ECHELON 4 CORPORATION

Theory of Enterprise Command & Control

Draft
Version 1.2

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Opinions, conclusions, and recommendations expressed or implied within are solely those of the author and do not necessarily represent the views of the Department of Defense or any other U.S. government agency.

Notice

Many of the concepts introduced in these pages, particularly Chapters 3-8, are the subject of claims pending in patent application US11/149,965. The conceptual basis for and key elements of the structure and function of *value production units* (VPU), *enterprise command structures* (ECS), *command processing services* (CPS) and the *performance measurement services* (PMS) are protected as intellectual property, as are current expressions in selected software implementations.

Acknowledgements

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The theory of time-utility functions and the companion utility accrual theory (TUF/UA) are adapted from ongoing work by Dr. E. Douglas Jensen, MITRE Corporation, Bedford, MA. TUF/UA concepts are used with Dr. Jensen's kind permission. Echelon 4 Corporation is a designated technology transfer and commercialization partner to MITRE during its FY06-08 MSR program period.

Preface

The *Theory of Enterprise Command and Control (EC2)* is about effective governance systems supporting *value production* in distributed "always-on" enterprises, about creating institutional awareness and its ability to facilitate effective, agile and sustainable action. EC2 is also about integration of human prerogatives and distributed computational systems that, acting in concert, are competent to establish and maintain the viability of large-scale interactive enterprise systems. The theory maintains that such *intelligent enterprise*s are not possible without an effective *command (decision) and control infrastructure*. Such an infrastructure necessarily sits above, yet intimately depends upon underlying information infrastructures such as commercial enterprise resource planning (ERP), the Department of Defense's (DOD) Global Information Grid (GIG) and its attendant *Network-Centric Enterprise Service*s (NCES). In this sense, the theory of EC2 provides a basis for, and thus enables, higher-level *service-centric operations*.

Our thesis is that the definition and development of service-centric EC2 systems requires a more comprehensive theory of command and control than provided by traditional and typically *ad hoc* social models. It postulates that without higher and more robust forms of enterprise automation and control, current institutions of government, commerce and society will be progressively constrained in their individual and collective actions in an increasingly complex, interdependent and interactive world. The goal of the theory of EC2 is to move the frontier of enterprise system conception, design and operation from its current communications (net-centric) and information sharing (*data-centric*) orientations forward to a theory capable of supporting unified (*service-centric*) operations.

Today the DOD emphasizes net-centric data fusion ("sensor fusion") as the centerpiece of its integration efforts. The ability to interconnect arbitrarily large numbers of distributed and diverse information sources is a logical necessity, but as a basis for unified command, is insufficient. Large quantities of volatile information streaming in from various geographically distributed sources are as likely to confuse a commander's assessment of a given situation as to clarify it, and therefore hamper his ability to act.

In addition, there are collateral issues of information context, pedigree, timeliness, accuracy, precision, semantics and a host of other matters that connectivity and data fusion alone cannot resolve. These issues belong to the domain of the *EC2 processes* (services) that ultimately use the data. They define the context in which these processes unfold in time and space and the missions of the organizations that rely on those processes.

In short, we believe that communications networks (e.g., the GIG) and their ability to support an abundance of data publishers and subscribers have a supporting role (however valuable) in enabling effective and collaborative C2. This thesis motivates the next developmental phases of institutional (e.g., military enterprise) governance systems. It argues that the focus needs to be on the manner in which information is *assimilated* and effectively *utilized* within and among communities of allied enterprises. This is the domain of distributed governance, of institutional and collective awareness, and the essential *processes* of enterprise C2. It is the domain requiring a more general *theory of EC2*.

In developing such a theory, we take into account current and near-future requirements deriving from the *evolution* in military, industrial and homeland security affairs, as viewed at the beginning of the 21st century. Contrary to opinions that we are witnessing a network-

centric *revolution* in the governance of the military enterprise, we see instead strong evidence of an evolution in command and control based on an enduring need for pragmatic incremental steps, important refinements motivated by continuous and accelerating, advances in technology, policy, doctrine, economics and political imperatives. These constant changes create the need for new capabilities in both present (i.e., legacy) and future command and control systems. Such enduring forces for change require C2 system concepts that support flexibility and adaptation – continuous evolution in platforms and services that provide individual and collective capabilities to govern effectively.

