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The Quest for Key Information: Does C2 Approach Matter?

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Abstract

An analysis of Command and Control (C2) failures has supported the generally held view that getting the right information to the right individuals in a timely manner is critical. Case studies of complex missions have also supported the hypothesis that success requires the adoption of an appropriate approach to Command and Control. Given that approaches to Command and Control differ in allocation of decision rights, patterns of interaction, and dissemination of information, it seems reasonable to assume that different approaches to C2 would result in significantly different flows of key information. This paper examines experimental results to explore the relationship between mission challenge, circumstances, key information flows, C2 Approach, and success. We find that more network-enabled C2 approaches manifest more cross-stovepipe information sharing and can succeed in more complex missions than less network-enabled approaches. We also find that information sharing policies and practices cannot be employed by an Enterprise to make an otherwise inappropriate C2 Approach succeed.

The Quest for Key Information: Does C2 Approach Matter?

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Introduction

An analysis of Command and Control (C2) failures in military operations, disaster response, and the response and run-up to terrorist attacks has shown that such failures generally manifest themselves as a lack of access to information or an absent, incomplete, irrelevant, delayed, or erroneous transfer of information from those who have it to those who need it.[1] This lack of information may be caused by a failure of the information and communications infrastructure to satisfy the requirements of the mission or circumstances. It may also be caused by behavioral failures. These proximate causes may, in turn, be a result of pre-existing or *a priori* problems in organizational approach, or a result of current stresses with which individuals, organizations and systems cannot adequately cope.

Why C2 Goes Wrong

In brief, one of the important ways C2 goes wrong is that there is a failure to get the right information to the right individuals at the right time. This "right information" may not always be in the form of massive multimedia files, or even buried therein. Sometimes, it may be as simple as a "yes" or "no".

[1] Vassiliou, Marius, and David S. Alberts (2013). "C2 Failures: A Taxonomy and Analysis." *Proc. 18th International Command and Control Research and Technology Symposium (ICCRTS)*; Marius S. Vassiliou, David S. Alberts, Jonathan Russell Agre (2015). *C2 Re-envisioned: The Future of the Enterprise*. New York: CRC Press; Chapter 7.

Consider the example of the response to Hurricane Katrina.[2] The Louisiana Superdome football stadium served as a collection center for people who would later be evacuated. The United States Federal Emergency Management Agency (FEMA) had an evacuation plan and was more or less ready to execute. The commander of Joint Task Force Katrina, General Russel L. Honoré, told the National Guard to cancel the plan—but he did not inform FEMA. This delayed the evacuation by at least a day.[3] In another example, New Orleans mayor Ray Nagin declared the Ernest N. Morial Convention Center as a refuge but did not broadly communicate this decision. FEMA and the United States Department of Homeland Security (DHS) were not aware of this until two days later, by which time about 19,000 people were stranded at the convention center without supplies. [4] A third example involves the Oslo bombing of 22 July 2011. After the bombing but before the mass shootings on the same day, a citizen gave police a description of the likely perpetrator, as well as his vehicle license number. The officers did not pass the information up the command chain for at least 20 minutes, and it did not reach the right people for two hours, by which time the shootings on Utøya Island had already begun.[5]

The aforementioned examples were behavioral failures to communicate relatively small amounts of key information. Such failures can also occur for technical reasons. During the ultimately successful U.S. invasion of Grenada on 25 October 1983, the Marines in the north and the Army Rangers in the south used their radios in such a way that interoperability was impeded, and they could not talk to each other. When the Marines ran into trouble at one point, the Rangers did not know about it for an unacceptably long time, and were thus unable to help. Interoperability problems also led to a highly publicized incident in which a soldier had to call for air support by placing a commercial long distance telephone call from Grenada to Fort Bragg, North Carolina.[6] In such cases, the problem is not inadequate bandwidth, storage, or processing; rather, it is a failure to deliver relatively small amounts of information reliably to those who need it.

[2] Hurricane Katrina occurred from 23-30 August 2005 and primarily affected the U.S. states of Louisiana and Mississippi. It caused 1836 deaths, $75 billion in damages, and had a total economic impact of $110 billion. See Knabb, Richard D., Jamie R. Rhome, and Daniel P. Brown (2005). Tropical Cyclone Report: Hurricane Katrina, August 23-30, 2005. Miami, FL: National Hurricane Center. http://www.nhc.noaa.gov/pdf/ TCR-AL122005_Katrina.pdf (accessed August 11, 2014).

[3] Moynihan, Donald P. (2006). What Makes Hierarchical Networks Succeed? Evidence from Hurricane Katrina. Annual Meeting of the Association of Public Policy and Management, Madison, WI, November 2–4. http:// www.lafollette.wisc.edu/appam/moynihankatrina.pdf (accessed August 11, 2014).

[4] Moynihan (2006).

[5] Commission on 22 July (2012). Norwegian Government Investigation 2012:14, Report of the Commission on July 22: Preliminary English Version of Selected Chapters. [Original: Norges Offentlige Utredninger 2012:14, Rapport fra 22.juli kommisjonen]. Oslo, Norway: Government of Norway, Commission on July 22.

[6] Cole, Ronald H. (1997). Operation Urgent Fury: The Planning and Execution of Joint Operations in Grenada, October 12–November 2, 1983. Washington, DC: Office of the Chairman of the Joint Chiefs of Staff.

Overview

Getting the right information to the right individuals in a timely manner is critical for mission success.[7] Experiments have shown that there is no universal approach to C2, and that different approaches to C2 work for different kinds of missions and in different circumstances. Given that approaches to Command and Control differ in allocation of decision rights, patterns of interaction, and dissemination of information, it seems reasonable to assume that different approaches to C2 would result in significantly different flows of key information. These differences in information flows, at least in part, account for the ability of the enterprise to bring necessary information to bear on the mission at hand, and ultimately succeed.

