Net-Centric Sustainment and Operational Reach on the Modern Battlefield

A Monograph
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AY 2012

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
26-03-2012

2. REPORT TYPE
SAMS Monograph

3. DATES COVERED *(From - To)*
June 2011 – May 2012

4. TITLE AND SUBTITLE
Net-Centric Sustainment and Operational Reach on the Modern Battlefield

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Lieutenant Colonel Jon A. Lust (U.S. Army)

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
School of Advanced Military Studies (SAMS)
250 Gibbon Avenue
Fort Leavenworth, KS 66027-2134

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Command and General Staff College
731 McClellan Avenue
Fort Leavenworth, KS 66027-1350

10. SPONSOR/MONITOR'S ACRONYM(S)
CGSC

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

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

13. SUPPLEMENTARY NOTES

14. ABSTRACT
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15. SUBJECT TERMS
Sustainment, Logistics, Transformation, Net-Centric Warfare, Complexity, Operational Reach, Culmination, Transitions, Distribution Management, Materiel Management, and Operation Iraqi Freedom.

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
					Thomas C. Graves, COL, U.S. Army
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			**19b. TELEPHONE NUMBER** *(include area code)*
Unclassified	Unclassified	Unclassified		71 pp.	913-758-3302

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

SCHOOL OF ADVANCED MILITARY STUDIES

MONOGRAPH APPROVAL

LTC Jon A. Lust

Title of Monograph: Net-Centric Sustainment and Operational Reach on the Modern Battlefield

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Abstract

NET-CENTRIC SUSTAINMENT AND OPERATIONAL REACH ON THE MODERN BATTLEFIELD by LTC Jon A. Lust, U.S. Army, 71 pages.

In 1996, *Joint Vision 2010* (*JV2010*) established a template for transforming the armed forces that continues to define sustainment transformation within the U.S. Army, while the publication of *Network Centric Warfare* in 1999 provided the theoretical framework for applying the concept of information superiority within the realm of warfare. The theory of network centric warfare (NCW) arose from the study of complexity, and promised the ability to achieve *JV2010*'s concept of "focused logistics" by building a network of information systems and people to leverage the power of information in complex environments.

While the effort to revolutionize Army sustainment has led to greater efficiency, current efforts face the problem of utilizing a lean network to support forces operating on a distributed and uncertain battlefield. Because sustainment prolongs the endurance of Army operations, this study analyzes sustainment transformation to determine if its logistics structure possesses the ability to provide effective distribution support outside of steady-state environments.

This study demonstrates the Army's current net-centric sustainment concept fails to adhere to the principles of complexity theory and lacks evidence of objective historical analysis, resulting in a logistics system that risks early culmination after transitions during major combat operations. The elimination of distribution management from the division and corps headquarters has separated the sustainment and operational systems in a way that current technology alone cannot overcome, and coupled the brigade to the strategic distribution system.

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> The first, the supreme, the most far-reaching act of judgment that the statesman and commander have to make is to establish . . . the kind of war on which they are embarking.
>
> - Carl von Clausewitz, *On War*

> As you know, you go to war with the Army you have. They're not the Army you might want or wish to have at a later time.
>
> - Donald H. Rumsfeld, *Secretary Rumsfeld Town Hall Meeting in Kuwait*

Even though they lived more than one hundred years apart, Carl von Clausewitz and Secretary Rumsfeld clearly identify the two major considerations that must inform any plan to transform a country's armed forces. Clausewitz identifies the requirement for the strategic leadership to understand the potential operating environments and utilize the appropriate theoretical framework when designing forces for future employment. Additionally, the startling clarity of Secretary Rumsfeld's comments highlights the criticality of getting force design right, since the Department of Defense (DOD) cannot accomplish significant adjustments in the early stages of a conflict. If the United States fails to heed the wisdom of their words, our nation may continue to find itself reliant on sub-optimally designed and equipped forces to defend its interests.

The United States Army has consistently sought through its transformation efforts since World War II to develop smaller, more independent, and self-sustaining units that still possess the capability to accomplish large, theater-wide campaigns. From the corps in the 1940s, to the division in the 1970s, to the modular brigade combat team (BCT) of today, the Army shifted the focus of major operation and campaign planning to increasingly lower echelons to address the evolving view of the projected threat and operational environment.

When the U.S. Army faced the largely symmetric threat presented by the Axis powers in World War II and the Soviet Union in the subsequent Cold War, corps and divisions possessed the majority of combat support and logistic support capability in functionally pure battalions and brigades of artillery, maintenance, supply, and other enablers.[1] This enabled corps and division commanders to temporarily apportion these centrally controlled units to create self-sustaining task forces based on the required mission. The vertically integrated and layered structure of the 1940s to 1990s enabled extremely flexible employment against a wide range of opponents once the entire division or corps deployed to a theater of operations. However, this force structure exhibited strategic weaknesses as the perceived threat changed from a similarly organized opponent to potential enemies with small, flexible units and a decentralized concept of global employment. Transformation since the 1990s has focused on addressing these perceived strategic weaknesses while seeking to maintain an Army with the capabilities necessary to win the nation's wars in support of the National Security Strategy.

The Problem

Sustainment ensures freedom of action, extends operational reach, and prolongs the endurance of Army operations seeking to retain and exploit the initiative.[2] The Army sustainment warfighting function consists of three major sub-functions – logistics, personnel services, and health service support.[3] The following analysis focuses on logistics, and more specifically its functional elements of supply and distribution. Although personnel services and health service support, and logistics' other sub-elements (maintenance, field services, operational contracting, and general engineering) indisputably contribute to the endurance of Army forces in today's operational environment, they exceed the scope of this study.

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[1] Richard L. Kugler, *Case Study in Army Transformation: Creating Modular Forces* (Washington, DC: National Defense University Press, 2008), 2.

[2] U.S. Army, *Army Doctrinal Publication 3-0, Unified Land Operations,* (Washington, DC: Headquarters, Department of the Army, 2011), 14.

[3] U.S. Army, *Field Manual 4-0, Sustainment*, (Washington, DC: Headquarters, Department of the Army, 2009), viii.

As it continues to transform, the U.S. Army faces the problem of developing a force structure with the doctrine, organization, processes, and materiel capable of operating against a wide range of threats in the uncertain and complex environment of the future. This study examines the transformation of sustainment structures and processes after Operation Desert Storm (ODS), to demonstrate that the application of Network-Centric Warfare (NCW) concepts to the transformation of Army logistics structure resulted in units that lack operational durability outside of steady-state environments. Therefore, the Army risks early culmination, particularly when conducting offensive operations and after major transitions.

Methodology

The publication of *Network Centric Warfare: Developing and Leveraging Information Superiority* by the DOD's Command and Control Research Program (CCRP) in 1998 served as a key spark in the debate on how to adjust the force structure and operations of the Army, along with the rest of the DOD, for Information Age warfare.[4] Formally adopted as the DOD's joint operating concept in 2003, NCW arose from the study of complexity theory and promised agile command and control in complex environments by building a networked organization of information systems and people to leverage the power of information superiority in warfare.[5] Unfortunately, adjustments to the Army's logistics structure occurred before the development, validation, and fielding of critical capabilities and concepts to network sustainment and operational forces, which resulted in a tightly coupled sustainment structure that lacks the robustness to respond rapidly to transitions in ongoing operations. Because NCW emerged from

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[4] Strategic Studies Institute, *U.S. Army War College Guide to National Security Policy and Strategy*, ed. J. Boone Bartholomees Jr. (United States Army War College, 2006), 374.

[5] U.S. Department of Defense, *Department of Defense Logistics Transformation Strategy: Achieving Knowledge-Enabled Logistics* (Washington, DC: Government Printing Office, 2004), 4; David S. Alberts, John J. Garstka, and Frederick P. Stein, "Network Centric Warfare: Developing and Leveraging Information Superiority." (Washington, DC: Department of Defense Command and Control Research Program, 2000), http://www.dodccrp.org/files/Alberts_NCW.pdf. xi, 27, 81.

the DOD's study of complexity theory, critically evaluating the transformation of Army sustainment structure against common principles of complex systems will reveal whether the current application of NCW reflects a valid foundation in complexity theory, while highlighting challenges in accomplishing the Army's goal of extending operational reach, and supporting recommendations for future force design and research.

This study utilizes evaluation criteria derived from several principles of complexity theory and DOD sustainment transformation goals. The principles represent the tension between maintaining command and control while allowing flexibility to innovate and adapt in ways that ensure the long-term ability of organizations to accomplish missions in uncertain environments. Complexity science reveals four key characteristics of networks: variety and difference in a network's elements provide resilience and enable adaptation; feedback between the elements and environment provides stability and the stimulus to adapt; self-organization occurs through local interactions based on rules governing behavior; and predictability in complex systems is probabilistic versus precise due to initial condition sensitivity.[6] Complementing those drawn from complexity, the goals of sustainment transformation yield the following principles: decentralized, adaptable, networked, reliable, and effective.[7]

These principles, taken in combination (see Figure 1 below), provide the following evaluation criteria: *robustness*, defined as the presence of connections between a variety of capable entities to allow coordination and synchronization; *redundancy*, defined as the presence of options for entities and flexibility of the network's structure and processes that lessens

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[6] Antoine Bousquet, *The Scientific Way of Warfare: Order and Chaos on the Battlefields of Modernity* (New York, NY: Columbia University Press, 2009), 165, 68, 72, 75, 218, 20, 29.

[7] U.S. Department of Defense, *Department of Defense Logistics Transformation Strategy: Achieving Knowledge-Enabled Logistics*, 6.

coupling between the tactical and theater-strategic level; and *velocity*, defined as the ability to deliver necessary supplies to the warfighter efficiently and responsively.[8]

Evaluation Criteria	Complexity				Transformation				
	Resilience	**Adaptation**	**Self-Organization**	**Sensitivity**	**Decentralized**	**Adaptable**	**Networked**	**Reliable**	**Effective**
Robustness		X	X		X	X	X		
Redundancy	X	X			X	X			
Velocity				X				X	X

Figure 1: Relation of Complexity and Transformation Principles to Evaluation Criteria

The following analysis of DOD sustainment transformation, network-centric warfare, and complexity addresses these evaluation criteria and the principles from which they were derived. Additionally, they provide a lens through which to view two sustainment case studies: one during initial Operation Iraqi Freedom (OIF) combat operations in 2003, and the other during the OIF "Surge" in 2007, which represented marked transitions from the previous environmental steady-state. The analysis of the case studies according to the evaluation criteria supports the study of the Army's innovation in sustainment following ODS, and provide the framework to demonstrate that Army sustainment lacks the organization, doctrine, and equipment to extend operational reach and prevent early culmination.

The content of this study relies on two significant assumptions: NCW, as an attempt to apply complexity theory to military doctrine, will remain the foundation for future operational concepts and force structure; and significant additions to sustainment organization end strength will remain inconsistent with U.S. Army goals for the foreseeable future.

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[8] Velocity, measured by the standard DOD metric of Customer Wait Time (CWT), represents the total elapsed time between when a unit generates a requirement and when a sustainment organization fulfills it. DOD views Time Definite Delivery, or responsiveness, as achieved when 95% of the requisitions meet the required CWT standard.

U.S. Army and Sustainment Transformation after Operation Desert Storm

The United States embarked on its current path of restructuring and force design in the mid-1990s, due to the belief that the nation faced a new strategic environment. Although the Army emerged from Operation Desert Storm as the world's premier ground combat force, the time required to deploy the forces and supplies to start the operation left the Chief of Staff of the Army (CSA), General Dennis J. Reimer, and the Department of Defense (DOD) convinced the U.S. armed forces needed a new vision.[9] In 1996, the Joint Chiefs of Staff published *Joint Vision 2010* (*JV2010*), inaugurating the concept of information superiority that continues to define transformation today.

JV2010 established DOD's conceptual template for channeling innovation and leveraging technology to achieve new levels of effectiveness in joint warfighting.[10] Seeking to retain the effectiveness of the forces that recently achieved victory in ODS while also creating efficiencies by reducing redundancy, the DOD envisioned future systems "providing decision makers with accurate information in a timely manner."[11] The DOD identified gaining and maintaining information superiority, with the goal of providing the capability to "collect, process, and disseminate an uninterrupted flow of information," as the key component in the doctrine and organization of future forces.[12] Information superiority underpinned the four new operational concepts of information age warfare: dominant maneuver, precision engagement, full dimensional

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[9] Kugler, *Case Study in Army Transformation: Creating Modular Forces*, 7; ibid; U.S. Government Accountability Office, *Defense Logistics: Preliminary Observations on the Effectiveness of Logistics Activities during Operation Iraqi Freedom* (Washington, DC: U.S. Government Accountability Office, 2003), 12.

[10] Department of Defense, *Joint Vision 2010* (Washington, DC: Government Printing Office, 1996), 1.

[11] Ibid., 13.

