12TH ICCRTS
"Adapting C2 to the 21st Century"
Teaching Command and Control Systems at the United States Military Academy
Track 1: C2 Concepts, Theory, and Policy
Track 5: Organizational Issues
Track 8: C2 Technologies and Systems

LTC Robert Kewley (Coordinating Author)
Dr. Tim Elkins
United States Military Academy
Department of Systems Engineering
4th Floor, Mahan Hall
West Point, NY 10996 (USA)
(845) 938-5206
Robert.Kewley@usma.edu

ABSTRACT: In response to emerging command and control theory, doctrine, and systems, the United States Military Academy Department of Systems Engineering has introduced an undergraduate command and control systems course designed to create a core of active duty engineers who understand the potential advantages to be gained through the systemic application of tactical command and control. This course poses this fundamental hypothesis for cadets to investigate – A trained and cohesive organization enabled by well-designed collaborative command and control systems will be able to apply decentralized command and control processes in order to increase unit agility and gain a tactical advantage as compared to units that are less collaborative and more centralized. In order to allow cadets to test this hypothesis, the course exposes to cadets to theoretical concepts including globalization, shared awareness and understanding, self-synchronization, and networked effects. They also investigate supporting technologies including the global information grid, shared data and communications models, and service oriented architectures. They learn how these concepts enable organizational agility by transforming how power and decision making are distributed. Finally, they exercise existing command and control systems including Future Battle Command Brigade and Below and Command Post of the Future in simulated tactical scenarios.

1. Introduction

This paper describes an effort to educate the next generation of military leaders in advanced command and control concepts as they relate to the design and implementation of command and control systems on the tactical battlefield. If we expect future leaders to realize the benefits of collaborative information age command and control systems, it is not enough to develop theory in the scientific community and design systems in the acquisition community. The leaders of tomorrow must also have a mature understanding of the scientific, technical, human, and organizational principles behind these theories so that they will be able to apply them in their own unique unit-level environments.

The tactical command and control systems of systems employed on the modern battlefield are becoming ever more complex and ever more important to the success of operations. During the Global War on Terror, commanders at battalion level find themselves having to integrate the capabilities of more than a dozen separately designed command and control systems inside the command center. Many of these systems arrive into theater after the unit has deployed. The technical challenge of getting these systems to communicate on the same network is difficult enough. In addition, tactical leaders must synchronize a myriad of full spectrum command and control functions to include intelligence, surveillance and reconnaissance management, human intelligence and detainee management, targeting, information operations, airspace management, daily patrols, reconstruction operations, and force protection. These challenges are further complicated by a myriad of information reporting requirements for their higher headquarters [1].

Army and Department of Defense initiatives such as the Global Information Grid, LANDWARNET, and Future Combat Systems (FCS) will only increase the complexity and integration challenges of command and control systems. In fact, the FCS program acknowledges that one of its greatest challenges is integration [2]. The program relies on an advanced network of interacting systems to enable higher levels of joint connectivity, situation awareness and understanding, and synchronized operations that will allow soldiers to dominate a complex environment [3].

West Point cadets will graduate into this environment and have to overcome these challenges to provide effective command and control for their assigned units. In order to better prepare its graduates for these challenges, the Department of Systems Engineering introduced a command and control course in the spring semester of 2007. This course approaches command and control systems from a holistic interdisciplinary perspective that focuses on collaboration, integration, and increased mission effectiveness.

2. The Cadets

Command and control is an interdisciplinary function. The target audience for this course is senior year cadets who have completed most of the core curriculum and a good portion of the requirements for their major. These cadets will have a solid foundation in mathematical statistics, behavioral sciences and leadership, social science, economics, military history, military science to include combined arms operations, database and information technology systems, and the engineering design process. The coursework draws upon this foundation of knowledge as it applies to exercising command and control in military operations or in industrial and government systems. Furthermore, the course learning model will draw upon the individual skills of each cadet in his or her academic major. The current enrollment consists of cadets with systems engineering, information engineering, systems management, and engineering management majors. Each of these groups applies the skill of its discipline in order to reinforce those skills. They also help educate cadets with other majors about the potential contributions of different disciplines.