Case studies of complex endeavors have shown that traditional hierarchies may be unsuited for complex missions that require higher levels of shared awareness and hence widespread sharing of information. These case studies suggest that success in complex endeavors requires the adoption of more network-enabled approaches to Command and Control.[8] This body of work suggests a number of hypotheses about the relative ability of different C2 approaches to bring information to bear in the face of a set of mission challenges.

An examination of experimental results suggests that the probability that key information is adequately disseminated can be maximized by selecting an appropriate approach to C2 among a number of choices of varying degrees of net-enablement, and designing information-related policies, systems and networks to support the selected C2 Approach.

The Enterprise Challenge

Military operations, as well as responses to major disasters and emergencies, almost always constitute "Big Problems." Such problems are characterized by large size, dynamic environments, complexity of both the problem and the organizational structure brought to bear on it, and a high cost of error. Success or failure in such endeavors has been shown to depend critically upon the ability of an enterprise to develop and exploit shared awareness. This, in turn, depends upon an enterprise's ability to ensure that key information and the conclusions drawn from this information are available to all that require it in a timely manner. However, this is a very difficult undertaking, for a variety of reasons, including the:

[7] Vassiliou, Marius, and David S. Alberts (2013). "C2 Failures: A Taxonomy and Analysis." *Proc. 18th International Command and Control Research and Technology Symposium (ICCRTS)*; Marius S. Vassiliou, David S. Alberts, Jonathan Russell Agre (2015). *C2 Re-envisioned: The Future of the Enterprise*. New York: CRC Press; Chapter 7.

[8] Marius S. Vassiliou, David S. Alberts, Jonathan Russell Agre (2015). *C2 Re-envisioned: The Future of the Enterprise*. New York: CRC Press; Alberts, David S. (2011). *The Agility Advantage*. Washington, D.C.: United States Department of Defense, Command and Control Research Program (CCRP Press), 615pp.

- extent of interdependencies among component tasks
- number of individuals that "need to know"
- amount of key information required
- amount of information and cognitive processing required
- quantity and quality of available information
- information and communications capabilities
- time available
- cost of failure

In addition, information can enter an enterprise at many different places, further complicating the organizational and technical processes required to route it to the right people. Not all information is "key," or even of high quality. Thus, an ability to recognize key information at its point of entry, and identify those who need it, is a critical Enterprise challenge. There are also various considerations and constraints that limit the amount of information sharing and processing that are possible and desirable. For example, information systems have limited connectivity and bandwidth. They may also operate in a contested environment where they are subject to attack, compromise, damage, and degradation. In cases where the amount of key information is small but critical, connectivity, reliability, fault tolerance, and resistance to attack will be paramount. In other cases, where the key information is larger in size, or where the key information is buried in a large "haystack" that may possibly require transport before processing, bandwidth may become more of a critical factor.

Even if technical systems and infrastructure work perfectly, mission success depends upon humans behaving appropriately. Ensuring appropriate behaviors depends, at least in part, on having an organizational design and C2 approach that is well matched to the mission at hand.

Solution Options

While there is ample evidence that there is no universal approach to C2, there is not yet a wide-spread consensus that it is imperative to have multiple C2 approach options in one's operational tool kit. Even among those who accept this imperative, there is disagreement about the range of C2 Approach options that should be available to commanders, as well as about the appropriateness of various options as a function of the circumstances and conditions.

C2 Agility is the capability to adopt an appropriate approach to C2 and, when the mission or circumstances change, move to a different and more appropriate approach if required. In the context of this paper, C2 Agility is about finding an enterprise approach to C2 that is aligned with the information dissemination challenges posed by particular missions and circumstances.

The North Atlantic Treaty Organization (NATO) SAS-065[9] Network-Enabled Capability (NEC) C2 Maturity Model[10] identifies a set of increasingly network-enabled C2 Approaches and examines their appropriateness for selected missions. Figure 1 depicts the conceptual C2 Approach Space, with different approaches occupying different regions according to their breadth of information dissemination and patterns of interaction, as well as their allocations of decision rights.

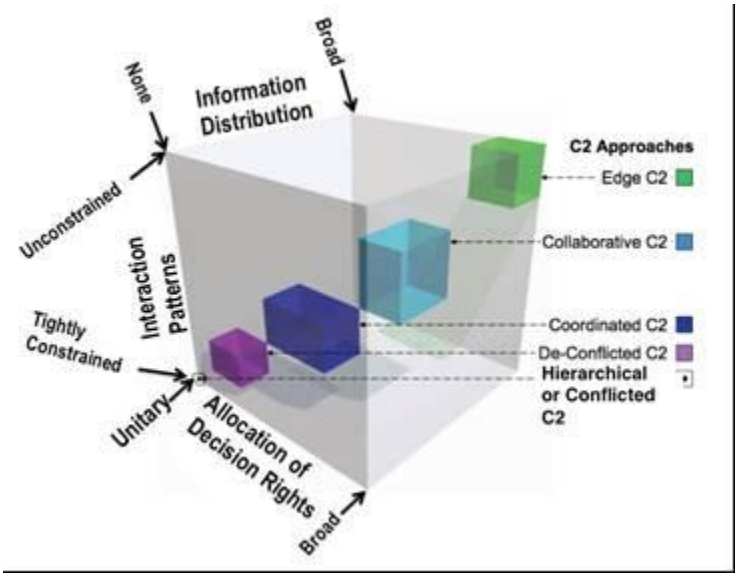

Figure 1: The NATO Networked Enabled Capability (NEC) C2 Model.

