carried to conduct an operation. The AAR concept eliminates the need for leaders to limit their plans by what soldiers can carry onto an objective. Data generated from previous studies shows that half of surveyed soldiers define responsiveness as "supplies on ground within 15 minutes of initiating call for resupply."[57] The JTARV's level of responsiveness provides a sustainment-on-demand capability to support the company's adaptability. With a top-speed of one hundred kilometers per hour, the JTARV supports this requirement out to twenty-five kilometers from the company outpost; in contrast, a ground supply convoy would require at least twice as much time to travel in restrictive, hostile terrain. This capability to provide responsive, dedicated sustainment support helps leaders overcome unforeseen challenges associated with ill-defined operational environments. The emphasis on responsiveness becomes even more important when operations take place with dispersed units due to the distances between soldiers and their bases of supply. In the scenario, Alpha Company uses their JTARVs to resupply Class I and V supplies prior to conducting movement into Lambella. The company commander could have chosen to begin movement prior to resupply and planned for replenishment on the move instead. This decision maintains tempo and helps the company retain the initiative by operating faster than the enemy can react.

[57] MCOE, "NCOA Assured Resupply Survey," 10.

An additional benefit provided by the JTARV includes a reduced demand on IBCT sustainment systems. The JTARV supports user-defined, tailorable load plans and further reduces the need to stockpile supplies. Throughout the scenario, Alpha Company relied heavily on the JTARVs to provide resupply of Class I and Class V. To avoid carrying burdensome weight, the company requested only what it intended to use. A reduced demand for supplies also reduces transportation requirements and promotes efficient resource distribution. However, the JTARV's payload limitations of 600 lbs. place it at a significant disadvantage when compared to the 5,000 pounds capacity of a Light Medium Tactical Vehicle. Two JTARVs require four trips from the company trains to a platoon's location to transport a comparable weight. As depicted earlier in this study, only in very rare circumstances might a platoon require 5,000 pounds of material for immediate delivery. Smaller loads, smarter planning, and more frequent resupply operations easily overcome this disadvantage.

Table 7. Adaptability Evaluation Matrix

Criterion	Improves (+1)	Degrades (-1)
Dynamic Tasking and Change of Mission	• Supports re-tasking better than non-organic assets. • Provides in-stride resupply. • Responsiveness increased.	• Range limits loiter time.
Non-standard Utilization	• Can perform several non-standard roles. • Presents multiple dilemmas to enemy.	• Sustainment should remain primary purpose. • Add-on features increase likelihood of requirement to secure crashed JTARV.
Mission Specific Equipment	• Overcomes challenge by providing options. • Not limited to what a unit can carry. • Mission specific equipment brought forward as needed. • Tailorable loads reduce demands on supply system.	• Large/bulky loads may still require ground base systems to transport. • Payload limits create requirements for additional turns.
Total Score	9	-5

Source: Created by author.

Summary of Findings

The primary research question of this study asks if employment of the JTARV increases the effectiveness of IBCT rifle companies. This study determines that the JTARV does increase the effectiveness of the rifle company by improving its mobility and adaptability (see table 8).

Table 8. Summary of Findings

Categories	Improves (+1)	Degrades (-1)	[redacted]
Mobility	10	-4	
Adaptability	9	-5	
Total Scores	19	-9	10

Source: Created by author.

This chapter provided the findings of the tactical scenario informed by a qualitative literature review to test the theory that employing the JTARV in an IBCT rifle company increased its effectiveness. Conclusions from the study and recommendations for further action and studies is presented in the next chapter.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

Introduction

Throughout the past century, fielding new technologies redefined wars and provided a marked advantage to the belligerent who could implement and better leverage the technology. This study highlights the many opportunities and challenges associated with the introduction of a new, autonomous machine class of warrior on the battlefield. This chapter builds on the findings described in the previous chapter and discusses the implications of this study's findings in a conclusions section. The next section, recommendations, provides input for further studies and action to take in the field of autonomous systems development.