3. Course Overview

This course is designed to allow cadets to investigate a fundamental hypothesis – A trained and cohesive organization enabled by well-designed collaborative command and control systems will be able to apply decentralized command and control processes in order to increase unit agility and gain a tactical advantage as compared to units that are less collaborative and more centralized. Cadets go through a series of theoretical studies, lab experiences, case studies, and design exercise to help them support or refute this hypothesis. This experiential and hands-on learning model encourages a deeper understanding of principles through critical analysis, personal experience, and application to the design of a real system. These principles lead to the following over-arching course objectives.

- Analyze the information age hypothesis that a trained and cohesive organization enabled by well-designed collaborative command and control systems will be able to apply decentralized command and control processes in order to increase unit agility and gain a tactical advantage as compared to units that are less collaborative and more centralized.
- Apply information age command and control concepts to the design and implementation of a command and control system. These concepts include globalization, mission command, agility, self-synchronization, and power to the edge.
- Using available technology, design information based command and control systems to maximize mission effectiveness.
- Apply network, data, and interoperability engineering concepts to the design and implementation of a command and control system.
- Identify specific decision processes and define command and control capabilities which best support those decisions.
- Estimate the value gained by using a specific command and control system with specific capabilities.
- Re-engineer unit organization and processes to best take advantage of capabilities provided by a command and control system.
- Become familiar with the use of Army Battle Command Systems to command and control Army and Joint tactical operations.

The course structure exposes command and control theory, practice, and engineering to cadets in four blocks. During the first block, cadets grasp the fundamental scientific and organizational concepts of information age command and control. These include network centric operations, network science and complexity, social networks, the Army's mission command concept for command and control. In the second block, cadets increase their understanding of the required engineering and organizational design concepts that are necessary to execute information age command and control. These design topics include interoperability, data and communications standards, service oriented architectures, information assurance, and "edge organizations." In the third block, cadets get hands-on experience with existing command and control systems. They conduct simulation

exercises using Future Battle Command Brigade and Below (FBCB2) and Command Post of the Future (CPOF). They also visit a local traffic management and emergency response control center to see how government executes command and control across several agencies and functions. During the fourth block, cadets put their combined experience into practice as they work with the cadet and officer chain of command to design and integrate the command and control systems, operations centers, and process for the execution of cadet field training during the upcoming summer. These experiences will reinforce their individual opinions about the course hypothesis. At the end of the course, cadets will have a good understanding of how to exercise command and control in complex organizations.

4. Command and Control Theory

The command and control theory portion of the course is build upon the information age command and control theories provided in a series of publications by the Department of Defense Command and Control Research Project [4]. In particular, the course uses Power to the Edge [5] as its primary text. This text provides a very complete treatment of the topic from an interdisciplinary perspective with a lot of emphasis on the social and organizational implementation of command and control. The course also includes readings from Understanding Command and Control [6] and The Agile Organization [7]. Understanding Command and Control provides a concise definition and functional decomposition of command and control while The Agile Organization provides an overview of the complexity science and network science concepts upon which information age command and control theory is built.

It is not enough to simply read about information age command and control theories. Cadets also spend several lessons working with the inter-related concepts from complexity science and network science that lead to information age command and control theory. They must understand the unpredictable and nonlinear behaviors of complex systems along with their emergent properties. In addition to their readings from The Agile Organization, cadets spend several class periods working with agent-based simulation to better understand complex systems. They work with the NetLogo [8] simulation to see how small changes to the parameters of simple rules can drastically affect emergent properties of natural systems such as the flocking behavior of birds or the foraging capabilities of insect colonies. They work with the Map Aware Non-Uniform Automata (MANA) [9] simulation developed by the New Zealand Defense Force to see how a small set of simple rules can lead to swarming tactics by the overall force. They supplement this exercise with a RAND study, *Swarming & the Future of Conflict* [10] to better understand the history, requirements, and potential use of swarming tactics on the battlefield. Cadets also briefly come to grips with some basic concepts of network science as they apply to characteristics of collaborative networks. In particular, they consider the advantages of robustness with respect to nodal attacks, high clustering coefficient, and short average path length in the network. They use NetLogo exercises to understand the structure of networks and study their application to leadership in organizations in an article by Margaret Wheatley which focuses on terrorist organizations

and disaster relief [11]. The Army applies these theories in its command and control doctrine based on mission command [12]. Cadets differentiate mission command from detailed command and learn the requirements for its use and its relationship to information systems.