(Adapted from Alberts, David S., Reiner K. Huber, and James Moffat (2010). NATO NEC C2 Maturity Model. Washington, D.C.: United States Department of Defense, Command and Control Research Program (CCRP Press))

The ability of an enterprise to move key information from where it enters the enterprise to where it is needed is a function of the specific C2 approach and associated policies, processes and practices. The selection and adoption of a specific C2 Approach impacts the pattern of interactions and the availability of information to individuals. Both can facilitate or constrain information-sharing behaviors. The selection of a C2 Approach also establishes how decision rights are allocated and this, in turn, determines who needs what information. The C2 Approach that is selected may be part of the problem or it can be part of the solution, depending upon its appropriateness for the mission and circumstances at hand.

NATO research groups have concluded that, given the range of missions and circumstances that NATO and its member nations face, C2 Agility is an essential force capability.[11] The final report for NATO System and Analysis Studies Group SAS-085 observed that "C2 Agility is a function

[9] North Atlantic Treaty Organization System and Analysis Studies group 065
[10] Alberts, David S., Reiner K. Huber, and James Moffat (2010). *NATO NEC C2 Maturity Model*. Washington, D.C.: United States Department of Defense, Command and Control Research Program (CCRP Press), 365pp.
[11] NATO (2013). C2 Agility. Technical Report STO-TR-SAS-085. Brussels, Belgium: North Atlantic Treaty Organization. http://dodccrp.org/sas-085/sas-085_report_final.pdf

of C2 Approach Agility and C2 Maneuver Agility[12]" This suggests that enterprises may not always need to alter their C2 approaches (maneuver in the C2 Approach Space); rather they may be able to deal with selected mission challenges and circumstances by making their existing C2 Approaches more agile by employing a set of information sharing policy options.

The first question to ask is what we can and cannot **reasonably** expect to be able to accomplish by varying information sharing policies. We may, *a priori*, have a good idea where we can expect some key information to 'enter' the enterprise, but we may still not be able to

- Identify 100% of the key information that is needed and who needs it
- Know where all known key information will enter the Enterprise
- Recognize all key information where and when it enters the Enterprise

We need to understand the nature of the mission challenges we are likely to face, and their implications for our ability to identify all of the key information needed and their points of entry for this information. Currently, we tend to organize and behave as if all missions are decomposable Industrial Age problems traditionally addressable by hierarchies of varying bureaucratic intensity. Recognizing and accepting that many of the problems we face will be more dynamic, complex, and non-decomposable is the first step on the road to agility.

The next step is to determine what can be done within existing C2 approaches. In some cases, it may be possible to create the conditions for success by making a change to information-sharing policies and practices rather than changing the allocation of decision rights. Thus, a near-term solution can involve modifying an existing C2 Approach by adding or changing cross-stovepipe interactions or, if the enterprise already has more than one C2 Approach in its tool kit, switching to a more appropriate C2 Approach.

The mid-term solution involves adding new C2 Approaches to the enterprise C2 tool kit. The long term solution will require additional basic research and re-conceptualizing C2 as a function of a "composite" network of networks. It will also involve developing an integrated design that accounts for interdependencies between and among those constituent networks. To be successful, this design will need to take advantage of the capabilities of the various network (human/C2, information, and communications) capabilities to ensure that information will be appropriately disseminated.

Mission Challenges and their Representation

[12] NATO (2013) p.79

Of the various C2-related challenges posed by different types of missions, this paper concentrates on the organization (or lack thereof) of information sources, and hence the ability of individuals to know where to find the information they need. Military organizations have, over time, established their own data collection systems or have identified sources of information that can be relied upon to provide needed information. These systems and sources work well when the mission is familiar and well understood. As missions become more complex and unfamiliar, these traditional sources of information may no longer reliably provide all the information needed. In other words, needed information will come in the form of the proverbial 'dots' that need to be 'connected.'

The experiments reported here were run in the environment known as "Experimental Laboratory for the Investigation of Collaboration, Information sharing and Trust (ELICIT)."[13] ELICIT has been used by researchers from around the world. Originally employed to compare the behaviors and performance of traditional military hierarchies and Edge organizations when faced with a set of mission challenges under a variety of stresses, ELICIT was later used to compare and contrast the different NATO NEC C2 Maturity Model C2 Approaches and then further extended to represent other organizations and mission challenges. ELICIT can be used to conduct human-in-the-loop experiments as well as agent-based experiments.

In the agent-based ELICIT experiments reported here, the information challenge is modeled by ELICIT "factoid" sets. ELICIT factoid sets contain all the information that is available to the enterprise, and specify when that information is available, as well as the point at which it 'enters' the Enterprise. One type of factoid set conforms to the expectations or assumptions upon which traditional hierarchies are built: that is, that the problem at hand is well understood and decomposable into pieces that can be tackled independently by different organizational units. These units consist of individuals who are experts in their areas of responsibility and are therefore aware of the origin of the information they need, as well as the quality and significance of available information related to their assigned task. Figure 2 depicts a traditional Hierarchy (Industrial Age Organizational Design) and its expectations for information.