During evaluation of the JTARV in the tactical scenario, this study identified three points associated with the employment of AUAS in a sustainment role. First, the infantry rifle company gains freedom of action by employing the JTARV. The JTARV and AAR provide an opportunity to extend supply lines and improve their responsiveness to soldiers. Tasks that previously required several humans can now be performed by a single AUAS. Second, the JTARV supports the concept of off-loading; thus, soldiers can carry less weight and conserve energy for combat related tasks rather than serving as pack mules. Conventionally held beliefs on what a soldier is required to carry no longer apply when a reliable, organic platform can support dynamic changes of mission. AUAS will enable increasingly audacious operations by decreasing risk margins associated with dispersed small unit operations. Third, autonomous systems do not remove the human dimensions involved in leadership and managing soldiers. The JTARV provides options to leaders, but leaders must still make decisions on how to employ the JTARV and how to leverage the efficiencies afforded by the platform. The implications of these points form the basis of this study's conclusions.

Conclusions

The JTAARS concept significantly increases a supported unit's freedom of action by providing additional options for leaders executing supply distribution operations. The opportunity exists for small units to possess an organic capability for aerial based systems to deliver supplies. This affords these units greater flexibility to deal with contingencies and to maintain momentum during high intensity conflicts. The JTAARS concept outlines a dispersed, multi-modal distribution system that conducts replenishment operations much faster than contemporary concepts of sustainment. Furthermore, AUAS increase the responsiveness of BCT sustainment systems by abating previous constraints associated with the availability of ground based distribution platforms and their inability to traverse restrictive terrain.

The automation of supply distribution, as already evidenced in commercial applications, generates even more efficiencies and cost savings by removing soldiers from dangerous conditions, and could significantly reduce the number of casualties associated with sustainment operations. In 2013 alone, 60 percent of U.S. combat causalities were related to ground based convoys conducting resupply operations.[58] A typical ground convoy consisting of a route clearance element, convoy security, and the

[58] David McNally, "Lab Showcases Futuristic Resupply Vehicle," U.S. Army Research Laboratory, September 9, 2016, accessed November 10, 2016, https://www.arl.army.mil/www/?article=2878.

vehicles carrying the supplies can involve up to fifty personnel. These personnel, as well those required to conduct resupply operations with LCLA or manned rotary wing assets, unnecessarily face threats just to move supplies to forward deployed units. The JTARV and AAR also reduce personnel requirements by eliminating many positions associated with sustainment operations such as drivers. Although some manned ground based platforms will remain in the short term, the Army plans to develop unmanned, self-driving vehicles to further reduce unnecessary casualties. Reductions in personnel translate into savings associated with recruiting, training, equipping, and deploying soldiers as well as costs for wounded veterans over the lifetime of their care. As of 2016, the United States spent over $212 billion on caring for veterans injured during their service in Iraq or Afghanistan.[59] By removing personnel from supply distribution operations and eliminating 60 percent of casualties, the United States could save billions, if not trillions of dollars over the next five decades.

AUAS also greatly reduce the amount of weight that dismounted soldiers carry in combat. The JTARV accomplishes this through its responsiveness and the ability for company leadership to precisely control the distribution of supplies. Numerous studies indicate that any amount of weight savings translates directly to improved mobility and performance of dismounted soldiers and units. The IBCT's lack of an organic platform capable of maintaining approach march loads nearby throughout the duration of combat operations, contributes to the soldier's carrying increased loads, especially when

[59] Neta C. Crawford, *US Budgetary Costs of Wars through 2016: $4.79 Trillion and Counting Summary of Costs of the US Wars in Iraq, Syria, Afghanistan and Pakistan and Homeland Security* (Boston, MA: Boston University Press, 2016), 15-16.