[12] Ibid., 16.

protection, and focused logistics.[13] Furthermore, *JV2010* anticipated that a responsive, flexible, and precise sustainment system would enable DOD to optimize the other three concepts, and concentrate combat power at the decisive time without requiring forces to physically mass on future dispersed and mobile battlefields.[14]

JV2010 defined focused logistics as the fusion of information, logistics, and transportation technologies to track and shift assets even while en route, and deliver tailored logistics packages and sustainment directly to employed forces.[15] Focused logistics envisioned utilizing advanced business practices, global networks, and information technology systems to reduce the redundancy of the rigid, vertical organizations of the 1990s and provide more efficient and effective support to deployed forces.[16] With the purpose of providing a "common direction for Services in developing… doctrine and programs as they prepare to meet an uncertain and challenging future," the Army sustainment community initiated the Revolution in Military Logistics (RML) to achieve the goals of focused logistics.[17]

In a note to the Army in 1999 – three years after the publication of *JV2010*, Army Chief of Staff General Dennis J. Reimer discussed the progress of the RML and his vision of the enhanced form of twenty-first century logistics it would enable. He described the RML as integrating all the functions of logistics to deliver the right stuff, at the right time, to the soldier on the battlefield, and fundamentally changing the way the Army projected and sustained forces.[18] Within that broad vision, Reimer outlined the six tenets of the RML: a seamless logistics system,

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[13] Ibid., 1.

[14] Ibid., 18, 24.

[15] Ibid., 24.

[16] Ibid.

[17] Ibid., 1; Mark J. O'Konski, "Revolution in Military Logistics: An Overview," *Army Logistician* 31, no. 1: 1-2.

[18] Dennis J. Reimer, "A Note From the Chief of Staff of the Army on The Revolution in Military Logistics," *Army Logistician* 31, no. 1 (1999): 1.

distribution-based logistics (DBL), agile infrastructure, total asset visibility (TAV), rapid force projection, and an adequate logistics footprint, to serve as Army's path to attain the goals of the joint focused logistics concept.[19] However, the tenet of agile infrastructure deals primarily with strategic factors, and does not factor into the subsequent analysis since this study deals with logistics at the operational level and below.

DBL represented the core of Reimer's vision, and entailed an entirely new way for the Army supply system to do business.[20] DBL replaced the mass of large echelons of supply inventory at the tactical, operational, and strategic levels in supply-based logistics with the concept of velocity that relied on managed flows of fast-moving materiel within the distribution system.[21] Velocity management, the Army's initiative to increase the flow of materiel in the supply system, mirrored concepts from the commercial sector to establish time definite delivery for an order by establishing metrics for the supply chain that increased flow and minimized handling.[22] In simple terms, the change entailed eliminating the supply-based system's massive stockpiles of forward-positioned materiel, relying instead on a precisely managed, efficient system to deliver requested supplies when and where units needed them.

From 1995 to 1998, the velocity management program decreased the average time from unit order to receipt of a part by over ten days, or fifty percent, for units in the continental United States (CONUS) and six days, or twenty nine percent, for outside CONUS (OCONUS) units.[23] However, DBL requires real-time situation awareness for materiel managers to use the velocity of materiel moving within the distribution system to supplement small inventories along the supply

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[19] Ibid.

[20] O'Konski, "Revolution in Military Logistics: An Overview," 3.

[21] Ibid.

[22] Jeffrey D. Witt and Shawn P. Feigenbaum, "Extending the Logistics Revolution at the Operational and Tactical Levels," *Army Logistician* 31, no. 1 (1999): 2.

[23] Thomas J. Edwards and Rick Eden, "Velocity Management and the Revolution in Military Logistics," *Army Logistician* 31, no. 1 (1999): 5.

chain and sustain forces between deliveries from the strategic base. Therefore, this new logistics system rests firmly on the concept of logistics information superiority.[24]

The RML provided the Army with a method of achieving focused logistics through precision logistics management, and intended for modern information systems and the networks that connected them to support the demands of a distribution-based logistics system.[25] The Army relied on the Global Command Support System-Army (GCSS-A) to achieve logistics information superiority. GCSS-A modernized the Army sustainment automation systems by integrating three hardware configurations, seven standard Army management information systems (STAMIS), eight programming languages, and five communication protocols into a single enterprise-wide system that fused information from the strategic base to the tactical unit.[26]

The Army visualized a three-tiered approach, from fiscal year (FY) 2003 through FY06, to design and implement GCSS-A, integrating the tactical to strategic systems in Tiers 1 and 2, and ultimately the other joint systems in Tier 3.[27] GCSS-A represented an ambitious program at the time and although technologically feasible when conceived, several issues significantly delayed fielding the enterprise resource program (ERP) to fully integrate Army sustainment systems. However, the Army completed the limited user test for the first tier, integrating the tactical and operational systems, in FY07, and after refinement projects fielding throughout the Army in FY12. The Army has also completed the second tier, which integrates strategic Army systems, but the DOD has not completed implementation of the third tier or integrated all of the Services' GCSS.[28] GCSS-A combined with vehicle-based sensors, such as Force XXI Battle

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[24] Edward J. Shimko and Thet-Shay Nyunt, "GCSS-Army Making the Revolution in Military Logistics Happen," *Army Logistician* 31, no. 1 (1999): 3.

[25] O'Konski, "Revolution in Military Logistics: An Overview," 2.

[26] Shimko and Nyunt, "GCSS-Army Making the Revolution in Military Logistics Happen," 2.

[27] Ibid., 3.

[28] David W. Coker and J. Gary Hallinan, "A Logistician's Primer on GCSS-Army (PLM+)," *Army Logistician* 38, no. 3: 1-2.

Command Brigade and Below (FBCB2) and Movement Tracking System (MTS), and networking systems like the Battle Command Support and Sustainment System (BCS3), connects units and enables logisticians to manage the sustainment battlefield. This represents the first steps toward achieving a seamless logistics system and total asset visibility.[29] However, for GCSS to succeed it requires a secure network environment that allows DOD users to access shared data and applications regardless of location, and must produce an integrated picture of combat support from the tactical to the strategic level to allow near-real time control of the logistics pipeline.[30]

Although the RML significantly improved Army sustainment policies and processes, it did little to alter the actual force structure of the operational force in the 1990s. However, that changed in 1999 as Army Chief of Staff General Eric K. Shinseki realized process and doctrinal changes alone left the Army incapable of deploying "in a manner that was both timely and relevant to the strategic environment."[31] In *Army Posture Statement FY01*, Shinseki set a course to change the force from a "Legacy Force" reflective of the experiences from World War II, the Cold War, and Operation Desert Storm, into a more capable, flexible, and deployable "Objective Force" that retained the ability to fight and decisively win the nation's ground wars.[32] Maintaining the concepts of *JV2010* for the design of the Objective Force, Shinseki also mandated the Army develop lighter forces to allow the deployment of a combat-capable brigade

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[29] Shimko and Nyunt, "GCSS-Army Making the Revolution in Military Logistics Happen," 1; O'Konski, "Revolution in Military Logistics: An Overview," 3.

[30] John M. McDuffie, "Joint Vision 2010 and Focused Logistics," *Army Logistician* 31, no. 1 (1999): 2.

[31] Gregory Fontenot, E.J. Degen, and David Tohn, *On Point: US Army in Operation Iraqi Freedom* (Annapolis, MD: Naval Institute Press, 2005), 20.

[32] Kugler, *Case Study in Army Transformation: Creating Modular Forces*, 2; Fontenot, Degen, and Tohn, *On Point*: 20.

anywhere in the world in ninety-six hours, a division in five days, and five divisions within thirty days.[33]

The FY01 Army Posture Statement depicted transformation from the Legacy Force to the Objective Force occurring over a thirty-year period with an “Interim Force” to bridge the gap.[34] Shinseki required the immediate development of the Interim Force to provide the time and flexibility for the deliberate development, experimentation, and validation of the organizations and equipment required for the Objective Force to increase strategic responsiveness and achieve *JV2010*’s full-spectrum dominance.[35] Although the interim force’s Striker Brigade Combat Teams operated under new sustainment doctrine and organizations, sustainment within the legacy force did not change significantly because the Army desired to incorporate new capabilities only after validation through experimentation and testing in the field.[36] However, observations from Operation Iraqi Freedom in 2003 generated calls for a new, more rapid course for transformation.

The rapid defeat of the Iraqi Army during OIF by a much smaller force than that employed during ODS seemed to many observers to validate NCW concepts. Therefore, in 2004 Army senior leaders accelerated transformation and created self-contained brigades with separate headquarters units to increase flexibility and enable distributed operations.[37] Simultaneously, the Army sustainment community set out to fundamentally redesign logistics support to the

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[33] U.S. Government Accountability Office, *Military Transformation: Army has a Comprehensive Plan for Managing Its Transformation but Faces Major Challenges* (Washington, DC: U.S. Government Accountability Office, 2001), 6.

[34] U.S. Army, *U.S. Army Posture Statement FY01 - Executive Summary* (Washington, DC: Government Printing Office, 2000), 3-6; U.S. Government Accountability Office, *Military Transformation: Army has a Comprehensive Plan for Managing Its Transformation but Faces Major Challenges*, 9.

[35] Eric K. Shinseki, "Statement on the Army Transformation by General Eric K. Shinseki, Chief of Staff, United States Army," ed. AirLand Subcommittee on Armed Services (Washington, DC: United States Senate, 2000), 7.

[36] Ibid.

[37] U.S. Department of Defense, *Department of Defense Logistics Transformation Strategy: Achieving Knowledge-Enabled Logistics*, 4; Michael Ivy, *Future Force Maneuver Sustainment Concept Overview* (Fort Lee, VA: U.S. Army Combined Arms Support Command, 2006), 26.

operational force despite having successfully supported highly dispersed combat troops from a line of communication more than three hundred fifty miles long.[38] Believing that the sustainment system in OIF supported forces on a twenty-first century battlefield with a twentieth century logistics structure, the Army concentrated on the lack of supply visibility and predictable support, which led to increased perceptions of risk during the initial three weeks of combat operations in March and April 2003.[39]

Lieutenant General (LTG) Claude V. Christianson, the Combined Forces Land Component Commander G4 in 2003, attributed the shortfalls of the OIF logistics system to three interrelated causes: inadequate connectivity; a disjointed, layered distribution system; and the lack of centralized command and control of the theater distribution system.[40] Determined to address the failure of past transformation strategies to achieve focused logistics and increase the efficiency of theater sustainment, the DOD updated its strategy for logistics transformation in 2004 and published the *Logistics Transformation Strategy* and *Focused Logistics Campaign Plan*.[41]

The DOD's *Logistics Transformation Strategy* reaffirmed that focused logistics remained the concept to support adaptive and distributed operations, and provided nine joint functional elements to reconcile its evolution since the mid-1990s with NCW's concepts for operations and logistics.[42] Of the nine elements – full integration, expeditionary, networked, decentralized,

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[38] Eric Peltz et al., *Sustainment of Army Forces in Operation Iraqi Freedom: Battlefield Logistics and Effects on Operations* (Arlington, VA: RAND Corporation, 2005), 5-6; Paul Needham and Christopher Snyder, *Speed and the Fog of War: Sense and Respond Logistics in Operation Iraqi Freedom-I* (Washington, DC: National Defense University Press, 2009), 1.

[39] "Testimony of Lieutenant General Claude V. Christianson, Deputy Chief of Staff, G-4 United States Army," GlobalSecurity.org, http://www.globalsecurity.org/military/library/congress/2004_hr/04-03-30christianson.htm.

[40] Ibid., 2.

[41] Ibid., 1.

[42] U.S. Department of Defense, *Department of Defense Logistics Transformation Strategy: Achieving Knowledge-Enabled Logistics*, 4.

adaptable, decision superiority, effective, reliable, and affordable – only decentralization represented a marked departure from previous goals.[43] However, DOD's assertion that decentralization would occur under globally established rules supported by real-time, net-enabled information systems providing accurate and actionable visibility created a much different framework than *JV2010* and required a new approach to achieve centralized command with distributed control of sustainment on the future battlefield.[44]

Further defining the *Logistics Transformation Strategy*, the *Focused Logistics Campaign Plan* reinforced the fact that transformation's goal remained leveraging information technology. The campaign plan directed focus areas to shape future transformation that addressed three major areas: accelerating implementation of decision support tools, enterprise integration, and demand reduction; flattening and streamlining organizations by making accurate, timely information available; and developing modern logistics systems with established metrics to compress the supply chain.[45] Ultimately, it sought to realize decentralized sustainment by combining information systems and innovative concepts to provide an integrated and scalable common operating picture (COP), which would allow command and control across the areas of operations, intelligence, and logistics.[46] Notably, the campaign plan identified merging timely operational and logistics information into an integrated COP as the essential element to realizing every other focused logistics capability, while simultaneously acknowledging that providing the timely information to build it remained the biggest challenge.[47]

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[43] Ibid., 6.

[44] Ibid., 4-6.

[45] Department of Defense, *Focused Logistics Campaign Plan* (Washington D.C.: Government Printing Office, 2004), 5-6.

[46] Ibid., 5.

[47] Ibid., 64-65.