[13] Ruddy, Mary (2007). "ELICIT – The Experimental Laboratory for the Investigation of Collaboration, Information sharing, and Trust." *Proc. 12th International Command and Control Research and Technology Symposium*. Newport, Rhode Island, USA. See also the DoD CCRP Website, http://www.dodccrp-test.org/elicit/

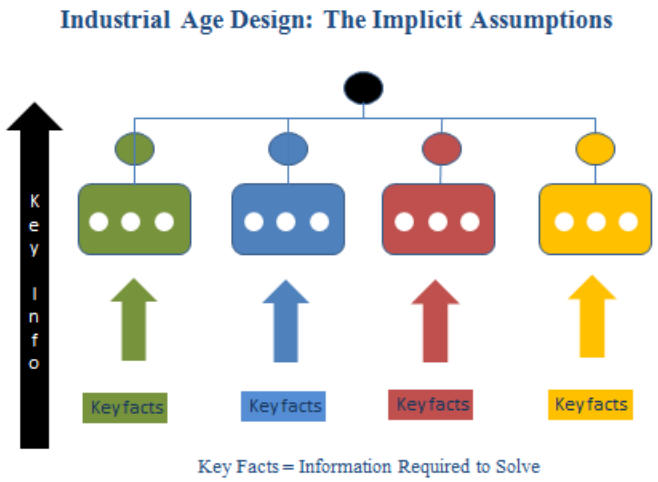

Figure 2: Industrial Age Design: The Implicit Assumptions

Both the task-organized units and the information they require are color coded. As depicted in Figure 2, the points of entry for all of the information required (key facts) are perfectly aligned with the organizational structure. Both the organization and the sources of information are stove-piped. Thus, no horizontal sharing is required to get the 'right information to the right place'. This, in turn, makes it easier to satisfy mission timeliness requirements. However, it would be unrealistic to assume that the only information that ever comes to the attention of individuals is both necessary and related to their areas of responsibility. Thus, in addition to key facts, (those facts without which completion of the task is not possible without 'guessing'), ELICIT factoid sets contain both supporting facts and 'noise' facts that are unrelated to the task or unneeded.

Previous ELICIT experiments have been run with Industrial Age factoid sets that vary with respect to the number of noise facts they contain, corresponding to noise levels considered to be low, normal or high. Figure 3 provides the point of entry for each of the facts that make up the low noise factoid set for the Industrial Age Challenge.

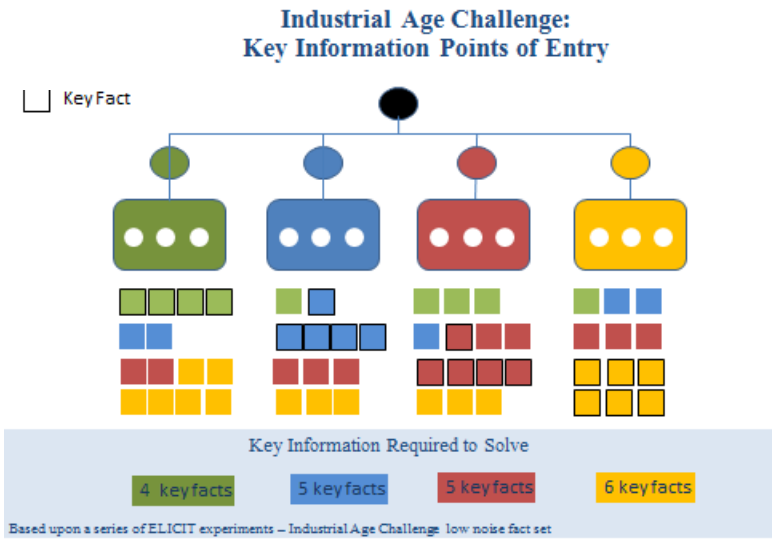

Figure 3: Industrial Age Challenge: Key Information Points of Entry

Key facts are indicated by a black border. Figure 3 also provides the number of key facts required for mission accomplishment. In this case, each task-organized unit directly gets all the key information it needs.

As we have already noted, key information can enter the enterprise far from where it is needed. Previous ELICIT experiments have created factoid sets that were designed to represent Complex Endeavors where the information is badly misaligned with the traditional hierarchy; that is, situations when key information needs to find its way beyond the point of entry.

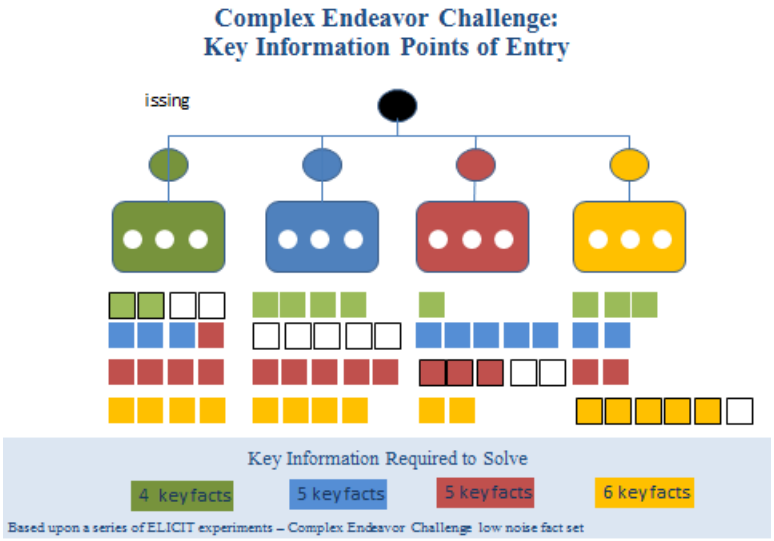

Figure 4: Complex Endeavor challenge: Key Information Points of Entry

Figure 4 presents the information alignment for a Complex Endeavor. Once again key facts are represented by black borders. In the case of a Complex Endeavor, a significant percentage of the facts (>50%) do not initially align properly and need to transit the enterprise. The 'missing' facts are depicted in Figure 4 by white squares with black borders.