operating in restrictive terrain. The JTARV's ability to address this capability gap offers the greatest possibility to reduce the soldier's load by carrying the equipment normally associated with approach march loads. Thus, the JTARV and AAR could potentially negate the need to carry approach march loads. Since the JTARV can conduct multiple flights between sustainment nodes and combat units, weight savings increases even more. Soldiers may no longer need to carry equipment to deal with contingencies, instead specialty equipment such as breaching devices (10.75 pounds) or pole-less litters (17.5 pounds) could deploy forward as needed or move to pre-determined rally points along the axis of advance. All this weight savings directly translates to improved soldier performance by reducing fatigue, enabling dismounted soldiers to operate further from ground lines of communication. Soldiers can also travel faster and quieter in increasingly restrictive terrain than if they were required to carry their approach march loads.

In order to provide an off-loading capability, the JTARV should carry equipment not considered a part of the soldier's fighting load (weapon, basic load of ammunition, clothing, helmet, and load-bearing equipment). As stated in FM 21-18, *Foot Marches*, "fighting loads must be light so that the bursts of energy available to a soldier are used to move and to fight, rather than to carry more than the minimum fighting equipment."[60] While this dictum may seem obvious, dismounted infantry soldiers commonly carry not only their fighting loads, but also their approach march loads throughout the duration of an operation. The modern rifleman carries a staggering assortment of additional equipment due to many reasons: risk aversion, standardized load plans without

[60] HQDA, FM 21-18, 5-4.

consideration of mission variables, the burden of technology, and a general belief to always carry more than you need. Few leaders possess the risk appetite to push the envelope, with regards to sustainment, and carry just enough to accomplish the mission lest they discover that they underestimated and come up short. Consequently, a preference for over-packing has pervaded over decades and resulted in habitual violations of soldier load planning.

Despite significant advancements in soldier systems, the issue of soldier's load cannot focus solely on technology development and ignore the role that leadership plays in assessing and managing risk with regards to what soldiers carry. The proclivity of leaders to increase individual soldier protection to reduce the likelihood of casualties creates the potential for the JTARV to have minimal effects on soldier mobility. An unpleasant, but critical, leader task involves balancing protection against mobility. The off-loading capability provided by the JTARV may tempt some leaders to replace weight savings with increased personal protective equipment. While the decision ultimately remains with commanders, this study highlights the ability to increase protection of soldiers by increasing their mobility. For the concept of AAR to function as designed, leaders must rethink how they conduct risk analysis and mitigation. The common practice of prescribing standard packing lists that favor protection over mobility (think seat belt cutters for every soldier or the ever-growing list of protective equipment that Soldiers must wear) will not disappear overnight.

The reliability of the JTARV affects the feasibility of the AAR concept, and this in turn impacts leader's risk appetites. Despite these concerns, the JTARV and the AAR concept overwhelmingly improved the mobility of the rifle company in the scenario. The weight savings achieved through off-loading and the ability to maintain a connection to unit supplies enabled the rifle company to conserve its energy during movement so that it could fight aggressively when needed. Additionally, the increased amount of cognitive load for dismounted soldiers remains a concern. The modern rifleman benefits from cutting-edge technology, but must simultaneously contend with an increasingly complex array of systems. Advancements in battlefield technology have created a side effect of increased cognitive requirements for soldiers. The complexity involved in air space management and operation of a small to medium sized UAS (should be flown below coordinating altitude) may create additional friction points for tactical formations trying to employ air-ground integration measures.

Recommendations

Consideration of this study's conclusions highlights the requirement for further study and action. Specifically, to continue the development and eventual fielding of AUAS, as well as highlighting opportunities to increase the buy-in of the operational force, three recommendations warrant discussion. Along with these recommendations, a recommendation for action supports future concept development.