Cadets reinforce their understanding of command and control theory with historical case studies that illustrate different approaches to command and control. Readings include studies from the Battle of Trafalgar [5], Chancellorsville [12], the German and Soviet approaches to command and control during World War II [13], and the US approach to command and control in the Dominican Republic [14]. The theory block of the course concludes with a written examination that requires cadets to apply information age command and control theory to the conduct of *Operation Al Fajr* in Fallujah [15].

5. Command and Control Design Considerations

It is one thing to understand the theory of information age command and control. It is entirely another to apply that theory to the design of command and control systems, to include the organizational design, used in the conduct of operations. The design of complex systems asks engineers to take a fundamentally different approach. Instead of specifying systems in great detail with great certainty, they must apply sufficient encouragement, guidance, and control that allow systems to evolve in uncertain environments [16]. In the second block of the course, cadets learn some design principles that directly follow from the theory. These include interoperability, data and communications standards, service oriented architectures, information assurance, and "edge organizations."

Power to the Edge describes the need for interoperability and develops a spectrum of interoperability that requires collaboration in the physical, information, cognitive, and social domains [5]. Each of these requires processes and standards that allow the sharing to take place. In order to design this into a command and control system, the systems engineer must have a firm grasp of interoperability design principles in each domain. A series of lessons provides this to cadets.

Collaboration in the information domain requires a common access to well-understood data, communications protocols, and software architectures. Each of these concepts is a challenging issue worthy of an entire course or program of study in itself. The goal of this course is to teach cadets enough about these concepts to be good cooperative players that enable, rather than inhibit, interoperability within their units and with other units.

There are several components to sharing information in tactical units. At the lowest level, cadets learn that data is a resource to be used by the entire organization as an advantage. In that light, it requires planning and effort to manage data. Commanders at all levels must encourage discipline and standards in data reporting. They must ensure that data is collected in a repository and posted for all to use, along with metadata that describes it to all potential users. They must understand that tactical units need to move

away from current practices of storing data in disparate Excel and PowerPoint files on individual computers to a system of collecting data in organized databases and shared file systems accessible by others who may have a need for the data. Cadets participate in a tactical planning exercise where they must analyze an operations order and develop a strategy to collect data and post it for all members of the unit to use during the operation. At higher levels, cadets develop an understanding of the Department of Defense Net-Centric Data Strategy [17]. While the technical details of implementing this strategy are beyond the scope of this course, cadets learn the fundamental principles that make data available and usable by decision makers across the unit. These principles include tagging data with metadata that describes it, posting that data on the network for others to use, and defining reference standards that allow translation of data into different formats required by different users.

At the technical level, cadets learn how policies, standards, and information assurance allow a complex information infrastructure such as the Global Information Grid (GIG) to grow and evolve as a community of interoperable systems without highly specified engineering detail or tight couplings between systems. Cadets get an overview of communications standards and protocols that enable information sharing. They learn how protocols such as hypertext markup language (HTML) and extensible markup language (XML) allow complex text and data to be shared between disparate systems. Programming standards such as web services description language (WSDL) and simple object access protocol (SOAP) enable developers to write programs that interact across the network on different platforms in different languages. Finally, they learn how conformance to common protocols and standards allows the entire organization to link its information functions with services in a service oriented architecture that increases collaboration between applications across the organization. Cadets use two case studies to better understand these concepts. They study how Crutchfield electronics used web services to enable collaboration between three different ordering systems [18]. They also study the Army's component of the GIG, LandWarNet, to see how standards based communications and integration systems such as Warfighter Information Network – Tactical (WIN-T), Everything Over Internet Protocol (EoIP), and System of Systems Common Operating Environment (SOSCOE) enhance collaboration [19][20]. Finally, cadets get an awareness of the information assurance requirements of the GIG and an understanding of the tactical unit's role in taking measures to protect their own information, enforcing standards to secure their networks, and properly training and certifying their people about information assurance [21]. They learn how to do an information assurance risk analysis in order to make decisions that enable access to information while preventing unauthorized access and disclosure.