The C2 challenge faced by traditional hierarchies is how to accommodate situations in which information sources are not aligned with the organization of the enterprise. Enterprises can consider other forms of organization, including more collaborative forms of hierarchy, when faced with mission challenges that present these information flow challenges.

C2 Approach Options

Of the four C2 Approaches instantiated in the experiment discussed here, three approaches have the same (centralized) allocation of decision rights but differ with respect to information distribution and allowable patterns of interaction. These three approaches, the Hierarchical, Coordinated, and Collaborative, are all based on a structure that is still fundamentally hierarchical in nature. The fourth C2 Approach, the Edge, features fully distributed decision rights, unconstrained interactions, and unlimited access to information.

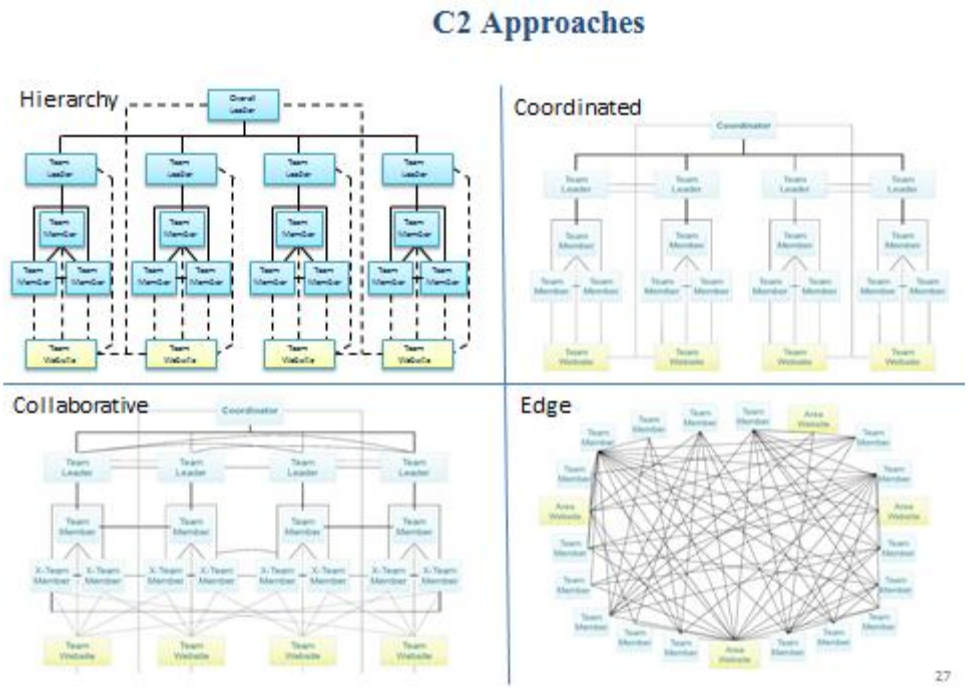

Figure 5: C2 Approaches in Experiments

Figure 5 presents the 'wiring diagrams' for each of these approaches. From inspection of Figure 5 it would appear that as one moves from a traditional hierarchy to an edge (diagonally up and to the right in the C2 approach space of Figure 1), the number of internal paths for information flows increases dramatically. Figure 6 confirms this.

Extent of Cross-Stovepipe Connections in C2 Approaches

C2 Approach*	Cross-Stovepipe Paths**
Traditional Hierarchy	1
Hierarchy with Coordination	14
Hierarchy with Collaboration	32
Edge	210

* Based upon ELICIT baseline experiments and NATO NEC C2 Maturity Model
**Based upon the ELICIT-IDA experiments reported on in the NATO SAS-085 Final Report

Figure 6: Extent of Cross-Stovepipe Connections in C2 Approaches

As the number of paths increases, so does the potential for redundant and unnecessary information flows that can adversely impact enterprise performance. Information sharing policies and practices offer an opportunity to tune the flows of information so that they are sufficient to satisfy requirements without being unduly burdensome. In this paper we consider the following Information Sharing Policies and Practices to be exercised based upon the mission and circumstances:

- Share Only, Post Only, or Share and Post

  This policy option provides guidance to individuals about their sharing modalities. A "post only" policy employs Web sites. Those with information they wish to share with others post it, and those in need of the information pull it. In a "share only" policy, individuals share with others, but do not post. In a "Share and Post" policy, individuals both post and share information.

- Post First or Process First

  This policy option provides guidance to individuals about whether they should 1) carefully evaluate the information they have received and determine whether it is worth sharing and, if so, with whom or 2) make information immediately available by sharing or posting with an appropriate individual or website.

Experimental Hypotheses and Expected Results

The experiment discussed here uses the ELICIT environment (see above) to instantiate four C2 Approaches, each with four information sharing policy variants. Each of these 16 C2 Approach Options is 'tested' under conditions that represent four mission challenges. The challenges differ with respect to where the information first 'enters' the organization. In the Industrial Age challenge, information is perfectly aligned with the organizational structure, as previously discussed. In the Complex Endeavor Challenge, a significant percentage of the facts (>50%) do not initially align properly and need to transit the enterprise. The Coordinated Response and Collaborative Response challenges represent situations in between these two.

ELICIT is a deterministic (not a stochastic) simulation. That is, for a set of initial conditions and design parameter values, ELICIT will produce the same results every time. Therefore, only one run per condition is needed.