These observations are not new or necessarily contentious. Command, or decision, and control practices employed to date embody concepts that have a long history in the conduct of governmental and civilian affairs. They constitute the principal management frameworks used by military commanders, civilian executives, government ministers, and others responsible for the conduct of complex, evolving, dynamic, typically distributed and (in the case of military and civilian law enforcement) lethal enterprises.

Across many domains of human endeavor, the basic tenets of C2 are generally consistent, defined by periodic execution of processes that perform information acquisition, situation assessment, policy, resources and action plan development, and ultimately plan execution and monitoring. However, there are wide variations in a) the lexicon used to describe these processes of governance, b) the definition and application of their core tenets, c) the attendant social systems they presume, d) the relative emphasis placed on each process and e) the capabilities of extant technical enablers. They vary within and across domains, their contained enterprises and each enterprise's constituent organizational components. As a result, there is today no broadly accepted *theory of C2*, one sufficient to define a conceptual basis for and core services of enterprise command and control. This condition exists for enterprises operating alone or in concert within a single domain (e.g., market or theater), let alone when on occasion and under the stress of critical situations they may need to interconnect, interoperate and synchronize their efforts across domain boundaries.

Within the domain of the DOD, C2 (in practice) relates to the unification of governance within and across tactical, operational strategic and national levels of command, across the Military Services of the Navy, Marine Corps, Air Force and Army, and within the National Command Authority (NCA). Within this domain, the lack of unified C2 continues to result in the fielding of well-intentioned but often incompatible and isolated systems. These "islands of C2" are typically costly, enterprise-specific and incompatible in intent, specification, scope and function. Compounded by post 09-11-2001 realities and sporadic and long-standing national and global conflicts, conditions continue to confound attempts at developing a *unified command structure.* Ideally, unified command emerges through continuous incremental implementations. It involves development of both new systems and legacy system upgrades, systems that support the needs of individual authorities at all levels of command while at the same time allowing for coordination within and across military and civil institutions, both domestically and in concert with foreign allies in multiple theaters of operation and against various threats.

This is admittedly a tall order, but not one without precedence. In the five decades following WWII, primarily motivated by our strategic nuclear posture, the US has invested heavily in efforts to field unified command structures. Development of the World Wide Military Command and Control System) and its contemporary successors, the Global Command and Control System (GCCS) and emerging Joint Command and Control (JC2)

System. All these efforts were well motivated, focused and aimed at providing the National Command Authority with tools for overseeing key strategic and operational military capabilities. Nevertheless, literature describing these systems is largely silent on overarching theories aimed to unify their designs and their evolution, let alone their respective roles in the governance of evolving U.S. military and non-military enterprises.

Our task is therefore to develop such a theoretical basis, along with its associated lexicon. The goal is to anticipate and support the development of a unified C2 architecture for the U.S. military enterprise, one that is competent to account for demands of multiple user communities, operating alone and in concert, and across various command levels. The work reported here, while intentionally technology-neutral, does recognize and respect the existence of certain capabilities of contemporary and near-future computing and communications technologies, and to a degree anticipates their roles as enablers in the DOD's global information grid and its associated *network centric operations* (NCO) imperatives.

Perhaps most important, unified C2 capabilities might well prove to be our most important next generation strategic weapon system. Unified C2 systems can simultaneously serve our national and global policy objectives while providing a coherent and extensible fabric on which coordinated policy and action may evolve and unfold. Kinetic weapons have been and will continue to be a focus of national military strategy, helping to maintain historical distinctions between and specializations within the military services. They most certainly help sustain and reinforce long-standing military and industrial political-economic relationships. Arms have experienced an inexorable march from their pre-historic mechanical roots, to chemical, to nuclear and now to information-based designs. Consequently, our thesis admits to arguments that properly conceived, designed and implemented, real-time distributed and unified C2 systems are of potentially greater value in enabling U.S. political influence and military force projection, enabling greater degrees of deterrence and strategic advantage than the tactical kinetic systems.