The *Logistics Transformation Strategy* and *Focused Logistics Campaign Plan*, along with the experiences of OIF shaped the course of Army sustainment transformation from 2004 to the present, and continue to shape the concepts for future force design. LTG Christianson, as the Department of the Army G4, published the *2004 Army Logistics White Paper* to focus the Army sustainment community's transformation efforts within the net-centric framework established by the DOD's transformation strategy and campaign plan. In the paper, Christianson identified connecting the logistician, modernizing theater distribution, and integrating the supply chain as the Army's three focus areas for improving the logistics elements of distribution and supply.[48]

The requirement to connect logisticians highlighted the need to provide a reliable capability for data transmission during the increased tempo of NCW operations, since an integrated COP and near-real time control of the distribution pipeline requires accurate and timely information. Although information systems like GCSS-A and BCS3 remained an integral part of this focus area, these systems alone could not produce the robust network required without being connected by communication systems. This immediate shortfall necessitated fielding a capability that allowed dependable and predictable data transmission of supply requirements across significant distances.[49]

The Army furnished the required capability with a very small aperture terminal (VSAT) system that provided non-line of sight communication capability from the support company in the maneuver battalion to the theater support command headquarters as the means to connect key nodes and form a theater-wide sustainment network.[50] Within the second focus area, the Army

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[48] Claude V. Christianson, "Army Logistics White Paper 'Delivering Materiel Readiness to the Army'," Headquarters, Department of the Army, http://www.quartermaster.army.mil/oqmg/professional_bulletin/2004/spring04/army_logistics_white_paper.htm.

[49] Ibid., 1.

[50] "Testimony of Lieutenant General Claude V. Christianson, Deputy Chief of Staff, G-4 United States Army".

targeted shortcomings in the RML tenets of a seamless logistics system and total asset visibility to modernize theater distribution. The Army reduced seams, which resulted in additional handling and delays, by integrating the command of the theater's distribution capability under the new modular theater support command (TSC) headquarters and introducing processes to allow shipments from the strategic base to the unit without repackaging.[51] These solutions allowed the Army to reduce or eliminate logistics capabilities within the modular division and corps headquarters because of the self-sustaining nature of the new brigade-based structure during initial employment, and envisioning support from the TSC and strategic base extending its initial reach during decentralized operations.[52]

Concurrently, the Army improved TAV by adopting automated identification technology (AIT) equipment to provide situational awareness of shipments moving in the distribution pipeline and increase in-transit visibility (ITV). To integrate the supply chain, the final focus area, the Army relied on solutions from the other two focus areas and continued efforts to develop a unified COP. In summary, the *2004 Army Logistics White Paper* addressed the need to field equipment that filled some of the critical capabilities necessary to achieve focused logistics, and remove the soldier from "the end of a very tenuous supply chain without readily available critical supplies, and at the mercy of a fragile theater distribution system."[53]

As the DOD's and Army's sustainment leadership looks to the future, the concept of sense and respond logistics (SRL) guides development across the realms of doctrine, organization, training, materiel, leadership, personnel, and facilities (DOTMLPF) for the force of 2016-2028. The DOD views SRL as its leading edge initiative, and describes it as a network-

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[51] Ibid.

[52] Bob Bradford, *Sustainment Transformation Overview* (Fort Lee, VA: U.S. Army Combined Arms Support Command, 2007), 3-4.

[53] "Testimony of Lieutenant General Claude V. Christianson, Deputy Chief of Staff, G-4 United States Army".

centric, knowledge-based concept reliant on highly adaptive, self-synchronizing, and dynamic processes and organizations that sense, predict, anticipate, and coordinate actions.[54] The Army also illuminates the requirement for SRL's characteristics and capabilities in the functional concept for sustainment and concept capability plan for logistics command and control.[55] Adopting SRL requires several critical capabilities not currently developed, primarily the development of systems and cognitive decision support tools capable of rapidly fusing data from an integrated COP and predicting future requirements.[56] In the end, the vision for the near and far-term future logistics system embodies the characteristics of a network-centric, distribution-based, anticipatory approach enabled by embedded prognostics, diagnostics, and sensors linked in a collaborative information environment to extend operational reach by preventing or minimizing operational pauses.[57]

Network-Centric Warfare

Discussions about network-centric warfare often center on disagreements regarding applications of the theory rather than a debate on the theory's validity, measured by its ability to achieve the desired results within a complex system and environment. Therefore, the analysis of NCW in this paper begins by outlining the theory as described in the 1999 edition of *Network Centric Warfare* by the DOD's CCRP before moving to show how the DOD subsequently defined the theory in application. The title of the book indicates the theory's origin lies only in

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[54] U.S. Department of Defense, *Department of Defense Logistics Transformation Strategy: Achieving Knowledge-Enabled Logistics*, 8.

[55] U.S. Army, *Training and Doctrine Command Pamphlet 525-4-1: The U.S. Army Functional Concept for Sustainment 2016-2028,* (Washington, DC: Headquarters, Department of the Army, 2010), 6, 19, 22; U.S. Army, *Training and Doctrine Command Pamphlet 525-7-8: The United States Army Concept Capability Plan for Logistics Command and Control for the Future Modular Force 2015-2024,* (Washington, DC: Headquarters, Department of the Army, 2009), 20, 22, 25.

[56] U.S. Department of Defense, *Department of Defense Logistics Transformation Strategy: Achieving Knowledge-Enabled Logistics*, 13-16.

[57] Department of Defense, *Focused Logistics Campaign Plan*, 90.

JV2010's concept of information superiority, but an honest appraisal reveals a broader vision of a network comprised of people and systems making better decisions based on increased situational awareness. The CCRP's distillation of the essence of NCW as "translating information superiority into combat power by effectively linking knowledgeable entities in the battlespace," presents a balanced view of the theory with respect to information.[58] Additionally, its assertion that NCW is more about networking or effective linking than networks, and derives power from linking geographically or hierarchically dispersed knowledgeable entities reveals information does not inherently provide the capability to reduce the number of entities and flatten the network.[59]

NCW establishes the entity or node as the basic building block of any network.[60] The node represents the organizations and processes of the military that "sense, decide, and react" to the environment, while the links between the nodes establish the network and allow the sharing of information.[61] Utilizing Metcalfe's Law, the CCRP observes that the maximum number of interactions for a single node equals the total number of nodes in the network (N) minus the individual node (or N-1), and establishes that a linear increase of N results in an exponential increase in the number of possible interactions within the entire network ($N^2 – N$).[62] NCW emphasizes the interactions made available by linking nodes into a network allows information sharing, and ultimately the creation of shared battlespace awareness through self-synchronization.

Self-synchronization, as defined in *Network Centric Warfare*, requires the combination of an ability to interact, and an agreed upon rule set directing a response between two or more

[58] Alberts, Garstka, and Stein, "Network Centric Warfare: Developing and Leveraging Information Superiority," 2.

[59] Ibid., 6.

[60] Ibid., 245.

[61] Ibid., 94.

[62] Ibid., 32, 250.

entities.[63] The combination of the rule set and interaction allows the nodes to operate in the absence of traditional command and control relationships, and still achieve the desired goal. The CCRP caveats the discussion of self-synchronization by acknowledging some relationships in nature resist the phenomenon, but highlight at least two potential areas where networking enables mission accomplishment in a decentralized manner. The first example relates to mission execution, and although described more than a decade before the concept of mission command became doctrine in the Army it visualizes freedom to modify certain tasks assigned by higher headquarters without explicit guidance or prior approval, as long as the change increases the likelihood of mission accomplishment within the commander's intent. The second example describes accomplishing logistics resupply based on the collection of fuel and ammunition consumption from sensors on equipment to automatically push replenishment without a request from the unit. [64]

The CCRP's discussion of the coevolution of mission capability packages to apply the theory of NCW in the development of new doctrinal concepts reflects a clear understanding of an open-system process. Arguing that new technology systems by themselves stand little chance of creating a competitive advantage for the DOD, *Network Centric Warfare* describes a process of continuous evaluation for new DOTMLPF practices in response to the environment and changes within it.[65] Far from conceiving a pre-ordained end state or advocating the immediate adoption of practices from the commercial sector, the CCRP prescribed experimentation and validation of new mission capability packages to achieve a network able to create shared awareness by sharing

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[63] Ibid., 176.This definition combines the CCRP's two elements of networked entities and shared awareness as they are interchangeably used later and describe the ability of two or more nodes to interact. Additionally, it replaces the term value-added interaction with response to reduce the statement to its core meaning, and separate it from the problem their definition of value-creation creates in application.

[64] Ibid., 176-78.

[65] Ibid., 22.

information.[66] Additionally, the DOD understood the net-centric environment required more than technology since they defined it as a "social construct supported by advanced information technology." [67] Comprised of two areas, a knowledge area consisting of the cognitive and social capabilities to function and a technical area covering the physical aspects to connect entities, the DOD's *Net-Centric Environment Joint Functional Concept* constitutes a balanced approach to enable decentralized operations.[68] However, the Army's overemphasis of select parts of the theory, as opposed to a balanced implementation, created challenges when developing new processes and organizations to operate in complex and uncertain environments.

The concept of infostructure represents the first area of overemphasis in application.[69] Although the CCRP initially described infostructure as the enabler allowing entities to create awareness, its concrete nature, as actual systems hardware, made it an easily quantifiable requirement. The commercial sector's simultaneous use of information systems to connect organizations and reduce layers within the supply chain also contributed to the Army's emphasis on infostructure.[70] Combined with the CCRP's assertion that resourcing the infostructure maximized the "value" of the network from an enterprise perspective by removing stovepipes and enabled the substitution of information for people and material, the Army's subsequent choice to emphasize mechanical sensors, communication hardware, and enterprise resource programs over the number of capable logistics entities within the network seems reasonable.[71]

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[66] Ibid., 26, 104.

[67] Department of Defense, *Net-Centric Environment Joint Functional Concept version 1.0* (Washington, DC: Government Printing Office, 2005), 12.

[68] Ibid., v.

[69] Alberts, Garstka, and Stein, "Network Centric Warfare: Developing and Leveraging Information Superiority," 35. Infostructure is defined as the entry fee for NCW that provides enterprise elements with access to high-quality information services.

[70] Ibid., 81.

[71] Ibid., 36; Christine Brim, *Logistics Transformation: Next Steps to Interoperability and Alignment* (Arlington, VA: Lexington Institute, 2005), 19, 29-30.

The CCRP's definition of value-creation within a network represents the other area often over emphasized when applied within the logistics community. *Network Centric Warfare* directly equated the value of information as a linear function of its relevance, accuracy, and timelines, with a higher value created by more timely interactions.[72] The CCRP's assertion that high performance networking of sensors, or the infostructure, reduced uncertainty and improved the ability of entities to make decisions by increasing the value of the provided information also established interdependence with the previous area of overemphasis.[73] The challenge in implementing net-centric sustainment using the CCRP's concept of value-creation lies in the ability to capture data that allows action before the data loses relevance.

Complexity and Network-Centric Sustainment

The Army of the 1990s and early 2000s foresaw future battlefields as complex and changing environments, and utilized NCW concepts to transform in response to this vision. Since NCW theory grew from a foundation in complexity theory, one must understand the key concepts of complexity theory and complex adaptive systems (CAS) to determine whether the interpretation of NCW theory that guided sustainment transformation remained consistent with complexity's theoretical framework.[74] Furthermore, understanding contemporary thinking on complex systems highlights the limitations of traditional command and control processes and hierarchical organizations in complex environments. The science of complexity represents an evolving, interdisciplinary field, but widespread consensus exists on its fundamental concepts,

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[72] Alberts, Garstka, and Stein, "Network Centric Warfare: Developing and Leveraging Information Superiority," 54-55, 253.

[73] Ibid., 254.

[74] Melanie Mitchell, *Complexity: A Guided Tour* (New York, NY: Oxford University Press, 2009), 13. Although differentiation is sometimes made between complex adaptive systems and nonadaptive complex systems, such of storms or flowing water, this paper deals with the complex and adaptive environment of warfare so the terms complex system, CAS, system of system, and even network are used interchangeably.

including the definition of a complex system and the characteristics that render traditional approaches to controlling one ineffective.

Complexity arises from variety and interdependence in a system, and a system becomes complex when the number of interacting elements within it produces collaborative effects that do not scale linearly with the input and are not traceable to an individual entity.[75] Although complex systems always exhibit non-linearity due to interdependence between constituent elements, several other features distinguish CAS from even the most complicated linear systems.[76] All complex systems harness positive and negative feedback between the autonomous agents of the system to adapt dynamically to emergent changes in the system's environment, enabling the system to continuously self-organize and accomplish goals.[77] Consequently, exploring the ideas of interdependence between autonomous agents, emergent effects, adaptation, and self-organization will highlight key characteristics that allow complex systems to achieve a desired goal and why predicting a complex system's future state is probabilistic versus precise.

The agent or entity represents the essential building block and composes the basis of every system. In complex systems, the autonomous agent represents the first departure from traditional systems because this self-directing entity possesses an internal set of rules that regulates its behavior with respect to the local environment versus reacting only to commands from a central authority.[78] Feedback, or input from the environmental surroundings, results in system-wide interdependence on multiple scales because the agents' local areas overlap and link

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[75] Alex Ryan, "The Foundation for an Adaptive Approach: Insights from the Science of Complex Systems," *Austrailian Army Journal* VI, no. 3 (2009): 71; Bousquet, *The Scientific Way of Warfare*: 200; Robert Axelrod and Michael D. Cohen, *Harnessing Complexity: Organizational Implications of a Scientific Frontier* (New York, NY: Basic Books, 2000), 7.

[76] The terms linear, complicated, and monolithic are used interchangeably to describe a non-complex system.

[77] David A. Fisher, *An Emergent Perspective on Interoperation in Systems of Systems* (Pittsburgh, PA: Carneige Mellon Software Engineering Institute, 2006), vii; Mitchell, *Complexity*: 12-13.