By analyzing spending projections, trends indicate that DOD funding of UAS will rise and double by 2023 to almost $89 billion.[61] Moreover, the 2016 National Defense Authorization Act outlines the DOD's technology offset program with the goal of maintaining military technological superiority of the United States by accelerating the

[61] DOD, *Unmanned Systems Integration Roadmap*, 4.

fielding of autonomous systems.[62] Increases in the funding for research, development, testing, and fielding of UAS and autonomous systems will likely continue into the foreseeable future. The implications of greater autonomy on the battlefield warrant the consideration of military leaders and policy makers alike to ensure that policy and spending support research and development. Questions on the role of autonomous systems and the appropriate level of autonomy for military purposes sit at the center of fierce debates held in public, governmental, and military circles.

Although AUAS provide a non-lethal function on the battlefield, misconceptions and fears about their autonomous status places them at risk. For example, DOD Directive 3000.09, Subject: Autonomy in Weapon Systems, signed in 2012, placed limitations on the development of lethally armed autonomous systems. A similar policy that concerns any system relying on AI could impact the ability of the United States to keep pace with other near-peer adversaries who seek to develop overmatch capabilities in the field of autonomous systems. Therefore, additional study should focus on defining a concept of implementing AUAS and provide an evolution of autonomy levels to satisfy concerns over the speed of AI development.

Along the same lines, consideration of other DOTMLPF-P changes warrant further study, especially doctrine and leadership and education. JTAARS and AUAS create an opportunity for increasing the operational reach of combat units. As autonomous systems continue to pass milestones along the DAS, the Army will need to translate strategy into doctrine. Systems like the JTARV represent more than just an

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[62] U.S. Congress, House, *H.R.1735 - National Defense Authorization Act for Fiscal Year 2016*, Washington, DC, 2015, 47.

aerial truck to carry supplies. Previous planning considerations and assumptions regarding operational frameworks stand to vanish, or at least change drastically. Whichever nation correctly identifies and implements the best way to employ AUAS stands to gain significant advantages over others.

Leadership and education considerations also require additional studies prior to the fielding of autonomous systems. Building a culture of trust in AUAS requires leaders to understand how to employ the platforms and their limitations. Topics of importance include how to integrate soldiers and machines to change relationships from tool to teammate and how to interact with autonomous systems, which may possess greater intelligence than soldiers. Both topics tie directly to policy and ultimately explore the future of manned/unmanned teaming in combat operations.

Lastly, this study was limited to a single iteration of the tactical scenario presented in chapter 3. Additional studies could explore various contingencies and events not covered in the scope of this study. Recommended events to incorporate into future experimentation include: loss of a AUAS due to enemy action, weather conditions or mechanical failure; a near-peer adversary fielding anti-AUAS; alternative fuel and power sources that extend operational range, and the use of AUAS to provide sustainment during stability operations and defense support to civil authorities.

This study identified one recommendation for action centered on the necessity to include the operational force in the development of autonomous systems' concepts. By facilitating leader symposiums to discuss the status of autonomy in military applications, concerns from the force, and the way ahead, the Army could empower concept developers with greater feedback. Similar to how the MCOE conducted a survey with various infantry officers and non-commissioned officers to help define the concept of assured resupply, the force management community should consider the input of sustainment and maneuver professionals. A simple web-based survey could accomplish this task of obtaining feedback with greater effect accompanied by a brief presentation on AUAS topics of importance.

Summary

This chapter highlighted the implications of this study's findings and identified three key points associated with the employment of AUAS in a sustainment role. Furthermore, this chapter provided recommendations for further study and action to support increased awareness on AUAS and considerations regarding its employment. This study concluded that the JTARV increases the effectiveness of the IBCT rifle company. The platform's ability to bypass terrestrial obstacles, carry a significant payload, operate as an organic asset within the company, and conduct operations without the direct control of a soldier provides a viable mitigation strategy for the capability gap facing the IBCT. While this study did identify some disadvantages with the JTARV its fielding may ultimately not depend on capability demonstrations, but rather on a greater acceptance for autonomous machines on the battlefield. For the United States to maintain its military superiority during the AI revolution requires the same bold leadership that carried the armed forces through professionalization, air-land battle, and network-centric warfare.

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