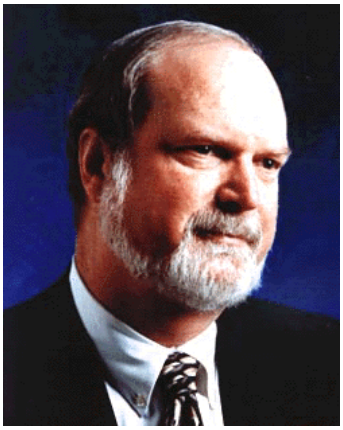
Finally, our intent is to avoid perpetuating historical tensions among the Military Services, the Executive Branch (and DOD) and Congress that derive from false dichotomies present in arguments concerning centralization versus decentralization of authority. On the contrary, it is our intent to significantly attenuate, if not dispel, such arguments. The theory of EC2 is predicated on an alternative paradigm, one recognizing the legitimacy of multiple levels of command within and among peer-level interactive enterprises. At the same time, the theory preserves and fortifies the degree of individual operational sovereignty that enterprises require to be effective. The theory's unifying principles include the concept of partitioning complex systems into semi-autonomous yet federated (according to Jeffersonian principles) subsystems, of compartmentalization and specialization of function into efficient network accessible (shared) services. Such service-oriented federations allow delegation of responsibility and accountability while providing support for *commanders' intent*, the principal operational concept establishing and legitimizing distributed intelligence and allegiance through *chains of command* – structures that create and continually reinforce *accountability hierarchies*. In this paradigm, the theory of EC2 simultaneously supports the cognitive art of management and the science of technology-enabled governance.

It is to these ends this document and its *Theory of EC2* is dedicated.

About the Author

History

PhD Electrical Engineering & Computer Science, University of California, Santa Barbara, 1976, supported by AFOSR; founder and President, Protocols Solutions (1973-1985); Professor of Computer Science, California Polytechnic State University (1973-1984); Executive Director Automation Technology, Combustion Engineering (CE) (1986-1989); VP Systems Products Development, Asea Brown Boveri (ABB, 1989-1991); VP Engineering R&D, Elsag Bailey Process Automation (EBPA, 1991-1998); VP Technology, Johnson Controls Inc. (JCI, 1998-2002); founder and CEO of Echelon 4 Corporation, a professional services, research and software development company specializing in distributed real-time enterprise command and control systems (2002-present)



Experience

Dr. Bayne has developed many automation and control systems, including flight controls and next generations of well-established distributed process control systems (Taylor's Mod 300, Bailey Control's Infi90, Hartmann & Braun's Advant, Asea Brown Boveri's Symphony and the Johnson Controls Inc.'s Metasys). In addition he has designed advanced automation systems (Lockheed's L1011 Flight Simulator, Hewlett Package's Unix OS Performance Analyzer, Vandenberg Air Force Base's MX Missile Range Safety System, Pacific Gas & Electric Co.'s Diablo Canyon Nuclear Power Plant Control System, Asea Brown Boveri's Symphony Distributed Control System, and Johnson Controls Inc.'s Remote Operations Center). In addition to these technical contributions, he has served as a senior technology executive on the management committees of such industry consortia as the Corporation for Open Systems, MAP-TOP, Fieldbus Foundation, working to develop open, reliable and scalable platform infrastructures to enable distributed interoperable real-time command and control. He is a regular contributor to publications and conferences associated with unified C2 for DOD and industrial use, including ICCRTS, IEEE (WORDS, ISORC), ISA and ACM where his interests include real-time object-oriented distributed systems, especially in the areas of systems science (cybernetics).

Dedication

This work is dedicated to my wife Carol, whose love and spirit energizes and inspires all that I do, and to Alison, our daughter, who is proof that love can create beauty, grace and intelligence.