[78] Bousquet, *The Scientific Way of Warfare*: 168, 75.

local actions and effects to the larger system through their interactions.[79] Feedback from the immediate environment takes a negative or positive form. Negative feedback increases system stability, while positive feedback causes systemic change.[80] The responses of the multitude of autonomous entities to their local, rather than the global environment, create variety in the system because of the different context for each agent.[81]

The diversity of responses and interdependence between the multitude of autonomous elements in the system leads to changes in their local environment, which result in emergent effects that lead to changes in the global properties of the larger system.[82] Emergence occurs as a direct result of the relationship between the system as a whole and its individual elements, and unavoidably occurs in systems with actors that possess a degree of independence in determining their specific actions.[83] The ability of individual constituents to act autonomously results in a cascade throughout the system because each interaction affects the environment and future interactions.[84] Emergence occurs in a bottom-up fashion due to the interactions of individual agents, and the blending of their interactions in the complex system to make it impossible to directly trace the cause to a single actor.[85] Emergence in complex systems reflects the adaptation of actions at the local level that allow the overall system to continue to viably function in a

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[79] Ryan, "The Foundation for an Adaptive Approach," 72.

[80] Bousquet, *The Scientific Way of Warfare*: 165; Dietrich Dörner, *The Logic of Failure: Recognizing and Avoiding Error in Complex Situations* (New York, NY: Basic Books, 1996), 74-75.

[81] Ryan, "The Foundation for an Adaptive Approach," 72; Axelrod and Cohen, *Harnessing Complexity*: 8.

[82] Yaneer Bar-Yam, *Making Things Work: Solving Complex Problems in a Complex World*, ed. Chitra Ramalingam, Laurie Burlingame, and Cherry Ogata (Cambridge, MA: New England Complex Systems Institute, 2004), 27.

[83] Ibid; Fisher, *An Emergent Perspective on Interoperation in Systems of Systems*, viii, 18, 25.

[84] Fisher, *An Emergent Perspective on Interoperation in Systems of Systems*, 16.

[85] Ibid., 13, 18; Ryan, "The Foundation for an Adaptive Approach," 72.

changing environment – a contrast to linear systems which lack emergence and therefore remain unchanging without direction from the central authority and display predictable behavior.[86]

The ability for the variety of agents, or subsystems, in a complex system to make independent decisions based on a set of rules creates the potential for adaptation and evolution of processes that govern their interaction with the environment.[87] The constant evolution of processes in a CAS reflects the attempt of each agent to respond to feedback and cope with an environment that constantly changes due to their individual actions and the actions of every other entity.[88] To design a system with the ability to adapt, one must create sufficient variety at the local level, connect the individual elements to enable interaction with each other and the environment, and allow subsystems to adjust their roles and functionality in response to emerging needs.[89] Organizations that properly balance these elements will theoretically possess the ability to adapt and self-organize to locally changing conditions, and reflect a departure from traditional approaches to optimize and control actions and system functions from a central authority.[90]

The structure and design of the network directly impacts the ability of individual entities to interact and transmit information. Increasing the connectivity between the elements of a network helps stabilize the system by incorporating negative feedback, and complements the use of adaptation in response to positive feedback.[91] The network's elements use information from feedback and their set of rules to develop new behavior, and self-organize or synchronize

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[86] Fisher, *An Emergent Perspective on Interoperation in Systems of Systems*, 13, 18; Mitchell, *Complexity*: 13.

[87] Ryan, "The Foundation for an Adaptive Approach," 81.

[88] Ibid., 79; Mitchell, *Complexity*: 217-18; Axelrod and Cohen, *Harnessing Complexity*: 7-8.

[89] Ryan, "The Foundation for an Adaptive Approach," 72, 81; Fisher, *An Emergent Perspective on Interoperation in Systems of Systems*, 10.

[90] Bousquet, *The Scientific Way of Warfare*: 221; Ryan, "The Foundation for an Adaptive Approach," 72.

[91] Steven Strogatz, *Sync: The Emerging Science of Spontaneous Order* (New York, NY: Hyperion, 2003), 237.

throughout the entire system when the individual elements share a common function or purpose.[92] However, self-organization only occurs within an open system (e.g. one that can exchange information and energy with the surrounding environment). Attempting to close the system by regulating or controlling the information received by individual elements hinders those elements' ability to continue to function within a CAS, and risks system-wide disorganization and failure.[93] Additionally, attempting to flatten a system to reduce redundancy (a common approach in attempts to increase organizational efficiency), while maintaining centralized control, results in tighter coupling within the network. This constrains the options of individual elements to adapt in the face of emergence.[94] Although coupling exists in every network due to the interdependency between the constituent elements, increasing the dependence between the highest and lowest elements undermines the ability to recognize and adapt to changing conditions due to the loss of multiple perspectives and capability across the system.[95] Tighter coupling reduces the resilience, or scale-free properties, of the network by increasing the direct dependence of one node on another. This, in turn, increases the likelihood of system-wide failures if the requirements placed on a node or sub-system of nodes exceeds its capability to complete or adapt to accomplish a task.[96]

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[92] Ibid. The synchronization requires no intelligence to achieve, and only requires interaction between the elements and a rule set governing the elements' responses; Bousquet, *The Scientific Way of Warfare*: 168, 75.

[93] Bousquet, *The Scientific Way of Warfare*: 189-91; Mitchell, *Complexity*: 40-43, 255-57; Fisher, *An Emergent Perspective on Interoperation in Systems of Systems*, 15-16. This thought process reflects Boyd's concept of "heat death" as well as Gell-Mann's operational process of complex adaptive systems and the use of information in the OODA loop/schema to reverse entropy and disorganization at the local level.

[94] Fisher, *An Emergent Perspective on Interoperation in Systems of Systems*, 21.

[95] Ibid., 35.

[96] Ibid., 21; Mitchell, *Complexity*: 245-46.

No single, optimized way exists to solve complex problems or viably operate over an extended period in a complex and changing environment.[97] Instead, organizations that match the complexity of their environment across multiple scales provide the necessary local context to give information meaning at the global level.[98] Building resilient organizations for operation in an uncertain environment does not render efforts to command and control them totally ineffective. However, these organizations must possess a sufficiently "fine grain" structure and tolerate the use of "focused" and "unfocused" processes at multiple levels to adapt current processes to function in new conditions and ensure the overall system continues to function.[99]

Combining organizations designed as interoperable systems of systems with a shared common purpose among the autonomous agents provides an approach that blends traditional control techniques for monolithic systems with an understanding of the implications of complexity theory, allowing centralized command with distributed control in a complex, adaptive environment.[100] However, because the nature of a CAS means the requirements for organizations constantly change and the information needed for precise prediction is unobtainable, centralized command entities must focus on maintaining unity of purpose and effort versus attempting to control local actions directly, or it risks undermining the individual components' autonomy and tightening the coupling that inhibits adaptation and self-organization.[101]

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[97] Bar-Yam, *Making Things Work*: 15; Ryan, "The Foundation for an Adaptive Approach," 70, 74, 86.

[98] Bar-Yam, *Making Things Work*: 100, 259; Ryan, "The Foundation for an Adaptive Approach," 76-77; Mitchell, *Complexity*: 183-84.

[99] Fisher, *An Emergent Perspective on Interoperation in Systems of Systems*, viii, 3, 32; Mitchell, *Complexity*: 182-84. The fine grain structure provides the resilience to the system allowing parallel action, while the use of focused and unfocused processes allows the system to use optimal practices based on past experience and also explore new processes better suited to changing conditions.

[100] Bar-Yam, *Making Things Work*: 104-09; Fisher, *An Emergent Perspective on Interoperation in Systems of Systems*, viii, 27-28, 33; Ryan, "The Foundation for an Adaptive Approach," 81-84.

[101] Bar-Yam, *Making Things Work*: 108; Fisher, *An Emergent Perspective on Interoperation in Systems of Systems*, viii, 28.

Historian Martin van Creveld's *Command in War* affirms the general assertions of complexity theory. No single system of organization or communication and data processing system can provide certainty within the complex, adaptive environment of war. Although technological infrastructure enables effective command of dispersed forces on the modern battlefield, the most crucial aspect remains the organization and social component of the network that translates data into relevant information. Attempting to improve performance primarily by increasing information requirements generally leads to excessive specialization of the organization, and within a hierarchical command structure raises decision thresholds and limits the ability of lower level units to adapt. Conversely, mission command provides a historically proven method of coping with uncertainty and exercising command in war. The concept of mission command calls for the organization's headquarters to establish the primary objective, and then grant freedom to its subordinate elements to select their own way to accomplish the task. Incorporating a robust mixture of formal and informal communication, mission command allows subordinate units to act on information based on their local context and reduces the amount of decisions required by higher headquarters.[102]

Since the theoretical frameworks of NCW and complexity coincide in many ways, exploring how the application of NCW within the sustainment community diverges from complexity's theoretical principles reveals the challenges that today's modular logistic force faces in supporting a decentralized force with a centralized sustainment structure. The fundamental difference between net-centric sustainment and complexity theory revolves around the centrality of information and its function and meaning in complex, uncertain environments.

Both complexity and NCW recognize the integral role of information, through feedback, in creating stability within a system and allowing adaptation due to changing conditions.

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[102] Martin Van Creveld, *Command in War* (Cambridge, MA: Harvard University Press, 1985), 253, 58, 59, 61, 62, 64-70, 74, 75; Bousquet, *The Scientific Way of Warfare*: 125, 28-32, 37, 205, 27, 33.

However, NCW emphasizes negative feedback, through the collection of real-time status from sensors throughout the organization, to allow faster decisions.[103] The components of accuracy and timeliness in the CCRP's definition of information value serve as the basis for the sustainment community's emphasis on negative feedback, and discount the sensitivity to initial conditions commonly exhibited in complex systems. Although data on the status of fuel, ammunition, and other classes of supply remains vitally important to logisticians, the ability to interpret the data in relation to the unit's environment and recognize change over time requires context rather than single snapshots.[104] Sensitivity renders the collection of precise data on local conditions meaningless at the global level without the often-discounted information value component of relevance. This establishes the basis for the complexity theory principle, supported by history and empirical evidence that uncertainty and imperfect knowledge serve as defining characteristics of all complex systems.[105]

The desire to enable control by developing a common operating picture (COP) that provides global visibility of requirements and actions throughout the system fuels the quest for more information through negative feedback. [106] The Army defines a COP as "a single display of relevant information within a commander's area of interest tailored to the user's requirements and based on common data shared by more than one command."[107] While the technology exists to develop systems that aggregate information from dispersed sources and account for differences in

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[103] Bousquet, *The Scientific Way of Warfare*: 231.

[104] Ibid., 221; Fisher, *An Emergent Perspective on Interoperation in Systems of Systems*, 13, 18.

[105] Bousquet, *The Scientific Way of Warfare*: 218, 20, 21; Carl von Clausewitz, *On War*, ed. Michael Howard and Peter Paret, trans. Michael Howard and Peter Paret (Princeton, N.J.: Princeton University Press, 1984), 117-21.

[106] U.S. Department of Defense, *Department of Defense Logistics Transformation Strategy: Achieving Knowledge-Enabled Logistics*, 6; "Defense AT&L Interviews Army Lt. Gen. Claude V. "Chris" Christianson, Deputy Chief of Staff for Logistics, G-4 Headquarters, Department of the Army," *Defense AT&L*, July-August 2004, 9, 13.

[107] U.S. Army, *Field Manual 6-0, Mission Command*, (Washington, DC: Headquarters, Department of the Army, 2011), Glossary-2.

delay and precision, the technology cannot guarantee the relevance of the model's picture or project that current picture to a precise future state or trend because achieving accuracy requires time independent information.[108] Additionally, building a COP that portrays global information and expecting subordinate elements to act on that information increases the requirement for explicit information exchange and risks systemically centralizing execution and control because subordinate organizations may make decisions based on a centralized pool of information not relevant to their situation.[109] In contrast to the single, integrated COP and global awareness sought by net-centric sustainment, system's theory asserts that allowing each node to develop and maintain their own unique picture offers the best approach to drive out inaccuracies irrelevant at the global level and maintain the variety that allows innovative execution when uncertainty exists.[110]

Army doctrine states that individual information systems such as BCS3 and MTS provide scalable COPs that allow each node to develop and act on relevant local information.[111] However, the continued development of information systems to provide "enterprise wide visibility to make logistics requirements known at once by all potential sources so the system can respond in near real-time," combined with transformation's reduction of robustness in the sustainment system indicate that integration remains the primary goal.[112] While net-centric sustainment seeks to eliminate the "stovepipes" in legacy systems to build an integrated COP with advanced

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[108] Fisher, *An Emergent Perspective on Interoperation in Systems of Systems*, 24; Bousquet, *The Scientific Way of Warfare*: 221; Ryan, "The Foundation for an Adaptive Approach," 77.

[109] Fisher, *An Emergent Perspective on Interoperation in Systems of Systems*, 24; U.S. Army, *Field Manual 6-0, Mission Command,* (Washington, DC: Headquarters, Department of the Army, 2003), 2-8.

[110] Department of Defense, *Logistics Transformation--Update, Focus, and Accelerate* (Washington, DC: Government Printing Office, 2001), B-5, B-6; Department of Defense, *Focused Logistics Campaign Plan*, 65; Bousquet, *The Scientific Way of Warfare*: 222; Ryan, "The Foundation for an Adaptive Approach," 72, 81; John P. Kotter, *Power and Influence: Beyond Formal Authority* (New York, NY: The Free Press, 1985), 13, 18, 32, 33.