In looking at the ability of different C2 Approaches to meet the mission challenges we expect that:

- More 'networked' C2 Approaches, with increased cross-stovepipe information sharing, will result in more information being available on average. Thus, the adoption of more-networked approaches will increase the probability that key information will be appropriate disseminated.
- Stresses that increase workload or reduce network performance will have a proportionately greater adverse impact on more-networked C2 Approaches.
- Stresses that reduce connectivity will adversely impact less-networked C2 approaches by increasing the probability that key information will not find its way to those that need it.

With respect to information sharing policies and practices we expect that:

- Post First encourages timely information dissemination
- Process First prevents unneeded information sharing
- Post Only minimizes load on the communication network but creates vulnerability to a loss of connectivity
- Share Only reduces information sharing transactions but maintains some redundancies in case of network damage or outages

Experimental Findings

To see if our expectations are justified, we consider three hypotheses, each of which considers the ability of a C2 Approach to get information to the right places in a timely manner.

H1: More-networked C2 Approaches are associated with increased cross-stovepipe information sharing

First, we want to verify the premise that more-networked C2 Approaches are associated with increased cross-stovepipe information sharing. Figure 7 and subsequent experimental results reported here are based upon a set of ELICIT experiments with low noise fact sets, low cognitive complexity, and no network damage. Figure 7 shows that the premise of H1 holds regardless of the mission challenge.

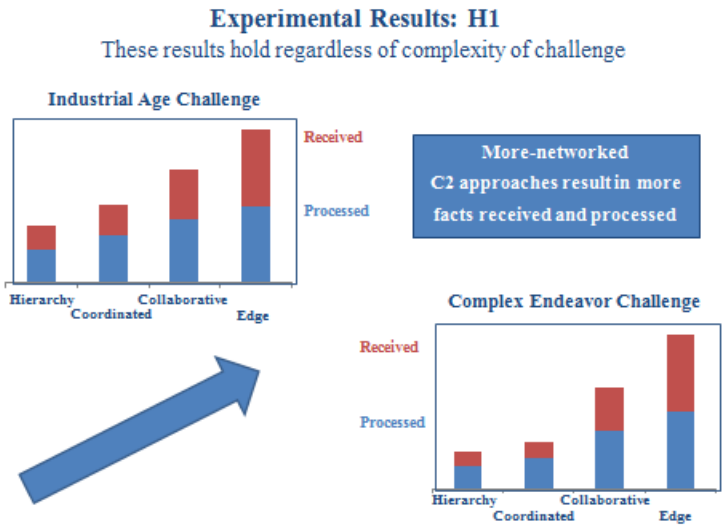

Figure 7: Experimental Results: H1

Figure 8 provides the numerical results. It shows the percentage of the total facts available that are received and processed by individuals as a function of C2 Approach and mission challenge[14]. In these experiments, as well as one with human participants, not all facts that are received by an individual are processed. Readers will note that individuals operating in a Hierarchy 'ignore' roughly 20% of the facts they receive. The processing rate is similar for the coordinated and collaborative approaches. However, individuals in an Edge approach process all information they receive. One of the reasons for this difference is the way responsibilities are allocated to individuals. Individuals in Hierarchies traditionally have limited responsibilities and focus. Thus, they do not spend time (or place a high priority on) processing information they deem 'irrelevant.' The adoption of information sharing policies, such as the US Department of Defense's 'post before process' policy, are designed to promote information sharing and avoid key information getting trapped.

[14] The number of data points that these percentages are based upon is quite large given the deterministic nature of the simulations. For each run (and this table reports upon the outcomes of 16 runs) there are 68 factoids that can be received by each of 17 individuals; thus each of these percentages is based upon 17*68 = 1156 distinct events.

% Facts Received / Processed
as a function of Mission Challenge and C2 Approach

Mission Challenge	C2 Hierarchy %Facts		Coordinated C2 %Facts		Collaborative C2 %Facts		Edge C2 %Facts	
	Received	Processed	Received	Processed	Received	Processed	Received	Processed
Industrial Age	43%	33%	62%	40%	84%	63%	100%	100%
Coordinated Response	41%	32%	60%	3%	82%	61%	100%	100%
Collaborative Endeavor	31%	22%	47%	29%	83%	63%	100%	100%
Complex Endeavor	27%	19%	41%	25%	75%	56%	100%	100%

Figure 8: % Facts Received and Processed as a function of Missions and C2 Approach

H2: More-networked C2 Approaches will succeed in complex mission challenges where less-networked approaches fail.

Figure 8, while verifying the premise of H2, does not allow us to conclude that a particular C2 approach will succeed or fail when faced with a given mission challenge. To determine this we examine the requirement for cross-stovepipe sharing as a function of the mission, and the ability of C2 approaches to satisfy that requirement.

Figure 9 provides the cross-stovepipe sharing requirements for each of the four mission challenges we consider.

% Facts Received / Processed
as a function of Mission Challenge and C2 Approach

Mission Challenge	C2 Hierarchy %Facts		Coordinated C2 %Facts		Collaborative C2 %Facts		Edge C2 %Facts	
	Received	Processed	Received	Processed	Received	Processed	Received	Processed
Industrial Age	43%	33%	62%	40%	84%	63%	100%	100%
Coordinated Response	41%	32%	60%	3%	82%	61%	100%	100%
Collaborative Endeavor	31%	22%	47%	29%	83%	63%	100%	100%
Complex Endeavor	27%	19%	41%	25%	75%	56%	100%	100%

Figure 9: Mission Challenge and Required Information Sharing

Figure 10 estimates the percentage of facts that need to be processed on average to satisfy mission requirements. These results show that considerably more facts on average need to be handled by individuals as the mission challenge moves from an Industrial Age one to a Complex Endeavor.