Having the technical ability to collaborate does not, by itself, produce an effective organization. That organization must also be supported by an organizational design, culture, and incentive system that encourage collaboration in the social domain. This is an edge organization [5]. Cadets study the requirements for an edge organization from a command and control perspective and from a case study about effective innovation in the business community [22]. At the completion of this block, cadets have an understanding about how to enhance collaboration with a combination of technical capabilities, policies,

and supporting organizational design that encourages constructive and disciplined sharing of information.

6. Existing Command and Control Systems

Cadets reinforce their understanding of command and control design considerations through exposure to three different systems currently in use. First, they take a trip to the Hudson Valley Transportation Management Center [23] to see how a state government performs command and control in the transportation management domain through a number of inter-related and cross-departmental programs to include the Intelligent Transportation System, closed circuit cameras at key choke points, incident reporting, flashing highway signs, and emergency notification. Cadets also execute in-class tactical simulations that allow them to control tactical forces in a short mission using Future Battle Command Brigade and Below (FBCB2) and Command Post of the Future (CPOF). In the use of these systems, cadets will consider design choices such as collaborative abilities, data sharing, communications protocols, client-server architecture, and adaptability.

7. Design Exercise

The culminating experience for the course is an opportunity for cadets to design a command and control system to support Cadet Field Training (CFT) during the summer at West Point. Each summer, approximately 1100 cadets from the sophomore class and a cadre of leaders from the junior class, senior class, and staff and faculty execute seven weeks of rigorous field training to further develop the individual soldier skills and begin to hone the tactical and leadership skills of the respective classes. Typically, this training is executed in a poorly networked environment with very traditional and prescriptive command and control processes. There is great opportunity for cadets in this course to work with the incoming leadership for cadet field training in order to improve information sharing and collaboration. By design, this will improve organizational agility and effectiveness. While some of this command and control will apply to the tactical domain, the tactical operations during summer training are somewhat scripted and focused on individual and small unit tasks. The leadership's greatest challenge is integrating the logistics and reporting necessary for smooth execution of training.

In order to improve this system, cadets approach this design exercise in a number of phases. In the first phase, cadets will interview the CFT leadership, staff, and other stakeholders in order to develop a functional analysis and value analysis to guide design of the overall system. They will then convert this to a model using Unified Modeling Language diagrams, and they will take these models back to the stakeholders during an in-progress review that ensures they have accurately identified their needs and modeled a system to best meet them. Based on these models, cadets will develop one or more alternatives for a system that meets the stakeholders' needs. These system designs will include an information system design, process design, organization design, a training plan, and implementation details for the system. They will assess the value of their system based on metrics in their value model. This will lead to a final briefing to the

CFT leadership for acceptance of the system and implementation guidelines. At the end of this process, cadets will have confidence in their ability to analyze a complex command and control scenario and design systems within those scenarios to increase effectiveness.

8. Conclusions

Upon completion of this course, cadets will enter the information age Army better prepared to apply the lessons of this age to enable command and control in their units. They will understand the complexity and network science that supports the theory. They will be able to relate that science to information age command and control concepts and to the supporting mission command doctrine. They will be catalysts in their units that enable collaboration and sharing of information and data across functional boundaries. They will bring an understanding of the required technical standards, information assurance principles, and organizational factors necessary to enable collaboration. And, from the experiences of the course, they will have confidence in their ability to apply critical thinking and systems engineering skills to design solutions to command and control problems and oversee implementation in their units.

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