[111] U.S. Army, *Field Manual 4-0, Sustainment*, 3-4.

[112] Department of Defense, *Logistics Transformation--Update, Focus, and Accelerate*, B-5, B-6.

information systems, it simultaneously creates a different “stovepipe” in the logistics force structure by centralizing operational level logistics command and control under the TSC.[113] In contrast to complexity theory’s assertion that matching the scale of the environment provides the best opportunity to operate continuously in a complex system, sustainment transformation reduced the scale of the logistics network in relation to the operational system it supports.[114] Because corps and divisions no longer possess the capability to perform logistics command and control above the brigade level, the modular logistics structure effectively couples the TSC to the brigade. Eliminating much of the layering in the legacy logistics structure decreased requirements to deploy forces, but left modular logistics commands unable to synchronize decisions with maneuver commands and support the operational tempo envisioned in future full-spectrum operations.[115]

For net-centric sustainment and the modular logistics structure to use information and negative feedback to provide precise control of the sustainment system, it requires a total understanding of all the variables in the complex environment of warfare and the belief in predictability.[116] However, a host of theorists and practitioners state that because warfare occurs between two thinking foes constantly trying to disrupt their opponents’ operations, efforts to use information systems and intelligent computer agents to achieve global visibility and predict future

[113] Alberts, Garstka, and Stein, "Network Centric Warfare: Developing and Leveraging Information Superiority," 66, 114, 24, 95; U.S. Army, *Field Manual 4-94, Theater Sustainment Command,* (Washington, DC: Headquarters, Department of the Army, 2010), 1-1.

[114] Bar-Yam, *Making Things Work*: 100, 03, 259; Ryan, "The Foundation for an Adaptive Approach," 77.

[115] U.S. Army, *Training and Doctrine Command Pamphlet 525-7-8: The United States Army Concept Capability Plan for Logistics Command and Control for the Future Modular Force 2015-2024*, iv.

[116] Bousquet, *The Scientific Way of Warfare*: 241; Ryan, "The Foundation for an Adaptive Approach," 75.

patterns in armed combat remain self-defeating.[117] Any effort to control and predict an outcome in war through a model requires simplifications that mask the complexity of the situation, degrade the accuracy and relevance of any prediction, and resemble cybernetic ideas rather than complexity theory.[118] Additionally, the stakes involved in warfare remain higher than those in the business or scientific community so efforts to adopt practices for warfare without validation through experimentation and testing involve significant risk to the state and its armed forces. Although many areas of logistics benefit from advances in technology and efforts to gather actionable data from supported elements, the pervasiveness of uncertainty and chance in war necessitate a military logistics system with greater redundancy than commercial systems if preventing culmination remains the goal.[119] During the last decade, logistics transformation sought to improve the efficiency of support to Army forces operating as independent, dispersed elements by increasing the flow of information. While resource constraints demand efficiency, the ultimate goal of the Army logistics system must remain providing effective support that allows maneuver units to adapt their operations quickly in response to changes in the environment and extend their operational reach.[120]

CASE STUDY

This section provides a case study analysis of two periods during Operation Iraqi Freedom, 2003 and “the Surge” period in 2007, to illustrate the impact of transformation on the sustainment of employed forces in complex and uncertain environments. Analyzing the doctrinal

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[117] Clausewitz, *On War*: 112; H.R. McMaster, "The Human Element: When Gadgetry Becomes Strategy," *World Affairs* (2009): 9; Bousquet, *The Scientific Way of Warfare*: 236-41; Fisher, *An Emergent Perspective on Interoperation in Systems of Systems*, 22; Mitchell, *Complexity*: 186-208.

[118] Ryan, "The Foundation for an Adaptive Approach," 76; Strogatz, *Sync*: 190; Bousquet, *The Scientific Way of Warfare*: 219.

[119] Bousquet, *The Scientific Way of Warfare*: 240-41.

[120] Ryan, "The Foundation for an Adaptive Approach," 84; McMaster, "The Human Element: When Gadgetry Becomes Strategy," 9-10; Martin van Creveld, *Technology and War: From 2000 B.C. to the Present* (New York, NY: Free Press, 1989), 316.

concepts as well as the performance of the organizational structures and equipment during these two periods against the evaluation criteria of robustness, redundancy, and velocity provides the necessary details for future conclusions on impacts to operational reach.

Operation Iraqi Freedom - 2003

The structure of combat operations to bring about the fall of Saddam Hussein's regime began to take shape in the summer of 2002, and relied on establishing the minimum required logistics footprint in theater, rather than building up all necessary forces and supplies, before starting ground operations. The modularization of BCTs and sustainment forces allowed the pursuit of a "running or generated start" for OIF operations that looked much different and utilized about seventy-five percent fewer troops than ODS, and relied on follow-on forces still deploying into the theater at the start of combat operations to maintain momentum and achieve all the objectives of the end state. The beginning of ground operations on March 20, 2003 to seize Baghdad, replace the regime, and withdraw after supporting the establishment of a new broad-based government relied heavily on the successful application of the RML's concepts.[121]

Although the capstone logistics manual in March 2003 remained *Field Manual 100-10, Combat Service Support* from 1995, the concepts enabling OIF's running start – DBL, a seamless logistics system, TAV, rapid force projection, and establishing an adequate logistics footprint – entered doctrinal debate as early as 1997 and formal doctrine in 2002. In 1997, *Training and Doctrine Pamphlet 525-53, Operational Concept for Combat Service Support* (CSS) outlined the conceptual basis for future logistics doctrine informed by the concept of information superiority and the ideas of complexity. Published two years before the CCRP's *Network Centric Warfare*, it envisioned the creation of a robust CSS network, with information and communication systems

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[121] Catherine Dale, *Operation Iraqi Freedom: Strategies, Approaches, Results, and Issues for Congress* (Washington, DC: Congressional Research Service, 2009), 34-35; Peltz et al., *Sustainment of Army Forces in Operation Iraqi Freedom: Battlefield Logistics and Effects on Operations*, xi, xii.

linking managers to allow effective control of supply distribution. Additionally, the pamphlet explicitly discussed that effective control of distribution required redundant management capability at each level of command to maintain the ability to adapt support to the changing conditions of the organization and provide the necessary context for the overall system to anticipate requirements. Balancing the positive effect of redundant management to allow improvisation by subordinate commanders with a deliberate integration of the transportation system to eliminate redundant handling and increase the velocity of supply delivery with throughput, the future doctrinal concepts represented a holistic and systematic approach to transform sustainment support. Most importantly, *Pamphlet 525-53* stated that successful implementation of the proposed concepts required the development and implementation of concepts and equipment to centralize command of the distribution pipeline, allow visibility of supplies at multiple levels of the sustainment system, and modularized forces to enable rapid force projection.[122]

Over the course of the next six years, 1997 to 2003, the sustainment community developed and evaluated *Pamphlet 525-53's* concepts resulting in new doctrinal manuals for the DISCOM, TSC, and capstone Army document, *Field Manual 4-0, Combat Service Support*. These manuals reflected the idea that robustness and redundancy in the CSS network made sustained land operations possible in complex environments while also allowing greater efficiency of supply delivery. To allow centralized command with decentralized control and execution the manuals redefined the role of the TSC and designated a single CSS operator at each echelon. The TSC's new mission focused on establishing early command of the theater distribution system to allow unity of command and throughput of support to follow-on forces,

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[122] U.S. Army, *Field Manual 4-0, Combat Service Support*, (Washington, DC: Headquarters, Department of the Army, 2003), i; Reimer, "A Note From the Chief of Staff of the Army on The Revolution in Military Logistics," 1; U.S. Army, *Training and Doctrine Command Pamphlet 525-53: Operational Concept for Combat Service Support*, (Washington, DC: Headquarters, Department of the Army, 1997), 2-3, 5-8, 13-15.

with the single operator at the battalion through corps providing control of support within their respective organization. The network described in doctrinal manuals from 2002 through 2003 stressed that robust links between different redundant operators provided the necessary visibility and capability to surge capabilities throughout the system and meet the needs of various supported units in different phases of an operation. The updates also maintained the dual perspective for sustainment with the G4 staff responsible for planning and the single CSS operator at that level charged with evaluating the viability of future courses of action. Finally, the doctrine stated the command and control system depended on multiple viewpoints of different human organizations to understand the trends over time and the commander's operational priorities as operations progress, and while technology represented a critical enabler to link organizations it could not reduce the importance of the human dimension.[123]

OIF combat operations from March 20 to April 9, 2003 achieved the distributed offensive in a large area of operations envisioned by NCW and doctrine, and required an agile system to maintain momentum. Achieving agility and preventing breaks in the distribution flow required visibility of unit requirements and incoming supplies from robust interactions, redundant capability from each echelon's staff and sustainment operator throughout the network, and velocity in force projection and supply delivery from the early establishment of a centralized command for the theater distribution system by a TSC. Analysis of these three areas highlights their importance to specific evaluation criteria, and the interdependence between the criteria and the ability to achieve the goals of the RML.[124]

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[123] U.S. Army, *Field Manual 4-93.4, Theater Support Command,* (Washington, DC: Headquarters, Department of the Army, 2003), 2-1, 2-2; U.S. Army, *Field Manual 4-93.52, Division Support Command (Digitized),* (Washington, DC: Field Manual 4-93.52, 2002), 1-9, 1-10, 3-1; U.S. Army, *Field Manual 4-0, Combat Service Support*, 1-1, 1-2, 1-4, 4-17, 5-3, 5-5, 5-14.

[124] Science Applications International Corporation, *Objective Assessment of Operation Iraqi Freedom Logistics* (Washington, DC: Department of Defense Headquarters, 2004), 14-15, 50.

The distribution management center (DMC) served as the building block for visibility in the transformed logistics network by linking the functions of material management – understanding requirements and their status, and movement control – delivering requirements to the right place. DMCs at each echelon formed the network's backbone with explicit and implicit reporting requirements extending up and down the units from division to theater and laterally to the various staff sections. However, the lack of non-line of sight (NLOS) communication capability degraded the robustness of interactions during the movement to Baghdad, and exacerbated other shortfalls in automated information systems that greatly reduced the visibility of requirements and movement of supplies.[125]

In early 2003, the mobile subscriber equipment network remained the communication link to submit requirements through automated logistics systems. Although the mobile subscriber system possessed NLOS capability between each echelon's nodes (brigade, division, corps, and theater), the requirement for units to remain within line of sight of their supporting node and the need to stop movement and synchronize the setup of the nodes between echelons resulted in limited requests from units through STAMIS for almost three weeks. Units utilized available satellite telephones and FBCB2/MTS to transmit critical requirements, but the inability to consistently submit requests on OIF's distributed battlefield with frequent movement left little visibility of units' needs throughout the system.[126]

Immature and inconsistent use of AIT also contributed to non-robust interactions in the movement control systems that inhibited DMCs from tracking the movement of incoming supplies and providing visibility to commanders and units. Army Central Command (ARCENT)

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[125] U.S. Army, *Field Manual 4-93.4, Theater Support Command*, 5-12; U.S. Army, *Field Manual 4-93.52, Division Support Command (Digitized),* 3-9; Eric Peltz et al., *Operation Iraqi Freedom: Major Findings and Recommendations* (Santa Monica, CA: RAND Corporation, 2005), xvi, 111.

[126] Peltz et al., *Sustainment of Army Forces in Operation Iraqi Freedom: Battlefield Logistics and Effects on Operations*, 28, 41-43; Peltz et al., *Operation Iraqi Freedom: Major Findings and Recommendations*, xvi, 31, 36, 111.

established a radio frequency identification (RFID) system, consisting of interrogators to read tags on shipments, to track the arrival of supplies at nodes in the transportation pipeline and allow the reprioritization or rerouting of supplies on a fast moving battlefield. However, failure to emplace readers at all transportation nodes, maintenance failures of readers from the desert environment, and inconsistent usage of the tracking tags on supply shipments degraded the ability to see critical supplies and control distribution throughout the transportation system.[127]

The combination of infrequent communication from units and a limited ability to track incoming supplies reduced the ability of information systems to provide accurate visibility for DMCs. In addition, the lack of interoperability between the numerous systems contributed to an inaccurate logistics COP of the battlefield. Managers researching the status of shipments or requirements dealt with as many as forty different information systems, resulting in significant differences in aggregate data as depicted in Figure 2 below.

	1/3 ID reported status					
	1-Apr	4-Apr	5-Apr	6-Apr	9-Apr	10-Apr
MRE	1.8			1.8	1.8	
Water	1			1	0.8	
CLIII(B)	3.9			3.1	2.3	
	3d COSCOM report for 3ID					
	1-Apr	4-Apr	5-Apr	6-Apr	9-Apr	10-Apr
MRE		4	5			1.8
Water		5	6			2
CLIII(B)		3+	3+			3+

Figure 2: Days of Supply on Hand[128]

[127] Science Applications International Corporation, *Objective Assessment of Operation Iraqi Freedom Logistics*, 62, 63, 65, 70; U.S. Government Accountability Office, *Defense Logistics: Preliminary Observations on the Effectiveness of Logistics Activities during Operation Iraqi Freedom*, 3, 20; Peltz et al., *Operation Iraqi Freedom: Major Findings and Recommendations*, 114.