Required Information Sharing Threasholds

Mission Challenge	% Facts Requiring Cross-Stovepipe Sharing*	Expected % Facts Needed to Process
Industrial Age	0%	25%
Coordinated Response	6%	30%
Collaborative Endeavor	35%	51%
Complex Endeavor	53%	65%

*based upon an analysis of DoD CCRP ELICIT datasets

Figure 10: Required Information Sharing Thresholds

Figure 11 shows information dissemination in a Hierarchical structure, under a variety of information sharing options. It notes mission success or failure (where red denotes failure and green denotes success) for each C2 Approach, Information Sharing Policy option, and Mission Challenge. The experimental results show that a traditional Hierarchy is only successful when faced with an Industrial Age Challenge. Furthermore, it shows that this limitation cannot be remedied simply by changing information sharing policy and practices.

Experimental Results: Fact Dissemination - Hierarchy

All Key Facts received and processed by those who required them – Mission Succeeded.

Some Key Facts not received or processed by those who required them – Mission Failed.

Mission Challenge (% needed to process)	C2 Hierarchy S and P Post 1st %Facts		C2 Hierarchy S and P Process 1st %Facts		C2 Hierarchy Post Only Process 1st %Facts		C2 Hierarchy Post Only Process 1st %Facts	
	Received	Processed	Received	Processed	Received	Processed	Received	Processed
Industrial Age (25%)	43%	33%	43%	33%	26%	25%	26%	25%
Coordinated Response (30%)	38%	29%	41%	31%	25%	23%	25%	23%
Collaborative Endeavor (51%)	30%	21%	31%	22%	20%	17%	20%	17%
Complex Endeavor (65%)	27%	20%	27%	19%	16%	13%	16%	12%

*based upon DoD CCRP ELICIT experiments with low noise fact sets, low cognitive complexity, and no network damage

Figure 11: Experimental Results: Fact Dissemination in a Hierarchy

Figure 12 shows the results from the Collaborative C2 Approach, the most-network-enabled of the 'hierarchies' – where decision rights are allocated to functional stovepipes.

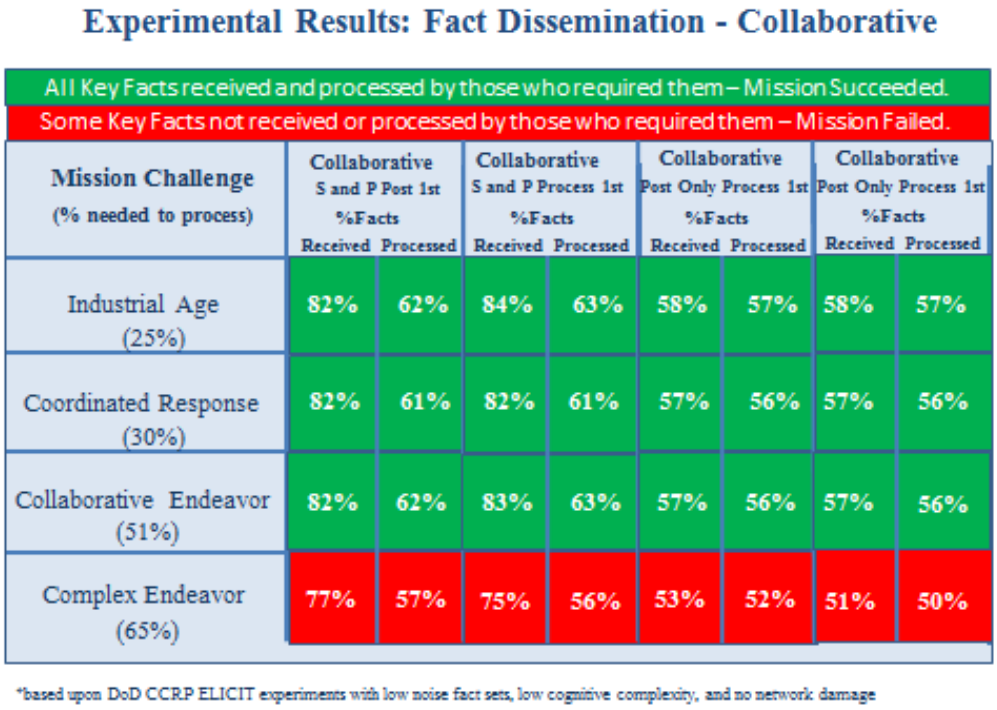

Figure 12: Experimental Results: Fact dissemination - Collaborative

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Comparing Figures 11 and 12, we can see that a more networked and collaborative hierarchy is able to meet all the mission challenges except for the Complex Endeavor. Furthermore, information sharing policies, while having some impact on the percentage of facts received and processed, cannot make the difference necessary in key information dissemination to make a less-networked C2 Approach succeed in a more complex mission.

H3: Since information sharing policies impact the efficiency of information dissemination, they can increase the ability of a C2 Approach to succeed in more stressful circumstances

Figure 13 shows the impact that stress has on the timeliness of a Hierarchy, as a function of information sharing policy. In this analysis, the 'stress' dimension incorporates a combination of cognitive complexity and noise in the information. In this case we see that information sharing policy and practice makes little difference in the timeliness observed.