[128] Peltz et al., *Sustainment of Army Forces in Operation Iraqi Freedom: Battlefield Logistics and Effects on Operations*, 31-32. The data in Figure 2 shows information collected from 1/3 ID status reports and 3d COSCOM update briefs from 29 Mar to 10 Apr, 2003.

Although the figure depicts the status that 3rd Corps Support Command (COSCOM) understood for 3rd Infantry Division (ID) overall and no direct match by day appears, the reports do not indicate that 3rd COSCOM understood a BCT in 3ID was within one or two days of running out of food, water or fuel. Latency from the sparse transmission of requests, an incomplete supply transportation status, and the lack of system interoperability resulted in differences in understanding of as much as 600%, or five days of supply, for the supply status of units. Overcoming the lack of an implicit logistics COP required the redundancy from echeloned staffs and sustainment operators providing relevant information and capability from their local area to maintain momentum on the drive to Baghdad.[129]

The redundancy of material and movement management from the BCT's BSB at the tactical level to the TSC at the theater level, and the backup transportation capacity in the division support battalion represented a deliberate attempt to mitigate uncertainty on the battlefield during the transition to DBL from the mass-based system. Although doctrine envisioned information systems and a robust network providing better forecasts, the Army also recognized the inevitability of surprise and errors by planners and units in predicting future requirements. Additionally, time limitations inherent in the planning for any operation result in greater focus on critical requirements – bulk fuel in OIF. The lack of an integrated system to forecast requirements for complex classes of supply such as repair parts and ammunition strengthen the need for redundant monitoring and control as depicted in Figure 3. Planners for OIF generally succeeded in forecasting the needs for supplies with a low number of unique items and regular consumption, and the Army pushes these items regardless of specific requests due to their relative predictability. However, the detailed plans developed at the division and corps level prior to

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[129] Science Applications International Corporation, *Objective Assessment of Operation Iraqi Freedom Logistics*, 61-69, 71-72; U.S. Government Accountability Office, *Defense Logistics: Preliminary Observations on the Effectiveness of Logistics Activities during Operation Iraqi Freedom*, 20; Peltz et al., *Operation Iraqi Freedom: Major Findings and Recommendations*, xvi; Peltz et al., *Sustainment of Army Forces in Operation Iraqi Freedom: Battlefield Logistics and Effects on Operations*, 31-32.

combat operations informed ARCENT of several potential shortfalls in capability to deliver supplies regularly to tactical units unless the road network remained secure, road conditions and weather allowed rapid and continuous movement, and throughput of supplies occurred from the corps to the BCT.[130]

Class of Supply Complexity	
Class of Supply	Number of Unique Items*
Bulk Fuel-CL III(B)	1
Water	1 (Bulk & Bottled)
MREs	1
Unitized Group Rations	4
Construction-CL IV	40
Packaged POL-CL III(P)	81
Ammunition-CL V	112
General Supplies-CL II	1,155
Repair Parts-CL IX	10,000

Planning and Execution for Fuel and Dry Cargo		
Factor	Bulk Fuel	Dry Cargo
Requirement	Met	Not Met
Division & BCT Augmentation	Yes	No
Detailed Planning	Significant	Less
Class Complexity**	No	Yes
Demand	Below Forecast	Above Forecast
Redundant inventory points	Yes	Limited
Movement rates for delivery	Slow	Slow
Weather Impacts	Yes	Yes
In-transit visibility	Limited	Limited

* For a combat maneuver BCT
** Represented by the number of unique items for the class above

Figure 3: Class of Supply Complexity and Planning/Execution Comparison[131]

The ability to recognize deviations from planning assumptions that increased risk perception in the forward BCTs became critical to extending operational reach. 3ID's rapid advance during the first three days resulted in longer than anticipated supply routes, and delayed

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[130] U.S. Army, *Field Manual 4-0, Combat Service Support*, 1-4, 5-14; Peltz et al., *Operation Iraqi Freedom: Major Findings and Recommendations*, xvi, 41-42, 53-55, 64-69, 107; Greg H. Parlier, "Transforming U.S. Army Logistics: A Strategic "Supply Chain" Approach for Inventory Management," (Arlington, VA: The Institute of Land Warfare, 2005), 14-16; Science Applications International Corporation, *Objective Assessment of Operation Iraqi Freedom Logistics*, 42.

[131] Peltz et al., *Operation Iraqi Freedom: Major Findings and Recommendations*, 53-54.

the throughput of supplies to the BCTs. Combined with issues at the theater level caused by the late arrival of the TSC, and attacks along the two hundred fifty mile supply route, the resupply of 3ID BCTs required immediate attention to prevent culmination. The explicit communication between the staffs and sustainment units from the division to the theater resulting from the network's unity of command enabled improvised solutions to overcome a lack of visibility and capability shortfalls at the theater level. The 3ID G4's and DISCOM's understanding of their local situation allowed them to direct the download of supplies at An Najaf and mass cargo trucks from the BCTs and the division support battalion to move projected shortfalls in food, water, and repair parts. Although movement towards Baghdad slowed from 25-28 March, the operational change to secure key locations along the line of communication occurred because of the invalid planning assumption about secure routes that led to the initiation of operations before the establishment of a sufficient theater logistics footprint. The redundant capability provided by division and corps logistics managers in combination with the spare transportation capacity in 3ID provided the necessary capacity to overcome forecasting errors and poor visibility of supplies on the battlefield.[132]

Although supply shortfalls did not directly result in the operational pause, the late deployment of the TSC reduced the velocity of supplies below the Army standard and created additional pressure on the system. The TSC's absence early in the operation meant ARCENT lacked the doctrinal sustainment operator to assess the viability of planning, and significantly impacted the adequacy of the theater's logistics footprint. Additionally, DOD's decision to execute a running start rather than a deliberate build-up of forces invalidated the pre-planned force flow. The subsequent ad hoc deployment of units based on projections of required

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[132] Ibid., 1, 42-44, 48, 51-55, 64-69, 71, 107; U.S. Army, *Field Manual 4-93.52, Division Support Command (Digitized)*, 1-3; U.S. Army, *Field Manual 4-0, Combat Service Support*, 1-1,1-2, 4-12, 5-19; Science Applications International Corporation, *Objective Assessment of Operation Iraqi Freedom Logistics*, 11.

capabilities from multiple units rather than an integrated theater wide assessment from the TSC prevented the establishment of a capable theater distribution center (TDC) or cargo truck capacity prior to 20 March.[133]

ARCENT directed the establishment of a TDC in the second week of February, but the growing supply demand from units preparing for combat quickly created a backlog of over two thousand containers and eight hundred 463L shipping pallets. Additionally, ARCENT lacked a trained unit to operate the location, which resulted in a shortage of resources and equipment to properly receive, inventory, and ship supplies. The redundancy of the system provided some assistance as 3ID contributed personnel and trucks to help move critical supplies, but could not make up the shortage of over seven hundred personnel and the material handling or communication equipment to properly operate the TDC in the five weeks before combat began.[134]

The shortage of trucks to move classes of supply other than bulk fuel also decreased velocity in supply distribution, and resulted from the supply complexity discussed above and the lack of an integrated theater plan justifying cargo truck requirements. The 377th TSC assessed that only half the required nine hundred thirty medium cargo trucks were on hand to support distribution at the start of combat operations. Based on historic figures – a 1:194 truck to person ratio existed in OIF versus the 1:73 ratio during ODS – and the low forecasting of dry cargo requirements as shown in Figure 3 meant the actual deficit was potentially much higher. Although the exact delay caused by the late establishment of the TDC and inadequate resourcing

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[133] Science Applications International Corporation, *Objective Assessment of Operation Iraqi Freedom Logistics*, 11, 12, 14, 25, 33, 51; "Testimony of Lieutenant General Claude V. Christianson, Deputy Chief of Staff, G-4 United States Army"; U.S. Government Accountability Office, *Defense Logistics: Preliminary Observations on the Effectiveness of Logistics Activities during Operation Iraqi Freedom*, 22; U.S. Government Accountability Office, *Defense Logistics: DOD Has Begun to Improve Supply Distribution Operations, but Further Actions Are Needed to Sustain These Efforts* (Washington, DC: U.S. Government Accountability Office, 2005), 6, 7; Peltz et al., *Sustainment of Army Forces in Operation Iraqi Freedom: Battlefield Logistics and Effects on Operations*, 20.

[134] Peltz et al., *Sustainment of Army Forces in Operation Iraqi Freedom: Battlefield Logistics and Effects on Operations*, 47.

of cargo trucks remains unknown, the increase in the total theater distribution time from four to over twelve days during combat operations significantly impacted CWT.[135]

The late deployment of the 377 TSC impacted the logistics preparation of the battlefield and establishment of an adequate footprint, but also created a void between the strategic and tactical level that affected velocity. The absence of the TSC reduced the theater system's redundancy, leaving no sustainment command or DMC to monitor updates to the strategic distribution system from task organization changes and arrival of new units into theater. This limited the strategic level's ability to configure shipments for throughput of supplies directly to BCTs, and increased the requirement to unpack and reconfigure shipments at the TDC, corps, and division level.[136]

The preparation of units for combat and the ground campaign to seize Baghdad marked a distinct transition from the steady state prior to January 2003, with a 66% increase in supply requests by March and subsequent doublings in May and June (see Figure 4 below). The period of transition, February through May, saw a corresponding increase in CWT from eleven to twenty or more days, with velocity still above the goal of sixteen days in July. The lack of equipment providing NLOS, on the move communication capability reduced the robustness of information exchange in the sustainment network, and revealed challenges in supporting rapidly moving combat forces on a distributed battlefield with implicit types of information exchange. However, the redundant capability in material management and movement control with doctrinally explicit communication requirements allowed the network to improvise solutions and surge capability within the overall intent. The adaptation of people and organizations throughout the network

[135] Peltz et al., *Operation Iraqi Freedom: Major Findings and Recommendations*, 38, 63; U.S. Government Accountability Office, *Defense Logistics: DOD Has Begun to Improve Supply Distribution Operations, but Further Actions Are Needed to Sustain These Efforts*, 7.

[136] U.S. Government Accountability Office, *Defense Logistics: DOD Has Begun to Improve Supply Distribution Operations, but Further Actions Are Needed to Sustain These Efforts*, 19; Science Applications International Corporation, *Objective Assessment of Operation Iraqi Freedom Logistics*, 25; Peltz et al., *Operation Iraqi Freedom: Major Findings and Recommendations*, xiv.

based on an intimate understanding of their local environment and the ability to provide the right context for the system's higher levels increased speed and predictability of distribution enough to sustain operations that changed in pursuit of perceived opportunities on the battlefield. The Army's challenge after the success of combat operations in 2003 became balancing efforts to increase efficiency in the logistics system without excessively coupling tactical units to the strategic level.[137]

Month	Qty of Requests	Average CWT	95% CWT
Oct-02	39,672	8	32
Nov-02	29,487	10	36
Dec-02	38,101	13	45
Jan-03	35,452	11	30
Feb-03	35,211	17	36
Mar-03	59,423	23	46
Apr-03	53,801	20	62
May-03	138,069	20	55
Jun-03	240,382	22	57
Jul-03	337,035	30	70

Figure 4: Average and 95th Percentile CWT from October 2002 to July 2003[138]

Operation Iraqi Freedom – "The Surge"

In January 2007, President George W. Bush announced the Surge, a new strategy to reduce violence and establish control of key areas in Iraq. More than 30,000 additional personnel deployed in support of OIF, an increase of approximately twenty percent, to implement the

[137] Science Applications International Corporation, *Objective Assessment of Operation Iraqi Freedom Logistics*, 1, 4, 59, 71, 88; Peltz et al., *Operation Iraqi Freedom: Major Findings and Recommendations*, 11; Dale, *Operation Iraqi Freedom: Strategies, Approaches, Results, and Issues for Congress*, 14; Marygail K. Brauner and Arthur Lackey, *CWT and RWT Metrics Measure the Performance of the Army's Logistics Chain for Spare Parts* (Santa Monica, CA: Army Research Division RAND Arroyo Center, 2003), 7; Department of Defense Inspector General, *Uniform Standards for Customer Wait Time* (Washington, DC: Department of Defense Headquarters, 2007), 4.

[138] Logistics Support Agency, "Logistics Information Warehouse," https://liw.logsa.army.mil/. CWT highlighted in yellow with red lettering depict data the DA standard of 16 days for the average and 50 days for the 95th percentile. CWT highlighted in red with white lettering depict data more than 33% above the DA standard.

strategy over the next six months. The addition of six brigade-sized and other supporting units represents a transition from the steady state environment that existed at the end of 2006, and provides a relatively unique window to examine the ability of the sustainment system to maintain velocity. Unlike combat operations in March and April 2003, units remained based in fixed sites during the Surge. Offensive operations did occur throughout Iraq during the Surge, but generally consisted of battalion-sized local actions versus the sustained two hundred fifty mile long attack, involving almost 300,000 personnel in 2003. Additionally, a theater infrastructure with established convoy security units and procedures, contracted transportation capability, and support centers to facilitate the movement of equipment and supplies from Kuwait into Iraq existed in January 2007. The Army also issued several pieces of new equipment and took significant steps to integrate the strategic and operational distribution systems, which addressed the major shortfalls identified in the OIF logistics system of 2003.[139]

Considerable stability existed in sustainment doctrine during the 2003 to 2007 timeframe, and *Field Manual 4-0* with the supporting TSC manual from 2003 remained the capstone sustainment documents until 2009. However, guidance in 2004 from General Peter Schoomaker, the Chief of Staff of the Army, to eliminate redundancy and design logistics systems to link sustainment and operations with emerging technologies, initiated a more information system dependent course for sustainment doctrine and organization. The resulting “big ideas” for transforming logistics eliminated the materiel management centers, which provided a DMC capability, in the division and corps, and strengthened the TSC’s role as the single logistics command and control headquarters in theater by expressly prescribing a general support relationship between sustainment brigades and divisions/corps under most circumstances. The

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[139] Dale, *Operation Iraqi Freedom: Strategies, Approaches, Results, and Issues for Congress*, 2, 25, 49-50; U.S. Government Accountability Office, *Operation Iraqi Freedom: Actions Needed to Enhance DOD Planning for Reposturing of U.S. Forces from Iraq* (Washington, DC: U.S. Government Accountability Office, 2008), 1.

general support relationship removed the sustainment brigade and Expeditionary Support Command (ESC) – the replacements for the DISCOM and COSCOM respectively – from the operational commander's control since the TSC, rather than the supported unit, set their priorities, leaving the brigade support battalion as the only support unit directly under the control of a division or corps commander.[140]

The actions to strengthen the role of the TSC and link operations and sustainment through technology reflected the view that future operations now required an integrated, rather than agile, system to maintain continuity of support and extend operational reach. Achieving integration of the sustainment system to prevent disruptions in the distribution pipeline still required visibility of unit requirements and incoming supplies from robust interactions, and centralized control of distribution by a TSC as in 2003. However, the Army now viewed the redundant perspectives of each echelon's staff based on the COP provided by information systems – rather than capability for distribution management and execution – as the means to maintain velocity. Analysis of the efforts to enable communication between the supported and supporting units, streamline the distribution management system, and integrate the theater distribution system under the centralized command of the TSC illuminates their impact on specific evaluation criteria, and the ability to maintain velocity in supply delivery.[141]

From 2004 to 2007, the Army fielded equipment to provide a NLOS communication capability to the force. This effort focused on increasing the implicit transfer of logistics data and achieving network-wide visibility through information systems, which allowed the distribution network to continuously self-optimize. Although observations from 2003 called for equipment

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[140] Bradford, *Sustainment Transformation Overview*, 3-4, 54; U.S. Army, *Field Manual 4-0, Sustainment*, ix; U.S. Army, *Field Manual 3-0, Operations,* (Washington, DC: Headquarter, Department of the Army, 2001), 4-28; U.S. Army, *Field Manual 3-0 Change 1, Operations,* (Washington, DC: Headquarters, Department of the Army, 2011), B-11.

[141] U.S. Army, *Field Manual 4-0, Sustainment,* vi, 1-2, 1-3, 4-1, 4-4. Agility and agile only appear three times in the 2009 version of Field Manual 4-0, and only in relation to the US Transportation Command and financial management support on the battlefield.

that supplied an on the move capability to allow continuous connectivity and real-time data capture, the costs and technical feasibility of providing an always on, mobile solution prevented implementation of the ideal solution. Nonetheless, the main systems, the VSAT and Joint Node Network, which replaced the mobile subscriber equipment system used in 2003 significantly improved capability to routinely transmit logistics requirements on a dispersed battlefield. The Joint Node Network and VSAT enabled every battalion to transmit data to its supporting unit within three hours if on the move, and continuously if operating from a fixed site. From the Army's perspective, the VSAT and JNN provided the same communication capability as a garrison environment, and the robust data transmission capacity needed to leverage information systems and reduce redundancy.[142]

The effort initiated in 2005 to reduce redundancy by linking sustainment and operations through information systems, originated from the belief that the technology existed to virtually eliminate logistics situational awareness as a source of uncertainty on the battlefield, a marked departure from sustainment doctrine in 2004. Although the Army did not develop or field a system to estimate requirements for complex classes of supply as discussed in the previous case study, emerging doctrine no longer discussed the likelihood of surprises in logistics requirements or units' committing forecasting errors.[143] The Army did introduce the Battle Command Sustainment Support System (BCS3), as discussed previously in the sustainment transformation section, to draw information from multiple logistics information systems and provide a tailorable

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[142] Peltz et al., *Operation Iraqi Freedom: Major Findings and Recommendations*, 36; Science Applications International Corporation, *Objective Assessment of Operation Iraqi Freedom Logistics*, 62, 81; U.S. Government Accountability Office, *Defense Logistics: DOD Has Begun to Improve Supply Distribution Operations, but Further Actions Are Needed to Sustain These Efforts*, 20-21; "Testimony of Lieutenant General Claude V. Christianson, Deputy Chief of Staff, G-4 United States Army"; U.S. Army, *Field Manual Interim 4-93.2, The Sustainment Brigade,* (Washington, DC: Headquarters, Department of the Army, 2009), 3-18.

[143] U.S. Army, *Field Manual 4-0, Sustainment*. The words surprise and error do not appear at all in the 2009 version of Field Manual 4-0, Sustainment.

sustainment COP. However, many units, both maneuver and sustainment, used it on a limited basis, which degraded the situational awareness of logistics requirements.[144]

Several factors contributed to low usage of BCS3, such as a non-intuitive user interface, data integrity problems from dual databases for unclassified and secret systems, and a basis of issue that provided a disproportionate number of systems to operational rather than tactical level units. Because commodities such as food, water, and fuel do not have a STAMIS tracking their status, units must manually input on hand balances and requirements. Additionally, the basis of issue may have provided systems to operational units needing access to the COP, but since the Army did not field BCS3 below the battalion level, companies still had to send manual spreadsheets to their higher headquarters for input into the system. This left the processes at the battalion and below level virtually unchanged, and minimized the effectiveness of BCS3 since it only seemed to add requirements without providing any benefit. Although information systems can improve organizational efficiency, the history of BCS3 confirms that such improvement only occurs when organizations utilize them in a manner consistent with its culture and in conjunction with mature business processes.[145]

Under the revised course of sustainment transformation, the DMC still represented the network's node charged with utilizing the visibility provided by redundant echelons of information systems and robust communications to maintain velocity in the distribution pipeline. However, after 2004 instead of each echelon, from the tactical to the theater level, possessing the capability for materiel and movement management, the Army removed the capacity for distribution management at the corps and division level (see Figure 5 below and Figure 9 in the

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[144] Peltz et al., *Sustainment of Army Forces in Operation Iraqi Freedom: Battlefield Logistics and Effects on Operations*, 69; Donald C. Santillo, "Increasing the Use of the Battle Command Sustainment Support System," *Army Sustainment* 43, no. 4: 22.

[145] Santillo, "Increasing the Use of the Battle Command Sustainment Support System," 22-23; Parlier, "Transforming U.S. Army Logistics: A Strategic "Supply Chain" Approach for Inventory Management," 2; McMaster, "The Human Element: When Gadgetry Becomes Strategy," 8; Department of Defense, *Net-Centric Environment Joint Functional Concept version 1.0*, 12.

Appendix). The new concept created a robust distribution management and execution capability within the BCT to make them nearly independent, and charged the sustainment staff at the division, corps, and theater army with the responsibility to monitor the COP provided by BCS3 and identify logistics shortfalls to the sustainment brigade, ESC, or TSC respectively in order to maintain readiness.[146]

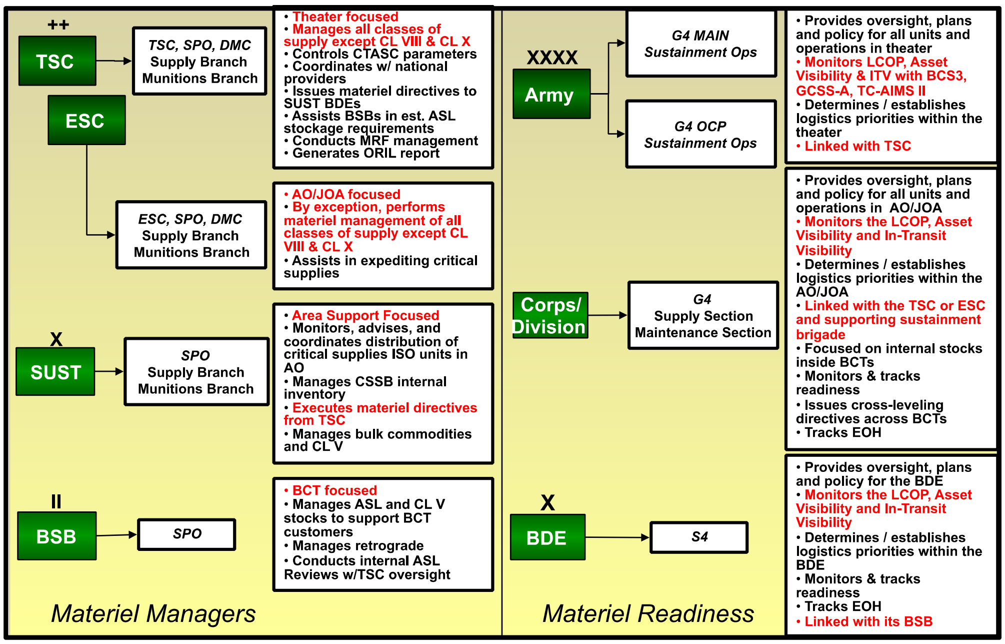

Figure 5: Modular Materiel Management and Readiness Agencies in Theater[147]

Initially when distribution management migrated from operational units above the BCT into sustainment units under the command of the TSC, the sustainment brigade and ESC were identified to perform the mission for the division and corps. Later refinement of the concept directed only limited materiel management below the TSC, specializing the function of the DMCs within the ESC and sustainment brigade. The Army now tasked the ESC with visibility of the theater's distribution system, and the sustainment brigade with management of its supply support

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[146] Mitchell H. Stevenson, "Where's My MMC?," *Army Logistician* 39, no. 3 (2007): 1, 4, 5.

[147] Bradford, *Sustainment Transformation Overview*, 20; U.S. Army, *Field Manual Interim 4-93.2, The Sustainment Brigade*, 2-35.

activity – or repair parts warehouse – and distribution to supported units within its area of operations.[148]

The removal of distribution management from operational units above the BCT and specialization of the DMCs in the ESC and sustainment brigade significantly strengthened the role of the TSC in theater sustainment. After the implementation of both measures, the TSC assumed responsibility for sixty percent of the theater's materiel management mission, a significant increase from the fifteen percent it executed within the Army of Excellence structure (see Figure 6 below).[149]

	Number of Materiel Managers								
	BSB	DMMC	Division Total[1]	CMMC	Corps Total[2]	Sust BDE[3]	ESC	TSC	Theater Total
Army of Excellence	7	141	148	122	122	110	82	82	544
Modular Force	20	0	20	0	0	80	94	138	332
Delta	**13**	**-141**	-128	**-122**	-122	**-30**	**12**	**56**	-212

[1] Division total reflects one BCT and division organic capability
[2] Corps total does not reflect capability organic to the division
[3] The Sustainment BDE is the same as the Army of Excellence Area/Corps Support Group

Figure 6: Migration of Materiel Managers in the Modular Force[150]

After 2007, a division only possessed the organic management capability within its assigned brigades, and only the TSC performed the function for the theater. This centralization allowed the Army to reduce the number of personnel, but also removed the redundant perspectives of distribution management between the BCT and theater army, eliminated the explicit

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[148] U.S. Army Combined Arms Support Command, *Materiel Management for the Modular Force in an Operational Theater* (Fort Lee, VA: U.S. Army Combined Arms Support Command, 2004), 26, 43-63; U.S. Army, *Field Manual Interim 4-93.2, The Sustainment Brigade*, 2-33.

[149] The Army of Excellence calculation of 15% comes from 82/544 since each subordinate layer below the TSC performed materiel management for its area. The calculation of 60% in the Modular Force comes from 138/238 (BSB+Sust BDE+TSC) since the ESC no longer performed materiel management.

[150] Guy C. Beougher, "Improving Division and Brigade Logistics in the Modular Force," *Army Logistician* 38, no. 3: 5; U.S. Army Combined Arms Support Command, *Materiel Management for the Modular Force in an Operational Theater*, 26, 43-63; U.S. Army, *Field Manual 4-94, Theater Sustainment Command*, 2-10, 2-11, 2-20, 2-24.

communication links between sustainment and maneuver from the division to the corps, and effectively coupled the BCT to the TSC.

The integration of the theater distribution system under the TSC, supported by robust communications should have resulted in acceptable velocity according to the Army's interpretation and subsequent application of NCW. However, the OIF sustainment system never attained a month with CWT below the standard of sixteen days from November 2006, just before the Surge, through January 2009 (see Figure 7 below).

Month	Qty of Requests	Average CWT	95% CWT
Nov-06	284,383	18	54
Dec-06	312,216	20	64
Jan-07	328,033	21	77
Feb-07	291,808	23	88
Mar-07	303,050	24	101
Apr-07	295,164	23	101
May-07	302,731	23	99
Jun-07	280,242	23	103
Jul-07	302,397	25	104
Aug-07	293,276	26	106
Sep-07	261,113	25	109
Oct-07	296,336	25	111
Nov-07	264,029	22	93
Dec-07	285,317	19	78
Jan-08	269,851	19	77
Feb-08	283,001	22	85
Mar-08	292,148	22	83
Apr-08	270,620	21	90
May-08	284,408	20	89
Jun-08	248,104	20	85
Jul-08	252,178	21	87
Aug-08	258,571	21	88
Sep-08	240,351	22	90
Oct-08	235,263	25	105
Nov-08	219,193	23	96
Dec-08	212,532	20	88
Jan-09	221,323	25	102

Figure 7: Average and 95th Percentile CWT from November 2006 to January 2009[151]

[151] Logistics Support Agency, "Logistics Information Warehouse".CWT highlighted in yellow with red lettering depict data the DA standard of 16 days for the average and 50 days for the 95th percentile. CWT highlighted in red with white lettering depict data more than 33% above the DA standard.