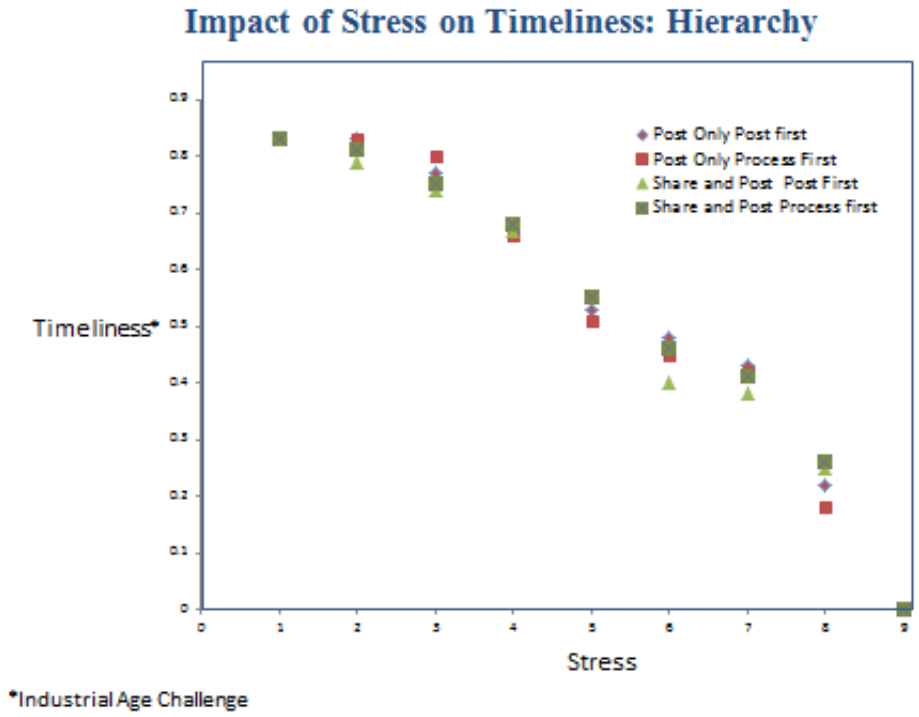

Figure 13: Impact of Stress on Timeliness: Hierarchy

Figure 14, however, presents a different story. For the most networked C2 Approach (Edge), the results show that timeliness is considerably better when a post-only policy is in place. Depending upon the level and nature of the stress, whether individuals post or process first makes a difference as well.

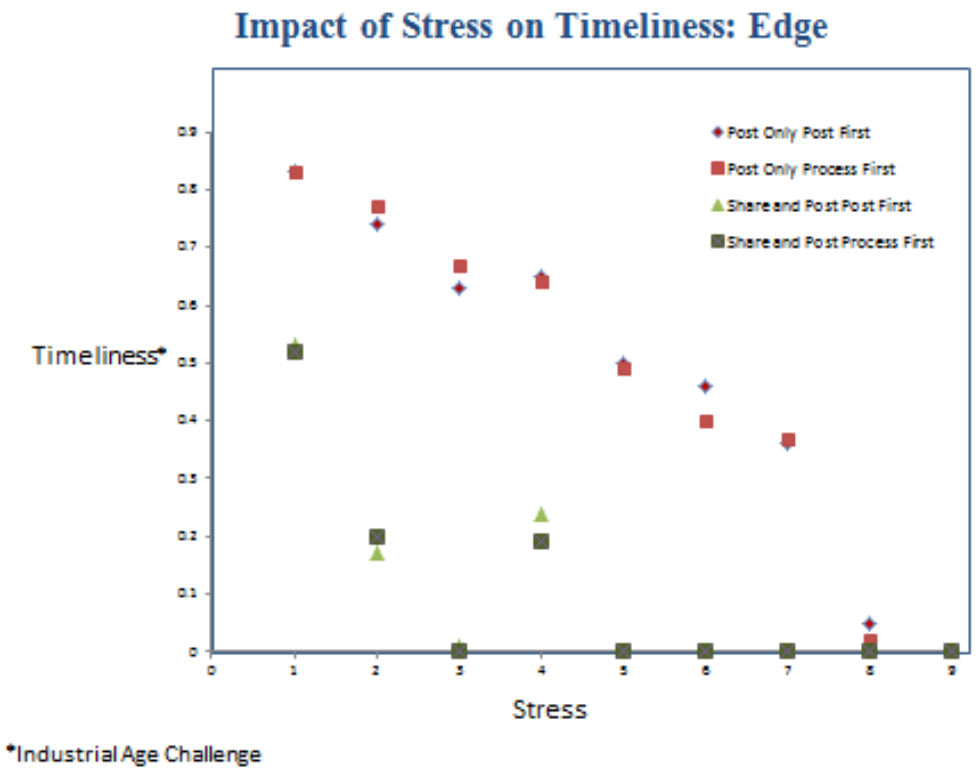

Figure 14: Impact of Stress on Timeliness: Edge

Summary and Conclusions

This paper examines the amount of cross-stovepipe information sharing in different C2 Approaches with various Information Sharing Policies, in light of the requirement for information sharing associated with a variety of missions. Three hypotheses are investigated. The experimental results support two of the three hypotheses.

The evidence shows that more network-enabled C2 approaches manifest more cross-stovepipe information sharing, as expected (first hypothesis). The evidence also shows that more network-enabled approaches can succeed in more complex missions (ones where information needs to

transit the Enterprise from its points of entry), where less network-enabled approaches fail (second hypothesis).

The third hypothesis, that information sharing policies and practices can be employed by an Enterprise to make an otherwise inappropriate C2 Approach succeed, is *not* supported by the experimental evidence. This result, while applying strictly only to the particular C2 approaches and information sharing policies tested here, is significant because it supports the emerging consensus that the most effective way for Enterprises to increase their C2 Agility is for them to develop a number of different C2 Approach options and adopt them appropriately. This will require both an understanding of the information sharing characteristics of individual C2 Approaches and the information sharing requirements associated with different missions.