The velocity of requested supplies, measured in CWT, actually slowed by almost fifty percent (or eight days) from November 2006 through August 2007. Additionally, the ninety-fifth percentile velocity for the twenty-five months after the announcement of the Surge remained thirty-three percent slower than the standard, even though the volume of requests per month varied less than ten percent.[152]

Despite the absence of major combat operations by armored forces as occurred in the beginning of OIF, significant turbulence in the environment did exist during the Surge due to the rotation of units in and out of theater and the variety of local unit operations. Due to the inability to predict the future state of a complex system with certainty, the variety and interdependence in the Surge's environment precluded determining the exact cause of the low velocity. However, even complex systems demonstrate patterns that one can identify or anticipate using historical and probabilistic analysis. In this case, historical analysis does identify the lack of explicit distribution management across the scale of the system as a likely cause for the reduction in velocity. The sustainment network possessed the capability for robust exchange of information, and an integrated distribution system with redundant transportation capability during the Surge. Even so, the information systems that replaced the management capability in the division and corps could not translate the data into relevant information that allowed the operational and strategic sustainment systems to assess trends in future requirements and maintain velocity. Eliminating the redundancy in distribution management and capability resulted in a more hierarchical sustainment structure that elevated rather than delegated decisions in resource allocation between units, which limits the ability to adapt operations in a changing environment.[153]

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[152] The ninety-fifth percentile CWT represents the average time it takes to receive all but five percent of the requested supplies.

[153] Bar-Yam, *Making Things Work*: 100, 03, 08, 09, 259; Van Creveld, *Command in War*: 261-62, 65-67, 69-71, 73-75; Jamshid Gharajedaghi, *Systems Thinking: Managing Chaos and Complexity-A*

CONCLUSION

The OIF 2003 and Surge case studies provide insight into the challenges facing the Army as it transforms to increase strategic responsiveness while maintaining the doctrine, organizational structure, and processes that enable the logistics system to continuously synchronize support with operational commands in a rapidly changing, uncertain environment. As depicted in Figure 8, neither logistics system possessed a sufficiently robust communication system and redundant organizational structure to provide relevant information and the system-wide visibility needed to maintain velocity within established standards.

Evaluation Criteria	Robustness		Redundancy		Velocity
	Implicit	Explicit	Management	Execution	
OIF 2003	--	++	++	+	-
The Surge	++	-	--	--	--

++ = Strong positive impact/trend - = Negative impact/trend
+ = Positive impact/trend -- = Strong negative impact/trend

Figure 8: Case study comparison by the evaluation criteria

After OIF's combat operations in March and April 2003, the Army initially focused on the lack of connectivity and integration of the information systems to increase the implicit exchange of information throughout the logistics network, allowing dynamic self-organization and increasing efficiency. However, in 2004 U.S. forces in Iraq reduced the robustness and redundancy of the theater distribution management and execution capacity based on the expected performance of new but untested information systems. These systems' failure to provide relevant and necessary information from collected data indicates that future sustainment transformation requires a synthesized approach to achieve the required velocity of supply distribution on a fluid battlefield.

Platform for Designing Business Architecture, 2nd ed. (New York, NY: Butterworth-Heinemann, 2006), 150; Bousquet, *The Scientific Way of Warfare*: 227, 33.

Put simply, the Army must find a balance between efficiency and effectiveness, and employ new technologies in combat only after objective tests demonstrate their reliability.

The Army's theater distribution and management system provided the preponderance of support to land operations during OIF, a real-world example that spans a period of more than ten years. This enabled an assessment of the capacity of the net-centric focused logistics concept – an application of NCW theory – to respond to transitions in the operational environment and prevent culmination over a lengthy period of significant change in the environment. The Army's implementation of NCW to achieve focused logistics steadily evolved from 2003 to 2007, and ultimately diverged from the CCRP's balanced work on the application of complexity theory in the realm of warfare first published in 1999, into a much more cybernetic and information intensive effort. The evolving logistics system increasingly prioritized real-time data collection through the infostructure, negative feedback, and specialization as more important facets of the system than maintaining variety and capability across the scale of the environment. This demonstrates that the course of sustainment transformation over the last seven years does not align with the DOD's *Net-Centric Joint Functional Concept* or historical observations and complexity theorists' thoughts on effectively operating in a complex environment.

The deviation of net-centric sustainment from the historical and theoretical observations of executing organizational command and control in a manner that allows adaptation in response to changes in the environment arises from the CCRP's concepts of information value and self-synchronization. Information exchange between organizations in the network enhances the stability and adaptability of the system in both schools of thought. However, the net-centric idea that local information increases in value at the global level when collected more quickly and with greater accuracy, and possesses global relevance without the subsystem's local context, represents a marked departure from foundational concepts of complexity theory. Additionally, self-synchronization in complex adaptive systems only requires the ability to receive information from the local environment and a rule set for acting on the local data within the goal or purpose of the overall system. It does not imply the self-synchronizing agents remain under the control of any centralized authority. By contrast, the current net-centric concept that self-synchronization can result from a collective situational awareness of global information simply does not match reality. Contrary to the Army's goals, its attempts to gain system wide visibility and centralized control by eliminating redundancy and increasing the use of information collection systems has historically resulted in greater organizational specialization and a corresponding reduction in the ability of lower level units to adapt operations dynamically in response to changes in the environment.

The two case studies illuminate the emergence of these two historical trends in the current sustainment force structure, and the subsequent impact of these trends on supply velocity in the distribution system. Although the logistics system supporting OIF operations in 2003 did not have the robust communication linkages and information systems necessary to enable the implicit transfer of data as envisioned in NCW theory, it did possess redundant management and execution capability along with explicit relationships between the sustainment and operational commands at multiple echelons. These explicit relationships integrated the sustainment system with the maneuver units it supported, and ensured that both entities maintained a common picture of relevant information. The velocity of supplies slowed after the transition to combat operations, but the common view between the maneuver and sustainment commands allowed innovation at multiple levels possessing redundant capability, enabling them to act within the system in accordance with the common commander's intent. Therefore, during the early stages of OIF units could extend operational reach despite substandard supply velocity.

Conversely, the presence of a robust implicit information sharing capacity in the absence of redundant explicit relationships between sustainment and operational units at the division and corps level during the Surge resulted in much slower velocity over a longer period than operations in 2003. Although the current sustainment system possesses the ability to collect greater amounts of information more quickly than before, its ability to understand the local context of the maneuver unit generating the data has diminished, making conversion of the data into relevant information more difficult. The general support relationship of sustainment brigades and expeditionary support commands to supported units as well as the functional specialization of the theater's distribution management centers may have enabled the distribution of supplies to become more efficient in steady state environments. However, they have also raised the decision threshold for adjustments to support priorities to the theater level, and effectively coupled the BCT to the TSC and strategic sustainment system. Although the current system adequately supported stability operations, the failure to bring customer wait time within the Army standard over a twenty-seven month period, despite the absence of significant increases in the volume of requests or large scale combat operations, indicates a lack of resilience that could lead to early culmination in high-intensity major combat operations like OIF in 2003.

As with most complex problems, potential solutions to improve the distribution capability of the sustainment system exist, even under the assumption that an increase in the end-strength of logistics units remains inconsistent with Army goals. The Army must readopt the a view of technology and information systems as enablers of a sustainment network of capable management entities as espoused in the net-centric joint functional concept and the Army's sustainment doctrine from 2003. Although computers and information systems can rapidly process and aggregate information, they currently lack the capability to ensure its relevance or recognize patterns outside a prescriptive rule set, which remains a critical capability in uncertain environments. Army forces must also reestablish the explicit links for distribution management between the sustainment brigade and expeditionary support commands and the division and corps respectively. Although this will not provide an inherent distribution capability to the division and corps, it will reintegrate the maneuver and sustainment systems across the scale of the theater's operational environment. Additionally, it restores the explicit link between sustainment and maneuver that will allow the synchronization of supply delivery to operations that seek to exploit opportunities on the battlefield. Finally, the Army must test objectively and thoroughly new processes and organizational structure prior to implementation. Numerous studies and historical analysis indicate that technology can significantly improve organizational efficiency and effectiveness. However, the increase only occurs consistently when incorporated in a manner compatible with the organizational culture and in support of mature processes.

In short, the Army must honestly evaluate observations with respect to the sustainment system from the last ten years of operations, and determine whether the overriding goal of logistics transformation is efficiency or effectiveness. The adjustment to sustainment doctrine and organizational structure from 2004 to 2007 without the intelligent agents and enterprise-wide information systems capable of fusing data into relevant and actionable information represented an inconsistent application of the CCRP's theory of network centric warfare. Without these critical capabilities, eliminating the robustness and redundancy of the Army's logistics and materiel management capabilities between the theater army and brigade combat team saves money in manpower, but renders the efforts to collect more data fruitless because higher command echelons cannot convert that data into relevant information that supports adaptive operations at lower echelons. Resource constraints inherent in today's strategic environment demand some degree of efficiency in the Army's sustainment system. However, a resilient sustainment system providing effective and sustained support allows maneuver commanders at the operational level to adapt operations and exploit opportunities without risking culmination.

APPENDIX

Acronyms

AIT	Automated Identification Technology
ARCENT	Army Central Command
BCS3	Battle Command Sustainment Support System
BCT	Brigade Combat Team
CAS	Complex Adaptive System
CCRP	Command and Control Research Program
CONUS	Continental United States
COP	Common Operating Picture
COSCOM	Corps Support Command
CSA	Chief of Staff of the Army
CSS	Combat Service Support
DISCOM	Division Support Command
DMC	Distribution Management Center
DBL	Distribution-based Logistics
DOD	Department of Defense
ERP	Enterprise Resource Program
ESC	Expeditionary Support Command
FBCB2	Force XXI Battle Command Brigade and Below
FY	Fiscal Year
GCSS	Global Command Support System
ID	Infantry Division
ITV	In-Transit Visibility
JV2010	*Joint Vision 2010*

LMP	Logistics Modernization Program
LTG	Lieutenant General
MTS	Movement Tracking System
NCW	Network-Centric Warfare
NLOS	Non-Line of Sight
OCONUS	Outside the Continental United States
ODS	Operation Desert Storm
OIF	Operation Iraqi Freedom
RFID	Radio Frequency Identification
RML	Revolution in Military Logistics
SALE	Single Army Logistics Enterprise
SRL	Sense and Respond Logistics
STAMIS	Standard Army Management Information Systems
TAV	Total Asset Visibility
TDC	Theater Distribution Center
TSC	Theater Support Command
VSAT	Very Small Aperture Terminal

Supporting Information

AOE	Category	Modular Force
• Property Book Management – Division: DMMC – Non-Division: Embedded PBO at Brigade • Asset Visibility: DMMC/CMMC/TMMC	Class VII Property Accountability Asset Visibility	• Property Accountability: BDEs (BCTs and SPT BDEs) with embedded PBOs • Asset Visibility: Division/Corps/Army Service Component Command (ASCC) G–4
• DMMC, CMMC, TMMC – Overlapping redundancy	General Supplies Class I, Water, Class IIIB	• TSC, ESC (if utilized), SUST BDE DMC manages stocks • BCT requirements sent to TSC/ESC DMC through supporting SUS BDE
• DMMC (DAO): Coordinates and controls Class V use within the Division • CMMC: Managed Corps CSAs/ASPs • TMMC: Managed Theater TSA/ASPs • TMMC ICW ASCC G–3: Establish CSRs	Class V	• BSB BAO: Coord BCT requirements • Div/Corps G–4: Planning and oversight • TSC/ESC/SUST BDE: Manage stocks, issues MROs to CSSBs ASAs • TSC ICW ASCC G–3: Establishes CSRs/ Stockage Obj/NICP requisitions
• DMMC/CMMC/TMMC with duplication at Division/Corps/Theater G–4	Maintenance/ Readiness Management	• BSB: maint mgmt/readiness for its BCT • Division/Corps G–4: Monitors readiness information for CDR, establishes priorities, write plans/orders
• Managed by hierarchal MMCs (DMMC, CMMC, TMMC) • Each level conducted manager reviews with SARSS–2 boxes • SARSS data communicated to hierarchal boxes (SARSS–1 to SARSS–2A/D to SARSS–2A/C)	Demand Supported Class II, IIIP, IV, IX	• SUST BDE single face to the customer • Overall centralized management at the TSC/ASC or ESC (if utilized) • Time sensitive RIC GEO functions pushed to SUST BDEs as required • SARSS–1 data communicated to CTASC directly

Figure 9: Materiel Management Comparison of the Army of Excellence and Modular Force[154]

[154] Bradford, *Sustainment Transformation Overview*, 19; U.S. Army, *Field Manual Interim 4-93.2, The Sustainment Brigade*, 2-33.

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